STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT IN SOUTH AFRICA

Integrated Biodiversity and Ecology (Terrestrial and Aquatic Ecosystems, and Species) Assessment Report

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT

Draft v3 Specialist Assessment Report for Stakeholder Review

BIODIVERSITY AND ECOLOGY
TERRESTRIAL AND AQUATIC ECOSYSTEMS, AND SPECIES

Contributing Authors	
Dr. Derek Berliner[4]	Albany Thicket
Albert Froneman[9] & Chris van Rooyen[9]	Avifauna
Kate McEwan[10, 11]	Bats
Lizande Kellerman[2] & Simon Todd[3]	Desert, Nama Karoo & Succulent Karoo
Dr. Lara van Niekerk[8], Carla-Louise Ramjukadh[8] Steven Weerts[8] & Dr. Susan Taljaard[8]	Estuaries
Gary de Winnaar[7] & Dr. Vere Ross-Gillespie[7]	Freshwater ecosystems
Dr. David le Maitre[1]	Fynbos
Dr. Graham von Maltitz[6]	Grassland & Savanna
Simon Bundy[5] & Alex Whitehead[5]	Indian Ocean Coastal Belt
Integrating Authors	
Luanita Snyman-van der Walt[2]	

[1] Council for Scientific and Industrial Research, Natural Resources and the Environment, Biodiversity and Ecosystem Services Research Group.
[2] Council for Scientific and Industrial Research, Environmental Management Services.
[3] Three Foxes Consulting.
[4] Eco-logic Consulting.
[5] SDP Ecological and Environmental Services.
[6] Council for Scientific and Industrial Research, Natural Resources and Environment, Global Change and Ecosystems Dynamics.
[7] GroundTruth
[8] Council for Scientific and Industrial Research, Natural Resources and the Environment Coastal Systems Research Group.
[9] Chris van Rooyen Consulting
[10] Inkululeko Wildlife Services (Pty) Ltd.
[11] South African Bat Assessment Association Panel

CONTENTS

TABLES

FIGURES

BOXES

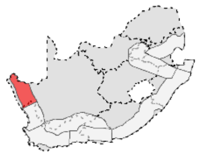
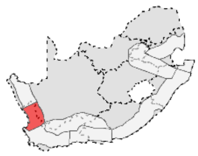
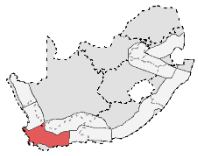
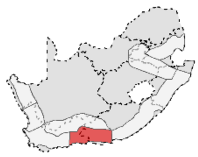
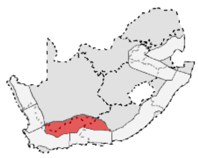
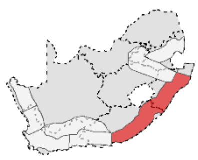
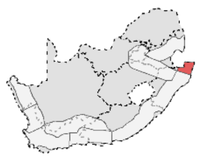
ABBREVIATIONS AND ACRONYMS

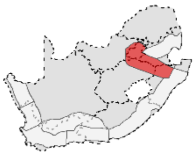
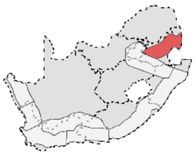
AOO	Area of Occupancy
EOO	Extent of Occurrence
CARA	Conservation of Agricultural Resources Act (43/1983)
CBA	Critical Biodiversity Area
CR	Critically Endangered
DEA	Department of Environmental Affairs
ECBCP	Eastern Cape Biodiversity Conservation Plan
EC	Eastern Cape Province
ESA	Ecological Support Area
EN	Endangered
EWT	Endangered Wildlife Trust
ECO	Environmental Control Officer
EIA	Environmental Impact Assessment
EFZ	Estuary Functional Zone
GA	General Authorisation
GIS	Geographic Information System
HDD	Horizontal Directional Drilling
IDP	Integrated Development Plan
IUCN	International Union for Conservation of Nature
IAP	Invasive Alien Plant
KZN	KwaZulu-Natal
MLRA	Marine Living Resources Act (18/1998)
MAR	Mean Annual Runoff
MBSP	Mpumalange Biodiversity Sector Plan
NEMA	National Environmental Management Act (107/1998)
NEM:BA	National Environmental Management: Biodiversity Act (10/2004)
NEM:ICM	National Environmental Management: Integrated Coastal Management Act (24/2008)
NEM:PAA	National Environmental Management: Protected Areas Act (57/2003)
NEM: WA	National Environmental Management: Waste Act (59/2008)
NFA	National Forest Act (84/1998)
NFEPA	National Freshwater Ecosystem Priority Areas
NP	National Park
NPAES	National Protected Area Expansion Strategy
NWA	National Water Act (36/998)
NWRS	National Water Resource Strategy
NT	Near Threatened
PES	Present Ecologcial State
PA	Protected Area
QDGC	Quarter Degree Grid Cell
ROW	Right of Way
SACAD	South African Conservation Areas Database
SANParks	South African National Parks
SAPAD	South African Protected Areas Database
SABAP	Southern African Bird Atlas Project
SADC	Southern African Development Community
SDF	Spatial Development Frameworks
SPLUMA	Spatial Planning and Land Use Management Act (16/2013)
SCC	Species of Conservation Concern
SEA	Strategic Environmental Assessment
SWSA	Strategic Water Source Areas
ToPS	Threatened or Protected Species Regulations (2013)
VU	Vulnerable
WC/WDM	Water Conservation and Water Demand Management
WUL	Water Use License
WCBSP	Western Cape Biodiversity Spatial Plan
WHS	World Heritage Site

1 SUMMARY

This chapter consolidates the potential impacts from the development of gas transmission pipeline infrastructure on terrestrial and aquatic ecology and biodiversity in nine proposed gas pipeline corridors in South Africa (Table i). The ecological and biodiversity environmental aspects of the proposed gas pipeline phases have been grouped according to the biomes that are found within the corridors, which act as the point of departure for terrestrial ecosystems and the fauna that inhabit these systems. The aquatic ecosystems considered include freshwater and estuarine habitats, and associated species.

Table i: Summary of key environmental features of the proposed gas pipeline corridors. Section references for the environmental description and sensitivity mapping for each corridor is indicated in the last column.

Proposed gas pipeline corridor	Brief description	§
Phase 6 	• Fynbos, Succulent Karoo, Nama Karoo, Desert vegetation types in the Northern Cape and Western Cape Provinces. • Mostly arid environment, with prominent protected areas that include the Richtersveld and Namaqua National Parks (NPs), with extensive areas earmarked as potential National Protected Areas Expansion Strategy (NPAES) focus areas. • Relatively untransformed when compared to the other proposed gas pipeline corridors.	4.2.1 5.2.1
Phase 5 	• Fynbos, Succulent Karoo vegetation types in the Northern Cape and Western Cape Provinces. • Notable protected environments include the Cederberg and Winterhoek Mountains. • Relatively transformed by settlements and cultivation.	4.2.2 5.2.2
Phase 1 	• Fynbos, Succulent Karoo, Nama Karoo, Albany Thicket vegetation types in the Western Cape Province. • Extensively transformed by settlements and cultivation, as such many of the remaining ecosystems are of conservation importance and currently protected.	4.2.3 5.2.3
Phase 2 	• Fynbos, Succulent Karoo, Nama Karoo, Albany Thicket, Grassland vegetation types in the Western Cape and Eastern Cape Provinces. • Extensively transformed around major towns (Mossel Bay, George, Port Elizabeth) due to urban settlement and agriculture.	4.2.4 5.2.4
Inland 	• Fynbos, Succulent Karoo, Nama Karoo, Albany Thicket, Grassland vegetation types in the Western Cape, Northern Cape and Eastern Cape Provinces. • Relatively untransformed when compared to the other proposed gas pipeline corridors.	4.2.5 5.2.5
Phase 7 	• Fynbos, Nama Karoo, Albany Thicket, Savanna, Grassland, Indian Ocean Coastal Belt vegetation types in the Eastern Cape and KwaZulu-Natal Provinces. • Transformed by urban settlement and agriculture, especially between Durban and Richards Bay in the KwaZulu-Natal Province. • Many aquatic systems (rivers, wetlands and estuaries) present.	4.2.6 5.2.6
Phase 4 	• Savanna, Indian Ocean Coastal Belt vegetation types in the KwaZulu-Natal Province. • Relatively untransformed when compared to the other proposed gas pipeline corridors, with many protected areas associated with large wetlands present.	4.2.7 5.2.7

Proposed gas pipeline corridor	Brief description	§
Phase 3 	• Savanna, Grassland vegetation types in the KwaZulu-Natal, Free State, Mpumalanga, Gauteng, and North-West Provinces. • Extensively transformed by settlements, agriculture and mining.	4.2.8 5.2.8
Phase 8 	• Savanna, Grassland vegetation types in the Mpumalanga Province. • Extensively transformed by settlements, agriculture and mining, with the Kruger NP occupying the eastern part of the corridor. • Kruger NP occupies most of the eastern corner of this corridor.	4.2.9 5.2.9

Highly sensitive ecological features exists in all corridors, and are mainly related to protected areas and areas identified in Provincial Conservation Plans as Critical Biodiversity Areas (areas characterised by key ecological processes, ecosystems and species required to meet conservation targets and protect South Africa's biodiversity) (Figures i and ii). Areas that have already been transformed by anthropogenic activities such as urbanisation and agriculture are mainly of low sensitivity (Figure i). Aligning the proposed pipeline routings to follow existing disturbance corridors presents an (environmental) opportunity.

Proposed gas pipeline corridors in more arid areas (i.e. Phases 6 and Inland) are less sensitive from an aquatic ecology perspective due to the relatively limited presence of aquatic features. Due to existing pressures from other anthropogenic activities many of the aquatic ecosystems in the rest of the country are threatened and are resultantly highly sensitive to new development (Figure ii). The most sensitive aquatic ecosystems must be avoided as far as reasonably possible, else mitigated using engineering solutions and best practice to reduce potential impact.

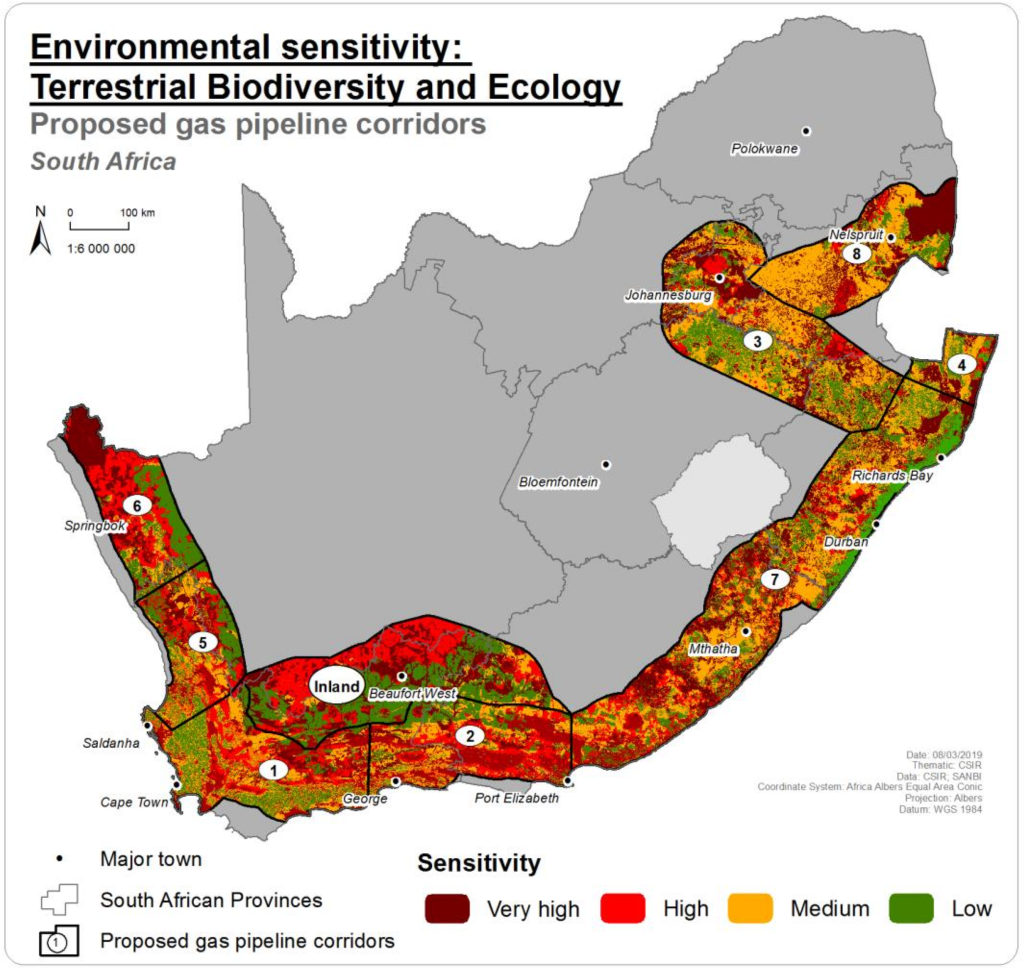


Figure i: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development.

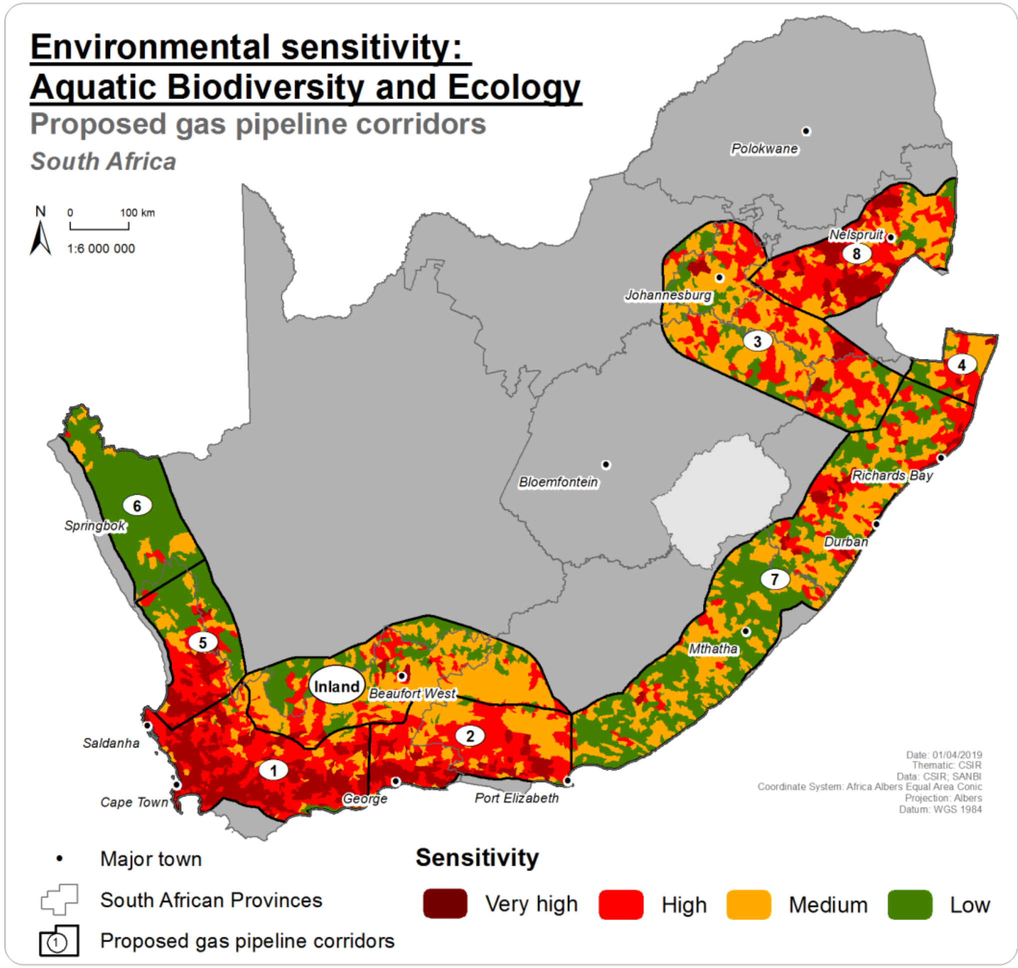


Figure ii: Environmental sensitivity of aquatic ecosystems to proposed gas pipeline development.

Key potential impacts of proposed gas pipeline development to terrestrial and aquatic ecosystems and biodiversity are mainly related to vegetation clearance and digging of trenches during construction, which may have consequences for terrestrial fauna directly (e.g. animals becoming trapped in open trenches), as well as birds (especially ground-dwelling species, and through habitat alteration and loss) and bats (mainly via habitat alteration and loss) (Figure iii) (Section 6).

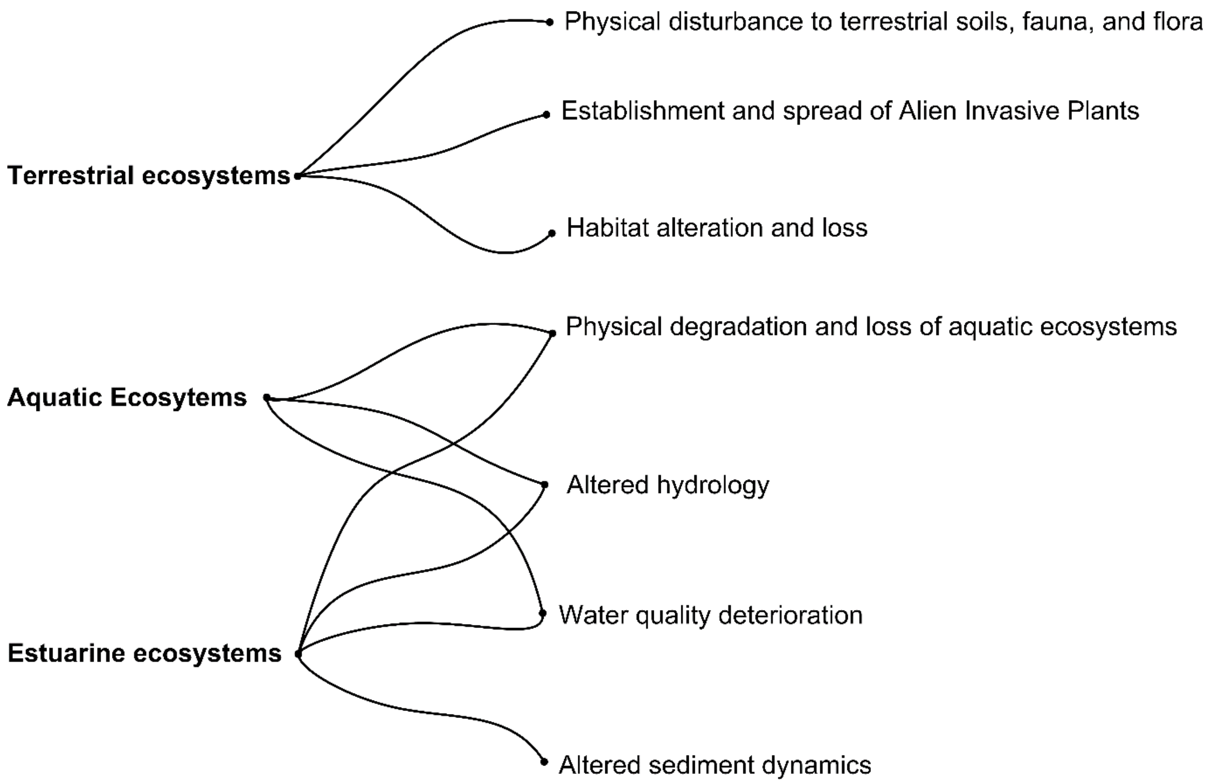


Figure iii: Key potential impacts of proposed gas pipeline development to terrestrial and aquatic systems.

The mitigation hierarchy must be applied for during all development phases of the proposed gas pipeline. Key mitigation measures include (Section 6):

- Avoid, as far as possible, the most sensitive areas identified in this assessment and areas identified by specialists in the field during subsequent environmental assessment (as and where required);
- Minimise footprint and construction duration;
- Minimise new development footprints through utilising existing infrastructure and disturbance corridors as far as possible;
- Minimise the potential impacts to terrestrial fauna through measures to ensure they do not get trapped in trenches and can continue to move freely;
- Manage and continuously control Invasive Alien Plants;
- Manage and continuously control soil erosion;
- Manage people and vehicles on- and around the site through proper induction, environmental awareness and monitoring of their activity; and
- Rehabilitate to a near-natural state as far as possible.

If mitigation and best practice measures are adhered to, it is expected that the risk to terrestrial and aquatic ecosystems and biodiversity from gas pipeline development can be reduced to acceptable levels (Section 7).

2 INTRODUCTION

This chapter consolidates and summarises the key findings from several independent specialist investigations (included as separate annexures to this chapter) as part of a Strategic Environmental Assessment (SEA) of the potential impacts from the development of gas transmission pipeline infrastructure in nine proposed corridors/phases (study areas) (Figure 1) on terrestrial and aquatic biodiversity and ecology. Furthermore, it recommends management actions and best practice mechanisms to avoid and minimise any potential negative impacts to sensitive ecosystems, the ecological processes that underpin their functioning, and the plant and animal species inhabiting those ecosystems.

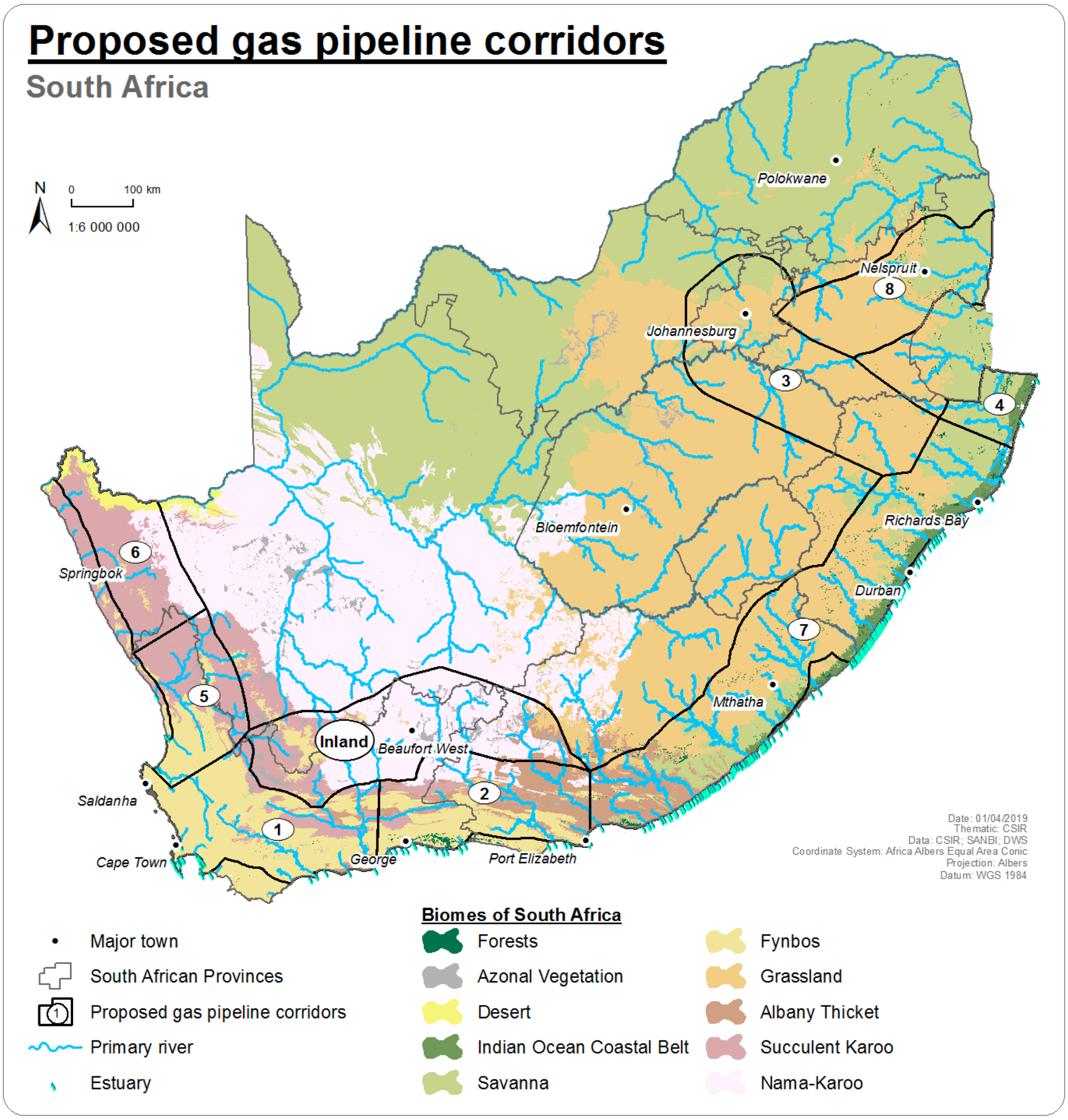


Figure 1: Location of the proposed gas pipeline corridors in South Africa with the key terrestrial and aquatic ecosystem components considered in this assessment.

2.1 Overview of gas pipeline development

Gas pipeline developments[1] are linear in nature and require total clearance of the aboveground vegetation for the installation of the underground pipes. Although this is a relatively narrow strip (~ 50 m wide for the construction right-of-way (ROW)), the cumulative length of hundreds of kilometres of pipelines can translate to thousands of hectares of destroyed biodiversity, if not restored appropriately. Furthermore, the soil disturbance during pipeline installation can leave these areas highly susceptible to invasion by invasive alien plant (IAP) species (e.g. Tyser & Worley, 1992), which will require active and long term control to prevent a number of secondary environmental impacts, such as sedimentation of watercourses.

The trench in which the pipeline is buried represents a substantial disruption of soil and drainage to a depth of approximately 2 m and width of 1.5 m, some effects of which, despite restoration, can persist for centuries. During construction, the trench acts as a temporary, but significant obstruction to animal movement.

Post-installation, and assuming full revegetation with indigenous flora, impacts are expected to be substantially less, although the vegetation in a narrow corridor (i.e. a 10 m wide operational servitude) will mostly exclude deep-rooted vegetation and large trees. Subsequently, the habitat along the pipeline may differ in species composition and structure from the original habitat, fragmenting the landscape, and impeding the movement of insects, small animals, birds, and plant propagules (Forman & Gordon, 1986; Xiao et al., 2014), especially if not fully restored to its initial biodiversity and vegetation structure. Additionally, if the routing of the pipeline is placed parallel to environmental gradients it is likely to have greater potential impacts on species movement and migration, and also may well cut through a large proportion of any one vegetation type as the vegetation also tends to follow gradients.

3 SCOPE OF BIODIVERSITY AND ECOLOGY FOR THIS ASSESSMENT

The ecological and biodiversity environmental aspects of the proposed gas pipeline phases have been grouped according to the biomes that are found within the proposed gas pipeline corridors (Figure 2). These act as the point of departure for terrestrial ecosystems and the fauna that inhabit these systems. Aquatic ecosystems considered include freshwater and estuarine habitats, and associated species (Figure 2). The Forest biome has not been included in this assessment (see Section 3.1 for all assumptions underpinning this assessment). Impacts to avifauna and bats posed by gas pipeline development is indirect, specifically due to habitat destruction potentially resulting in displacement and/or mortality.

[1] See Part 2 of the SEA report (Identification of gas pipeline corridors) for a detailed project description.

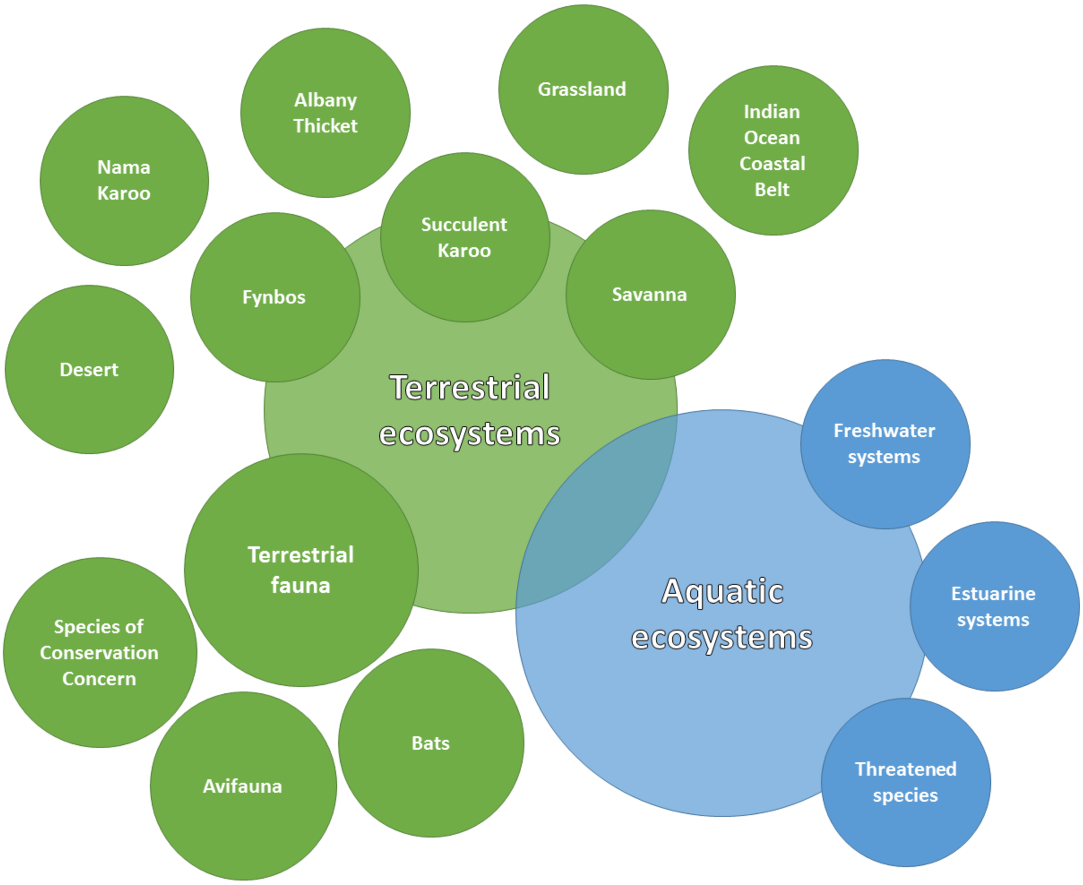


Figure 2: Overview of the terrestrial and aquatic ecosystem topics forming part of this strategic assessment, focussing on biomes, sensitive ecosystems, the ecological processes that underpin their functioning, and the plant and animal species inhabiting those ecosystems.

3.1 Assumptions and Limitations

The following assumptions and limitations form the point of departure for this assessment:

General

- This is a strategic-level, desktop assessment, aimed to identify potential environmental sensitivities based on existing spatial data at a high-level. The consideration of ecological pattern and process is limited by the resolution and scale of the spatial data. For site-specific routings of gas pipeline infrastructure, real-world conditions must be verified on the ground.
- This assessment makes use of information available and in a useable format. No fieldwork was done and no additional raw data were collected and/or processed.
- The onshore gas pipeline infrastructure considered in this assessment excludes:
    - associated infrastructure such as compressor stations, onshore facilities at the landfall and the facilities at the termini of the gas pipeline for distributing the gas (e.g. receiving terminals).
    - other facilities for servicing the line and detecting gas leaks; and
    - other aspects such the specific location and impacts of access routes, worker site camps, lay down and storage areas, waste disposal or borrow pits.
- Species records are limited to primarily areas which are easy to access and where monitoring is safe to undertake e.g. in Protected Areas (PAs). Datasets used in this study are likely to contain sampling bias. This has not been adjusted for or improved.

Terrestrial ecology

- The scales and spatial resolutions of input data varies (e.g. 30x30 m for land cover to units mapped at approximately 1:250 000 scale such as vegetation types). This heterogeneity is inappropriate for fine-scale analysis and interpretation, but can inform strategic, high-level planning.
- Provinces use separate approaches in their Biodiversity Spatial Plans to determine areas of high biodiversity importance and conservation concern. Sensitivity levels between provinces differ, with some provinces potentially using higher sensitivities than others. Provincial biodiversity conservation plans are used subject to all the assumptions that underpin the creation of those plans.
- The Forest biome has not been included in this assessment as it represents an engineering constraint for the gas pipeline due to the deep rooted systems. Therefore, the forest biome will be avoided for the routing of the gas pipeline. However, where the forest biome cannot be avoided by the gas pipeline route, due to the rare and sensitive environments that are associated with the biome, developers would be required to fulfil the requirements of the Environmental Impact Assessment (EIA) Regulations at the time.
- Biodiversity value, equates to biodiversity sensitivity, implying that for any given activity (like vegetation clearing) the associated impacts will be higher on areas of 'high biodiversity' value than on areas with 'medium' or 'low' value biodiversity. However, it requires the assumption that the same sensitivity designations will respond to impacts in a similar way. This is not always true as there may be different reasons (biodiversity features) for sensitivity classifications, and these biodiversity features may not respond the same to any particular stress.

Freshwater

- Quinary/sub-quaternary catchments were used as the primary unit of scale for analyses allowing for integration of multiple datasets (e.g. points, lines, polygons) to ensure continuity in the output that are also comparable.
- The conservation importance/threat status of wetlands was determined using the national wetland vegetation groups.
- PA layers were not used for the freshwater ecosystems assessment. Freshwater features are inherently less sensitive given the levels of protection. It was assumed that PAs will be accounted for in the main integration of all data layers and development of the cost surface - in this regard all freshwater ecosystems and features will be treated with a high sensitivity.

Estuaries

- This assessment assumes that only below-ground construction methods will be considered for estuary crossings by gas pipelines. Three below-ground methods have been investigated, namely wet open-cut construction, isolated (dry-open cut) construction and Horizontal Directional Drilling (HDD).
- Given elevated water tables, corrosion associated with salt water and scouring potential associated with estuaries, above ground construction methods for the proposed gas pipeline (i.e. diverting over the river bed in the form of pipe-bridges or suspension below existing bridge infrastructure) were also assessed for completeness.
- At the broad, overview scale of this strategic assessment, operational phases involving pipeline maintenance is assumed largely to be similar for all of the above-mentioned pipeline construction options.
- Due to the strategic nature of the assessment and the expansive area under investigation, a generic approach was applied, selecting a suite of key estuarine attributes considered appropriate, to assess impact and associated risks for various construction methods, and during operation.
- This assessment provides a broad scale sensitivity rating for estuaries in the various corridors. As all estuaries are sensitive to altered sediment and hydrodynamic processes, more detailed spatially scaled sensitivity demarcation within the study areas will need to be refined during the detailed planning and construction phases.

Species

- The potential presence of fauna species, in particular terrestrial invertebrate groups in each of the assessed biomes was evaluated based on existing literature and available databases. However, data contained within some of these species databases are coarse and insufficient to be able to identify endemics with any certainty, and the threat status of most invertebrate groups has not been assessed according to the International Union for Conservation of Nature (IUCN) criteria. A further limitation was that some datasets are outdated, or lacking data for certain areas of ecological importance within each biome.

3.2 Spatial Data

This analysis made extensive use of data resources arising from the following spatial datasets listed Table 1 - Table 6.

3.2.1 Terrestrial ecology

Table 1: Available spatial data pertaining to terrestrial ecological features used in this assessment.

Feature	Source	Summary
TERRESTRIAL ECOSYSTEMS		
Provincial conservation planning	Northern Cape DENC. 2016. Critical Biodiversity Areas of the Northern Cape. http://bgis.sanbi.org/.	The Northern Cape Critical Biodiversity Area (CBA) Map identifies biodiversity priority areas, called CBAs and Ecological Support Areas (ESAs), which, together with protected areas, are important for the persistence of a viable representative sample of all ecosystem types and species as well as the long-term ecological functioning of the landscape as a whole.
	Western Cape CapeNature. 2017. Western Cape Biodiversity Spatial Plan 2017. http://bgis.sanbi.org/. Cape Town CoCT. 2016. City of Cape Town Biodiversity Network. http://bgis.sanbi.org/.	The Western Cape Biodiversity Spatial Plan (WCBSP) is the product of a systematic biodiversity planning assessment that delineates, on a map (via a Geographic Information System (GIS)), CBAs and ESAs which require safeguarding to ensure the continued existence and functioning of species and ecosystems, including the delivery of ecosystem services, across terrestrial and freshwater realms. These spatial priorities are used to inform sustainable development in the Western Cape Province. This product replaces all previous systematic biodiversity planning products and sector plans with updated layers and features.
	Eastern Cape DEDEAT. 2017. Eastern Cape Biodiversity Conservation Plan Handbook. DEDEAT: King Williams Town. Compiled by G. Hawley, P. Desmet and D. Berliner. Draft version, December 2017.	Significant strides have been made with respect to refining the spatial representation of biodiversity pattern and biodiversity processes, as well as establishing standardised minimum requirements for spatial biodiversity planning that ensure a level of consistency throughout the country (SANBI, 2017). The Eastern Cape Biodiversity Conservation Plan (ECBCP) 2017 replaces the ECBCP 2007 in its entirety, and is a tool that guides and informs land use and resource-use planning and decision-making by a full range of sectors whose policies, programmes and decisions impact on biodiversity, in order to preserve long-term functioning and health of priority areas – CBAs and ESAs.
	KwaZulu-Natal Ezemvelo KZN Wildlife. 2016. KwaZulu-Natal Biodiversity Sector Plans. http://bgis.sanbi.org/.	Critical biodiversity assets in KwaZulu-Natal District Municipalities with associated management guidelines which aim to maintain the integrity of these biodiversity features. The key purpose is to assist and guide land use planners and managers within various district and local municipalities, to account for biodiversity conservation priorities in all land use planning and management decisions, thereby promoting sustainable development and

Feature	Source	Summary
TERRESTRIAL ECOSYSTEMS		
		the protection of biodiversity, and in turn the protection of ecological infrastructure and associated ecosystem services.
	Mpumalanga MTPA. 2014. Mpumalanga Biodiversity Sector Plan. http://bgis.sanbi.org/.	Mpumalanga Biodiversity Sector Plan (MBSP) terrestrial assessment is based on a systematic biodiversity planning approach to identify spatial priority areas that meet both national and provincial targets in the most efficient way possible, while trying to avoid conflict with other land-uses. It actively tries to build-in landscape resilience to a changing climate. These spatial priorities are used to inform sustainable development within Mpumalanga. It replaces the MBCPv1 product with updated layers and features. Terminology follows that of South Africa's Biodiversity Act governing the gazetting of Bioregional Plans. A 2010 land-cover map is used based on SPOT5 imagery, as well as old lands mapped of earliest 1: 50 000 topographical maps and earliest suitable Landsat 7 imagery.
	Gauteng GDARD. 2011. Gauteng CPlan Version 3.3. http://bgis.sanbi.org/.	The C-Plan serves as the primary decision support tool for the biodiversity component of the Environmental Impact Assessment (EIA) process; informs protected area expansion and biodiversity stewardship programmes in the province; and serves as a basis for development of Bioregional Plans in municipalities within the province.
	North West NW READ. 2015. North West Terrestrial Critical Biodiversity Areas. http://bgis.sanbi.org/.	A refined and updated CBA map for the North West Province planning domain was developed through integrating existing and new data.
	Free State DESTEA. 2015. Free State Biodiversity Plan. http://bgis.sanbi.org/.	A key output of the systematic biodiversity planning process is a map indicating CBAs and ESAs. CBAs are areas that are important for conserving biodiversity while ESAs are areas that are important to ensure the long term persistence of species or functioning of other important ecosystems. Degradation of CBAs or ESAs could potentially result in the loss of important biodiversity features and/or their supporting ecosystems.
**Aquatic components of provincial conservation plans were also considered in the spatial sensitivity analysis for freshwater ecosystems*		
Protected and Conservation Areas	DEA. 2018a. South African Protected Areas Database (SAPAD). Q2, 2018. https://egis.environment.gov.za/. DEA. 2018b. South African Conservation Areas Database (SACAD). Q2, 2018. https://egis.environment.gov.za/.	Protected areas as defined in the National Environmental Management: Protected Areas Act, (Act 57 of 2003) (NEM:PAA). Protected areas: • Special nature reserves; • National parks; • Nature reserves; • Protected environments (1-4 declared in terms of the National Environmental Management: Protected Areas Act, 2003); • World heritage sites declared in terms of the World Heritage Convention Act; • Marine protected areas declared in terms of the Marine Living Resources Act;

Feature	Source	Summary
TERRESTRIAL ECOSYSTEMS		
		• Specially protected forest areas, forest nature reserves, and forest wilderness areas declared in terms of the National Forests Act, 1998 (Act 84 of 1998); • Mountain catchment areas declared in terms of the Mountain Catchment Areas Act, 1970 (Act 63 of 1970). Conservation Areas: • Biosphere reserves; • Ramsar sites; • Stewardship agreements (other than nature reserves and protected environments); • Botanical gardens; • Transfrontier conservation areas; • Transfrontier parks; • Military conservation areas; • Conservancies.
**Protected and conservation areas were considered used in the spatial sensitivity analysis for avifauna*		
National Protected Area Expansion Strategy (NPAES) focus areas	SANParks. 2010. National Protected Areas Expansion Strategy: Focus areas for protected area Expansion. http://bgis.sanbi.org/.	Focus areas for land-based protected area expansion are large, intact and unfragmented areas of high importance for biodiversity representation and ecological persistence, suitable for the creation or expansion of large protected areas. Representative of opportunities for meeting the ecosystem-specific protected area targets set in the NPAES, and were designed with strong emphasis on climate change resilience and requirements for protecting freshwater ecosystems.
Vegetation of South Africa	SANBI. 2018. Vegetation Map of South Africa, Lesotho and Swaziland. http://bgis.sanbi.org/.	Update of the Vegetation Map of South Africa, Lesotho and Swaziland (Mucina & Rutherford, 2006; SANBI, 2012) based on decisions made by the National Vegetation map Committee and contributions by various partners.
Threatened ecosystems	DEA (2011). South African Government Gazette. National Environmental Management: Biodiversity Act: National list of ecosystems that are threatened and in need of protection. Government Gazette, 558(34809). http://bgis.sanbi.org/.	The Biodiversity Act (Act 10 of 2004) provides for listing of threatened or protected ecosystems, in one of four categories: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or protected. The purpose of listing threatened ecosystems is primarily to reduce the rate of ecosystem and species extinction. This includes preventing further degradation and loss of structure, function and composition of threatened ecosystems. The purpose of listing protected ecosystems is primarily to preserve sites of exceptionally high conservation value.
**Vegetation of South Africa was also considered in the spatial sensitivity analysis for avifauna.*		
National Land Cover	Geoterraimage. 2015. 2013-2014 South African National Land-Cover. Department of Environmental Affairs. Geospatial Data.	Recent global availability of Landsat 8 satellite imagery enabled the generation of new, national land-cover dataset1 for South Africa, circa 2013-14, replacing and updating the

Feature	Source	Summary
TERRESTRIAL ECOSYSTEMS		
	https://egis.environment.gov.za/.	previous 1994 and 2000 South African National Landcover datasets. The 2013-14 national land-cover dataset is based on 30x30m raster cells, and is ideally suited for ± 1:75,000 - 1:250,000 scale GIS-based mapping and modelling applications. Land cover are categorised into different classes, which broadly include: • Bare none vegetated • Cultivated • Erosion • Grassland • Indigenous Forest • Low shrubland • Mines/mining • Plantation • Shrubland fynbos • Thicket /Dense bush • Urban • Water • Woodland/Open bush
**National Land Cover was also considered in the spatial sensitivity analysis for avifauna and bats.*		
Ecoregions	Burgess et al. 2004. Terrestrial ecoregions of Africa and Madagascar: A conservation Assessment. Island Press: Washington DC. Geospatial data by SANBI.	Biodiversity patterns, threats to biodiversity, and resulting conservation priorities of biological units (rather than political units).
National Forests	DAFF. 2016. National Forest Inventory. https://www.daff.gov.za/daffweb3/Branches/Forestry-Natural-Resources-Management/Forestry-Regulation-Oversight/Forests/Urban-Forests/Forestry-Maps	Indigenous forest patches protected in terms of the NFA.
Karoo ecological and biodiversity sensitivity	Holness et al. 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/	Terrestrial and aquatic ecosystem sensitivities specific to Karoo ecology and biodiversity, including fauna and flora that were mapped in the Shale Gas Strategic Environmental Assessment (SEA) are specific to that SEA and Shale Gas development as such, and these are not considered directly transferrable to the current Gas Pipeline Corridor study. But areas that were mapped as Very High sensitivity are considered in this study to represent biodiversity priority areas and are also used here within the area of overlap of these two assessments.
	Skowno et al. 2015. Terrestrial and Aquatic Biodiversity Scoping Assessment. In: Van der Westhuizen, C., Cape-Ducluzeau, L. and	Terrestrial and aquatic ecosystems sensitivities specific to Karoo ecology and biodiversity, including fauna and flora that were mapped in the Wind and Solar SEA (REDZ) are specific

Feature	Source	Summary
TERRESTRIAL ECOSYSTEMS		
	Lochner, P. (eds.). (2015). Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa. Department of Environmental Affairs, 2015. CSIR Report Number: CSIR/CAS/EMS/ER/2015/0001/B. Stellenbosch. Available athttps://redzs.csir.co.za/wp-content/uploads/2017/04/ Wind-and-Solar-SEA-Report-Appendix-C-Specialist-Studies.pdf	to that SEA and renewable energy development as such, and these are not considered directly transferrable to the current Gas Pipeline Corridors SEA study. But areas that were mapped as Very High sensitivity are considered in this study to represent biodiversity priority areas and are also used here within the area of overlap of these two assessments.
Field crop boundaries	DAFF. 2014. Field Crop Boundaries. Available at: http://bea.dirisa.org/resources/metadata-sheets/WP03_00_META_FIELDCROP.pdf	Data on field crop extent and type of cultivation DAFF for South Africa.

3.2.2 Aquatic ecosystems

3.2.2.1 Freshwater ecology

Table 2: Available spatial data pertaining to freshwater ecological features used in this assessment.

Feature	Source	Summary
FRESHWATER		
SQ4 sub-quaternary drainage regions (referred to as SQ4 catchments)	DWS. 2009. Working copies of sub-quaternary catchments for delineation of management areas for the National Freshwater Ecosystem Priority Areas (NFEPA) in South Africa project - 2009 draft version. http://www.dwa.gov.za/iwqs/gis_data/.	Catchment areas that define the drainage regions of the NEFPA river reaches, which include 9 433 catchments ranging from 0.25 to 400 000 hectares. The gas pipeline corridors include 4 843 SQ4 catchments ranging from 0.1 to 115 000 hectares. These catchment areas are used as the primary spatial unit for analysis in the freshwater component.
River Ecoregions (Level 1 and 2)	Kleynhans, C.J., Thirion, C. & Moolman, J., 2005. A level I river ecoregion classification system for South Africa, Lesotho and Swaziland. Pretoria: Department of Water Affairs and Forestry.	A delineation of ecoregions for South Africa as derived from terrain, vegetation, altitude, geomorphology, rainfall, runoff variability, air temperature, geology and soil. There are 31 Level 1 and 219 Level 2 River Ecoregions in South Africa, of which 25 Level 1 and 97 Level 2 River Ecoregions occur within the gas pipeline corridors.
River Present Ecological State (PES), Ecological Importance (EI) and Ecological Sensitivity (ES)	DWS. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx.	A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa conducted in 2013.

Feature	Source	Summary
FRESHWATER		
NFEPA Rivers and Wetlands	Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L. and Nienaber, S. 2011. Technical Report for the National Freshwater Ecosystem Priority Areas project. Pretoria: Water Research Commission, WRC Report No. K5/1801.	The NFEPA coverages provide specific spatial information for rivers according to the DWS 1:500 000 rivers coverage, including river condition, river ecosystem types, fish sanctuaries, and flagship/free-flowing rivers. The NFEPA coverages also provide specific information for wetlands such as wetland ecosystem types and condition (note: wetland delineations were based largely on remotely-sensed imagery and therefore did not include historic wetlands lost through transformation and land use activities).
Ramsar Sites	Ramsar Convention. 2018. Convention on Wetlands of International Importance especially as Waterfowl Habitat. https://www.ramsar.org/	Distribution and extent of areas that contain wetlands of international importance in South Africa.
National Wetland Vegetation Groups	Nel, J.L. and Driver, A. 2012. South African National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component. Stellenbosch: Council for Scientific and Industrial Research. CSIR Report Number: CSIR/NRE/ECO/IR/2012/0022/A.	A vector layer developed during the 2011 NBA to define wetland vegetation groups to classify wetlands according to Level 2 of the national wetland classification system (SANBI, 2010). The wetland vegetation groups provide the regional context within which wetlands occur, and is the latest available classification of threat status of wetlands that are broadly defined by the associated wetland vegetation group. This is considered more practical level of classification to the Level 4 wetland types owing to the inherent low confidence in the desktop classification of hydrogeomorphic units (HGM) that was used at the time of the 2011 NBA.
Provincial Wetland Probability Mapping	Collins, N. 2017. National Biodiversity Assessment (NBA) 2018. Wetland Probability Map. https://csir.maps.arcgis.com/apps/MapJournal/index.html?appid=8832bd2cbc0d4a5486a52c843daebcba#	Mapping of wetland areas based on a concept of water accumulation in the lowest position of the landscape, which is likely to support wetlands assuming sufficient availability water to allow for the development of the indicators and criteria used for identifying and delineating wetlands. This method of predicting wetlands in a landscape setting is more suitable for certain regions of the country than in others.
Mpumalanga Highveld Wetlands	SANBI. 2014. Mpumalanga Highveld Wetlands. http://bgis.sanbi.org/.	Wetland delineations for the Mpumalanga Highveld based on desktop mapping using Spot 5 imagery, supported by Google Earth, 1:50 000 contours, 1:50 000 rivers, exigent data, and NFEPA wetlands. This is an update of previous mapping through desktop digitising, ground-truthing and reviewing mapped data. Additional analysis was conducted to determine changes to ecosystem threat status, protection level and FEPAs.
**Wetlands and rivers were also considered in the spatial sensitivity analysis for bats.* **Coastal rivers, wetlands and seeps above or adjacent to estuaries were also considered in the spatial sensitivity analysis for estuaries.*		

3.2.2.2 Estuarine ecology

Table 3: Available spatial data pertaining to estuarine ecological features used in this assessment.

Feature	Source	Summary
ESTUARINE		
Estuarine health	Van Niekerk, L. & Turpie, J.K. (Eds). 2012. National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch. http://bgis.sanbi.org/nba/project.asp.	A desktop national health assessment for n early 300 estuaries in South Africa. Estuary health assessment was based on the Estuarine Health Index developed for South African ecological water requirement studies that has been applied systematically to over 30 estuaries at various levels of data richness and confidence.
	Van Niekerk, L. et al. 2013. Country-wide assessment of estuary health: An approach for integrating pressures and ecosystem response in a data limited environment. Estuarine, Coastal and Shelf Science, 130: 239-251.	A country-wide assessment of the ~300 functional South African estuaries examined both key pressures (freshwater inflow modification, water quality, artificial breaching of temporarily open/closed systems, habitat modification and exploitation of living resources) and health statue.
	SANBI. 2018. Interim findings of the National Biodiversity Assessment (work in progress). As available.	Assessment of the state of South Africa's estuarine biodiversity based on best available science, with a view to understanding trends over time and informing policy and decision-making. In progress – to be published in 2019.
Estuary ecological classification	Van Niekerk, L. et al. 2015. Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa. Water Research Commission Report No K5/2187.	EcoClassification for estuaries that provided a comparative, regional scale assessment. The Provisional EcoClassification refers to the Present Ecological Status (PES), the ecological importance and protection status, a Provisional Recommended Ecological Category (REC), as well as mitigation measures towards achieving the Provisional REC.
Estuaries in Formally /desired protected areas	Turpie, J.K. et al. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.	Marine, estuarine and terrestrial areas that are under formal protection or estuaries identified as desired protected areas in the National Estuaries Biodiversity Plan.
Estuaries of high biodiversity importance	Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S., & Van Niekerk, L. 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA,* 28: 191-206.	In South Africa, estuary biodiversity importance is based on the importance of an estuary for plants, invertebrates, fish and birds, using rarity indices. The Estuary Importance Rating takes size, the rarity of the estuary type within its biographical zone, habitat and the biodiversity importance of the estuary into account.

Feature	Source	Summary
ESTUARINE		
Important nurseries	Van Niekerk, L. et al. 2017. A multi-sector Resource Planning Platform for South Africa's estuaries. Water Research Commission Report No K5/2464 Lamberth, S.J. & Turpie, J.K. 2003. The role of estuaries in South African fisheries: economic importance and management implications. *African Journal of Marine Science*, 25: 131-157.	Estuaries that are critically important nursery areas for fish and invertebrates and make an important contribution towards estuarine and coastal fisheries.
Important estuarine habitats		Estuaries that support important rare or sensitive habitats (saltmarsh, mangroves, swamp forest) that provide important ecosystem services.
Natural or near natural condition estuaries		Estuaries in good condition (designated by an A or B health category are more sensitive to development (likely to degrade in overall condition).
**Estuaries were also considered in the spatial sensitivity analysis for avifauna*		

3.2.3 Species

3.2.3.1 Terrestrial and aquatic fauna

Table 4: Available spatial data pertaining to terrestrial and aquatic species used in this assessment.

Feature	Source	Summary
TERRESTRIAL AND AQUATIC FAUNA		
Red Data species	<u>Mammals</u> Child et al. (*Eds*). 2016. The 2016 Red List of Mammals of South Africa, Swaziland and Lesotho. SANBI & EWT: South Africa	Known spatial locations for recorded Red Listed mammals in South Africa.
	<u>Reptiles</u> Bates et al. (*Eds*). Atlas and red data list of the reptiles of South Africa, Lesotho and Swaziland. SANBI: Pretoria (Suricata series; no. 1).	Known spatial locations for recorded Red Listed reptiles in South Africa.

Feature	Source	Summary
TERRESTRIAL AND AQUATIC FAUNA		
	Amphibians Minter, L.R. 2004. Atlas and red data book of the frogs of South Africa, Lesotho, and Swaziland. Avian Demography Unit: UCT.	Known spatial locations for recorded Red Listed ambhibians in South Africa.
	Plants Raimondo et al. 2009 (as updated in 2018). Red list of South African plants 2009, 2018 update. South African National Biodiversity Institute.	Known spatial locations for recorded Red Listed terrestrial and aquaticplants in South Africa.
	Fish distributions IUCN. 2017. The IUCN Red List of Threatened Species, 2017. http://www.iucnredlist.org/	Distribution data for selected fish species where point data was found to be lacking/insufficient was obtained from the IUCN Red List of Threatened Species Map Viewer with data presented as catchment distributions. The IUCN distributions were spatially inferred using the SQ4 catchments for 22 of the selected fish species.
	Freshwater fish Coetzer, W. 2017. Occurrence records of southern African aquatic biodiversity. Version 1.10. The South African Institute for Aquatic Biodiversity. https://doi.org/10.15468/pv7vds	Known spatial locations for recorded Red Listed freshwater fish in South Africa.
	Aquatic macro-invertebrates DWS. 2015. Invertebrate Distribution Records. [online] Department of Water and Sanitation RQIS-RDM, Pretoria. Available at: http://www.dwa.gov.za/iwqs/biomon /inverts/invertmaps.htm/ and http://www.dwa.gov.za/iwqs/biomon/inverts/ invertmaps_other.htm/	Known spatial locations for recorded aquatic macro-invertebrate Families from 4 350 monitoring sites on South African rivers.
	Butterflies Henning, G.A., Terblanche, R.F. and Ball, J.B., 2009. South African red data book: butterflies. Mecenero S, Ball JB, Edge DA, Hamer ML, Henning GA, Kruger M, Pringle EL, Terblanche RF, Williams MC (*Eds*). 2013. Conservation assessment of butterflies of South Africa, Lesotho and Swaziland: Red List and Atlas.	Known spatial locations for recorded Red Listed butterflies in South Africa.

Feature	Source	Summary
TERRESTRIAL AND AQUATIC FAUNA		
	Saftronics, Johannesburg and Animal Demography Unit, Cape Town.	
	<u>Dragonflies and damselflies (Odonata)</u> IUCN. 2017. The IUCN Red List of Threatened Species, 2017.3. http://www.iucnredlist.org/ Samways, M.J. & Simaika, J.P. 2016. Manual of Freshwater Assessment for South Africa: Dragonfly Biotic Index. SANBI: Pretoria: Suricata 2, p. 224.	Known spatial locations for recorded dragonflies and damselflies taken from a total of 38 887 records within South Africa. This data includes records of the conservation important Odonata selected for this assessment.

3.2.3.2 Birds

Table 5: Available spatial data pertaining to avifauna species and their environment used in this assessment.

Feature	Source	Summary
AVIFAUNA		
The Southern African Bird Atlas 1 (SABAP1)	UCT.1997. The Southern African Bird Atlas 1 (SABAP1). Animal Demography Unit, UCT.	The Southern African Bird Atlas Project (SABAP) was conducted between 1987 and 1991.Because a new bird atlas was started in southern Africa in 2007, the earlier project is now referred to as SABAP1. SABAP1 covered six countries: Botswana, Lesotho, Namibia, South Africa, Swaziland and Zimbabwe. At the time, Mozambique was engulfed in a civil war, and had to be excluded. The resolution for SABAP1 was the quarter degree grid cell (QDGC), 15 minutes of latitude by 15 minutes of longitude, 27.4 km north-south and about 25 km east-west, an area of about 700 km². Fieldwork was conducted mainly in the five-year period 1987–1991, but the project coordinators included all suitable data collected from 1980–1987. In some areas, particularly those that were remote and inaccessible, data collection continued until 1993. Fieldwork was undertaken mainly by birders, and most of it was done on a volunteer basis. Fieldwork consisted of compiling bird lists for the QDGCs. All the checklists were fully captured into a database. The final dataset consisted of 147 605 checklists, containing a total of 7.3 million records of bird distribution. Of the total 3973 QDGCs, only 88 had no checklists (2.2% of the total).

Feature	Source	Summary
AVIFAUNA		
The Southern African Bird Atlas 2 (SABAP2)	UCT. 2007 - present. The Southern African Bird Atlas 2 (SABAP2). Animal Demography Unit, UCT.	SABAP2 is the follow-up project to the Southern African Bird Atlas Project (for which the acronym was SABAP, and which is now referred to as SABAP1). This first bird atlas project took place from 1987-1991. The second bird atlas project started on 1 July 2007 and plans to run indefinitely. The current project is a joint venture between the Animal Demography Unit at the University of Cape Town, BirdLife South Africa and the South African National Biodiversity Institute (SANBI). The project aims to map the distribution and relative abundance of birds in southern Africa and the atlas area includes South Africa, Lesotho and Swaziland. SABAP2 was launched in Namibia in May 2012. The field work for this project is done by more than one thousand five hundred volunteer birders. The unit of data collection is the pentad, five minutes of latitude by five minutes of longitude, squares with sides of roughly 9km. At the end of June 2017, the SABAP2 database contained more than 189,000 checklists. The milestone of 10 million records of bird distribution in the SABAP2 database was less than 300,000 records away. Nine million records were reached on 29 December 2016, eight months after reaching 8 million on 14 April 2016, which in turn was eight months after reaching seven million on 22 August 2015, and 10 months after the six million record milestone. More than 78% of the original SABAP2 atlas area (i.e. South Africa, Lesotho and Swaziland) has at least one checklist at this stage in the project's development. More than 36% of pentads have four or more lists.
Crane, raptor and vulture nests	EWT. 2006a (as supplemented by more recent unpublished data). Nest database for cranes, raptors and vultures. Endangered Wildlife Trust.	Data on crane, vulture and raptor nests collected by the various programmes of the EWT. Absence of records does not imply absence of the species within an area, but simply that this area may not have been surveyed. All recorded nesting sites were included, no verification of current status of nests were conducted.
National vulture restaurant database	VulPro 2017. National vulture restaurant database. http://www.vulpro.com/.	The register contains a georeferenced list of vulture restaurants throughout South Africa as compiled by VulPro. All recorded vulture restaurants were included; no verification of current status of vulture restaurants was conducted.
Eagle nests on Eskom transmission lines in the Karoo	EWT. 2006b (as supplemented by more recent unpublished data). List of eagle nests on Ekom transmission lines in the Karoo.	The dataset contains a georeferenced list of Tawny Eagle, Martial Eagle and Verreaux's Eagle nests on transmission lines in the Karoo as at 2006. All recorded nesting sites were included, no verification of current status of nests were conducted.
Locality of Red Data nests	Unpublished data from pre-construction monitoring at renewable energy projects from 2010 - 2018, obtained from various avifaunal specialists.	Nests of various raptors, including Verreaux's Eagle, Martial Eagle, Tawny Eagle, African Crowned Eagle, Wattled Crane, White-backed Vulture collected in the course of pre-construction monitoring at proposed renewable energy projects in the Western, Northern, and Eastern Cape, and KZN.
Cape Vulture colonies	VulPro & EWT. 2018. The national register of Cape Vulture colonies.	The dataset contains a georeferenced list of Cape Vulture colonies, as well as the results of the 2013 aerial survey of Cape Vulture colonies conducted by Eskom, EWT and Birdlife South Africa (BLSA) in the former Transkei, Eastern Cape.
Blue Swallow breeding areas	Ezemvelo KZN Wildlife. 2018. Blue Swallow breeding areas.	The KZN Mistbelt Grassland Important Bird Area (IBA) which incorporates all the known patches of grassland where Blue Swallows are known to nest and forage, plus additional nests sites outside the

Feature	Source	Summary
AVIFAUNA		
		IBA. No verification of current status of nests was conducted.
Southern Ground Hornbills nesting areas.	MGHP. 2018. Potential nesting areas of Southern Ground Hornbills. http://ground-hornbill.org.za/	The data consists of a list of pentads where the species was sighted in Kwa-Zulu-Natal, Mpumalanga and the Eastern Cape. Data was provided in pentad format. The assumption was made that the species would be breeding within the pentad.
Various Red Data bird species nests	CSIR. 2015. Information on various Red Data species nests obtained from the Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa.	The data comprise nest localities of Black Harrier, Martial Eagle, Verreaux's Eagle, Blue Crane, Lanner Falcon, in the 8 solar and wind focus areas where they overlap with the gas phases.
Southern Bald Ibis breeding colonies.	BLSA. 2015a. Nest localities of Southern Bald Ibis. https://www.birdlife.org.za/	The data comprises nest localities of Southern Bald Ibis collected by Dr. Kate Henderson as part of her PhD studies.
Important Bird and Biodiversity Areas of South Africa	BLSA. 2015b. Important Bird and Biodiversity Areas of South Africa. https://www.birdlife.org.za/	National inventory of the Important Bird or Biodiversity Areas of South Africa, compiled by BirdLife South Africa.
Potential Bush Blackcap, Spotted Ground-Thrush and Orange Ground-Thrush breeding habitat.	BLSA. 2018a. A list of potential Bush Blackcap, Spotted Ground-Thrush and Orange Ground-Thrush breeding habitat. https://www.birdlife.org.za/.	The results of a modelling exercise undertaken by BirdLife South Africa to identify critical breeding habitat for three key forest – dwelling Red Data species.
Yellow-breasted Pipit core distribution	BLSA. 2018b. Yellow-breasted Pipit core distribution mapping. https://www.birdlife.org.za/.	Map of core distribution/breeding areas based on the modelling of key aspects of the species' biology.
Rudd's Lark core distribution	BLSA. 2018c. Rudd's Lark core distribution mapping. https://www.birdlife.org.za/.	Map of core distribution/breeding areas based on the modelling of key aspects of the species' biology.
Botha's Lark core distribution	BLSA. 2018d. Botha's Lark core distribution mapping. https://www.birdlife.org.za/.	Map of core distribution/breeding areas based on the modelling of key aspects of the species' biology.
White-winged Flufftail confirmed sightings 2000 – 2014	BLSA. 2014. White-winged Flufftail confirmed sightings 2000 – 2014. https://www.birdlife.org.za/.	A list of wetlands where this Critically Endangered (CR) species has been recorded in South Africa which includes the locality where the first breeding for the region has recently been confirmed.
Bearded Vulture nest sites in KwaZulu – Natal	Ezemvelo KZN Wildlife. 2013. Bearded Vulture nest sites in KwaZulu – Natal Maloti-Drakensberg Vulture Project, Dr Sonja Krűger.	The results of nest surveys conducted from 2000 -2012
Red Data nest localities in the Western Cape	CapeNature. 2018. Red Data nest localities in the Western Cape. https://www.capenature.co.za/	A list of nest localities of Black Harrier, Blue Crane, Verreaux's Eagle.

1

3.2.3.3 Bats

Table 6: Available spatial data pertaining to bat species and their environment used in this assessment.

Feature	Source	Summary
BATS		
Terrestrial Ecoregions	TNC. 2009. Terrestrial ecoregions. http://maps.tnc.org/gis_data.html	The terrestrial ecoregions for South Africa, Swaziland and Lesotho. From numerous monitoring assessments, Inkululeko Wildlife Services has calculated average bat passes per hour for the seven of the ecoregions to gain an understanding of the bat activity levels in each.
Geology	CGS. 1997. 1: 1M geological data.	Four main lithologies were selected as relevant to bats in terms of bat roosting potential: Limestone, Dolomite, Arenite and Sedimentary and Extrusive rock.
Bat Roosts	Published and unpublished data obtained from a variety of scientists and bat specialists, including: Animalia fieldwork database. Obtained from Werner Marais in July 2013. Bats KZN fieldwork database. Obtained from Leigh Richards and Kate Richardson in July 2017. David Jacobs fieldwork database. Obtained from David Jacobs in May 2018. Herselman, J.C. and Norton, P.M. 1985. The distribution and status of bats (Mammalia: Chiroptera) in the Cape Province. Annals of the Cape Province Museum (Natural History) 16: 73-126. Inkululeko Wildlife Services fieldwork database. Obtained from Kate MacEwan in March 2018. Rautenbach, I.L. 1982. Mammals of the Transvaal. No. 1, Ecoplan Monograph. Pretoria, South Africa. Wingate, L. 1983. The population status of five species of Microchiroptera in Natal. M.Sc. Thesis, University of Natal.	A few of the points known to not be true bat roost locations were removed. Some points were moved, as the projection had put them in the ocean. Due to mainly construction phase impacts being the concern for bats, a minimum 500 m radial buffer was placed on each roost, irrespective of size or species.
Bat species occurrence data	Database from a collection of scientists and organisations. Collated by SANBI and the EWT	Extent of Occurrences (EoOs) were compiled for conservation important and certain high-risk bat species using the Child et al. (2016) species point data. These are simply points where one or more

Feature	Source	Summary
BATS		
	in 2016 for use in the National Bat Red Data listings. Child, M.F., Roxburgh, L., Do Linh San, E., Raimondo, D., Davies-Mostert, H.T. (*Eds*). 2016. The 2016 Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa.	individuals from a particular species were confirmed from museum and scientific records. Because bats travel extensive distances nightly and some seasonally, these points are an under-estimation of the area each individual will occupy in their lifetime. Therefore, an arbitrary 50 km radius was placed around each confirmed point record to buffer for some or all of the potential movement or habitat spread. Then, a best fit polygon (the tightest possible polygon) was drawn around these radii to create an EoO for each relevant species. This is deemed as the maximum known extent that each species occurs in. However, the process did not exclude areas within the polygon where the bats are unlikely to occur due to disturbance or unfavourable habitat, i.e. the polygons did not represent the true area of occupancy (AoO). AoO is defined as the area within its EoO which is occupied by a taxon, excluding cases of vagrancy. In other words, the AoO is a more refined EoO that takes the detailed life history of each species into account. An AoO reflects the fact that a taxon will not usually occur throughout its entire EoO because the entire area may contain unsuitable or unoccupied habitats. To compile more AoOs per species is a significant task, beyond the scope of this SEA.

3.3 Relevant international, provincial and local legal instruments

Table 7 presents legislation and legal instrument relating to sustainable development and nature conservation that would have to be taken into account and adhered to (where relevant) for the development of gas pipeline infrastructure in South Africa.

Table 7: Key international, provincial and local legal instruments that aim to guide and promote sustainable development and nature conservation in South Africa.

Instrument	Key objective
INTERNATIONAL INSTRUMENTS	
Ramsar Convention (The Convention of Wetlands of International Importance (1971 and amendments)	Protection and conservation of wetlands, particularly those of importance to waterfowl and waterfowl habitat.
Convention concerning the Protection of the World Cultural and Natural Heritage, adopted by UNESCO in 1972 (World Heritage Convention)	Preservation and protection of cultural and natural heritage throughout the world.
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)	Aims to conserve terrestrial, marine and avian migratory species throughout their range.
The Agreement on the Conservation of African- Eurasian Migratory Waterbirds, or African- Eurasian Waterbird Agreement (AEWA)	Intergovernmental treaty dedicated to the conservation of migratory waterbirds and their habitats across Africa, Europe, the Middle East, Central Asia, Greenland and the Canadian Archipelago.

Instrument	Key objective
International Finance Corporation (IFC) Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	To protect and conserve biodiversity, maintain the benefits from ecosystem services, and promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities through the adoption of practices that integrate conservation needs and development priorities.
Convention on Biological Diversity (1993) including the CBD's Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets	The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.
Conservation of Agricultural Resources Act (Act 43 of 1983) (CARA) and associated regulations	This Act provides for, inter alia, restrictions on the cultivation of land, the protection of soils and water courses, the combating and prevention of erosion, and the prevention of the weakening or destruction of water sources on agricultural land. One of the provisions of the Act includes measures to protect wetlands and watercourses by maintaining uncultivated buffers along water courses and around water bodies to reduce sedimentation and for reducing agro-chemical pollution. Other key aspects include legislation that allows for: Section 6: Prescription of control measures relating to the utilisation and protection of vleis, marshes, water sponges and water courses. These measures are described in regulations promulgated in terms of the Act, as follows; Regulation 7(1): Subject to the Water Act of 1956 (since amended to the Water Act 36 of 1998), no land user shall utilise the vegetation of a vlei, marsh or water sponge or within the flood area of a water course or within 10 m horizontally outside such flood area in a manner that causes or may cause the deterioration or damage to the natural agricultural resources. Regulation 7(3) and (4): Unless written permission is obtained, no land user may drain or cultivate any vlei, marsh or water sponge or cultivate any land within the flood area or 10 m outside this area (unless already under cultivation).
NEMA Bioregional Planning regulations (Government Gazette No. 32006, 16 March 2009)	Guideline regarding the Determination of Bioregions and the Preparation and Publication of Bioregional Plans. Sets out the standards for Bioregional Planning including systematic conservation plans such as those consulted for this assessment.
Spatial Planning and Land Use Management Act (No 16 of 2013) (SPLUMA)	Provides for a uniform, effective and comprehensive system of spatial planning and land use management. The Act recognizes that development be sustainable and aligned with everyone's right to have their environment protected. It also requires all levels of government to work together to realise these outcomes.
REGIONAL INSTRUMENTS	
Southern African Development Community (SADC) Protocol on Shared Watercourse Systems (1995)	The protocol provides for the utilisation of a shared watercourse system for the purpose of agricultural, domestic and industrial use and navigation within the SADC region. The protocol established river basin management institutions for shared watercourse systems and provides for all matters relating to the regulation of shared watercourse systems

Instrument	Key objective
NATIONAL INSTRUMENTS	
National Environmental Management: Protected Areas Act (57 of 2003) (NEM:PAA)	No development, construction or farming may be permitted in a nature reserve without the prior written approval of the management authority (Section 50 (5)). Also in a 'protected environment' the Minister or Member of the Executive Committee may restrict or regulate development that may be inappropriate for the area given the purpose for which the area was declared (Section 5).
National Environmental Management Act (107 of 1998) (NEMA)	Restrict and control development and potential harmful activities through the Environmental Impact Assessment (EIA) regulations and the undertaking of relevant assessments prior to commencement of listed activities (Section 24 (5) and 44). Imposes "duty of care" (Section 28) which means that all persons undertaking any activity that may potentially harm the environment must undertake measures to prevent pollution and environmental degradation.
National Environmental Management Act, EIA 2014 Regulations, as amended in 2017	These regulations provide listed activities that require environmental authorisation prior to development because they are identified as having a potentially detrimental effect on natural ecosystems. Different sorts of activities are listed as environmental triggers that determine different levels of impact assessment and planning required. The regulations detail the procedures and timeframes to be followed for a Basic Assessment or full Scoping and EIA.
National Water Act (36 of 1998) (NWA)	This act provides the legal framework for the effect and sustainable management of water resources. It provides for the protection, use, development, conservation, management and control of water resources as a whole. Water use pertains to the consumption of water and activities that may affect water quality and condition of the resource such as alteration of a watercourse. Water use requires authorisation in terms of a Water use licence (WUL) or General Authorisation (GA), irrespective of the condition of the affected watercourse. Includes international management of water.
National Environmental Management: Integrated Coastal Management Act (24 of 2008) (NEM:ICM)	To determine the coastal zone of South Africa and to preserve and protect coastal public property. To control use of coastal property (Section 62, 63 and 65) and limitation of marine pollution (Chapter 8). Recreational waters. Water quality guidelines for the coastal environment: Recreational use (DEA, 2012). Set water quality targets for recreational waters to protect bathers. Protection of aquatic ecosystems. Water quality guidelines for protection of natural coastal environment (DWAF, 1995, in process of being reviewed by DEA). This will set targets for use of specific chemicals in marine waters and sediments to protect ecosystems.
National Forest Act (84 of 1998) (NFA)	Protection of natural forests and indigenous trees species through gazetted lists of Natural Forests and Protected Trees (Sections 7 (2) and 15 (3) respectively). Disturbance of areas constituting natural forest or the disturbance of a protected tree species requires authorisation from the relevant authority.
National Environmental Management: Biodiversity Act (10 of 2004) (NEM:BA)	Protection of national biodiversity through the regulation of activities that may affect biodiversity including habitat disturbance, culture of and trade in organisms, both exotic and indigenous. Lists of alien invasive organisms, threatened and protected species and threatened ecosystems published and maintained (Sections 97 (1), 56 (1) and 52 (1) (a) respectively). The NEMA provides for listing threatened or protected ecosystems, in one of four categories: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Protected. Activity 12 in Listing Notice 3

Instrument	Key objective
	(Government Notice R324 of April 2017 as per the 2014 EIA Regulations, as amended) relates to the clearance of 300 m² or more of vegetation, within Critical Biodiversity Areas.
National Environmental Management: Waste Act (59 of 2008) (NEM:WA)	Minimising the consumption of natural resources; avoiding and minimising the generation of waste; reducing, re-using, recycling and recovering waste; treating and safely disposing of waste as a last resort; preventing pollution and ecological degradation; securing ecologically sustainable development while promoting justifiable economic and social development; promoting and ensuring the effective delivery of waste services; remediating land where contamination presents, or may present, a significant risk of harm to health or the environment: and achieving integrated waste management reporting and planning; to ensure that people are aware of the impact of waste on their health, well-being and the environment; to provide for compliance with the measures set out in paragraph (a) and generally, to give effect to section 24 of the Constitution in order to secure an environment that is not harmful to health and well-being.
Threatened or Protected Species Regulations of 2013 (ToPS)	The TOPs relates to Section 56 of NEMBA. Species categorised as CR, EN, VU or Protected require permits for activities relating to: i. Hunt / catch / capture / kill ii. Gather / collect / pluck iii. Pick parts of / cut / chop off / uproot / damage / destroy iv. Import into South Africa / introduce from the sea v. Export (re-export) from South Africa vi. Possess / exercise physical control vii. Grow / breed / propagate viii. Convey / move/ translocate ix. Sell / trade in / buy / receive / give / donate/ accept as a gift / acquire /dispose of x. Any other prescribed activity
Draft National Biodiversity Offset Policy	A Draft National Biodiversity Offset Policy was gazetted in March 2017 (NEMBA, 2017), and is in the process of being finalised. The offset policy is intended to establish the foundation for establishing an offset for biodiversity (including river and wetland ecosystems), ensuring that offset procedures are properly integrated into the EIA process to make sure that the mitigation hierarchy is exhausted. Should it be determined in the EIA that there will be residual impact that cannot be avoided and/or mitigate, then an offset will need to be established to account for the loss of biodiversity. The core principles for offsetting, as set out in the policy, should be used to guide the process of evaluating, designing and implementing an offset. It is essential that the offset process is introduced from the outset of the EIA
National Water Resource Strategy (NWRS) 2004 and NWRS 2013	Facilitate the proper management of the nation's water resources; provide a framework for the protection, use, development, conservation, management and control of water resources for the country as a whole; provide a framework within which water will be managed at regional or catchment level, in defined water management areas; provide information about all aspects of water resource management; identify water-related development opportunities and constraints

Instrument	Key objective
The Water Services Act (108 of 1997)	The right of access to basic water supply and the right to basic sanitation necessary to secure sufficient water and an environment not harmful to human health or well-being; the setting of national standards and norms and standards for tariffs in respect of water services; the preparation and adoption of water services development plans by water services authorities; a regulatory framework for water services institutions and water services intermediaries; the establishment and disestablishment of water boards and water services committees and their duties and powers; the monitoring of water services and intervention by the Minister or by the 5 relevant Province; financial assistance to water services institutions; the gathering of information in a national information system and the distribution of that information; the accountability of water services providers: and the promotion of effective water resource management and conservation. Water supply services in an efficient equitable manner, as well as measures to promote water conservation and demand management which through Water Conservation and Water Demand Management (WC/WDM) strategies
Marine Living Resources Act (18 of 1998) (MLRA)	Marine Living Resources Act. The management and control of exploited living resources in estuaries fall primarily under the Marine Living Resources Act (MLRA) (No. 18 of 1998). The primary purpose of the act is to protect marine living resources (including those of estuaries) through establishing sustainable limits for the exploitation of resources; declaring fisheries management areas for the management of species; approving plans for their conservation, management and development; prohibit and control destructive fishing methods and the declaration of Marine Protected Areas (MPAs) (a function currently delegated to the DEA). The MLRA overrides all other conflicting legislation relating to marine living resources.
National Estuarine Management Protocol	National Estuary Management Protocol sets the standards for Estuarine Management in South Africa (Regulation No. 341 of 2013 promulgated in support of section 33 of the ICM Act).
National Port Act (12 of 2005)	Legal requirements as stipulated in terms of the National Ports Act (No. 12 of 2005) must be complied with in commercial ports – relevant to estuaries which have ports in them.
PROVINCIAL INSTRUMENTS	
Catchment Management Strategies applicable to all provinces	Progressively develop a catchment management strategy for the water resources within its water management area. Catchment management strategies must be in harmony with the national water resource strategy. CMA must seek cooperation and agreement on water -related matters from the various stakeholders and interested persons. CMA must be reviewed and include a water allocation plan, set principles for allocating water to existing and prospective users, taking into account all matters relevant to the protection use, development conservation, management and control of resources
Eastern Cape	
Eastern Cape Nature and Environmental Conservation Ordinance (19 of1974)	This Ordinance includes rules for conservation areas, and enables the protection of wild animals and plants including lists of protected species. Note: Much of the Eastern Cape legislation relies on the pre-1994 legislation of the Eastern Cape, Transkei and Ciskei.

Instrument	Key objective
Transkei Environmental Conservation Decree (9 of 1992); Ciskei Nature Conservation Act 1987	Legislation promulgated for the former Transkei and Ciskei proved lists of indigenous fauna and flora and outline various management measures such as hunting seasons, bag limits and other recreational activities. Allowances are made for the proclamation of nature reserves and the general protection of the environment.
Cape Local Authorities Gas Ordinance 7 of 1912	Regulates gas and control gas related water pollution
Divisional Councils Ordinance 18 of 1976	Provides for the regulation and control of effluents refuse and stormwater
Free State	
Free State Nature Conservation Ordinance, 1969 (Act 8 of 1969)	To provide for the conservation of fauna and flora and the hunting of animals causing damage and for matters incidental thereto.
Gauteng	
Gauteng Nature Conservation Bill 2014	This bill provides rules for conservation areas; and enables the protection of wild animals and plants including lists of protected species.
KwaZulu-Natal	
Natal Nature Conservation Ordinance No. 15 of 1974 and KwaZulu-Natal Nature Conservation Management Act, (Act 9 of 1997)	According to the Natal Nature Conservation Ordinance No. 15 of 1974 and the KwaZulu-Natal Nature Conservation Management Act, 1992 (Act 9 of 1997), no person shall, among others: damage, destroy, or relocate any specially protected indigenous plant, except under the authority and in accordance with a permit from Ezemvelo KZN Wildlife (EKZNW). A list of protected species has been published in terms of both acts.
The KwaZulu-Natal Environmental, Biodiversity and Protected Areas Management Bill, 2014	The Management Bill, 2014 was passed to provide for the establishment, functions and powers of Ezemvelo KZN Wildlife; the protection and management of the environment and biodiversity; the protection and conservation of indigenous species, ecological communities, habitats and ecosystems; the management of the impact of certain activities on the environment; the sustainable use of indigenous biological resources; the declaration and management of protected areas; and to provide for matters connected therewith. The Bill includes lists of provincial protected animal and plant species, and it sets rules for activities in protected areas, as well as for the protection of biodiversity.
Various KZN Ordinances (e.g. South Barrow Loan and Ext Powers Ordinance 12 of 1920; South Shepstone Loan and Extended Powers Ordinance 20 of 1920; Water Services Ordinance 27 of 1963; Kloof Loan and Extended Powers Ordinance 16 of 1967; Umhlanga Extended Powers and Loan Ordinance 17 of 1975; Durban Extended Powers Cons Ordinance 18 of 1976; Kwa-Zulu and Natal Joint Services Act 84 of 1990)	Regulation of matters relating to water, water pollution and sewage in various areas in Kwa-Zulu Natal.
Mpumalanga	
Mpumalanga Nature Conservation Act, No. 10 of 1998	This Act relates to the establishment and management of conservation areas, and provides legislation relating to protected animals and plants

Instrument	Key objective
Northern Cape	
Northern Cape Nature Conservation Act, 2009 (Act 10 of 2009).	To provide for the sustainable utilization of wild animals, aquatic biota and plants: to provide for the implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora; to provide for offences and penalties for contravention of the Act: to provide for the issuing of permits and other authorisations: and provide for the matter connected therewith.
Divisional Councils Ordinance 18 of 1976	Provides for the regulation and control of effluents refuse and storm water
Western Cape	
Western Cape Nature Conservation Board Act, 1998 (Act 15 of 1998)	To provide for the establishment, powers, functions and funding of the Western Cape Nature Conservation Board and the establishment, funding a control of a Western Cape Nature Conservation Fund, and to provide for matters incidental thereto. The object of the board shall be, (a) promote and ensure nature conservation and related matter in the Province.
Western Cape Nature Conservation Laws Amendment Act, 2000. (Act 3 of 2000)	To provide for the amendment of various laws on nature conservation in order to transfer the administration of the provisions of those laws to the Western Cape Nature Conservation Board; to amend the Western Cape Nature Conservation Board Act, 1998 to provide for a new definition of Department and the deletion of a definition; to provide for an increase in the number of members of the Board; to provide for additional powers of the Board; to amend the provisions regarding the appointment and secondment of persons to the Board; and to provide for matters incidental thereto.
LOCAL INSTRUMENTS	
Local Government: Municipal Systems Act (Act 32 of 2000)	Requires municipalities to develop Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDFs). The IDP is a comprehensive five-year plan for a municipal area that gives an overall framework for development, land use and environmental protection. The SDF is a compulsory core component of an IDP that must guide and inform land development and management by providing future spatial plans for a municipal area. The SDF should be the spatial depiction of the IDP, and should be the tool that integrates spatial plans from a range of sectors.
Regulations 21 (published in terms of section 120 of the Municipal Systems Act)	Municipal Planning and Performance Management standards require SDFs to include a Strategic Environmental Assessment (SEA) which must be aligned with those of neighbouring municipalities. A municipal SEA identifies spatial constraints on developments and highlights sensitive areas for inclusion of detailed spatial information and policy guidelines for incorporation into a Strategic Environmental Assessment map.
Municipal Bylaws	Numerous municipalities have promulgated bylaws that relate to conservation of the environment and these may include the application of land uses through the town planning scheme. E.g. eThekwini Municipality's Open Space System as well as the iLembe and uMhlathuze Municipal bylaws. These will need to be considered in more detail during the detailed planning and EIA phases.

Instrument	Key objective
OTHER	
Bophuthatswana Nature Conservation Act, 1973 (Act 3 of 1973; still in force)	To provide for the protection of game and fish, the conservation of flora and fauna and the destruction of vermin in the former Bophuthatswana.
Transvaal Nature Conservation Ordinance No 12 of 1983 as amended (still in force)	Provides for the protection of fauna and flora in the North-West and Gauteng Provinces (former Transvaal Province).
Cape Nature Conservation Ordinance, No. 19 of 1974 (still in force)	Provides for the protection of fauna and flora in parts of the North-West Province and the Northern, Western and Eastern Cape Provinces (former Cape Province).
Water Resource Directed Measures including: the Ecological Reserve, National Water Resource Classification System and Resource Quality Objectives	The main objective of the Chief Directorate: Resource Directed Measures is to ensure protection of water resources, as described in Chapter 3 of NWA and other related water management legislation and policies. The role of Resource Directed Measures is to provide a framework to ensure sustainable utilization of water resources to meet ecological, social and economic objectives and to audit the state of South Africa's water resources against these objectives The aim of Water Resource Quality Objectives is to delineate units of analysis and describe the status quo of water resources, initiate stakeholder process and catchment visioning, quantify ecological water requirements and changes in ecosystem services, identify scenarios within IWRM, draft management classes, produce Resource Quality Objectives (EcoSpecs, water quality).

4 KEY ENVIRONMENTAL ATTRIBUTES AND SENSITIVITIES

4.1 Overview

4.1.1 Terrestrial ecosystems (per biome)

4.1.1.1 Desert

The Desert biome of South Africa is broadly divided into two bioregions, namely (i) the Southern Namib Desert bioregion and (ii) the Gariep Desert bioregion. The former comprises the desert areas stretching from the Atlantic coast near the mouth of the Orange River penetrating inland along the course of the lower Orange River to Sendelingsdrift and is characteristic of winter rainfall. The Gariep Desert is characterised by summer rainfall and includes the desert areas from Sendelingsdrift further east to the vicinity of Onseepkans and Pofadder in northern Bushmanland. The Desert biome borders the Nama Karoo biome to the east, and the Succulent Karoo biome in its western parts (Jürgens, 2006).

This arid environment is characteristic of extreme ecological conditions with erratic rainfall across the area (MAP <70 mm), high maximum daily temperatures (>48°C), high incidence of coastal fog, strong winds and frequent sandstorms. The desert landscape is highly dissected ranging from tall, rugged mountains with deep gorges to broad, sloping valley plains. The desert substrate is generally very rocky with little to no soil present. Desert soils, where present, are slow-forming, shallow alluvial sands created from a variety of rock types that are easily eroded by wind and high-impact rainfall from thunderstorms (Jürgens, 2006).

The Southern Namib Desert vegetation is characteristic of stem- and leaf-succulent trees and shrubs such as the Quiver tree (*Aloidendron dichotomum*) and the Giant Quiver tree (*Aloidendron pillansii*), with species from key genera including *Euphorbia, Fenestraria, Mesembryanthemum* (formerly *Brownanthus*)*, Monsonia* (formerly *Sarcocaulon*), *Salsola, Stoeberia* and *Tylecodon* dominating the desert plains and rocky hilly landscape. The Gariep Desert, in addition to the presence of stem- and leaf-succulents such as *Aloidendron dichotomum, Commiphora* species*, Euphorbia* species and *Pachypodium namaquanum* ('halfmens'), is typified by non-succulent woody perennials such as *Boscia albitrunca* (Shepherds tree), *Parkinsonia africana* (Green-hair thorn tree) and *Schotia afra* (Karoo boer-bean tree) with grasses like *Stipagostis* and *Enneapogon* species being distinctive of the sandy plains (Van Jaarsveld, 1987; Jürgens, 2006).

The Gariep Desert flora is dominated by ephemeral plants, often annual grasses and non-woody forbs, especially after a good rainy season. Normally the vast desert plains appear barren and desolated with aboveground vegetation persisting underground in the form of seed, but following abundant rainfall in winter the desert plains and lower mountain slopes can be covered with a sea of short annual grasses and striking mass flowering displays of short-lived forbs and succulents in spring. Perennial plants such as stem- and leaf succulent trees and shrubs, including some non-succulent plants, are usually encountered in specialised habitats associated with local concentrations of water, like dry river beds, drainage lines and rock crevices. Lichen fields are also a conspicuous marvel of the open coastal belt utilising the moisture-filled fog originating from the adjoining Atlantic Ocean (Van Jaarsveld, 1987; Jürgens, 2006).

Plant species richness of the vegetation types included in the Desert biome is exceptionally high when compared to other desert environments with similar aridity levels globally (Jürgens, 2006). The most profound feature of the Desert biome is the Gariep Centre of Endemism which covers the northern most part of the biome stretching inland along the Lower Orange River Valley. The Richtersveld forms the core of the centre boasting a total of approximately 2 700 vascular plant species of which more than 560 species are endemic and near-endemic to the Gariep Centre. More than 80% of species among these endemics are succulents (Van Wyk and Smith, 2001). Also, the Orange River Mouth is located at South Africa's coastal border with Namibia and contains two threatened vegetation types which are both highly disturbed, namely the Arid Estuarine Salt Marshes that is a National Freshwater Ecosystem Priority Area (NFEPA) and Endangered Wetland, as well as the Critically Endangered Alexander Bay Coastal Duneveld (SANBI, 2011; Driver et al*.,* 2012; Holness and Oosthuysen, 2016).

The Desert biome, interfacing with the highly diverse and species-rich Succulent Karoo biome, is considered to be one of the most biologically diverse and environmentally sensitive deserts in the world. Although the region is sparsely populated with only few small villages, communal livestock farming (mainly sheep and goats) across large areas of the biome has had a significant impact on vegetation cover. Overgrazing due to overstocking, intensified by extended periods of drought, especially surrounding some permanent settlements in the Richtersveld, resulted in severe deterioration of veld condition, and in some places total desertification (Hoffmann et al., 1999; Jürgens, 2006; Hoffmann et al., 2014).

Commercial scale crop farming along the lower Orange River has also substantially increased during the past century now having extensive areas cultivated with inter alia vineyards, dates and subtropical fruit orchards. In addition to irrigation agriculture, open-cast diamond mining and exploration activities, mostly along the lower Orange River from Alexander Bay to Swartwater, have largely scarred the desert landscape adding to the human impact on this sensitive ecosystem. Although alien invasive plants such as *Prosopis* spp., *Nicotiana glauca, Ricinus communis* and *Atriplex lindleyi* are a common phenomenon of dry river beds, drainage lines and around human settlements, its distribution has been limited by the lack of subsurface water in the greater desert area (Milton et al., 1999; Jürgens, 2006). Unfortunately, unique species richness and high levels of endemism associated with the Desert biome have also seen the illegal removal of succulents by collectors and traders (Van Wyk and Smith, 2001).

So far, only approximately 22% of the Desert biome is formally protected in statutory and non-statutory reserves of which the Richtersveld National Park, the Nababieps Provincial Nature Reserve and the Orange River Mouth Provincial Nature Reserve constitute the largest area of conservation (Jürgens, 2006; Taylor and Peacock, 2018). The average conservation target for vegetation types in the Desert biome is 32%. Other efforts to preserve this unique desert ecosystem include the Richtersveld Community Conservancy and two proclaimed National Heritage Sites, namely (i) the lichen field near Alexander Bay and (ii) the renowned population of *Aloidendron pillansii* on Cornellskop (Jürgens, 2006).

Transformation of the Desert biome has so far been relatively limited transformed despite the effect of the aforementioned impacts on desert ecosystems (Jürgens, 2006). However, rising temperatures and decreasing rainfall as a direct result of climate change could intensify desertification of the Desert biome over the next 50 years (Hoffmann et al., 1999; Rutherford et al., 1999).

The Desert biome is not particularly rich in natural resources, hence providing employment to a relatively small number of people. The main economic drivers in this arid area are commercial scale crop cultivation and mining activities along the Lower Orange River Valley, whereas small stock farming is the main agricultural land use practised in most of the remaining biome. Ecotourism and conservation, as well as collection of plants for the horticultural trade, specifically succulents, add to the economic value of the Desert biome (Hoffmann et al., 1999; Jonas, 2004; Jürgens, 2006).

Due to the ecologically sensitive nature of this biome, not all of the aforementioned land uses are sustainable. Clearance of vegetation and removal of topsoil for irrigated croplands as well as large scale surface mining along the Orange River have resulted in total biodiversity loss and increased soil erosion. In addition to overstocking of small livestock, which leads to overgrazing, unsustainable land use exacerbated by global climate change is causing desertification which could have a negative impact on the socio-economic value of the Desert biome (Hoffmann et al., 1999; Jonas, 2004; Jürgens, 2006; Milton, 2009).

Box 1: Terrestrial fauna of the Desert Biome

More than 60 different mammal species are known to occur in the Desert biome (UCT, 2018a). Three species are considered Vulnerable, namely the Hartmann's zebra (*Equus zebra hartmannae*), the Black-footed cat (*Felis nigripes*) and the Cape leopard (*Panthera pardus*). A further three mammals have a Near-Threatened status including the Brown Hyena (*Hyaena brunnea*), the African Clawless Otter (*Aonyx capensis*) and Littledale's Whistling Rat (*Parotomys littledalei*). Antelope species common to the desert plains include Gemsbok (*Oryx gazella*), Springbok (*Antidorcas marsupialis*), Steenbok (*Raphicerus campestris*) and Kudu (*Tragelaphus strepsiceros*) (Williamson, 2010; Child et al., 2016; Walker et al., 2018).

The reptile diversity of the Desert biome is fairly high with about 84 species (UCT, 2018b), three of which are of conservation concern. These include the Near-Threatened Richtersveld Pygmy Gecko (*Goggia gemmula*), the Critically Endangered Namib Web-footed Gecko (*Pachydactylus rangei*) and the Vulnerable Speckled Padloper (*Chersobius signatus*) (Bates et al*.,* 2014).

A total of 13 frog species can potentially occur in the Desert biome (UCT, 2018d) of which two species are listed as being Vulnerable, namely the Desert Rain Frog (*Breviceps macrops*) and the Namaqua Stream Frog (*Strongylopus springbokensis*) (Minter, 2004).

The Desert Biome includes an abundant insect fauna which includes many Scarabaeidae and Tenebrionidae beetles. Its insect diversity further includes about 69 species of moths and butterflies, 20 species of dragonflies and 32 species of lacewings (Mecenero et al*.,* 2013). Up to 24 scorpion species could potentially be found in this desert environment (UCT, 2018c).

4.1.1.2 Succulent Karoo

The Succulent Karoo biome covers an area of approximately 103 000 km² and extends from the coastal regions of southern Namibia through the western parts of the Northern Cape and Western Cape provinces of South Africa, as well as inland of the Fynbos biome to the Little Karoo in the south (Rundel and Cowling, 2013). The Succulent Karoo biome interfaces with the Albany Thicket to the east, the Nama Karoo to the north and west, and the Desert biome to the north (Jonas, 2004; Mucina et al., 2006a).

The Succulent Karoo biome is a semi-desert region that is characterised by the presence of low winter rainfall, with a mean annual precipitation of between 100 and 200 mm, and daily temperature maxima in summer in excess of 40°C the norm. Fog is a common occurrence in the coastal region and frost is infrequent. Desiccating, hot berg winds may occur throughout the year (Desmet and Cowling, 1999; Jonas, 2004; Mucina et al., 2006b; Walker et al., 2018).

Topographically the Succulent Karoo varies from flat to gently undulating plains at altitudes generally below 800 m that are situated to the west and south of the escarpment and are typical of the Knersvlakte and Hantam/Roggeveld/Tankwa Karoo, towards a more hilly and rugged mountainous terrain characteristic of the Namaqualand, Robertson Karoo and Little Karoo at higher elevations reaching up to 1 500 m in the east. The geology of the Succulent Karoo is ancient and complex with weakly developed, lime-rich sandy soils that easily erode and are derived from weathering of sandstone and quartzite (Allsopp, 1999). An unusual but abundant feature of the Succulent Karoo soils are low, circular mounds called 'heuweltjies' which were created by harvester termites thousands of years ago (McAuliffe et al., 2018; McAuliffe et al., in press). Their rich soils support an entirely different vegetation from the surrounding land cover making them truly unique (Jonas, 2004; Mucina et al., 2006b; Jacobs and Jangle, 2008).

The Succulent Karoo is an arid to semi-arid biome which is known for its exceptional succulent and bulbous plant species richness, high reptile and invertebrate diversity, as well as its unique bird and mammal life (Rundel and Cowling, 2013). It is also recognised as one of three global biodiversity hotspots in southern

Africa with unrivalled levels of diversity and endemism for an arid region (Cowling et al., 1999; Desmet, 2007; Hayes and Crane, 2008). The Succulent Karoo vegetation is dominated by dwarf leaf-succulent shrublands with a matrix of succulent shrubs and very few grasses, except in some sandy areas. Species of the plant families *Aizoaceae* (formerly the *Mesembryanthemaceae*), *Crassulaceae* and *Euphorbiaceae*, as well as succulent members of the *Asteraceae*, *Iridaceae* and *Hyacinthaceae* are particularly prominent. Mass flowering displays of annuals (mainly *Asteraceae* species), often on degraded or fallow agricultural lands are a characteristic occurrence in spring.

The varied Succulent Karoo landscape lends itself to the adaptation of a diversity of plant growth forms, ranging from extensive plains often littered with rocks or pebbles such as the Knersvlakte to rocky areas occasionally dotted with solitary trees and tall bush clumps (e.g. *Ficus ilicina, Pappea capensis, Searsia undulata, Schotia afra* and *Vachellia karroo*) often found in deeper valleys and along drainage lines. In some higher altitude areas of the Succulent Karoo, particularly on rain shadow mountain slopes, the vegetation contains elements similar to an arid daisy-type fynbos (Mucina et al., 2006b; Jacobs and Jangle, 2008).

The Succulent Karoo biome is recognised as one of 25 internationally acclaimed biodiversity hotspots due to its exceptional abundance and rich diversity of unusual succulent plants and animal life (Myers et al., 2000; Jonas, 2004; Noroozi et al., 2018). Despite its amazing ecological and socio-economic diversity, the hotspot is a vulnerable ecosystem with about 8% of the Succulent Karoo biome formally protected in statutory and non-statutory reserves, including the Richtersveld, Namaqua and Tankwa Karoo National Parks, as well as the Goegap, Nababieps and Oorlogskloof Provincial Nature Reserves (Mucina et al., 2006b; Hoffmann et al., 2018).

The predominant land use is agriculture with about 90% of the region subjected to livestock grazing (mainly sheep, goats and ostrich farming). Although crop farming is limited due to nutrient-poor soils with low agricultural potential and the lack of sufficient irrigation water, severe overgrazing and unsustainable cultivation practices have contributed to widespread loss of topsoil through sheet erosion and the accelerated degradation of veld condition reducing the overall species diversity in this arid environment (Mucina et al., 2006b; Le Maitre et al., 2009; Walker et al., 2018).

Mining for diamonds, gypsum and heavy metals, although an important economic driver which is only affecting about 1% of the biome, is another major threat to biodiversity in the Succulent Karoo as it irreversibly transforms landscapes making ecological restoration extremely challenging (Jonas, 2004; Milton and Dean, 2012). An increase in urban settlements due to a growing population, in addition to overharvesting of fuel wood and the illegal harvesting of plants for the medicinal and horticultural trades, further threatens conservation efforts of the Succulent Karoo biome (Milton et al., 1999; Walker et al., 2018).

Cropping, mining, linear structures such as fences, roads, railways and power lines, and the eutrophication of water further exacerbate the spread and establishment of alien invasive plant species in the Succulent Karoo such as *Arundo donax*, *Atriplex lindleyi*, *Atriplex nummularia*, *Nerium oleander*, *Pennisetum setaceum*, *Prosopis glandulosa* and *Tamarix ramossissima* (Van Wilgen et al., 2008; Rahlao et al., 2009; Le Maitre et al., 2016; Dean et al., 2018; Walker et al., 2018). The invasion of members of the Cactaceae family such as the Bilberry cactus (*Myrtillocactus geometrizans*) is becoming an increasing conservation concern especially in the southern Karoo (Dean and Milton, 2019).

Furthermore, climate change has been identified as one of the most significant threats to biodiversity as increasing temperature levels and decreasing rainfall over the next five decades could exacerbate desertification of the Succulent Karoo biome (Hoffmann et al., 1999; Rutherford et al., 1999; Walker et al., 2018). Also, a recent increase in renewable energy developments (solar and wind) in the Succulent Karoo has seen approval of about 160 applications for environmental authorisation to date of which another almost 50 are currently in process (DEA, 2019). Notwithstanding the effect of the aforementioned impacts on Succulent Karoo ecosystems, to date approximately 4% of the biome has been transformed (Mucina et al., 2006b).

Box 2: Terrestrial fauna of the Succulent Karoo Biome

The fauna of the Succulent Karoo biome does not reflect the same level of diversity or endemism shown by the flora (Vernon, 1999; Mucina et al., 2006b; Rundel and Cowling, 2013).

Mammal diversity in the Succulent Karoo biome is relatively high with about 75 species of mammals (UCT, 2018a) of which two are endemic, namely the Critically Endangered De Winton's golden mole (*Cryptochloris wintoni*) and the Namaqua dune mole rat (*Bathyergus janetta*). Another important species of conservation concern in the region is the Critically Endangered riverine rabbit (*Bunolagus monticularis*), the Near-Threatened brown hyena (*Hyaena brunnea*), the Vulnerable Hartmann's mountain zebra (*Equus zebra hartmannae*), the Vulnerable Cape leopard (*Panthera pardus*) and the Vulnerable Grant's golden mole (*Eremitalpa granti*) (Rundel and Cowling, 2013; Child et al. 2016).

Major concentrations of large mammals, including the African elephant (*Loxodonta africana*), the Critically Endangered black rhinoceros *(Diceros bicornis*), the hippopotamus (*Hippopotamus amphibious*) and the African buffalo (*Syncerus caffer*), used to roam the riverine forests along major rivers in the Succulent Karoo, but these populations have now all disappeared from this hotspot. Today, only smaller herds of gemsbok (*Oryx gazella*), mountain zebra (*Equus zebra*) and springbok (*Antidorcas marsupialis*) are commonly found mainly within the confines of formally protected areas and privately owned game farms (Williamson, 2010; Walker et al., 2018).

Reptile diversity is relatively high in the Succulent Karoo with approximately 94 species of which about 15 are endemic (UCT, 2018b). All of the endemics are geckos and lizards, representing about 25% of the nearly 60 gecko and lizard species in the biome. These endemics include seven species of girdled lizards of the genus *Cordylus*, including the armadillo girdled lizard (*Cordylus cataphractus*) that is endemic to the region. Tortoise diversity is very high in the Succulent Karoo with seven taxa of which two are endemic, namely the Namaqualand tent tortoise (*Psammobates tentorius trimeni*) and the Namaqualand speckled padloper (*Homopus signatus signatus*) (Bates et al*.,* 2014).

Amphibians are poorly represented in the Succulent Karoo with just over 20 species (UCT, 2018d). All of these species are frogs of which one is endemic, namely the Desert Rain Frog (*Breviceps macrops*). This frog species occurs along the Namaqualand coast of South Africa northwards to Lüderitz in the coastal south-west of Namibia. Also noteworthy is the Namaqua Stream Frog (*Strongylopus springbokensis*) that has a Near-Threatened status (Minter, 2004).

Invertebrate diversity is relatively high in the Succulent Karoo biome and evidence suggests that more than half of the species in some insect groups are endemic to this biodiversity hotspot. These include amongst others monkey beetles (*Clania glenlyonensis*), bee flies, long-tongued flies and bees, as well as a variety of masarid and vespid wasps (Rundel and Cowling, 2013). The Succulent Karoo also boasts 50 scorpion species of which nearly 22 species are endemic to the biome (Rundel and Cowling, 2013; UCT, 2018c).

Historically, the Succulent Karoo biome has mainly supported livestock farming, mostly sheep and goats, but it was not until the late 1700's that land occupation and urban settlement by colonial pioneers expanded throughout most of the area. By late 1800's both cattle and ostrich farming also became an important agricultural revenue stream and today almost 90% of the Succulent Karoo supports commercial and subsistence pastoralism, in addition to cropland farming in areas where irrigation water is readily available (Hoffmann et al., 1999; Smith, 1999; Jonas, 2004; Hoffmann et al., 2018; Walker et al., 2018).

A study by Jonas in 2004 revealed the following economic land uses in the Succulent Karoo:

- Agriculture – Livestock farming (e.g. sheep, goats, cattle and ostrich);
- Agriculture – Cropland farming (barley, lucern, dates, vineyards, etc.);
- Conservation (e.g. National Parks and Nature Reserves);

- Fuel wood (e.g. *Prosopis* spp).
- Game farming (e.g. trophy hunting, live game sales, venison sales, etc.);
- Horticulture (e.g. succulents);
- Medicinal bioprospecting (e.g. cancer bush and kougoed);
- Mining (e.g. diamonds, copper, zinc, etc.); and
- Tourism (including ecotourism).

Recent statistics have shown that wind and solar energy installations cover approximately 5.2% of land in the Succulent Karoo of which the largest percentage of affected areas is situated in the Namaqualand bioregions (Hoffmann et al*.,* 2018).

All life and economic activities occurring within the Succulent Karoo are highly driven by the availability of water. Both surface and groundwater are generally very limited and often of naturally poor quality, especially in the driest regions of the biome. Exacerbated by climate change and compounded by increased pressure from human demand, sufficient water quality and quantity pose serious challenges to current and future land use and development opportunities in the Succulent Karoo (Hoffmann et al., 2009; Le Maitre et al*.,* 2009; Milton, 2009; Hoffmann et al*.,* 2018; Walker et al., 2018).

4.1.1.3 Nama Karoo

The Nama Karoo biome occurs on the central plateau of the western half of South Africa and is the largest of the three biomes that comprise the semi-arid Karoo-Namib Region covering about 23% of the interior of southern Africa (Ndhlovu et al., 2011; Walker et al., 2018). The word 'Karoo' comes from the Khoi-San word *kuru* which means dry, an apt description for this vast, open, arid thirstland. The Nama Karoo interfaces with the Succulent Karoo biome to the west, the Desert biome in the extreme northwest, the Savanna biome to the north and northeast, the Fynbos and Albany Thicket biomes in its southern and south-eastern extremities, and the Grassland biome infringing on its eastern border (Mucina et al., 2006a).

The geology underlying the Nama Karoo biome is exceptionally varied and consists of a 3 km thick succession of millennia old sedimentary rocks rich in fossils (Lloyd, 1999; Mucina et al., 2006a). Shallow, weakly developed lime-rich soils with high erodibility cover more than 80% of the Nama Karoo landscape (Watkeys, 1999). The climate is typically harsh with considerable fluctuations in both seasonal and daily temperatures. Droughts are common with frost a frequent occurrence during winter. Rainfall is highly seasonal, peaking in summer with a mean annual precipitation (MAP) ranging from 100 mm in the west to about 500 mm in the east, decreasing from east to west and from north to south (Palmer and Hoffmann, 1997; Desmet and Cowling, 1999; Mucina et al., 2006a; Walker et al., 2018).

The Nama Karoo is mostly a complex of extensive, flat to undulating gravel plains dominated by grassy, dwarf shrubland vegetation of which its relative abundances are dictated mainly by rainfall and soil type (Cowling and Roux, 1987; Palmer and Hoffmann, 1997; Mucina et al., 2006a). Towards the Great Escarpment in the south and west, a much dissected landscape exists characteristic of isolated hills, koppies, butts, mesas, low mountain ridges and dolerite dykes supporting sparse dwarf Karoo scrub and small trees (Dean and Milton, 1999; Mucina et al., 2006a; Jacobs and Jangle, 2008).

Nama Karoo vegetation is not particularly species-rich and the biome does not contain any centres of endemism (Van Wyk and Smith, 2001). There are also very few rare or endangered indigenous plant species occurring in the biome. Dwarf shrubs (generally <1 m tall) and grasses dominate the current vegetation that is intermixed with succulents, geophytes and annual forbs. As a result, the amount and nature of the fuel load is insufficient to carry fires and fires are rare within the biome. Grasses tend to be more common in depressions and on sandy soils, whereas small trees occur mainly along drainage lines and on rocky outcrops (Palmer and Hoffmann, 1997; Mucina et al., 2006a).

Some of the more abundant shrubs include species of *Drosanthemum, Eriocephalus, Galenia, Lycium, Pentzia, Pteronia*, *Rhigozum*, and *Ruschia*, while the principal perennial grasses are *Aristida, Digitaria, Enneapogon*, and *Stipagrostis* species. Trees and taller woody shrubs are mostly restricted to watercourses such as rivers and wetlands, and include *Boscia albitrunca, B. foetida, Diospyros lycioides, Grewia robusta, Searsia lancea, Senegalia mellifera, Tamarix usneoides* and *Vachellia karroo* (Palmer and Hoffmann, 1997; Mucina et al., 2006a).

The Nama Karoo biome, considered the third largest biome in South Africa after the Grassland and Savanna biomes, comprises an area of approximately 248 278 km² of which only approximately 1.6% is formally protected in statutory reserves such as the Augrabies and Karoo National Parks (Hoffmann et al., 2018). About 5% of the Nama Karoo has been transformed by human impact relative to other biomes in South Africa, leaving the majority of the land still in a state classified as Natural (Mucina et al., 2006a; Hoffmann et al., 2018). However, according to Hoffmann and Ashwell (2001) approximately 60% of the Nama Karoo landscape is characterised by moderately to severely degraded soils and vegetation cover (Mucina et al., 2006a). Despite the increasing impact of mainly soil erosion and overgrazing (Atkinson, 2007), the ecosystem threat status of all 14 Nama Karoo vegetation types are considered least threatened (South African Government Gazette, 2011).

The large historical herds of Springbok (*Antidorcas marsupialis*) and other game native to the Nama Karoo no longer exist as most of the Nama Karoo has been converted to fenced rangeland for livestock grazing during the past century, in particular sheep and mohair goats (Hoffmann et al., 1999). Although the habitat is mostly intact, heavy grazing has left certain parts of the Nama Karoo seriously degraded (Lloyd, 1999; Milton, 2009; Ndhlovu et al., 2011; Ndhlovu et al., 2015). Vegetation recovery following drought can be delayed due to increased stocking rates that in turn exacerbate the effects of subsequent drought periods. Under conditions of overgrazing many indigenous shrubs may proliferate, while several grasses and other palatable species may be lost (Mucina et al., 2006a), contributing to the gradual increase of land degradation in the Nama Karoo (Milton and Dean, 2012; Walker et al., 2018).

In addition to pastoralism, alien plant infestation, anthropogenic climate change, agricultural expansion, construction of linear structures, urban sprawl, the collection of rare succulents and reptiles for illegal trade, as well as the construction and failure of dams also threaten the Nama Karoo's biodiversity (Lovegrove, 1993; Lloyd, 1999; Rutherford et al., 1999; Mucina et al., 2006a; Milton, 2009; Dean et al., 2018). The introduction of a number of alien, drought-hardy ornamental and forage plants have the potential to seriously alter the biome's ecology and hydrology (Milton et al. 1999). Alien invasive plants currently common in the Nama Karoo region include *Argemone ochroleuca*, *Arundo donax*, *Atriplex* spp., *Limonium sinuatum*, *Opuntia* spp., *Pennisetum setaceum*, *Phragmites australis, Prosopis* spp., *Salsola kali and Schkuhria pinnata,* as well as various members of the Cactaceae family such as *Echinopsis* spp. and *Tephrocactus articulates* (Van Wilgen et al., 2008; Walker et al., 2018).

Box 3: Terrestrial fauna of the Nama Karoo Biome

The Nama Karoo never had the variety of wildlife that can be found for example in the Savanna biome; however, before pastoralism brought along fenced rangelands, vast herds of Springbok used to migrate through the region in search of water and grazing. Today, these free roaming herds are mostly replaced with livestock and game ranching. The majority of mammals in the Nama Karoo are species with a widespread distribution that originate in the Savanna and Grassland biomes (Dean et al., 2018). The Nama Karoo boasts a mammal diversity of approximately 177 species of which more than 10 threatened species are known to occur in this biome. Common animals include the Bat-Eared Fox, Black-Backed Jackal, Spring Hare, Springbok, Gemsbok, Kudu, Eland and Hartebeest. Most noteworthy is the Critically Endangered Riverine Rabbit (*Bunolagus monticularis*) which is an endemic species of the central Nama Karoo (Holness et al., 2016; UCT, 2018a).

Other mammal species of conservation concern include the Endangered Southern Tree Hyrax (*Dendrohyrax arboreus*), as well as the Vulnerable Hartmann's Zebra (*Equus zebra hartmannae*), Cheetah (*Acinonyx* *jubatus*), Leopard (*Panthera pardus*), Black-footed Cat (*Felis nigripes*) and White-tailed Mouse (*Mystromys albicaudatus*). The Grey Rhebok *(Pelea capreolus*), Mountain Reedbuck (*Redunca fulvorufula* subsp. *fulvorufula*), Brown Hyena (*Hyaena brunnea*) and the Southern African Hedgehog (*Atelerix frontalis*) are all listed as Near-Threatened (UCT, 2018a).

Reptile diversity of the Nama Karoo is moderately high with nearly 221 species that can be found in this arid to semi-arid environment (UCT, 2018b). Important tortoise species include the Vulnerable Speckled Padloper (*Chersobius signatus*) and the Near-Threatened Karoo Padloper (*Chersobius boulengeri*). The Plain Mountain Adder (*Bitis inornata*), which is restricted to the Nuweveldberge, is the only snake species that is endemic to the Nama Karoo and it is categorised as Endangered. Also, the Elandsberg Dwarf Chameleon (*Bradypodion taeniabronchum*) is currently listed as endangered and the Braack's Pygmy Gecko (*Goggia braacki*) is considered Near-Threatened. Three other lizard species, the Dwarf Karoo Girdled Lizard (*Cordylus aridus*), the Karoo Flat Gecko (*Afroedura karroica*) and Thin-skinned Gecko (*Pachydactylus kladaroderma*) have much of their distribution in the Karoo.

The Nama Karoo boasts a fairly moderate diversity of Amphibia with about 50 frog species that could be found in this biome. Noteworthy species include the endemic Karoo Caco (*Cacosternum karooicum*) and the Near-Threatened Giant Bull Frog (*Pyxicephalus adspersus*) (Minter, 2004).

Terrestrial invertebrate diversity in the Nama Karoo is considerably high with up to 575 species of Lepidoptera (moths and butterflies), 84 species of dragonflies, 115 species of lacewings and more than 80 different species of dung beetle. Five butterfly species are wholly endemic to the Central Karoo (*Aloeides pringlei, Lepidochrysops victori, Thestor compassbergae, T. camdeboo* and *Cassionympha camdeboo*). The butterfly species, *Lepidochrysops victori* is categorised as Vulnerable (Mecenero et al. 2013; Holness et al., 2016). Nearly 40 species of scorpions could occur in the Nama Karoo region (Holness et al., 2016).

The Nama Karoo is also threatened by increased mining activities such as open-cast zinc mining at Black Mountain and the Gamsberg near Aggeneys, as well as the potential threat of uranium mining around Beaufort West and the greater Lower Karoo region. The possibility of large scale shale gas fracking presents a further threat to the Nama Karoo biodiversity (Khavhagali, 2010; Milton and Dean, 2012; Cramer, 2016). An increased need for renewable energy has already seen the impact of several wind farms being developed in the Karoo region and along its margins, as well as planning and construction of a number of solar power projects (Walker et al., 2018).

Furthermore, the increased clearing of natural vegetation for cultivation along the lower Orange River destroys the natural habitat of many Nama Karoo fauna and flora. Pesticides used to control Brown Locust (*Locustana pardalina*) and Karoo Caterpillar (*Loxostege frustalis*) outbreaks also impact wildlife habitat severely, with the highest concentration of pesticides particularly within the avifauna, specifically raptors (Lovegrove, 1993; Khavhagali, 2010; Walker et al., 2018).

The overall improvement of ecosystem health and to ensure ecological sustainability of the Nama Karoo biome will require a dedicated effort and strategic collaboration from a wide range of stakeholders to achieve the preservation, conservation and management of its biodiversity.

The Nama Karoo provides natural resources for a wide array of business activities; however, social wellbeing and economic viability of these enterprises greatly rely on the availability and spatial distribution of water. The main industry sectors underpinning economic growth in the Nama Karoo are agriculture (including game and livestock ranching, and crop cultivation), mining (including diamonds, granite, heavy metals and marble, as well as the potential for shale gas and uranium) and tourism (including ecotourism). All three of these sectors have potential to contribute to socio-economic growth of the region but are heavily dependent on sustainable water resources to exist (Hoffmann et al., 1999; Mucina et al., 2006a; Milton, 2009; Walker et al., 2018).

Other economic opportunities characteristic of the Nama Karoo relates to the development and commercial exploitation of medicinal plants (such as *Hoodia gordonii*), horticulture, manufacturing, biodiversity conservation (e.g. National Parks, Nature Reserves, game farms) and the significance of cultural heritage (Milton, 2009; Todd et al., 2016; Dean et al., 2018; Walker et al., 2018). A recent increase in renewable energy installations (solar and wind) in the Nama Karoo has shown a total land cover of about 3.6% to date (Hoffmann et al., 2018).

4.1.1.4 Fynbos

The Fynbos Biome is globally recognised for its high diversity of plant species with about 7 500 species, 69% of which are endemic (Bergh et al., 2014; Rebelo et al., 2006) and 1 889 are listed as threatened (Turner, 2017). The biome is centred in the south-western part of the Western Cape with areas extending north-westwards for about 650 km, almost to the Orange River, and eastwards for 720 km to the Kap River mountains east of Grahamstown. Fynbos is closely associated with the north-south and east-west ranges of mountains comprising the Cape Folded Belt mountain ranges, some inselbergs, the lowlands between the coast and the coastal ranges and also the wetter inland valleys. It also occurs inland on the Roggeveld mountains that are part of the Great Escarpment. The mountains are dominated by the quartzitic sandstones of the Table Mountain Group (TMG) which give rise to sandy soils that are low in nutrients (Bradshaw and Cowling, 2014; Rebelo et al., 2006). The lowlands and the Roggeveld are underlain by shales which give rise to more fertile clay-loam soils and granites with more fertile, sandy soils which also support Fynbos in places. Parts of the lowlands have deep, infertile sandy soils particularly the west coast and parts of the southern coast that support Fynbos.

On the inland side and in the drier valleys in the western part of the biome the Fynbos adjoins the Succulent Karoo, southern part Succulent Karoo and Albany Thicket in the inland valleys, and in the east Albany Thicket in low rainfall areas and Grasslands in high rainfall areas. Both the Succulent Karoo and the Albany Ticket biomes are fire sensitive and the boundaries appear to be largely fire-maintained. There are numerous patches of Afromontane Forest in fire-protected kloofs throughout the Fynbos with extensive areas of forest on the coastal slopes in the Outeniqua-Tsitsikamma region (Geldenhuys, 1994; Mucina et al., 2006c). The Forests embedded within the Fynbos are excluded from this analysis as they are considered no-go areas.

The western part of the biome receives its rainfall primarily in the winter months (June to August) and the eastern part has peaks in the spring and summer with some rain every month (Bradshaw and Cowling, 2014; Rebelo et al., 2006). The temperatures are hot in summer and cold in winter, especially when there is snow. The summers are also characterised by strong, desiccating, south-easterly winds and the winters by the passage of cold fronts with north-westerly and sour-westerly winds. Warm to hot berg winds occur when warm drains from the interior prior to the passage of cold fronts and can lead to fires (Geldenhuys, 1994; Heelemann et al., 2008). The hot, dry conditions in summer dry out plant litter and dead fuels, creating high-fire danger conditions in the west but in the east, large fires can occur at any time of the year (Kraaij et al., 2013b; Kraaij and Wilgen, 2014). Lightning strikes are infrequent, around 1 per km^2 per year but were, historically the main cause of fires; most fires are now caused by people (Van Wilgen et al., 2010).

Box 4: Fire dependent ecosystems and gas pipeline infrastructure

During a vegetation fire, heat reduces significantly within the upper layers (~ 30 cm) of the soil (e.g. Badía et al., 2017; Valette et al., 1994; Raison, 1979). Therefore, a gas pipeline buried at 1 m below the soil surface is at low risk of being exposed to heat that may damage the pipe or cause an explosion. With deep-rooted vegetation, a surface fire may cause roots in deeper soil layers to combust (if conditions are right, e.g. enough oxygen is present). Thus, keeping the operational servitude above the pipeline clear of deep-rooted vegetation reduces the risk of underground root-fires coming in close proximity to the gas pipeline.

The vegetation types in the Fynbos can be divided into three major types (Bergh et al., 2014; Rebelo et al., 2006): (a) the typical Fynbos vegetation on the nutrient poor soils which is a mixture of reeds (Restionaceae), sedges and grasses (Cyperaceae, Gramineae), ericoid (fine-leaved) shrubs (e.g. Ericaceae, Asteraceae) and an overstorey of broad leaved shrubs (e.g. Proteaceae); (b) Renosterveld vegetation on more nutrient-rich soils with a mixture of evergreen fine leaved shrubs, mainly Asteraceae and herbaceous species including a rich flora of geophytes; and (c) Western Strandveld with a dense overstorey of evergreen shrubs and herbaceous species in the gaps. Fynbos is found in two main settings on the shallow, rocky soils of the TMG sandstones of the mountains and foothills (montane Fynbos) and on the deep, leached sands of the lowlands and wetter inland valleys (sand plain Fynbos). Renosterveld is found on the shale-derived soils of the lowlands, the dry lower slopes and valleys, including the Roggeveld mountains. Strandveld generally occurs near the coast on more calcium-rich deep sands and on limestone soils.

The ecology of these major types differs as well. Sandstone, Granite, Shale, Limestone and Sand Plain Fynbos all require fires at intervals of 10-30 years to maintain their biodiversity and ecosystem functioning (Kraaij and Wilgen, 2014; Le Maitre et al., 2014). Many species' seeds will only germinate after fires and many species require fires to flower, produce seed and reproduce. The fire-ecology of Renosterveld is less well understood than that of Fynbos. Fires do stimulate regeneration in the Renosterveld, which is dominated by sprouting species, lacks slow-maturing species, and has some species whose seeds require fire to germinate (Kraaij, 2010; Kraaij and Wilgen, 2014). Yet it is able to persist for decades without fires, especially in the drier areas such as the inland slopes of the mountains and the Roggeveld escarpment. Fires in western Fynbos and Renosterveld occur primarily in the dry summer months but fires can occur at any time, including winter in the southern and eastern parts of the biome (Kraaij et al., 2013b; Kraaij and Wilgen, 2014). In the western and southern Fynbos, fire season has a marked impact on the regeneration of non-sprouters such as the Proteaceae, being most successful after fires in summer and autumn and least successful after fires in late-winter or spring (Bond et al., 1990; Kraaij et al., 2013d; Kraaij and Wilgen, 2014; Le Maitre et al., 2014). In the eastern Fynbos fire season has relatively little impact. Fire return intervals need to be long-enough for slow-maturing, non-sprouting species like many Proteaceae to produce sufficient seeds to maintain their populations; this typically requires fire return intervals of at least 10-12 years, preferably longer (Kraaij and Wilgen, 2014; Van Wilgen et al., 2010). Strandveld rarely burns but can do so under extreme fire conditions and regeneration apparently is not fire-dependent.

Box 5: Fire and the germination of Fynbos plant species

Although the seeds of many Fynbos species require some form of stimulation to germinate (e.g. shifts in soil temperature regimes, heat from the fire, chemicals from smoke) (Esler et al., 2014; Hall et al., 2017; Holmes and Richardson, 1999; Ruwanza et al., 2013), the level of knowledge at present is not sufficient to determine whether or not specific treatments should be given as part of the rehabilitation process.

Soil removal and replacement may provide some stimuli for germination but heat would not be practical to apply. The effectiveness of smoke treatment in the field, as opposed to the nursery, needs more research. A precautionary approach would be to conduct tests in different communities, especially in arid Fynbos and Renosterveld vegetation types, during the initial stages of the construction, to see whether the results justify its continued use.

All forms of Fynbos are susceptible to invasion by alien (introduced) tree species, notably the Australian *Acacia* (wattle), *Hakea* and *Leptospermum* species, and *Pinus* species (pines) (Wilson et al., 2014). Sand-plain Fynbos is also very prone to invasion by alien herbaceous species, particularly grasses, and so is Renosterveld. Some of the grass invasion may be due to soil enrichment by the nitrogen-fixing *Acacia* species (Heelemann et al., 2010; Krupek et al., 2016; Le Maitre et al., 2011; Musil et al., 2005; Visser et al., 2017).

Arid Fynbos, especially on the deep sands of the Sandveld, would be expected to require fire, but fires are very infrequent in these Fynbos types. Only single occurrences of fires have been detected in the past 16 years and these affected <1% of the Fynbos in the area, with the largest fire being in the Kamiesberg (unpublished data, Advanced Fire Information System, Meraka Institute, CSIR). There have not been any studies of the effects of fire on these Fynbos vegetation types to assess the modes of regeneration (e.g. sprouting and non-sprouting, fire stimulated seed germination or flowering, seedling establishment) or of the time required for species to reach reproductive maturity. The low frequency of fires suggests that fire may not play a significant role in maintaining these communities so they may not require fire to maintain themselves.

There is a growing body of research on the restoration of Fynbos, but it is still a developing science (Gaertner et al., 2012a, 2012b, Heelemann et al., 2013, 2012; Holmes, 2008). There are some guides for restoration in books on the management of the Fynbos and Karoo but mainly developed for higher rainfall areas or the Nama Karoo (Esler et al., 2014, 2010; Esler and Milton, 2006; Krug, 2004). It is clear that removing the upper few centimetres of the topsoil and returning with minimal storage, and the use of treatments to simulate seed-germination can facilitate recovery, but this it still the subject of active research (Hall et al., 2017). Most of this work and experience has been gained in the higher rainfall parts of the biome and there is little experience in the arid areas. Much of the Fynbos vegetation in Phase 5 and, particularly, Phase 6 is at the limits of the climatic tolerance which means that recovery after disturbance could be slow, with a high risk of failure, and probably will require active restoration, as demonstrated by experience at the Namaqua Sands mine in Strandveld vegetation (Blignaut et al., 2013; Pauw, 2011) which is in an area with more higher and more reliable rainfall. There has been research on restoration in Namaqualand but the studies have been located in the Strandveld or Succulent Karoo and not in the Fynbos (Carrick et al., 2015; Carrick and Krüger, 2007; James and Carrick, 2016; Todd, 2008). The uncertainties about the role of fire and the poor understanding of the potential for restoring Fynbos in these areas are strong rationales for making every effort to avoid Fynbos in arid areas when selecting the final gas pipeline routes. Disturbance also facilitates invasion so regular monitoring and control operations will be required as part of the Environmental Management Plans (EMPs).

Many vegetation types (e.g. forests) follow the classical succession model where certain species will regenerate or colonise after a disturbance creates and opening. These initial or pioneer species will then create and environment which can be colonised by other species before they die off and so species replace each other. In Fynbos and Renosterveld all the species re-establish themselves after a fire (disturbance) from seeds or by sprouting, but different growth forms tend to recover at different rates so their prominence and the structure changes over time, creating an apparent succession (Kraaij and Wilgen, 2014; Kruger and Bigalke, 1984). The long evolutionary history of the dominance of regeneration from *in situ* sources in Fynbos after fires, combined with the stable soils, seems to be why Fynbos lacks a pioneer flora capable of colonising sites where the top soil (essentially the upper 50-100 mm) has been removed or markedly disturbed. A long period of dense invasion by alien plant species can also result in the loss of the seed banks and re-sprouting species (Holmes, 2005; Holmes et al., 2000; Holmes and Cowling, 1997). This means that successful recovery on such sites typically requires the reintroduction of seeds or plants. Fynbos and Renosterveld also have a remarkable flora of geophytic species, only a few of which seem to be able to survive soil disturbance. They may also not be well-dispersed and would need to be reintroduced during the rehabilitation of the pipeline corridor and construction areas.

Box 6: Terrestrial fauna of the Fynbos Biome

The diversity and endemism of the terrestrial fauna in Fynbos is not particularly high except for certain groups such as amphibians (60 species in the Western Cape, 36 endemic and 15 threatened), reptiles (146 species, 18 threatened), fossorial mammals (moles) and invertebrates (particularly butterflies, dragon flies, long-tongued flies, beetles) (Anderson et al., 2014; Colville et al., 2014; Turner, 2017). Many of the Fynbos shrub species are known to be deep rooted and the pipeline servitude would have to be kept clear of these plants. The loss of these plant species will change the habitat suitability for fauna that live or feed on, shelter under, or otherwise use or depend on them, so that areas without them may become a barrier to the movement of some terrestrial fauna, notably reptile and invertebrate species.

Biotic interactions are essential for the pollination of many species and many species depend on ants for seed dispersal (myrmecochory) (Anderson et al., 2014; Rebelo et al., 2006). Ant seed dispersal is disrupted by the Argentinian ant which is able to invade disturbed areas and care will be needed to ensure that invasions by this ant species are not facilitated by, for example, ensuring that construction material does not contain colonies of this species (Anderson et al., 2014; Bond and Slingsby, 1990; Wilson et al., 2014).

Although much has been said about the uniqueness of Fynbos and its high plant biodiversity, Fynbos has many other values which generally are not adequately appreciated by the public. These include the benefits derived from the sustained flows of high quality water from Fynbos catchment that support cities and towns and their economies and are used for the production of irrigated crops. Other benefits include species with commercial value in the form of flowers or herbal teas and medicinal products, fibre and thatch, crop pollination, and landscapes that attract tourists (Turpie et al., 2017, 2003). The impacts of unwise developments on the commercial benefits provided by these ecosystems also need to be taken into account.

4.1.1.5 Albany Thicket

Subtropical thicket is a closed shrubland to low forest dominated by evergreen, sclerophyllous or succulent trees, shrubs and vines, many of which have stem spines. It is often almost impenetrable, is generally not divided into strata, and has little herbaceous cover. According to certain definitions subtropical thickets can be considered as a low forest, however this definition is problematic, for several reasons, in that it often occurs in many areas with a rainfall too low to support forests (<800 mm/yr.), does not have the horizontal stratification of forests, and does not have the signature species typical of Southern African afrotemperate forests, (Vlok et al., 2003).

The vegetation of the Albany Thicket can be divided into three eco-regions: the dry, inland areas of the Fish, Sundays, and Gamtoos river valleys; the mesic coastal areas of these river valleys; and the intermontane valleys to the north and west. The vegetation contains a high proportion of both leaf and stem-succulent shrubs such as Spekboom (*Portulacaria afra), Euphorbia bothae* (dominant along the Fish River Valley), *Euphorbia ledienii* and Noorsdoring (*Euphorbia coerulescens*), (Vlok et al., 2003).

The distribution of Albany Thicket communities is determined by a complexity of interrelated factors. The most important of these appears to be soil type. Albany Thicket is restricted to deep, well-drained, fertile sandy loams with the densest thickets occurring on the deepest soils (Cowling, 1983). Soil moisture is another important limiting factor. The vegetation is adapted to grow in hot, dry river valleys where soil moisture is limited for extended periods. Soil moisture increases towards the east, resulting in thickets that are more open, less succulent and less thorny.

This biome was originally described as 'Valley Bushveld' (Acocks, 1953), for good reasons, it typically occurs within the steep slopes of river valleys. This has been a particularly problematic veld type in terms of its delimitation, origins, affinities and dynamics. Tinley (1975) was the first to recognise Valley Bushveld and allied types (Spekboomveld and Noorsveld) as part of a ‘thicket biome’, characterised by a closed-canopy vegetation consisting of an impenetrable tangle of shrubs and low tree. However, Cowling (1984) was the first to formalise the thicket concept in the South African phyto-sociological literature, and Low & Rebelo (1996) recognized the thicket biome in a revised map of Southern Africa vegetation types. The first comprehensive study of the vegetation patterns of diversity was done by Vlok et al., (2003). This yielded 112 unique thicket vegetation types, 78 of which comprised thicket clumps in a matrix of non-thicket vegetation (mosaics).

Box 7: Important aspects of the Albany Thicket biome

Albany Thicket vegetation has some unique characteristics that need to be considered in a biodiversity vegetation monitoring programme as well as in the restoration of natural habitat following pipeline construction. These include the following:

- High vulnerability to overgrazing by livestock, in particular *Portulacaria* dominated vegetation types. This is particularly relevant when rehabilitating sensitive habitat where livestock may be present.
- High vulnerability of some thicket types to fire damage;
- Invasive alien vegetation, especially rooikrans, (*Acacia cyclops*) poses a real threat to Thicket by increasing the fuel load. This renders it prone to hot fires that will severely damage if not destroy the succulent and tree component; and
- Slow re-growth and recovery after vegetation removal. This is particularly true for arid and some mesic thicket vegetation types.
- Disturbance in arid areas of succulent thickets are prone to invasion of karroid species and arid adapted alien vegetation (Milton, & Dean, 2010). This needs to be considered in restoration plans.

The Albany Centre is a major centre of botanical diversity and endemism for succulents of karroid affinity, especially in the Mesembryanthemeceae, Euphorbiaceae and Crassulaceae, as well as a centre for certain bulb groups. Subtropical thicket is renowned for its high plants species richness and levels of endemism (i.e. species that grow nowhere else). Vlok & Euston-Brown (2002a) provide a tally of 1 588 subtropical thicket species for the planning domain, 322 (20 %) of which are endemic. Most of these endemics are succulents associated with the vygie, euphorbia, crassula, aloe and stapeliad plant groups (Vlok & Euston-Brown, 2002a). The subtropical thicket is associated with two globally recognised centres of succulent plant endemism, namely the Little Karoo Centre of the Succulent Karoo in the west and the Albany Centre in the east (van Wyk & Smith, 2001). The Albany Centre encompasses elements of the Cape, Succulent Karoo and Maputaland-Pondoland regions. The Subtropical Thicket biome comprises the south-western sector of the Maputaland-Pondoland hotspot.

According to Mucina and Rutherford (2006), overall 60 % of this biome has been severely degraded, with only 11 % still in pristine condition, and around 7.3 % totally lost. The mesic thicket, which has the highest levels of endemism and species richness within the Thicket biome, is under the greatest pressure. A more detailed analysis by Lloyd et al. (2002) and Vlok & Euston-Brown (2002b) provides figures on levels of severely degraded and moderately degraded thicket for each vegetation sub-class. This analysis shows that except for the Mainland Montane Solid (Thicket) and Coastal Dune Solid Thicket, all the vegetation units described show high levels of severe and moderate degradation.

Forms of thicket vegetation that have been especially ravaged by overgrazing in the past century, are those rich in spekboom or igwanishe, *Portulacaria afra*. There is evidence that even in the short space of a decade, heavy browsing, especially by mohair-producing angora goats, can convert dense shrubland into a desert-like state (Vlok & Euston-Brown, 2002a). Of some 16,000 km^2 formerly covered in spekboom-rich thicket, some 46 % has undergone severe degradation and 34 % moderate disturbance. This is predominantly from overgrazing, although clearing for crop cultivation is another major threat to the Thicket vegetation. Land has been cleared along the rivers, and lucerne and other crops are grown under irrigation. Land has also been cleared for orange orchards in the Addo region (Vlok & Euston-Brown, 2002b).

The role that indigenous herbivores may have played in determining vegetation boundaries, as do domestic livestock today under certain management regimes has been the subject of much speculation (Hoffman & Cowling, 1990). Several studies have shown that African elephant (*Loxodonta Africana*) has a substantial impact on subtropical thicket composition (Stuart-Hill, 1992), however, these animals as well as black rhinoceros (*Diceros bicornis)*, even under exceptionally high population density (unlike goats) do not convert solid thicket into a mosaic savannah, as Thicket types are probably much more resilient to the impacts of indigenous herbivores. Overgrazing by domestic livestock, in particular goats, has caused dramatic changes in thicket vegetation, with Nama-Karoo shrub like elements invading Arid Thicket types, and subtropical grasses massively increasing in cover in some Valley Thickets, creating savanna-like vegetation that burns at regular intervals, further eliminating succulents and fire-sensitive shrubs (Hoffman & Cowling, 1990).

Box 8: Terrestrial fauna of the Albany Thicket Biome

The fauna of the Albany Thicket biome, although diverse, does not demonstrate the level of endemism shown by the flora (Vlok et al., 2002a).

Mammal diversity is relatively high, with 48 species of large and medium-sized mammals, a consequence of the diversity of biomes within the STEP planning domain. Unfortunately, many of these species have been extirpated and all have undergone extensive reductions in their distribution. The smaller mammals include at least two endemic species (long tailed forest shrew and Duthie's golden mole), none of which is restricted to subtropical thicket.

The avifauna is diverse, with 421 species of birds recorded within the planning domain (with no endemics), of which 307 species utilise thicket (Dean, 2002). Birds appear to play an important role in seed dispersal of thicket plants (Dean, 2002). A total of 10 "Important Bird Areas" occur within the planning domain, although only three of these include subtropical thicket (Dean, 2002).

The reptile fauna includes five tortoise species – an exceptional tally - as well as relatively high endemism (six species) among the lizards and snakes (Branch, 1998). The amphibian fauna includes at least three endemic species (Passmore & Carruthers, 1995). Although the invertebrate diversity and endemism is probably high, little is known about this group, other than charismatic species such as the flightless dung beetle (*Circellium bacchus*),which is restricted to subtropical thicket.

Unfortunately, removing livestock and resting the veld does not lead to natural recovery of the vegetation, as seedling establishment is constrained by the exposed soil's temperature extremes and reduced water-holding capacity. Essentially, to restore this thicket type requires active interventions (Vlok & Euston-Brown, 2002a).

4.1.1.6 Indian Ocean Coastal Belt

The climate of the east coast of southern Africa is controlled by the presence of a high pressure system lying to the east of the sub-continent and intermittently, the area is influenced by low pressure systems arising from the Southern Ocean, particularly during winter. In the late summer, cyclonic systems moving across the Indian Ocean often lead to catastrophic storm events along the coastline (Tinley, 1985). This meteorological regime plays a significant role in determining the form of habitats that are found within the Indian Ocean Coastal Belt (IOCB) (Mucina and Rutherford, 2006) and gives rise, in part, to fundamentally differing habitat types within the biome. For example, within the northern areas, grasslands and forest habitats that are proximal to the coastline, are subject to intensive storm activity associated with cyclonic activities, which play a key role in forest gap dynamics (Yamamoto, 1996) while the high level precipitation associated with these events is an important driver in grassland and woodland communities in the north of KZN. Rainfall in the southern extent of the IOCB is comparatively less than that encountered in the north, although less seasonal with a more bimodal rainfall regime. It is perhaps due to these drivers that these vegetation types are primarily grassland and open woodland-mosaic environments which form an association of habitats within any given range.

Additionally, edaphic form and function within the IOCB can also be considered a primary driver of many of these habitats, tempering growth in woody species through the availability of freshwater and nutrients. The influence of anthropogenic factors, mainly fire but often the grazing of livestock, must also be considered one of the major drivers of the habitat forms within the IOCB, particularly over the last 500 years (McCracken, 2008).

The main vegetation types comprising the IOCB are:

- Maputaland Coastal Belt (CB1): Flat coastal plain. Densely forested in places. Range of non-forest vegetation communities – dry grasslands/palmveld, hygrophilous grasslands and thicket.
- Maputaland Wooded Grassland (CB2): Flat coastal plain. Sandy grasslands rich in geophytic suffrutices, dwarf shrubs, small trees and rich herbaceous flora.
- Kwazulu-Natal Coastal Belt (CB3) - Highly dissected undulating coastal plains. Subtropical coastal forest presumed to have been dominant. *Themeda triandra* dominated primary grassland.
- Pondoland-Ugu Sandstone Coastal Sourveld (CB4): Coastal peneplains and undulating hills with flat table lands and very steep slopes of river gorges. Species rich grassland punctuated with scattered low shrubs or small trees.
- Transkei Coastal Belt (CB5): Highly dissected, hilly coastal country. Alternating steep slopes of low reach river valleys and coastal ridges. Grasslands on higher elevations alternative with bush clumps and small forests.

Parts of the IOCB are threatened by heavy metal dune mining - prospecting and extraction; IAP invasion; tourism development; exploitation for commercial and small scale woodlot plantation; urban settlement and other agriculture (Mucina & Rutherford, 2006).

Box 9: Terrestrial fauna of the Indian Ocean Coastal Belt Biome

The IOCB occupies a climatic niche identified using the Koppen – Geiger classification system as Cfa (*warm temperate; fully humid; hot summer*) (Kottek et al., 2006). This climatic regime, as explained above, as well as a topographically diverse environment and a relatively recent history of human settlement has given rise to some diverse ranges of habitat and a concomitantly diverse faunal assemblage. It follows that both **habitat form and structure** and **faunal presence** as well as the interface between these two elements forms the guiding pre-requisites for evaluation of suitable routes for the gas pipeline within the IOCB.

However, the rapid expansion of human settlement in the region, particularly following the nagana of the 1860s has seen the confinement of much of the larger fauna to protected areas and private game farms, while smaller species, including invertebrates are confined to niche environments, such as scarp forest, that are not affected by human activities. Notably, some species have benefitted from human settlement and agricultural activities, at the expense of others. The subtropical climate experienced by the IOCB, as well as the availability of water, offer suitable habitat for a wide range of fauna. The network of protected areas, particularly in the northern portion of the IOCB are critical for the maintenance of faunal biodiversity, in the wake of the extensive disturbance which has been associated with urbanisation, peri-urban settlement and agriculture in surrounding area with the IOCB.

More specific to the Margate region and the sandstone grasslands of the lower KwaZulu-Natal South Coast in particular, is the presence of two butterfly species, *Lepidochrysops ketsi leucomacula* (white blotched ketsi blue) and *Durbania amakosa albescens* (whitish amakhoza rocksitter). The presence of these two species has been verified by EKZN Wildlife during field reconnaissance undertaken as recently as March 2017 (Armstrong pers comm, 2017). *L. ketsi leucomacula*, according to Armstrong, is endemic to the coastal stretch between Margate and Port Edward and is probably only associated in the Margate region. Due to a complex lifecycle including an association with the presence of formicids (ants) (Woodhall, 2005), the species may be considered to be susceptible to impacts of both a direct and indirect nature. *D. amakosa albescens* is considered to be “vulnerable” from a conservation perspective, primarily on account of a decline in suitable habitat. Habitat includes “rocky ledges” and open lichen-encrusted terrain. Open areas of rugged terrain, unaffected by development, are considered to be important for the continued preservation of the species. This is an example of a faunal species that may be significantly impacted by the disturbance caused by the construction of a pipeline, due to its dependence on specific habitat, interactions and associations. Many larger, more mobile and adaptable fauna species may simply relocate temporarily and remain largely unaffected.

4.1.1.7 Grassland

Grasslands, as the name implies, are dominated by a grass layer. However, from a biodiversity perspective it is the huge diversity of non-grass species, often referred to as forbs, that give the Grasslands biome their high diversity (O'Connor and Bredenkamp, 1996; Mucina and Rutherford, 2006). It is also these forbs that are typically the rare and endangered species within the Grassland biome. Identifying and conserving these non-grass species will be of particular importance during the construction phase. In many cases these plants can be dug up and replanted once construction is completed.

Grasslands are arguably one of the most threatened biomes in the country, with many Grassland types very poorly conserved. In addition, Grasslands have some of the most transformed vegetation types, with a large proportion of the national cereal crop agriculture taking place in the Grasslands (Rayers, 2001; Fairbanks et al., 2000). Most of the plantation forestry, a large proportion of mining as well as some of the biggest metropolitan areas are also located within the Grasslands. In Gauteng, there is exceptionally limited natural or even semi-natural Grassland remaining. Similarly, large amounts of the Grassland in the Eastern Cape corridor have also been transformed. This places a high conservation importance on all remaining Grassland.

4.1.1.8 Savanna

The unique feature of Savanna that separates it from Grassland is the occurrence of a tree layer in addition to an herbaceous layer. Savanna, although having a high *alpha* diversity (i.e. species diversity at the plot level), the species turnover, *beta* diversity, and landscape (*gamma*) diversity is relatively low (Scholes, 1997). This attribute of Savanna makes them relatively resistant to small-scale disturbances as a small disturbance is unlikely to have catastrophic loss to any particular species. However, there are specific locations with threatened and endangered species where these species would need protection. In addition, a number of the individual tree species within Savannas are protected, such as Camel thorns, Baobabs, and Stinkwood, require a permit in terms of the NFA to be cut.

Box 10: Terrestrial fauna of the Grassland and Savanna Biomes

Savanna and Grassland are the home to a large number of mammals, and these animals move over considerable distances to locate grazing. During the pipeline construction phase it is feasible that the movement of animals might be hindered if not managed appropriately, but this is not likely to be a factor in the post-construction phase assuming adequate rehabilitation is conducted. Small mammals, rodents, reptiles, invertebrates and ground birds may also be hindered during construction. If the post-construction habitat does not have the same functional attributes (e.g. vegetation type and density) as the original habitat, then some of these species may have difficulty crossing or utilizing the new habitat. Many of the large and charismatic threatened mammal species such as both black and white rhinoceroses (*Diceros bicornis* & *Ceratotherium simum*), cheetah (*Acinonyx jubatus*) and cape hunting dogs (*Lycaon pictus)* are found in the Savanna and Grassland corridors. These species are almost exclusively limited to protected areas and private reserves and as such their distribution is easily identified. Despite preventative measures being in place, during construction there is a potential threat of these species falling into the construction trench, although post construction impacts will be minimal. A few large endangered mammals such as leopard (*Panthera pardus)*, mountain reedbuck (*Redunca fulvorufula)* and Oribi (*Ourebia ourebi)* may occur in suitable habitats outside of conservation areas and will need specialists to identify potential locations where these species may be encountered (Child et al. 2016).

The distribution of small mammals, reptiles and insects are far harder to ascertain, although a large number of Critically Endangered, Endangered and Vulnerable species occur within the pipeline corridors. In many cases these species have small ranges and often use burrows for shelter and breeding. As such the construction phase could potentially have high significance impacts. For instance, some of the golden moles e.g. the Critically Endangered rough-haired golden mole (*Chrysosphalax villosus)* or the endangered Juliana's golden mole (*Eamblysomus julianae)* are limited to a few sites. A pipeline trench could conceivably cut through a population and create a habitat that cannot be crossed by this burrowing species. A number of golden moles are found within the potential corridors. The sungazer lizard (*Smaug giganteus)* is an example of an endemic and Vulnerable reptile from the arid Grasslands.

Savanna as a biome, is well conserved; however, many of the specific Savanna vegetation types found within the corridors, are very poorly conserved (Mucina and Rutherford, 2006).

Both Savanna and Grassland are fire dependent environments. Fire frequency is dependent on mean annual precipitation, with fire return intervals being once every two to three years in moist area, but reducing in dry areas. Maintaining a fire frequency on the restored land is important for maintaining biological integrity of the vegetation type (Mucina and Rutherford 2006; O'Connor and Bredenkamp, 2006; Scholes, 1997).

4.1.2 Freshwater ecosystems

Freshwater ecosystems, i.e. wetlands and rivers, are valuable ecosystems and it is well documented that they provide numerous ecological and hydrological functions (Cowan, 1995; Breen et al., 1997; Mitchell, 2002). These functions include improving water quality (reductions in suspended sediments, excess plant nutrients and other pollutants), streamflow regulation (flood attenuation, water storage and sustaining streamflow), groundwater recharge, erosion control, and the maintenance of biodiversity for wetland-dependant fauna and flora (Kotze and Breen, 1994). Consequently, wetlands and rivers provide many important services to human society. At the same time, through continued negative perceptions by humanity, they remain ecologically sensitive and vulnerable systems (Turner et al., 2003).

Historically, freshwater ecosystems have been subjected to numerous pressures from surrounding developments and changing land use, to the extent that many wetlands and rivers have been severely degraded or completely lost (Kotze et al., 1995). This has largely been as a result of human activities, either through direct disturbance, or indirectly from impacts upstream (Breen et al., 1997). More than two decades ago, it was estimated that over half of South Africa's wetlands had been lost (Kotze et al., 1995).

The current situation is no doubt even greater, and of the remaining systems, 48% are classified as Critically Endangered (CR) (Nel and Driver, 2012). Thus, freshwater ecosystems need to be safeguarded as much as possible from on-going and future development in order to maintain, or even improve the status of existing wetland and river habitats.

Box 11: Gas pipeline development and groundwater

The proposed gas pipelines will be constructed below ground at a depth of about 1 – 2 m from the earth's surface to the top of the pipeline. The relatively shallow placement of the pipeline and associated construction activities are unlikely to significantly impact on ground water and deep aquifers. Since aquatic systems are not driven significantly by ground water resources, and the impacts from gas pipelines will be minor when considering deep ground water flows, groundwater is not considered and assessed in detail as a strategic issue in this SEA.

Aspects relevant to potential contamination of groundwater or subsurface drainage are discussed under Aquatic Ecosystems throughout this chapter.

The most common methods involved in pipeline construction spanning water bodies are trenched (wet open-cut and dry open-cut techniques) or trenchless techniques (such as HDD). Trenchless techniques require excavation of pits intermittently along the pipeline route and the assistance of drilling fluids or bentonite based "muds", which in the long term can affect ground water flows.

It is important to note that site specific assessments will be undertaken prior to actual gas pipeline development, and if warranted, Geohydrological and/or Geotechnical Assessments will be commissioned by the Pipeline Developer once a specific pipeline route has been determined.

Strategic Water Source Areas (SWSAs) are defined as "areas of land that either: (a) supply a disproportionate (i.e. relatively large) quantity of mean annual surface water runoff in relation to their size and so are considered nationally important; or (b) have high groundwater recharge and where the groundwater forms a nationally important resource; or (c) areas that meet both criteria (a) and (b)" (Le Maitre et al., 2018:1). Changes in the quantity and quality of the water produced by these areas can have adverse effects on economic growth and development in the regions that they support (CSIR, 2017). Thirty-seven groundwater SWSAs have been identified in South Africa and are considered to be strategically important at a national level for water and economic security (Le Maitre et al. 2018). The total area for groundwater SWSAs extends approximately 104 000 km^2, and covers approximately 9 % of the land surface of South Africa (Le Maitre et al. 2018). Based on this, the SWSAs have been rated as high sensitivity areas for proposed gas pipeline development.

Groundwater SWSAs are present within the proposed gas pipeline Phases 1, 2, 3, 4, 5 and 7 (Figure 3). The Phase 5 Corridor includes the Sandveld Groundwater SWSA. The Phase 1 corridor includes the West Coast Aquifer, North-Western Cape Ranges, Tulbagh-Ashton Valley, South-Western Cape Ranges, and Cape Peninsula and Cape Flats Groundwater SWSAs. The Phase 2 corridor includes the Coega TMG Aquifer, and George and Outeniqua Groundwater SWSAs. The Phase 7 corridor includes the Transkei Middleveld, Ixopo, KwaDukuza, and the Richards Bay Ground Water Fed Estuary Groundwater SWSAs. The Phase 4 corridor includes the Zululand Coastal Plain Groundwater SWSA. The Phase 3 corridor includes portions of the Richards Bay Ground Water Fed Estuary, Zululand Coastal Plain, Far West Karst Region, West Rand Karst Belt, Eastern Karst Belt and Ventersdorp/Schnoonspruit Karst Belt Groundwater SWSAs. Extremely small areas of the Rompco Pipeline Corridor (Phase 8) and Inland Corridor contain Groundwater SWSAs. No Groundwater SWSAs are located within the Phase 6 Corridor.

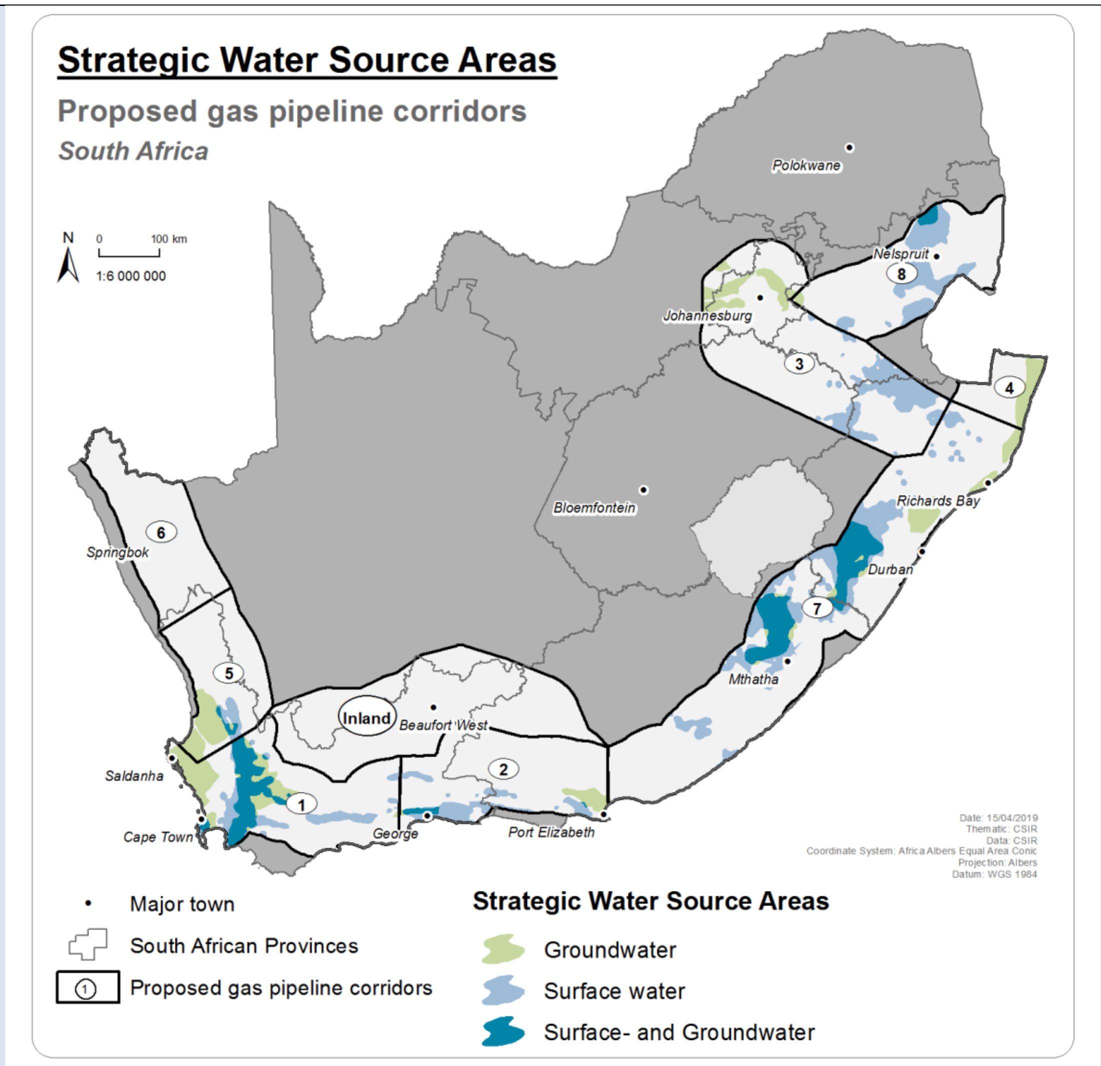


Figure 3: Strategic Water Source Areas of South Africa.

4.1.3 Estuaries

An estuary is defined as ''a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action, back-flooding or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area, and when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline" (Van Niekerk and Turpie, 2012:29).

South African estuaries differ considerably in terms of their physicochemical and biotic characteristics (Colloty et al., 2002; Vorwerk et al., 2008). Despite their differences, proactive planning and effective management of estuaries require an understanding of changing estuarine patterns, processes and responses to global change pressures (i.e. those that arise directly from anthropogenic activities as well as climate change). As human population pressures escalate, the need for strategic management becomes increasingly evident (Boehm et al., 2017; Borja et al., 2017). Reactive planning of resource allocation in these systems on an estuary-by-estuary basis is costly, time consuming and not feasible. Proactive planning requires a strategic assessment of change at a range of scales to ensure optimum resource use.

Estuaries and adjacent ecosystems form an interrelated network of life-support systems that includes neighbouring terrestrial and marine habitats. Many estuarine species are dependent on different habitats in order to complete their life cycles (Whitfield, 1998). Estuarine ecosystems are, therefore, not independent and isolated from other ecosystems. Rather, estuaries form part of regional, national and global ecosystems, directly through connections via water flows (e.g. the transport of nutrients and detritus) and indirectly via the movement of estuarine fauna (e.g. Gillanders, 2005; Ray, 2005). Linkages between individual estuaries and other ecosystems span scales ranging from a few hundred metres to thousands of kilometres. Therefore, impacts to a specific estuarine ecosystem may affect ecosystems seemingly remote from that estuary, and have ramifications for ecosystem goods and services that people rely on from areas distant over large spatial scales. The closure of Lake St Lucia for example, resulted in declines and eventual closure of a prawn fishery on the Thukela Banks over 100 km to the south.

South Africa has nearly 300 relatively small estuaries, the majority (>70%) of which are <50 ha in size. These estuaries fall into three biogeographical regions which characterise the South African coast; namely the Cool Temperate west coast, the Warm Temperate southern and south-east coast, and the Subtropical east coast (Emanuel et al., 1992; Harrison, 2002; Turpie et al., 2002) (Figure 4). In addition to obvious sea temperature differences, rainfall patterns in these regions vary significantly (Davies and Day, 1998; Lynch, 2004; Schulze and Lynch, 2007; Schulze and Maharaj, 2007). Annual runoff of South African rivers is highly variable and unpredictable in comparison with larger Northern Hemisphere systems, fluctuating between floods and extremely low (to zero) flows (Poff and Ward, 1989; Dettinger and Diaz, 2000; Jones et al., 2014). Estuary catchment sizes range from very small (<1 km^2) to very large (>10 000 km^2), with those in the Cool Temperate region tending to be larger than those in the Warm Temperate and Subtropical regions (Jezewski et al., 1984; Reddering and Rust, 1990).

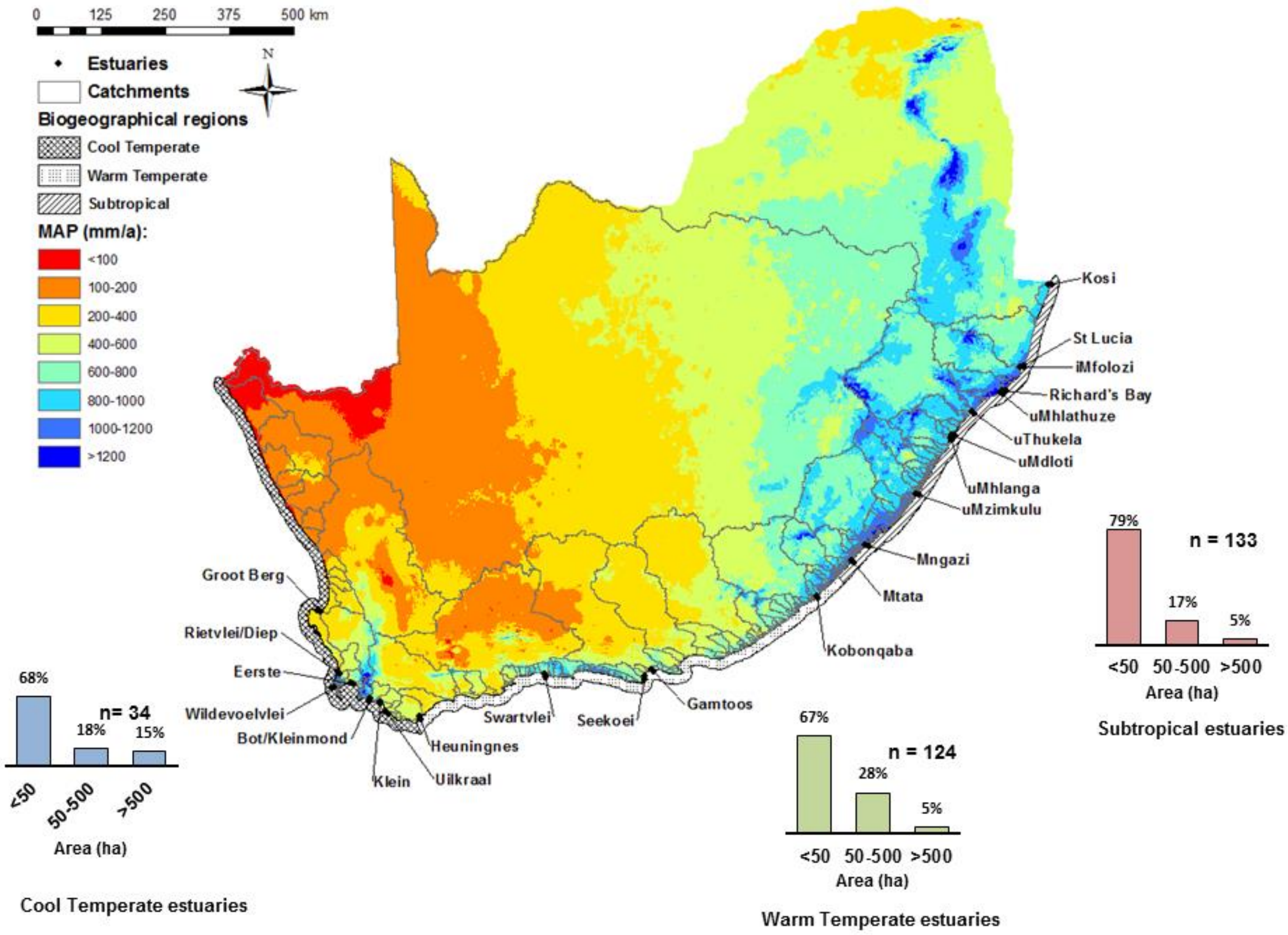


Figure 4: Map showing the three biogeographical regions, relative catchment size, mean annual precipitation (MAP) (in mm/a) and estuary size distribution (in ha) for South Africa (van Niekerk et al. 2013).

Strong wave action and high sediment availability results in more than 90% of South African estuaries having restricted inlets (or mouths). More than 75% of estuaries close for varying periods of time due to sand bar formation across the mouth (Whitfield, 1992; Cooper, 2001; Taljaard et al., 2009; Whitfield and Elliott, 2011). Most estuaries are highly dynamic with an average water depth of 1-5 m. The tidal range around the whole coast is microtidal (<2 m) but high wave energy, makes it a wave-dominated coast (Cooper, 2001).

Estuaries exhibit a high spatial heterogeneity, with each system characterised by its own unique geomorphology and physicochemical processes. Individual systems can be highly variable temporally and the full spatial extent (i.e. tidal limit or back-flooding mark) of many systems remains unknown. This makes it difficult to delineate the dynamic spatial area where estuarine processes occur within each system, the so-called Estuary Functional Zones (EFZ). In South Africa the EFZ is generally defined by the +5 m topographical contour (as indicative of 5 m above mean sea level) and includes all the estuarine open water area; estuarine habitats (sand and mudflats, rock and plant communities) and adjacent floodplain area whether developed or undeveloped. It therefore encompasses not only the estuary water-body but also all the habitats that support physical and biological processes that characterise an estuarine system.

For the purposes of this study, and as is typical in estuarine assessment in a South African context, all permanent coastal water bodies (i.e. not ephemeral water bodies) sporadically or permanently linked to the sea were regarded as estuarine systems. Using existing estuarine vegetation and fish data sets, published and unpublished literature, as well as anecdotal information, all systems were evaluated by an expert panel and their health evaluated (Van Niekerk and Turpie, 2012).

4.1.3.1 Sedimentary processes of importance

Estuaries are complex water bodies and differ considerably from fluvial systems. In estuaries the flow reverses due to tidal inflows being stronger than freshwater outflows. Water quality charges in an estuary are also complex due to both upstream and downstream sources.

Estuaries also have two sources of sediment; that from the river (delivered primarily during floods) and a supply of marine sediment from the ocean delivered by littoral drift and transported by tidal currents into the estuary. Within estuaries, tidal sediment transport is a result of the interaction of both currents and waves. This is especially dynamic in the mouth region of estuaries and further up the system wave action is rapidly reduced. Wave-current interaction considerably complicates sediment transport predictions. During neap tides, maximum water velocities in the estuary are low with little sediment transport, while both velocities and transport increase towards spring tides. Significantly, in some estuaries over this neap to spring period, there is a net upstream sediment transport, e.g. in the Goukou (Beck et al., 2004). If there is a long-term net ingress of marine sediment (which is often the case), then the only plausible way for a long-term equilibrium to be established is for occasional large river floods to flush out this accumulated sediment.

Floods therefore, are the most important natural processes which erode and transport sediments out of estuaries. Large volumes of sediments can be removed in a very short time during major floods with a return period of 1 in 50 years and more. Smaller floods with return periods of 1-2 years can sometimes also have a significant influence. Floods of various scales therefore play a major role in the equilibrium between sedimentation and erosion in estuaries (Beck et al., 2004).

This is an important consideration because sedimentation of South African estuaries has created several environmental and social problems. Sediment transport imbalances are caused by changes in the river inflow (especially floods), increased catchment sediment yields and hard structures in estuaries that change flow velocities. Reduced sediment transport capacities within estuaries and decreased flushing efficiencies cause increased sedimentation and in the long-term this may lead to the complete closure of estuaries.

Estuary channel formation is also highly dynamic on decadal time scales. During low flow periods shallow tidal flows can meander several sand banks in the EFZ. During floods rapid changes in estuarine morphology occur over very short time frames. The system can be completely reset and channels can be scoured by meters, only to be filled in over time again by catchment and marine sediment. These types of changes can be illustrated using the Thukela Estuary as an example (Figure 5). Scouring during flooding can be significant with numerical modelling studies indicating possible scour depths on larger river systems of between 20 and 30 m (Basson et al., 2017).

These dynamic processes are an integral part of the natural functioning of South African estuaries and need to be accounted for in proposals to develop within EFZs. In the context of the present work, proposed crossings of estuaries by pipelines need to be assessed with the knowledge that estuary channel formation can occur anywhere in the EFZ and that scouring during floods (with a return period of 1:10 years) is significantly deeper than the observed estuary bed levels under typical (non-flood) conditions.

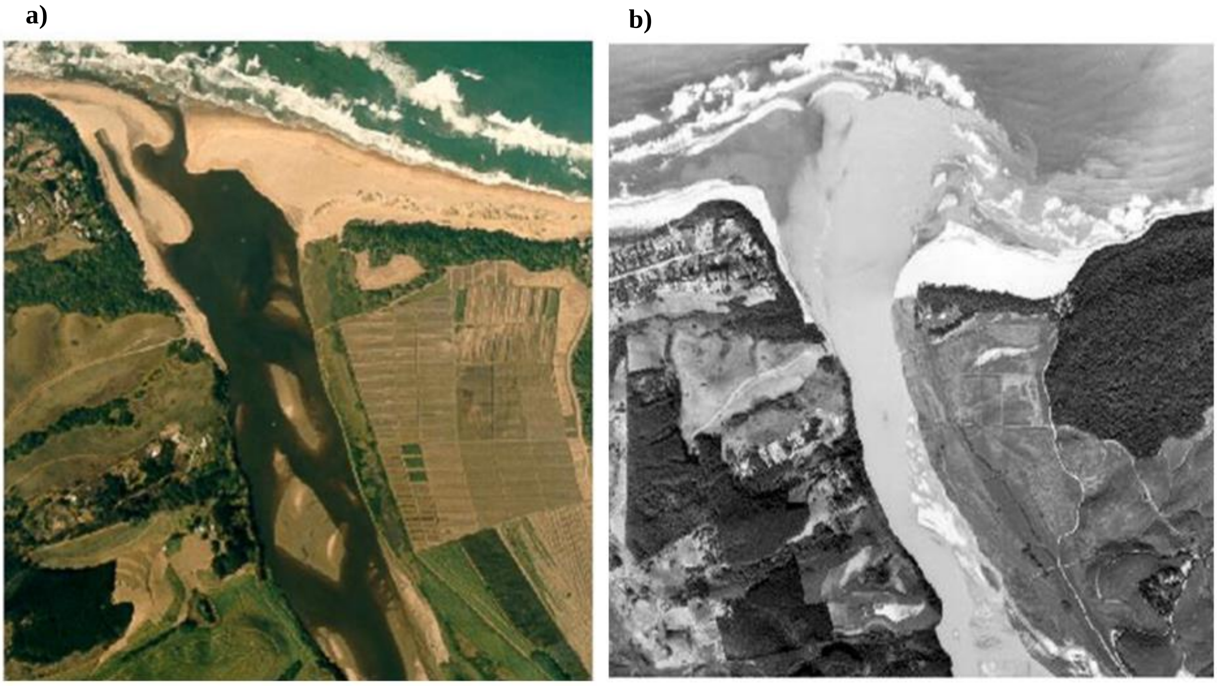


Figure 5: a) Thukela Estuary under low flow conditions with a stable channel meandering between sand banks; and b) under resetting flood conditions with high volumes of sediment being eroded from the system.

4.1.3.2 Habitat of importance

Estuaries are generally made up of a high diversity of habitat types, which include open water areas, un-vegetated sand-, mudflats and rock areas, and vegetated areas (plant communities). Plant community types can be subdivided into submerged macrophytes, salt marsh, mangroves, reeds and sedges (Adams et al., 2018).

- **Open water area:** Un-vegetated basin and channel waters which are measured as the water surface area. The primary producers are the phytoplankton consisting of flagellates, dinoflagellates, diatoms and blue-green algae which occur in a wide range of salinity ranging from freshwater to marine conditions.
- **Sand / mudflats / rock:** Soft (mobile) substrates (sand and mud) and hard (non-mobile) substrates (rocks) and shorelines areas. Habitat mapping from aerial photographs cannot distinguish between sand and mud habitats and therefore in databases used for the purposes of this study are presented as a single area. The dominant primary producers of these habitats are the benthic microalgae.
- **Macroalgae:** Macroalgae may be intertidal (intermittently exposed) or subtidal (submerged at all times), and attached or free floating. Filamentous macroalgae often form algal mats and increase

in response to nutrient enrichment or calm sheltered conditions when the mouth of an estuary is closed. Typical genera include *Enteromorpha* and *Cladophora*. Many marine species can get washed into an estuary and providing that the salinity is high enough, can proliferate. These include *Codium*, *Caulerpa*, *Gracilaria* and *Polysiphonia*.

- **Submerged macrophytes:** Submerged macrophytes are plants that are rooted in the substrate with their leaves and stems completely submersed (e.g. *Stukenia pectinata* and *Ruppia cirrhosa*) or exposed on each low tide (e.g. the seagrass *Zostera capensis*). *Zostera capensis* occupies the intertidal zone of most permanently open Cape estuaries whereas *Ruppia cirrhosa* is common in temporarily open/closed estuaries. *Stukenia pectinata* occurs in closed systems or in the upper reaches of open estuaries where the salinity is less than 10 ppt.
- **Salt marsh:** Salt marsh plants show distinct zonation patterns along tidal inundation and salinity gradients. Zonation is well developed in estuaries with a large tidal range e.g. Berg, Knysna and Swartkops estuaries. Common genera are *Sarcocornia*, *Salicornia*, *Triglochin*, *Limonium* and *Juncus*. Halophytic grasses such as *Sporobolus virginicus* and *Paspalum* spp. are also present. Intertidal salt marsh occurs below mean high water spring and supratidal salt marsh above this. *Sarcocornia pillansii* is common in the supratidal zone and large stands can occur in estuaries such as the Olifants.
- **Reeds and sedges:** Reeds, sedges and rushes are important in the freshwater and brackish zones of estuaries. Because they are often associated with freshwater input they can be used to identify freshwater seepage sites along estuaries. The dominant species are the common reed *Phragmites australis*, *Schoenoplectus scirpoides* and *Bolboschoenus maritimus* (sea club-rush).
- **Mangroves:** Mangroves are trees that establish in the intertidal zone in permanently open estuaries along the east coast of South Africa, north of East London where water temperature is usually above 20°C. The white mangrove *Avicennia marina* is the most widespread, followed by *Bruguiera gymnorrhiza* and then *Rhizophora mucronata*. *Lumnitzera racemosa*, *Ceriops tagal* and *Xylocarpus granatum* only occur in the Kosi Estuary.
- **Swamp forest:** Swamp forests, unlike mangroves are freshwater habitats associated with estuaries in KwaZulu-Natal. Common species include *Syzygium cordatum*, *Barringtonia racemosa* and *Ficus trichopoda*. It is often difficult to distinguish this habitat from coastal forest in aerial photographs.

Box 12: Estuarine Species of Conservation Concern

Plants

Some macrophyte species (mangroves and eelgrass) have only recently been reassessed in the Red Data List and freshwater mangrove *Barringtonia racemosa* was only added in 2016 (IUCN, 2012). If categorised as a species of special concern the data provided for each assessment was tabulated. Further research on these species was also captured. If categorised as ‘Least Concern’ details pertaining to the state of the population was not captured unless noted in a particular study. While the spatial location of all species of special concern is not known for South Africa’s estuaries, what is still clear is all estuaries support estuarine habitat of concern and should be deemed as highly sensitive.

Interference (harvesting, clearing, removal) of mangrove and swamp forest is regulated under the National Forests Act 84 of 1998 and destruction or harvesting of indigenous trees requires a licence. All mangrove trees and swamp forests are protected under this act. The taxonomy of some salt marsh species is under currently under review; which makes it difficult to determine their population sizes, report on their threat status or set targets for protection. However according to the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008, as amended), all coastal wetlands, which include salt marshes and mangroves, form part of the coastal protection zone. The purpose of establishing this zone is to restrict and regulate activities in order to achieve the aims as set out in the Act. Other laws pertaining to species in these areas: National Environmental Management Act 1998, Marine and Living Resources Act 1998, The National Environmental Management: Biodiversity Act 2004, and National Forestry Act 1998.

Fish

The IUCN Red List of Threatened Species includes many fish that occur in estuaries in South Africa (ICUN, 2018). By far the majority of these fish are categorised as species of Least Concern. The IUCN Red List categories and criteria (IUCN, 2012) are designed to be applied to the entire (global) range of a species and fish listed in the Least Concern category here range from those which are actually quite common and (still) abundant in South African systems (e.g. *Rhabdosargus sarba*) to species which are uncommon, rare and in a national sense could be considered as endangered (e.g. *Microphis brachyurus*). A species of special concern, in the process of being IUCN red listed, is *Argyrosomus japonicus* (Dusky Kob), a species with South African populations at critically low levels (Griffiths, 1997, Mirimin et al., 2016). Predominant threats faced by the listed species include development (urban, commercial, recreational and industrial), agriculture, mining, resource use (fishing and harvesting of aquatic resources), modification of natural systems (flow modification and other), pollution, and climate change (ICUN, 2018). **All estuaries in the corridors function as nurseries for Critically Endangered or Endangered fish species of high recreational or conservation importance.**

4.2 Description of the proposed gas pipeline corridors

Due to the vast extent of the proposed gas pipeline corridors, all of the biomes of South Africa are potentially affected[2] (Table 8). Note that proposed gas pipeline corridor Phases 3, 8 and Inland and 6 do not border the coastline, as such, estuaries are not directly affected by these corridors.

Table 8: Extent of the biomes within each of the proposed gas pipeline corridors.

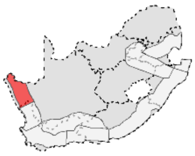
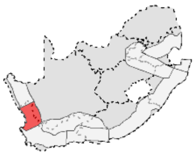
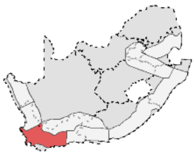
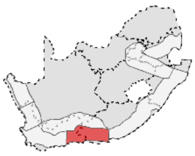
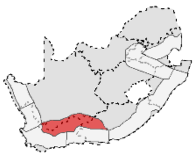
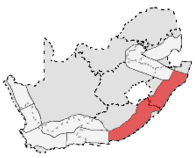
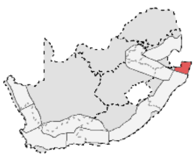
Biome	Extent (% of each proposed gas pipeline corridor)								
	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Inland Phase
Succulent Karoo	15	10			56	65			16
Nama-Karoo	1	15				21	1		62
Fynbos	79	36			38	2	1		7
Azonal Vegetation	2	4	< 1	2	4	1	1	< 1	8
Albany Thicket	4	33					11		4
Grassland		1	86	2			46	62	3
Indian Ocean Coastal Belt				16			7		
Savanna			14	73			31	38	
Desert						12			
*Forests**	*< 1*	*1*	*< 1*	*5*	*< 1*		*2*	*< 1*	

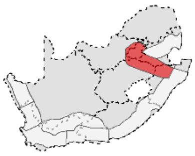
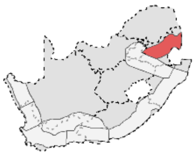
**The Forest biome presents and engineering constraint for gas pipeline development and also contains sensitive and rare environments. Therefore it is assumed that it will be avoided and not considered for regulatory streamlining.*

The ecological and biodiversity environmental description for the proposed gas pipeline phases have been grouped according to biomes. The sequence of the descriptions are arranged from arid/winter rainfall areas to higher rainfall areas (Table 9).

[2] Not all the corridors will eventually be developed. The development of the phased gas pipeline network is based on a viable business case, market demand, and finding a gas source. It is likely that only one of the corridors will be developed, depending on where natural gas is imported or exploited locally.

Table 9: Summary of key environmental features in each of the proposed gas pipeline phases, arranged in the sequence in which they are described in this Section.

Proposed gas pipeline corridor	Brief description	
Phase 6 	• This proposed gas pipeline corridor is situated within Desert, Fynbos, Succulent Karoo, Nama Karoo vegetation types in the Northern Cape and Western Cape Provinces. • Mostly arid environment, with prominent protected areas that include the Richtersveld and Namaqua National Parks (NPs), with extensive areas earmarked as potential NPAES focus areas. • Relatively untransformed when compared to the other proposed gas pipeline corridors.	Arid / winter rainfall
Phase 5 	• This proposed gas pipeline corridor is situated within Fynbos, Succulent Karoo vegetation types in the Northern Cape and Western Cape Provinces. • Notable protected environments include the Cederberg and Winterhoek Mountains. • Relatively transformed by settlements and cultivation.	
Phase 1 	• This proposed gas pipeline corridor is situated within Fynbos, Succulent Karoo, Nama Karoo, Albany Thicket vegetation types in the Western Cape Province. • Extensively transformed by settlements and cultivation, as such many of the remaining ecosystems are of conservation importance and currently protected.	
Phase 2 	• This proposed gas pipeline corridor is situated within Fynbos, Succulent Karoo, Nama Karoo, Albany Thicket, Grassland vegetation types in the Western Cape and Eastern Cape Provinces. • Extensively transformed around major towns (Mossel Bay, George, Port Elizabeth) due to urban settlement and agriculture.	
Inland 	• This proposed gas pipeline corridor is situated within Fynbos, Succulent Karoo, Nama Karoo, Albany Thicket, Grassland vegetation types in the Western Cape, Northern Cape and Eastern Cape Provinces. • Relatively untransformed when compared to the other proposed gas pipeline corridors.	
Phase 7 	• This proposed gas pipeline corridor is situated within Fynbos, Nama Karoo, Albany Thicket, Savanna, Grassland, Indian Ocean Coastal Belt vegetation types in the Eastern Cape and KwaZulu-Natal Provinces. • Transformed by urban settlement and agriculture, especially between Durban and Richards Bay in the KwaZulu-Natal Province. • Many aquatic systems (rivers, wetlands and estuaries) present.	
Phase 4 	• This proposed gas pipeline corridor is situated within Savanna, Indian Ocean Coastal Belt vegetation types in the KwaZulu-Natal Province. • Relatively untransformed when compared to the other proposed gas pipeline corridors, with many protected areas associated with large wetlands present.	

Proposed gas pipeline corridor	Brief description	
Phase 3 	• This proposed gas pipeline corridor is situated within Savanna, Grassland vegetation types in the KwaZulu-Natal, Free State, Mpumalanga, Gauteng, and North-West Provinces. • Extensively transformed by settlements, agriculture and mining.	Higher / summer rainfall
Phase 8 	• This proposed gas pipeline corridor is situated within Savanna, Grassland vegetation types in the Mpumalanga Province. • Extensively transformed by settlements, agriculture and mining, with the Kruger NP occupying the eastern part of the corridor. • Kruger NP occupies most of the eastern corner of this corridor.	

4.2.1 Phase 6

The proposed Phase 6 gas pipeline corridor is located from the Namibian border to the northern most part of the Western Cape Province (Figure 1) predominantly within Fynbos, Succulent Karoo and Nama Karoo vegetation types.

The annual rainfall ranges from <50 mm in the Orange River valley to 100-200 mm over the lowlands and more than 400 mm in the Kamiesberg and is supplemented by fog along the coast. The rain falls mainly in the winter months. The summers are hot and dry. The temperatures are moderated by the typically strong winds but these winds also have a drying effect, creating harsh conditions for plants and animals.

The dominant features of the Phase 6 corridor are the large Protected Areas present in the northern section of the corridor, which includes the Richtersveld National Park and the Richtersveld World Heritage Site, as well as the Orange River Mouth and the Nababieps Provincial Nature Reserves (Figure 6).The central section of the corridor is characterised by several Protected Areas including the Goegap Provincial Nature Reserve and the Namakwa National Park. Other sensitive areas include the Kamiesberg Mountains which are considered largely unsuitable for pipeline construction due to the rugged terrain as well as diversity of this area. Also, elements of sensitive ecosystems can be found in this corridor as isolated fragments located mostly on mountain tops in the Kamiesberg (central), Richtersveld (north) and Bokkeveld (south), or on the coastal plain (west). The Knersvlakte Nature Reserve is an important Protected Area located in the southern section of the corridor.

4.2.1.1 Succulent Karoo, Nama Karoo and Desert

This arid environment is typified by Desert and Karoo vegetation rich in succulents with a high level of species richness and endemism, many of which are of conservation concern such as the Endangered Giant Quiver tree (*Aloidendron pillansii*) and the ‘halfmens’ (*Pachypodium namaquanum*). The abundance of fauna of conservation concern in this corridor is also quite high, with numerous locally-endemic gecko species present along the mountains of the Orange River valley. Along the coast, there are also several fauna of concern including the Namib Web-footed Gecko and Grant’s Golden Mole.

In general, this Phase of the pipeline corridor is considered generally fairly high sensitivity due to the diversity of the underlying Succulent Karoo and Desert vegetation, and the high abundance of features and fauna of conservation concern within this area (Figures 6 and 8). In the north, along the Orange River, as well as in the west, along the coast, there is little scope for avoidance of very high and high sensitivity areas. Also, both the Namaqualand Hardeveld and the Namaqualand Sandveld, as well the Knersvlakte in the south are considered areas of conservation concern. However, some areas in a southerly direction along the centre of the corridor have a medium sensitivity due to the presence of extensive degraded rangeland. The far eastern section of the corridor located within Bushmanland is typified by Nama Karoo vegetation with very few species of conservation concern (SCC) and are thus generally considered to be of low sensitivity.

Although there are these low sensitivity areas situated in the far eastern parts of the corridor, within Bushmanland, it is not likely that this area can be easily accessed by the pipeline route given that the Bushmanland plains are situated on the inland plateau, which are separated from the western section of the corridor by the escarpment. Also, it is recommended that this Gas Corridor is extended westwards towards the coast as there are some less sensitive as well as transformed areas located in the Sandveld along the coast where the topography and soils are also far more conducive for pipeline construction than through the rugged mountains within the current corridor alignment.

4.2.1.2 Fynbos

The Fynbos Biome in the corridor comprises four vegetation types: Namaqualand Granite Renosterveld, Kamiesberg Granite Fynbos, Namaqualand Sand Fynbos, Stinkfonteinberge Quartzite Fynbos (Rebelo et al., 2006). No Azonal vegetation types occur in the areas of the Fynbos vegetation types in the corridor.

Namaqualand Granite Renosterveld and Kamiesberg Granite Fynbos are found on the upper slopes and peaks of Kamiesberg Mountains with the latter confined to the highest peaks in the area. Stinkfonteinberge Quartzite Fynbos is only found on the upper slopes and peaks of some of the Vandersterrberg range in the Richtersveld. They are all endemic to the corridor. Namaqualand Sand Fynbos is found on the leached, deep sands on the coastal plain where the patches are embedded in and grade into the Strandveld vegetation types, which are part of the Succulent Karoo Biome. Most of this vegetation lies to west of the corridor with small portions extending into it.

None of these vegetation types were considered threatened in the 2011 National Biodiversity Assessment (Driver et al., 2012). Many of the plant species are endemic to these vegetation types, especially in the Kamiesberg and Richtersveld (Rebelo et al., 2006). In the 2016 Northern Cape Critical Biodiversity Area (CBA) plan, the Kamiesberg Granite Fynbos is considered a CBA1 (Figure 6) because of its extreme rarity and endemism (with less than 5000 ha of the original area remaining) and because it is confined to the Northern Cape province (Holness and Oosthuysen, 2016). Most of the Namaqualand Granite Renosterveld and Namaqualand Sand Fynbos fall into areas which are CBA1 or CBA2. None of the Namaqualand Sand Fynbos in the Western Cape extends into the corridor.

The northern section of the Stinkfonteinberge Quartzite Fynbos falls within the Richtersveld National Park (NP) and the southern portion within the Richtersveld World Heritage Site. There are no protected areas in the Namaqualand Granite Renosterveld, Kamiesberg Granite Fynbos or the portions of Namaqualand Sand Fynbos that fall into the corridor. The Richtersveld NP and World Heritage site form an extensive protected area in the north (Figure 6), and the Namaqualand NP forms a link between the coast and the Namaqua Highlands. Linking this park to the Kamiesberg is seen as a very high conservation priority.

4.2.1.3 Birds and bats

Bat species of Conservation Importance likely to be encountered in the proposed Phase 6 gas corridor include:

- Angolan hairy bat
- Namibian long-eared bat

Table 10 presents red data species that occur in the biomes present in the proposed Phase 6 gas pipeline corridor.

Table 10: Red Data bird species likely to be encountered in the proposed Phase 6 gas corridor.

Species	Status	Biome				
		Fynbos	Succulent Karoo	Nama Karoo	Desert	Azonal
African Marsh-Harrier	EN	✓				✓
Barlow's Lark	VU		✓		✓	
Black Harrier	EN	✓	✓	✓	✓	
Black Stork	VU	✓	✓	✓	✓	✓
Blue Crane	NT	✓	✓			✓
Burchell's Courser	VU		✓	✓	✓	✓
Caspian Tern	VU					✓
Chestnut-banded Plover	NT					✓
Great White Pelican	VU					✓
Greater Flamingo	NT	✓	✓	✓	✓	✓
Karoo Korhaan	NT	✓	✓	✓	✓	
Kori Bustard	NT		✓			
Lanner Falcon	VU	✓	✓	✓	✓	✓
Lesser Flamingo	NT	✓	✓	✓	✓	✓
Ludwig's Bustard	EN	✓	✓	✓	✓	
Maccoa Duck	NT					✓
Martial Eagle	EN	✓	✓	✓	✓	
Red Lark	VU		✓	✓		
Sclater's Lark	NT		✓			
Secretarybird	NT	✓	✓	✓		
Southern Black Korhaan	VU	✓	✓			
Verreaux's Eagle	VU	✓	✓	✓	✓	
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened						

4.2.1.4 Freshwater ecosystems

Rivers within the proposed Phase 6 gas pipeline corridor are all non-perennial/ephemeral in character with exception of the Gariep (Orange) River (Figure 7), which receives most of its flow from its headwaters in Lesotho and the Vaal River. Most of the river habitats fall within the Namaqua Highland Ecoregion, while a smaller number of systems occur within the Nama Karoo and the Orange River Gorge. Only 5% of the river habitat is considered to be Threatened (i.e. EN and VU). The Present Ecological State (PES) of rivers is generally good, with 30% of the rivers assessed to be in fair condition, while a very small proportion (1%) are in a poor state.

Wetland habitats occupy a very low proportion of the corridor (<1%) owing to the xeric climatic conditions of the Succulent Karoo. Nevertheless, the area supports up to 44 wetland types, dominated by floodplain wetland habitat along the lower Gariep River and channelled-valley bottom wetlands within the Namaqualand Hardeveld region. One Ramsar wetland occurs within the corridor, and is located at the mouth of the Gariep River. A moderate proportion (17%) of the wetlands in the corridor are characterised as NFEPA wetland, which predominantly include floodplain wetland along the Gariep River and seeps within the Namaqualand Hardeveld region. A small proportion (12%) of the wetland habitats are associated with the Endangered Gariep Desert wetland vegetation group.

Approximately 98% of the proposed Phase 6 gas pipeline corridor comprises land that is largely natural, thus only a very small proportion is transformed through urbanisation, agricultural and mining developments. Impacts on freshwater ecosystems from associated land use activities of the transformed landscape are relatively localised within the corridor context. More widespread impacts to freshwater systems tend to be linked to livestock farming practices and infestation of IAPs. The combined effect of anthropogenic pressures results in both localised and widespread impacts that affect functioning and integrity of freshwater ecosystems.

The Kamiesberg is an important water source area at the local level but not at the national level.

Box 13: Red Data aquatic biota likely to be encountered in Phase 6

There are no known occurrences of Red Listed Odonata and fish in the proposed Phase 6 gas pipeline corridor. Three Red Listed amphibians are known to occur in the corridor, namely Breviceps macrops (Near Threatened), which inhabits sandy habitats along Namaqualand coast, *Capensibufo deceptus* (Data Deficient) which occurs in shallow temporary pools with emergent sedge-like plants in Mountain Fynbos or Grassy Fynbos in the Fynbos Biome (IUCN, 2017) and *Breviceps branchi* (Data Deficient), which is only known from a single specimen collected near the Holgat River. One Critically Endangered reptile, *Pachydactylus rangei*, inhabits dry river beds and surrounding dunes/sanding environments in the north western corner of the corridor. One Red Listed mammal occurs within the corridor, namely the Near Threatened *Otomys auratus*. This corridor supports a low diversity of (up to 6) Red Listed plants. Of these, two are Vulnerable (i.e. *Isoetes eludens* and *Oxalis dines*), while four are Near Threatened.

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 6 pipeline corridor include:

- Pollution from application of fertilizers, herbicides and pesticides, as well as point-source discharges from urban centres (e.g. Springbok and Vioolsdrif);
- Grazing by livestock, particularly high/concentrated levels of along watercourses, causing overgrazing and trampling within and adjacent to river and wetland systems, which in turn leads to increased erosion and changes in vegetation structure (notably, the loss of riparian habitat);
- Increases in woody vegetation along rivers, in particular by *Acacia karoo*, as well as infestations of invasive alien species (e.g. *Tamarix* spp. and *Prosopis glandulosa*). These deep-rooted species are able to readily consume groundwater. Heavily infested areas have a significant impact on the hydrology of catchments, as well as outcompeting indigenous species;
- More localised, yet severe impacts, linked to sand mining and other mining activities (e.g. alluvial diamond mining at the mouth of the Gariep River and along the west coast);
- Groundwater utilisation both for domestic and agricultural uses;
- Construction of weirs and dams along river systems, which alters the natural hydrological flows, which is most notable for the Gariep River as a consequence of numerous, large dams/impoundments in the catchment; and
- Road crossings, which cause concentration of surface runoff and localised sheet and gulley erosion in proximity to rivers and wetlands.

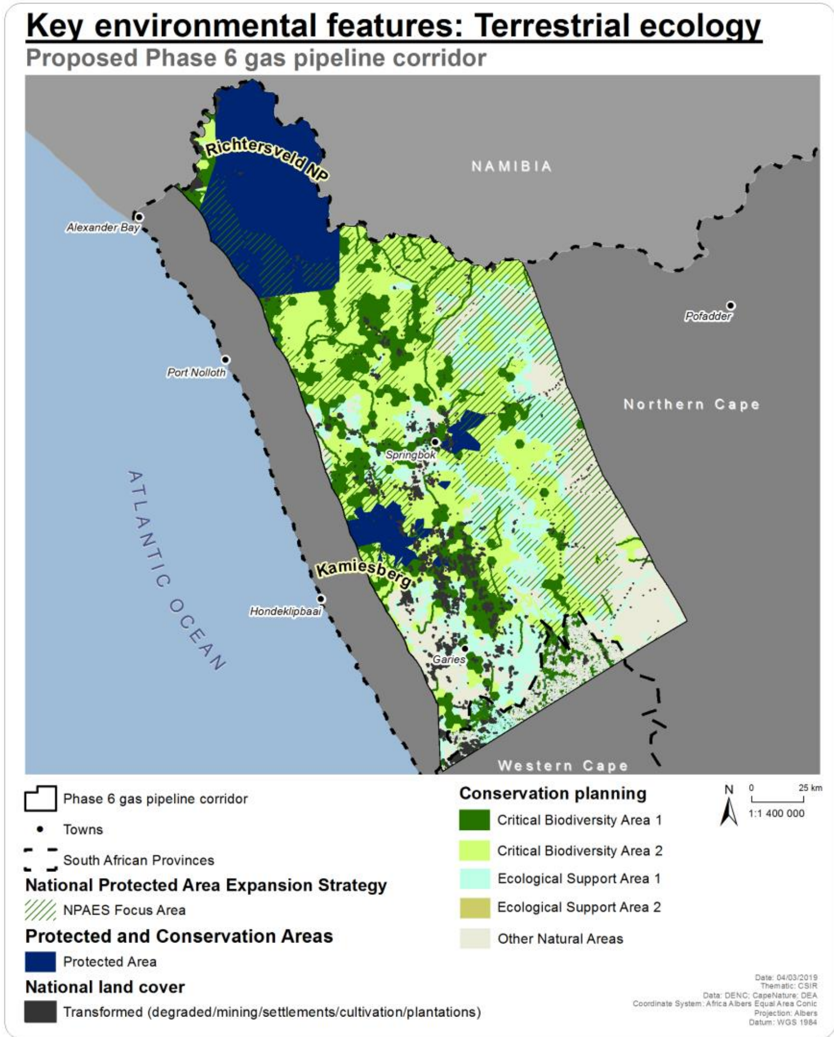


Figure 6: Key environmental features of the proposed Phase 6 gas pipeline corridor.

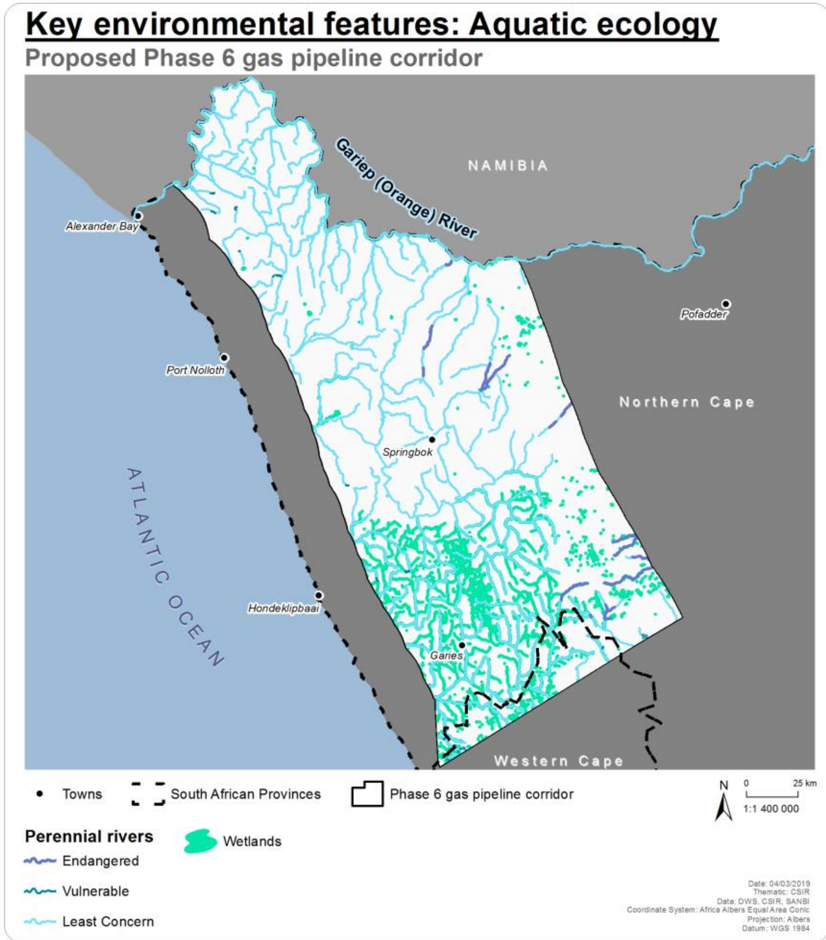


Figure 7: Key aquatic ecosystem features of the proposed Phase 6 gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extents.

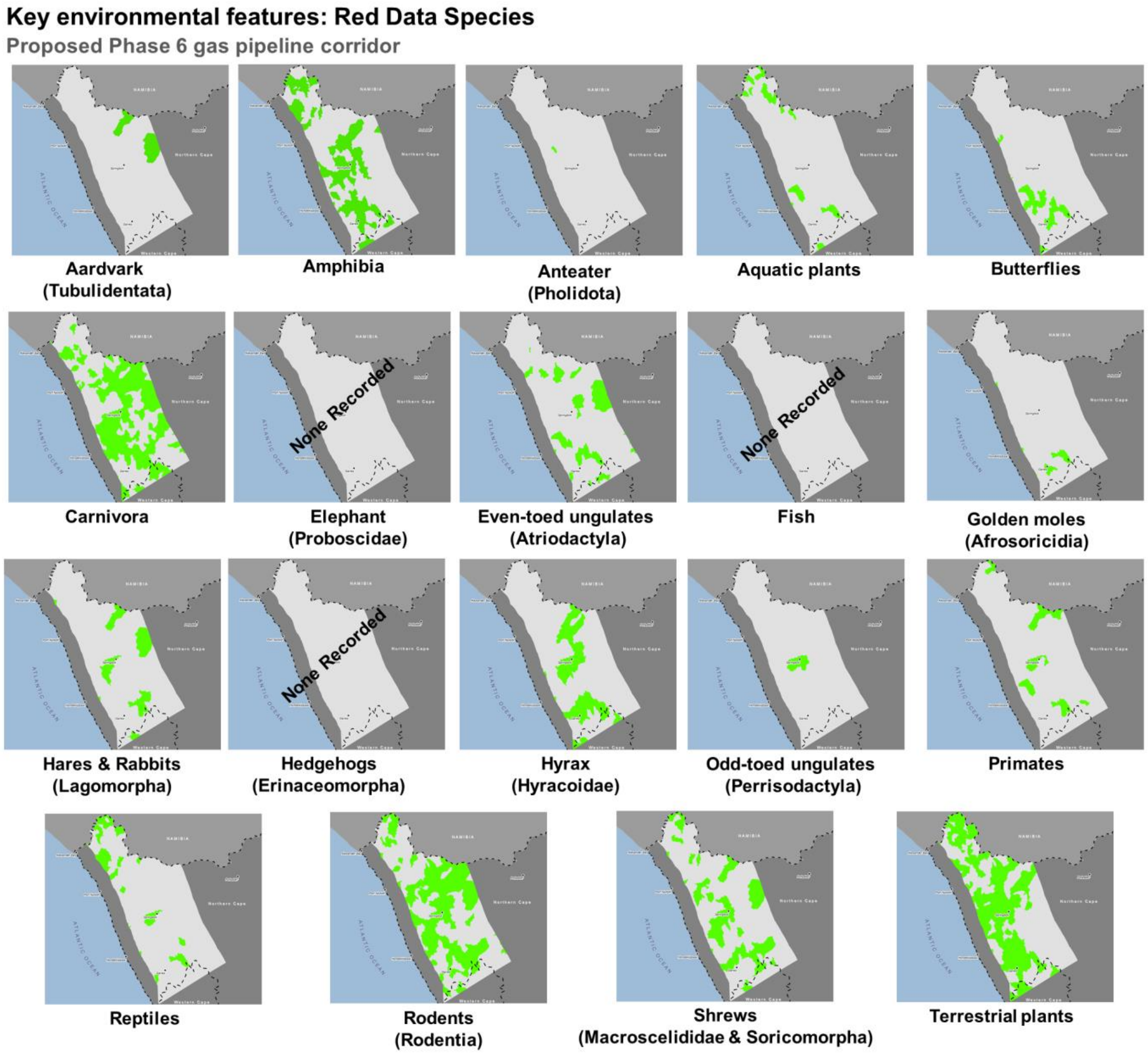


Figure 8: Distribution of recorded Red Data species in the proposed Phase 6 gas pipeline corridor (at quinary catchment scale).

4.2.2 Phase 5

The proposed Phase 5 gas pipeline corridor is located from the northern part of the Western Cape Province towards Piketberg (Figure 1) predominantly within Fynbos and Succulent Karoo vegetation types.

The rainfall falls mainly in the winter months and the summers are hot and dry with strong, drying winds. The rainfall decreases from about 400 mm on the coastal lowlands in the south to 200 mm in the north, and reaches about 800-1 000 mm on the Piketberg, Piekenierskloof and Cedarberg mountains.

4.2.2.1 Fynbos

The northern and inland parts of the corridor fall primarily into the Succulent Karoo Biome and the south-western and southern part in the Fynbos biome. Fires occur at intervals of 8-15 years in the mountain Fynbos but at longer intervals in the Renosterveld and sand plain Fynbos of the lowlands. The rainfall is too low for cultivation in the north and the vegetation is fairly intact and used as rangelands. The extent of the cultivated dryland areas increases south of Vredendal as do cultivated areas on the Nieuwoudtville plateau and the Gifberg (Figure 9). Almost all of the Swartland is under cultivation. Areas under irrigation are found along the Olifants River, in the Sandveld and along the Berg River southwards to Hopefield.

The extent of vegetation transformation has resulted in 11 of the 14 Fynbos vegetation types in this part of the corridor being classified as threatened (6 Vulnerable (VU), 4 Endangered (EN), 1 Critically Rare) due to habitat loss in the Western Cape Biodiversity Spatial Plan (Pool-Stanvliet et al., 2017). All of these are lowland vegetation types with the Swartland Shale Renosterveld (CR) having only 6.3 % of its original extent remaining and every remnant classified as a CBA 1. The high degree of transformation means that every remnant that can form part of a corridor is a CBA 1, resulting in a nearly continuous CBA 1 from the coast to the inland mountains north of the Piketberg (Figure 9). The Nieuwoudtville-Gifberg plateau in the Northern Cape also is an extensive area where all natural vegetation is categorised as CBA 1 (Figure 9). At the scale of this map many of the small CBA 1s in highly transformed areas like the Swartland are not visible but minimising impacts on them will be critical at the route planning stage. The main pinch point is from the Piketberg through the Sandveld to Graafwater. The route westwards into the Olifants River valley also is through high sensitivity areas and difficult terrain.

The extensive Azonal vegetation types are primarily salt marshes and wetlands associated with estuaries (e.g. The Berg and Olifants Rivers) and river floodplains.

The Cape mountains are important water sources for the rivers and streams that flow into the adjacent lowland with the Cederberg, Piekenierskloof and Kouebokkeveld forming part of the Groot Winterhoek Strategic Water Source Areas (SWSA) (Nel et al., 2013; 2017). There are also extensive SWSAs for groundwater in this area and in the inland valleys.

4.2.2.2 Succulent Karoo

The proposed Phase 5 gas pipeline corridor includes the transition from the arid Knersvlakte in the north to the wetter Swartland and Cedarberg Mountains in the south (Figure 9). Significant features include the various parts of the Knersvlakte Nature Reserve, as well as the Bokkeveld Escarpment. The Knersvlakte is considered especially sensitive due to the exceptional levels of endemism which characterise this area as well as its arid nature and associated difficulty in effectively rehabilitating disturbed areas.

4.2.2.3 Birds and bats

The Namibian long-eared bat is the only bat species of Conservation Importance occurring in the proposed Phase 5 gas pipeline, whilst several red data bird species may be present (Table 11).

Table 11: Red Data bird species likely to be encountered in the proposed Phase 5 gas corridor.

Species	Status	Biome		
		Fynbos	Succulent Karoo	Azonal
African Marsh-Harrier	EN	✓		✓
Black Harrier	EN	✓	✓	
Black Stork	VU	✓	✓	✓
Blue Crane	NT	✓	✓	✓
Burchell's Courser	VU		✓	✓
Burchell's Courser	VU		✓	✓
Cape Rock-jumper	NT	✓		
Caspian Tern	VU			✓
Chestnut-banded Plover	NT			✓
Eurasian Curlew	NT			✓
European Roller	NT	✓		
Great White Pelican	VU			✓
Greater Flamingo	NT	✓	✓	✓
Karoo Korhaan	NT	✓	✓	
Lanner Falcon	VU	✓	✓	✓
Lesser Flamingo	NT	✓	✓	✓
Ludwig's Bustard	EN	✓	✓	
Maccoa Duck	NT			✓
Martial Eagle	EN	✓	✓	
Protea Seedeater	NT	✓		
Red Lark	VU		✓	
Secretary bird	NT	✓	✓	
Southern Black Korhaan	VU	✓	✓	
Verreaux's Eagle	VU	✓	✓	
Yellow-billed Stork	EN			✓
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened				

4.2.2.4 Freshwater ecosystems

Rivers within the proposed Phase 5 gas pipeline corridor are mostly ephemeral/non-perennial (approximately 61%), while around 39% are considered to be perennial/permanently-flowing. These rivers drain a number of ecoregions, such as the South Western Coastal Belt, Western Folded Mountains and the Great Karoo. Major river systems include the Doring, Olifant and Sout (Figure 10). Less than 25% of the rivers are considered to be Threatened (i.e. CR, EN and VU). More than 60% of the rivers are in a natural/good condition, 8% are in a fair condition, while 30% are in a poor/very poor condition.

Wetland habitats occupy a small proportion of the corridor (~3%) comprising up to 90 different wetland types, dominated by channelled-valley bottom wetlands, particularly within the Northwest Sand Fynbos region. The corridor contains a single Ramsar wetland, namely Verlorenvlei (Figure 10), which is approximately 1,500 ha. A moderate proportion (~23%) of the wetlands in the corridor are characterised as NFEPA wetlands. Almost all of the wetland habitats within the corridor are associated with Least Threatened (LT) wetland vegetation groups (e.g. the Knersvlakte and Trans-Escarpment Succulent Karoo).

A large portion (81%) of the proposed Phase 5 gas pipeline corridor comprises land that is largely natural, with a fairly small proportion (8%) of the corridor protected by a number of conservation areas (e.g. Cederberg Wilderness Area, Moedverloren Nature Reserve and Tankwa Karoo National Park). The remaining area is mostly transformed by cultivation (~19%), with <1% attributed to plantations, urbanisation (e.g. Citrusdal and Vredendal) and mining.

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 5 pipeline corridor include:

- Pollution from application of fertilizers, herbicides and pesticides, as well as point-source discharges from urban centres (e.g. Bitterfontein);
- Grazing by livestock, particularly high/concentrated levels of along watercourses, causing overgrazing and trampling within and adjacent to river and wetland systems, which in turn leads to increased erosion and changes in vegetation structure (notably, the loss of riparian habitat);
- Increases in woody vegetation along rivers, in particular by *Acacia karoo*, as well as infestations of invasive alien species (e.g. *Tamarix spp.* and *Prosopis glandulosa*). These deep-rooted species are able to readily consume groundwater. Heavily infested areas have a significant impact on the hydrology of catchments, as well as outcompeting indigenous species;
- More localised, yet severe impacts, linked to sand mining and other mining activities (e.g. alluvial diamond mining at the mouth of the Gariep River and along the west coast);
- Groundwater utilisation both for domestic and agricultural uses;
- Construction of weirs and dams along river systems, which alters the natural hydrological flows, which is most notable for the Gariep River as a consequence of numerous, large dams/impoundments in the catchment; and
- Road crossings, which cause concentration of surface runoff and localised sheet and gulley erosion in proximity to rivers and wetlands.

4.2.2.5 Estuaries

Three estuaries are situated within the Phase 5 corridor; the Olifants, Verlorenvlei and the Groot Berg (Figure 10). They have a combined estuarine habitat area of 8 600 ha and are amongst the longest of South Africa's estuaries with the Groot Berg Estuary nearly 70 km and the Olifants Estuary about 40 km long. The Groot Berg roughly extends about 40 km into the Phase 5 corridor. Their health statuses vary between C and D Categories on the Department of Water and Sanitation (DWS) scale ("A" being near natural and "F" being extremely degraded) (Van Niekerk et al., 2018, in progress).

All three estuaries are national conservation priorities as identified in the national estuaries biodiversity plan (Turpie et al., 2012). The Olifants and Groot Berg are of very high biodiversity Importance, ranking in the top five estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). These systems are also important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). From a habitat diversity and abundance perspective the Olifants and Groot Berg are also considered highly important as they support large areas of sensitive estuarine habitats such as intertidal and supratidal saltmarsh.

Box 14: Red Data aquatic biota likely to be encountered in Phase 5

Two species of Odonata that are listed as Vulnerable (i.e. *Syncordulia gracilis* and *S. legator*) occur in the corridor, along with two species that are Near Threatened. Of the 14 Red Listed fish species that occur within the corridor, three are listed as Critically Endangered (i.e. *Pseudobarbus burchelli, P. erubescens* and *P.* sp. Nov. 'doring'), while six are considered Endangered, four are Near Threatened, and one is Data Deficient. The only Red Listed amphibian that occurs within the corridor includes the Near Threatened *Breviceps gibbosus*. There is also only one Red Listed reptile that occurs within the corridor, namely the Vulnerable *Bradypodion pumilum*. The Critically Endangered Riverine Rabbit *Bunolagus monticularis* occurs in a few, isolated localities within the corridor. The only other Red Listed mammals include two that are Near Threatened. This corridor supports a moderate diversity of Red Listed plants of up to 25 species, including two that are Critically Endangered (i.e. *Pilularia bokkeveldensis* and *Senecio cadiscus*), while ten are Endangered, nine are Vulnerable and four are Near Threatened.

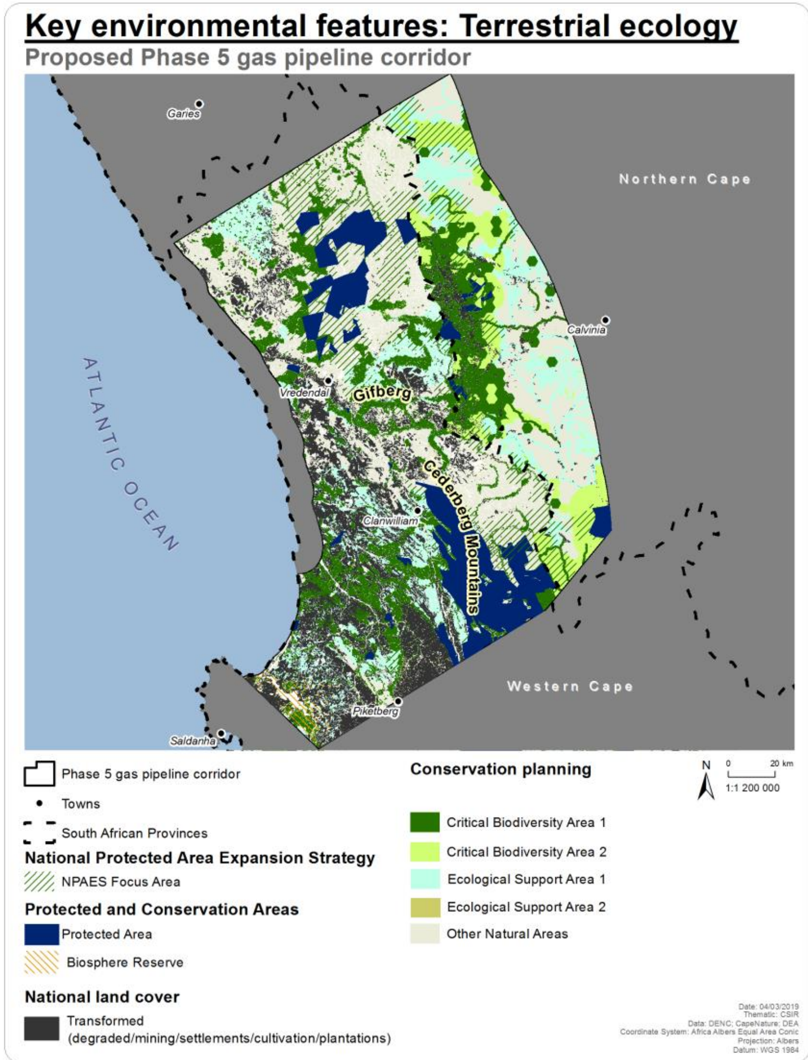


Figure 9: Key environmental features of the proposed Phase 5 gas pipeline corridor.

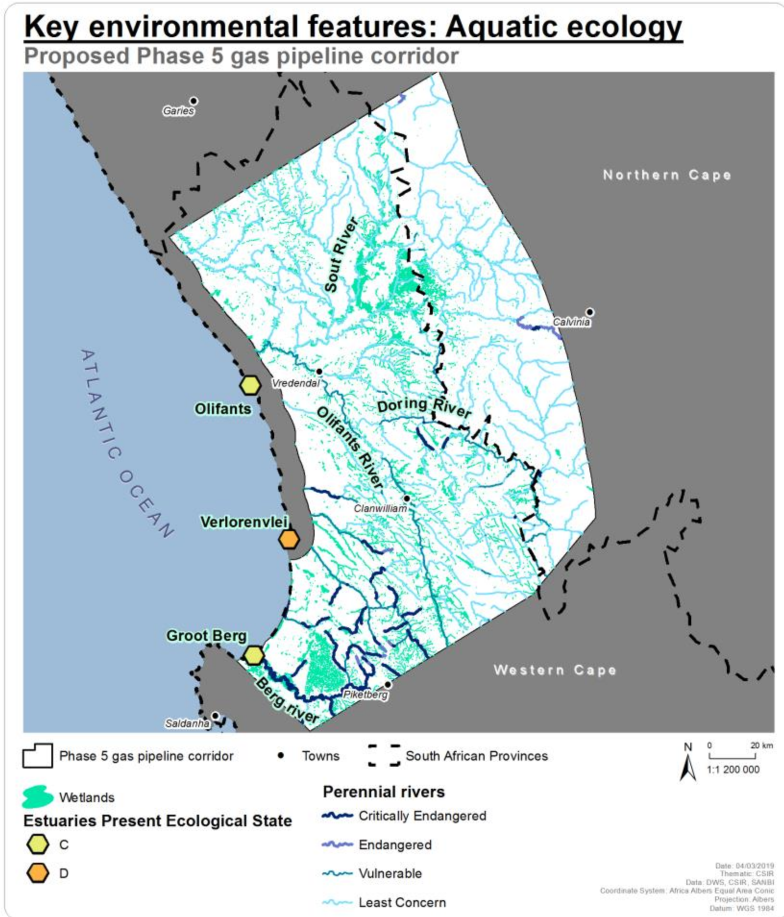


Figure 10: Key aquatic ecosystem features of the proposed Phase 5 gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extent.

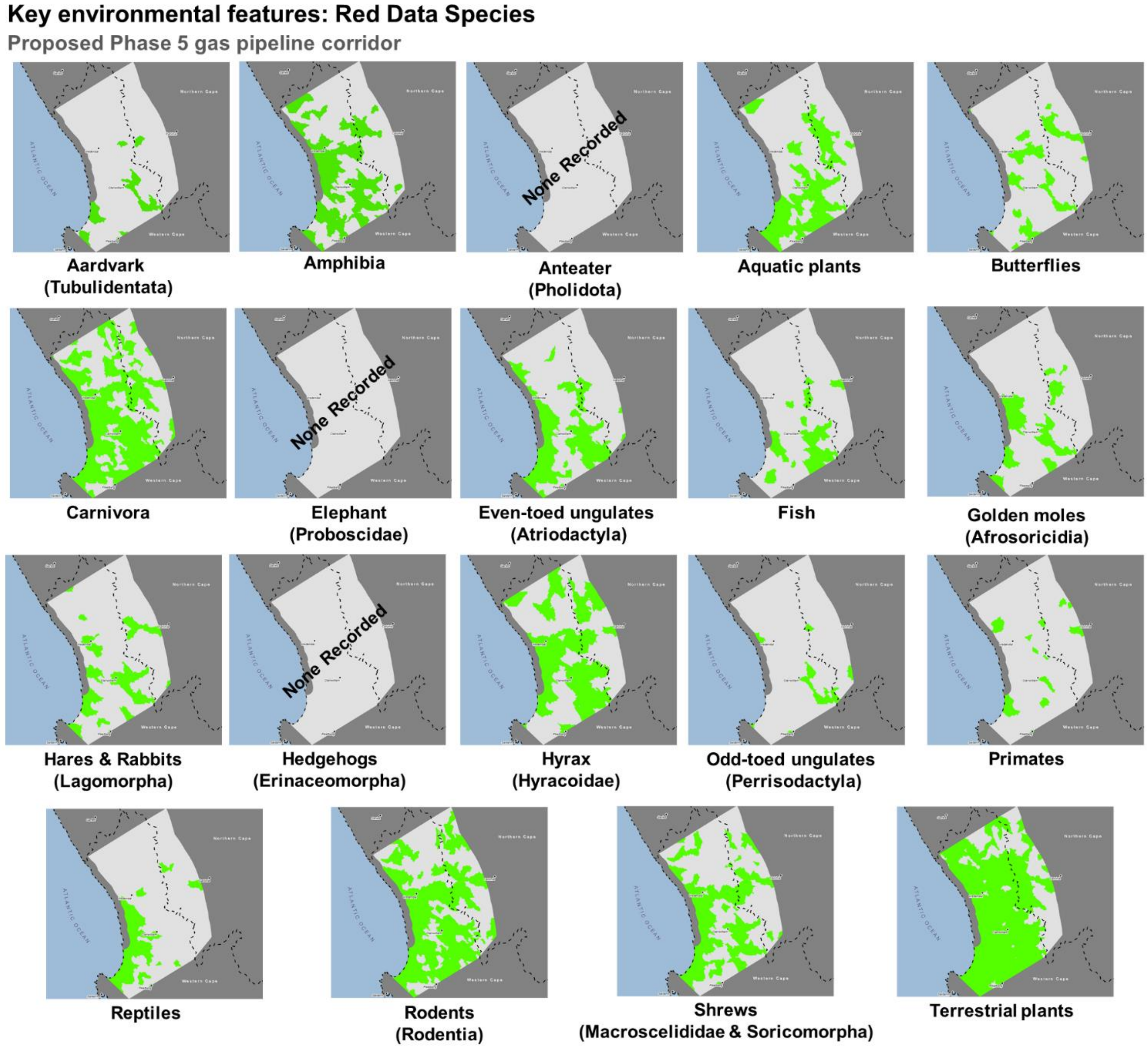


Figure 11: Distribution of recorded Red Data species in the proposed Phase 5 gas pipeline corridor (at quinary catchment scale).

4.2.3 Phase 1

The proposed Phase 1 gas pipeline corridor is located approximately from Saldanha to Mossel Bay (Figure 1), predominantly within the Fynbos and Succulent Karoo vegetation types. The lowlands to the south of the cape Fold Mountains are extensively transformed by settlements and agriculture.

A prominent feature of this corridor is the rugged Cape Folded Belt mountains extending roughly north-south from the northern Cederberg to Cape Hangklip, the Kouebokkeveld and Hex inland, and the Riviersonderend, Langeberg, and Swartberg which run more or less east-west. The rainfall falls primarily in winter in the west and centre but becomes bimodal with spring and ranges from about 400 mm in the northwest to over 2 500 mm in the Boland mountains. The summers are warm and dry, with strong, desiccating south-easterly winds. The rainfall is lower on the inland mountains and east-west ranges but exceeds 1 000 mm in the central Langeberg. These mountain ranges are important water sources for the rivers and streams that flow into the adjacent lowland and nationally significant SWSAs (Nel et al., 2013; 2017).

The western part of this corridor is dominated by the sandy plains and granite and shale hills of the West Coast and the Swartland with sandstone inselbergs. The West Coast NP and adjacent CBAs form a block that extends right across the corridor at this point, forming a pinchpoint. The coastal mountain chain is almost unbroken from Piekenierskloof in the north to Hangklip in the south, with only a narrow gap formed by the Klein Berg River valley (Nuwekloof Pass). These ranges are either in Nature Reserves, Mountain Catchment Areas or Informal Protected Areas. The inland mountain chain from the Cederberg to the Langeberg is also only broken by narrow river valleys. The remaining natural vegetation adjoining these protected areas is all in CBAs or ESAs. The Hex River Mountains extend inland from this mountain chain to the inland boundary of this corridor. There is a pinch point near Robertson and routes over the north-south oriented river systems between Swellendam and Mosselbay (e.g. GouKou, Duiwenhoks, Gouritz) will have to be chosen with care as these are also climate change adaptation corridors.

4.2.3.1 Fynbos

This corridor covers the core area of the Fynbos Biome, as well as some of the most transformed portions, and so includes a large number of threatened ecosystems and a high proportion of the threatened species in the biome. The entire corridor falls within the biome except for the areas of the Succulent Karoo in the drier inland valleys, islands of Afromontane Forest, and some small areas of Albany Thicket in river valleys both on the coastal lowlands and in inland valleys. The corridor overlaps with a total of 113 vegetation types, including 86 from the Fynbos Biome. Of these, 18 are rated CR, 14 EN and 15 VU, making a total of 54 threatened. All of the Sand Fynbos, 78 of the Renosterveld, 50 of the Strandveld and 44 of the other Fynbos vegetation types are considered threatened. Threatened flora and the full range of threatened terrestrial fauna are found in the CBA areas within the corridor, especially in the lowlands.

These findings clearly highlight the extensive transformation of the lowland vegetation types and that all their natural remnants are considered highly or very highly sensitive. So, even if the lowlands look like the best options for a route, some careful routing will be needed to minimise impacts.

4.2.3.2 Succulent Karoo and Nama Karoo

Important features present in the proposed Phase 1 gas pipeline corridor include the Tankwa Karoo, which includes the Tankwa Karoo National Park as well as several areas where the Riverine Rabbit is known to occur (Figure 12). The Riverine Rabbit is also known to occur more widely within the corridor, from Touws River, through to the Robertson area and Sanbona Private Nature Reserve and northwards towards Anysberg Nature Reserve. The Worcester-Robertson Succulent Karoo region is also considered to be an area of high plant diversity and endemism and the vegetation in this area is considered fairly high sensitivity. In the east the corridor also includes the area around Calitzdorp as well as the open plains between Laingsburg and Prince Albert, where the major features are the larger drainage systems present including the Dwyka, Gamka, Groot and Touws Rivers. The mountains in this area are generally important areas for the Grey Rhebok, as well as potential habitat for the Cape Mountain Zebra and Cape Leopard.

4.2.3.3 Albany thicket

The Albany Thicket vegetation in the proposed Phase 1 gas pipeline corridor is highly diverse with at least four distinct vegetation biomes forming a mosaic with Albany Thicket mostly in river valleys. Albany Thicket is restricted to deep, well-drained, fertile sandy loams with the densest thickets occurring on the deepest soils (Cowling, 1983). Soil moisture is another important limiting factor. The vegetation is adapted to grow in hot, dry river valleys where soil moisture is limited for extended periods. Soil moisture decreases towards the west, resulting in thickets that are more dense, succulent and thorny.

According to Mucina and Rutherford (2006), overall 60 % of this biome has been severely degraded, with only 11 % still in pristine condition, and around 7.3 % totally lost. The mesic thicket, which has the highest levels of endemism and species richness within the Thicket biome, is under the greatest pressure.

A more detailed analysis by Lloyd et al. (2002) and Vlok & Euston-Brown (2002b) provides figures on levels of severely degraded and moderately degraded thicket for each vegetation sub-class. This analysis shows that except for the Mainland Montane Solid (Thicket) and Coastal Dune Solid Thicket, all the vegetation units described show high levels of severe and moderate degradation.

Forms of thicket vegetation that have been especially ravaged by overgrazing in the past century, are those rich in spekboom or igwanishe, *Portulacaria afra*. There is evidence that even in the short space of a decade, heavy browsing, especially by mohair-producing angora goats, can convert dense shrubland into a desert-like state (Vlok & Euston-Brown, 2002a). Of some 16,000 km^2 formerly covered in spekboom-rich thicket, some 46 has undergone severe degradation and 34 moderate disturbance. This is predominantly from overgrazing, although clearing for crop cultivation is another major threat to the Thicket vegetation. Land has been cleared along the rivers, and lucerne and other crops are grown under irrigation. Land has also been cleared for orange orchards in the Addo region (Vlok & Euston-Brown, 2002b).

The role that indigenous herbivores may have played in determining vegetation boundaries, as do domestic livestock today under certain management regimes has been the subject of much speculation (Hoffman & Cowling, 1990). Several studies have shown that African elephant (*Loxodonta Africana*) has a substantial impact on subtropical thicket composition (Stuart-Hill, 1992), however, these animals as well as black rhinoceros (*Diceros bicornis)*, even under exceptionally high population density (unlike goats) do not convert solid thicket into a mosaic savannah, as Thicket types are probably much more resilient to the impacts of indigenous herbivores. Overgrazing by domestic livestock, in particular goats, has caused dramatic changes in thicket vegetation, with Nama-Karoo shrub like elements invading Arid Thicket types, and subtropical grasses massively increasing in cover in some Valley Thickets, creating savanna-like vegetation that burns at regular intervals, further eliminating succulents and fire-sensitive shrubs (Hoffman & Cowling, 1990).

Unfortunately, removing livestock and resting the veld does not lead to natural recovery of the vegetation, as seedling establishment is constrained by the exposed soil's temperature extremes and reduced water-holding capacity. Essentially, to restore this thicket type requires active interventions (Vlok & Euston-Brown, 2002a).

The Albany Centre is a major centre of botanical diversity and endemism for succulents of karroid affinity, especially in the Mesembryanthemeceae, Euphorbiaceae and Crassulaceae, as well as a centre for certain bulb groups.

Subtropical thicket is renowned for its high plants species richness and levels of endemism (i.e. species that grow nowhere else). Vlok & Euston-Brown (2002a) provide a tally of 1 588 subtropical thicket species for the planning domain, 322 (20 of which are endemic). Most of these endemics are succulents associated with the vygie, euphorbia, crassula, aloe and stapeliad plant groups (Vlok & Euston-Brown, 2002a).

The subtropical thicket is associated with two globally recognised centres of succulent plant endemism, namely the Little Karoo Centre of the Succulent Karoo in the west and the Albany Centre in the east (van Wyk & Smith, 2001). The Albany Centre encompasses elements of the Cape and Succulent Karoo regions.

4.2.3.4 Birds and bats

The Namibian long-eared bat is the only bat species of Conservation Importance occurring in the proposed Phase 1 gas pipeline, whilst several red data bird species may be present (Table 12).

Table 12: Red Data bird species likely to be encountered in the proposed Phase 1 gas corridor.

Species	Status	Biome					
		Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Forest	Azonal
Abdim's Stork	NT						
African Crowned Eagle	VU					✓	
African Marsh-Harrier	EN	✓					✓
African Rock Pipit	NT	✓	✓	✓			
Agulhas Long-billed Lark	NT	✓					
Black Harrier	EN	✓	✓	✓			
Black Stork	VU	✓	✓	✓			✓
Black-winged Pratincole	NT	Vagrant					
Blue Crane	NT	✓	✓				✓
Burchell's Courser	VU						
Burchell's Courser	VU		✓	✓			✓
Cape Rock-jumper	NT	✓					
Cape Vulture	EN	✓					
Caspian Tern	VU						x
Chestnut-banded Plover	NT						✓
Damara Tern	CR						✓
Denham's Bustard	VU	✓					
Eurasian Curlew	NT						✓
European Roller	NT	✓			✓		
Great White Pelican	VU						✓
Greater Flamingo	NT	✓	✓	✓			x
Greater Painted-snipe	NT						✓
Half-collared Kingfisher	NT						✓
Hottentot Buttonquail	EN	✓					
Karoo Korhaan	NT	✓	✓	✓			
Knysna Warbler	VU				✓	✓	
Knysna Woodpecker	NT				✓	✓	
Kori Bustard	NT		✓	✓			
Lanner Falcon	VU	✓	✓	✓	✓	✓	✓
Lesser Flamingo	NT	✓	✓	✓			✓
Ludwig's Bustard	EN	✓	✓	✓			
Maccoa Duck	NT						x
Marabou Stork	NT	Vagrant					
Martial Eagle	EN	✓	✓	✓	✓		
Protea Seedeater	NT	✓					
Red-footed Falcon	NT						
Sclater's Lark	NT						

Species	Status	Biome					
		Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Forest	Azonal
Secretarybird	NT	✓	✓	✓			
Southern Black Korhaan	VU	✓	✓				
Striped Flufftail	VU	✓					
Tawny Eagle	EN						
Verreaux's Eagle	VU	✓	✓	✓			
Yellow-billed Stork	EN						
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened							

4.2.3.5 Freshwater ecosystems

Rivers within the proposed Phase 1 gas pipeline corridor are either perennial/permanently-flowing (approximately 55%) or ephemeral/non-perennial (approximately 45%), and are characteristic of the South Western Coastal Belt, Western Folded Mountains, Southern Folded Mountains and the Southern Coastal Belt ecoregions. Major river systems include the Berg, Bree, Gourits and Doring Rivers (Figure 13). Most (approximately 65%) of the river habitat in the corridor is currently Threatened (i.e. CR, EN and VU). The rivers are generally in a poor condition – 30% of rivers are in a natural/good condition, 20% are in a fair condition, 44% are in a poor condition, and 6% are either very poor/critical condition.

Wetland habitats within this corridor occupy a fair proportion of the corridor (~7%) comprising up to 221 different wetland types, dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the East Coast Shale Renosterveld region. The corridor boasts five Ramsar wetlands, namely Langebaan, False Bay Nature Reserve, Bot-Kleinmond Estuarine System, De Mond (Heuningnes Estuary) and De Hoop Vlei. A moderate proportion (~18%) of the wetlands in the corridor are characterised as NFEPA wetlands. Most notable is that 50% of the wetlands of the corridor are associated with the CR wetland groups: East Coast Shale Renosterveld (20%), Rainshadow Valley Karoo (15%), West Coast Shale Renosterveld (9%) and Western Fynbos-Renosterveld Shale Renosterveld (6%).

The Cape Mountains are important water sources for the rivers and streams that flow into the adjacent lowlands. The ranges from the Cederberg to the Langeberg and south to Cape Hangklip, and Table Mountain all being SWSAs (Nel et al., 2013; 2017). There are also extensive SWSAs for groundwater in this area including the West Coast aquifer and the Sandveld aquifer, as well as in the inland valleys.

Box 15: Red Data aquatic biota likely to be encountered in Phase 1

Three Endangered Odonata (*Proischnura polychromatica, Orthetrum rubens* and *Spesbona angusta*), as well as four Vulnerable and three Near Threatened species. *Orthetrum rubens* is a restricted species that is only known from the mountains of the Western Cape: since 2016 the only known extant population is in the Hottenstots-Holland Mountains, at Victoria Peak. *Spesbona angusta* is also restricted to a wetland at the base of Franschhoek pass, and thus careful conservation planning and improvement of wetland in terms of water depth and density of pools is required for this species (Veldtman et al., 2017). *Proischnura polychromatica* has also only been recently recorded near Ceres, and also at the base of Franschhoek Pass, and are only known from sites where alien invasive trees have been removed (Veldtman et al., 2017).

The corridor supports an exceptionally high number of Red Listed fish (up to 22 species) of which four are Critically Endangered: *Pseudobarbus burchelli*, which is found in the Breede and Tradouw river systems, Pseudobarbus erubescens (endemic to the Twee River Catchment within Olifants system), *Pseudobarbus* sp. nov. 'doring' (Breekkrans and Driehoeks Tributaries of the Doring river, Olifants system), and *Pseudobarbus* sp. nov. 'heuningnes' (Heuningnes River System). In addition, 10 fish species are Endangered, three are Vulnerable, four are Near Threated and one is Data Deficient. The corridor also supports a high number of Red Listed amphibians (up to 16 species) of which five are Critically Endangered (*Arthroleptella rugosa, A. subvoce, Capensibufo rosei, Heleophryne rosei* and *Microbatrachella capensis*), two are Endangered, six are Near Threated and three are Data Deficient. *Arthroleptella rugosa* (Rough Moss frog) is a highly restricted species occurring only on the Klein Swartberg Mountain near Caledon, A. subvoce's status may be changed to a more threatened category (Turner and de Villiers, 2017); *Capensibufo rosei* is only found to occur on the Cape Peninsula, in two or three remaining populations; *Heleophryne rosei* is restricted to four streams on Table mountain area, and *Microbatrachella capensis* is a vital indicator of a unique and threatened ecosystem: coastal lowland blackwater wetlands. There is only one Red Listed reptile that occurs within the corridor, namely the Vulnerable *Bradypodion pumilum*. The Phase 1 Corridor supports known occurrences of the Critically Endangered Riverine Rabbit *Bunolagus monticularis*, which is restricted to the semi-arid Karoo, with an estimated extent of occurrence (EOO) of 54,227 km^2 and area of occupancy (AOO) 2,943 km^2 (2016 Mammal Red List *Bunolagus monticularis* CR). The Riverine Rabbit inhabits dense, discontinuous scrub vegetation along seasonal river beds and is dependent on soft, deep alluvial spoils along these river courses, for constructing burrows in order to breed. Other Red Listed mammals include the Vulnerable *Dasymys capensis*, as well as three species that are Near Threatened. This corridor supports the highest diversity of Red Listed plants with up to 75 species. Of this diversity, 16 are Critically Endangered, 23 are Endangered, 22 are Vulnerable, six are Near Threatened, four are Data Deficient and four are rare.

Approximately 67% of the Phase 1 Corridor comprises land that is largely natural with a small proportion (~1%) degraded. A significant proportion (20%) of the corridor is protected by over 100 different conservation areas (e.g. Koue Bokkeveld Mountain Catchment Area, Matroosberg Mountain Catchment Area, Langeberg Mountain Catchment Area). The remaining area is largely transformed by cultivation (~29%), but also urbanisation in and around Cape Town (2%) and plantations (1%). Impacts on freshwater ecosystems caused by land use activities vary across the corridor, however, combined effect has had a significant effect on freshwater ecosystem functioning and integrity.

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 1 pipeline corridor include:

- There has been rapid population growth within the Western Cape, and thus urbanization has increased, particularly since 2009. Informal settlements in particular have expanded and reactive spatial planning has led to poor or even absent basic service infrastructure. The result is unsustainable practices including increased illegal dumping and waste disposal in rivers, contributing to water pollution. The greatest instances of transformation are reported to be in Cape Town itself and other coastal nodes.

- Very high (unacceptable) faecal contamination in the Berg, Bree, Diep, Gouritz and Kuils River systems. Inland water is generally considered not fit even for agricultural or industrial use.
- Alien invasive species, which reduce both surface and ground water availability, increase fire risk and compete with indigenous species, which result in habitat loss and degradation. Alien invasive plants are a large problem, as are invasive fish species within rivers – 17 in total.
- Agriculture, also reported to be increasing in the Western Cape region, contributes to the pollution of freshwater resources, as a result of run-off of pesticides and fertilizers. In addition, over-abstraction of water for both agriculture and urban use forms a major problem in many areas.
- Damage to river beds, wetlands and floodplains (channel modification) as a result of agricultural practices is also considered to be a major threat to freshwater ecosystems in this region.
- Other pressures which impact on these systems include overgrazing and illegal harvesting of species.
- Further to this, within the Western Cape, water has been identified as a provincial risk, based on increased urbanization, climate change, failing infrastructure and consumer behaviour.

4.2.3.6 Estuaries

In total 25 estuaries are situated within the Phase 1 corridor, with a combined estuarine habitat area of 3 100 ha (Figure 13). Most are not particularly long and extend less than 10 km into the proposed Gas Pipeline corridor. Exceptions are the Breede (<30 km), Gourits (<25 km), Duiwenhoks (<15 km), Goukou (<15 km), Sand (<10 km), Sout (Wes) (<10 km) and Rietvlei/Diep (<10 km).

The Langebaan, Wildevoëlvlei, Breë, Duiwenhoks and Goukou estuaries are of very high biodiversity importance, ranking in the top estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). In addition, the Rietvlei/Diep, Sand, Palmiet, Gourits estuaries are also rated as important from a biodiversity perspective.

Only eight estuaries in this corridor are in excellent or good conditions (Categories A to B). These systems have a high sensitivity to change as they will degrade from their near pristine state relatively easily.

Eleven estuaries in the corridor are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012), most of which are identified as important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). From a habitat diversity and abundance perspective the Langebaan, Rietvlei/Diep, Wildevoëlvlei, Sand, Palmiet, Breë, Duiwenhoks, Goukou and Gourits estuaries are also considered important for habitat diversity and abundance, as they support sensitive estuarine habitats such as intertidal and supratidal saltmarsh.

See Addendum 1 to this chapter for a complete list of estuaries present in the proposed Phase 1 gas pipeline corridor.

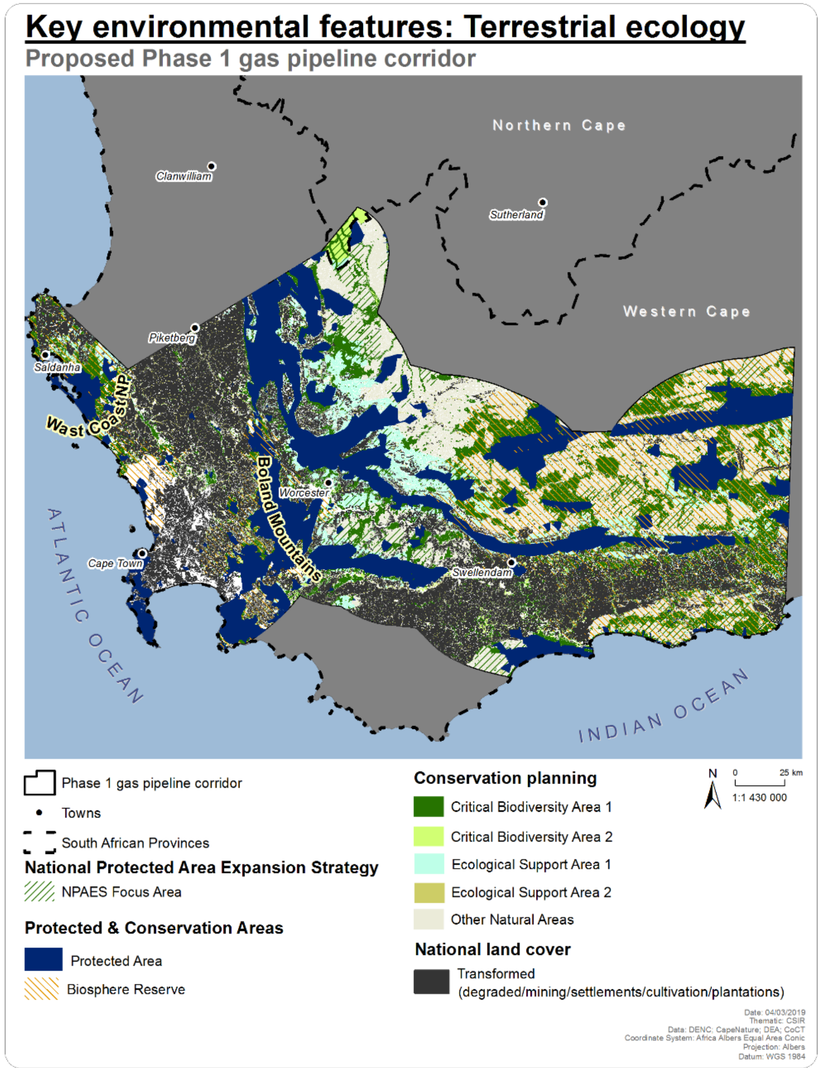


Figure 12: Key environmental features of the proposed Phase 1 gas pipeline corridor.

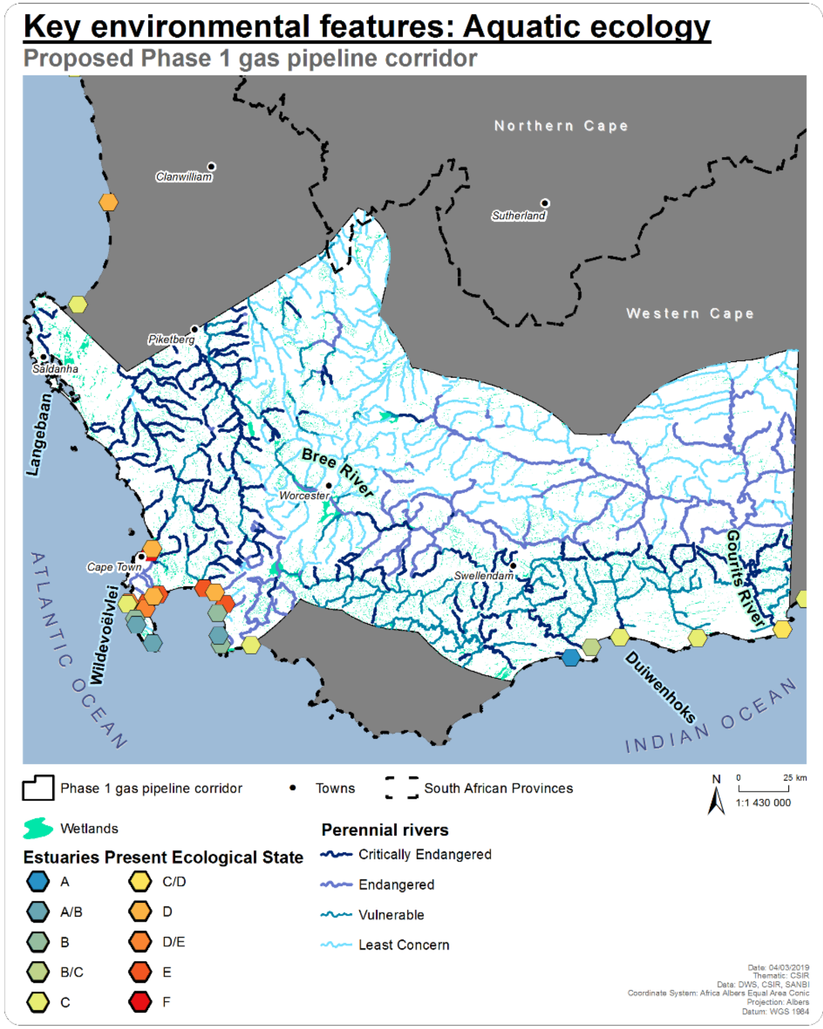


Figure 13: Key aquatic ecosystem features of the proposed Phase 1 gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extent.

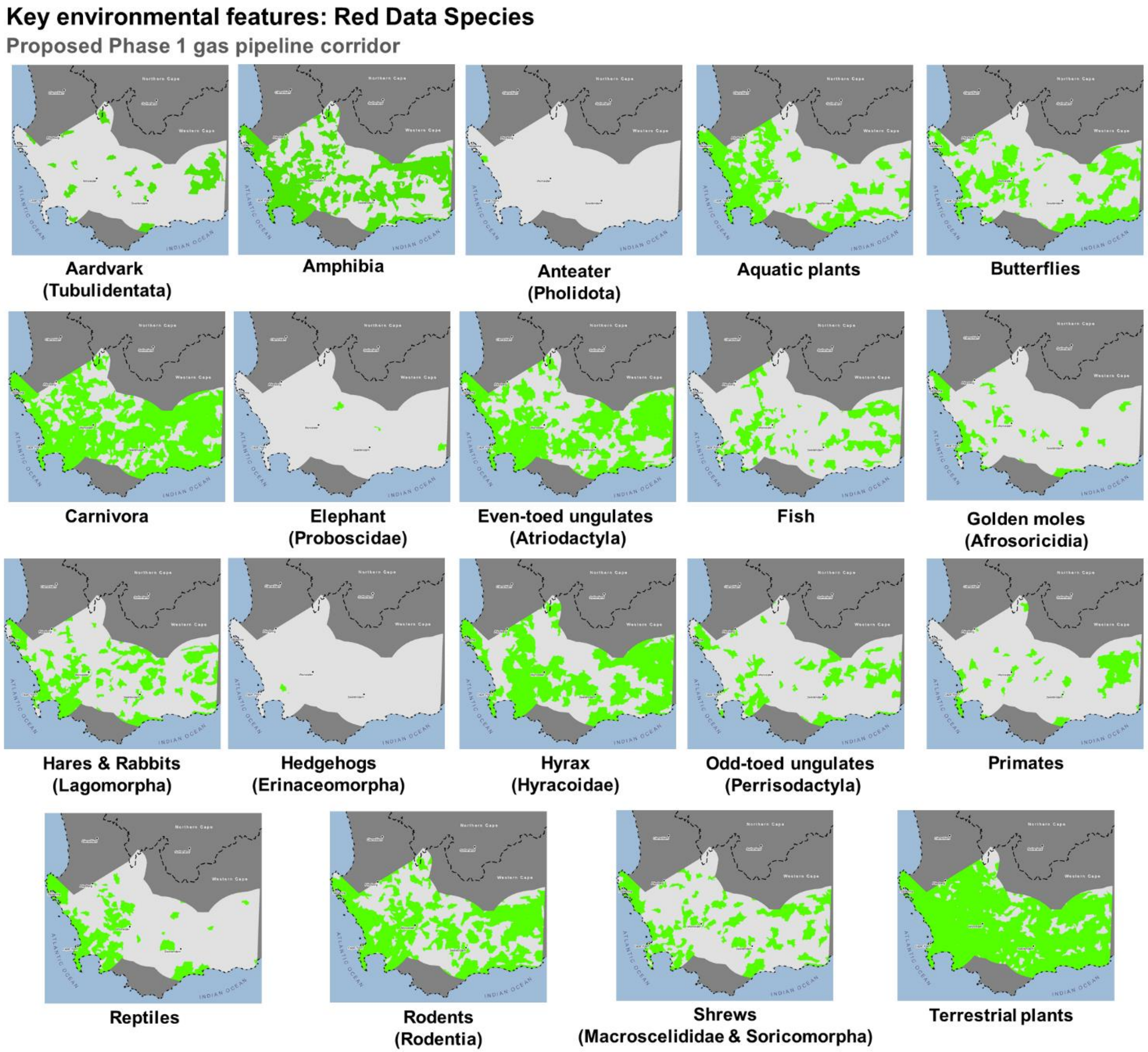


Figure 14: Distribution of recorded Red Data species in the proposed Phase 1 gas pipeline corridor (at quinary catchment scale).

4.2.4 Phase 2

The proposed Phase 2 gas pipeline corridor is located approximately from to Mossel Bay to Port Elizabeth (Figure 1). Transformation has occurred around major towns (Mossel Bay, George, Port Elizabeth) due to urban settlement and agriculture.

The climate is characterised by mild temperatures, except in the interior valleys, and evenly distributed rainfall with spring and autumn peaks. Berg winds are common in the winter and are often associated with fires in the Fynbos biome (Geldenhuys, 1994; Kraaij et al., 2013a).

4.2.4.1 Fynbos

A prominent feature is the east-west mountain ranges, with the Huisrivier-Outeniqua-Tsitsikamma-Kouga-Baviaanskloof in the south and the Swartberg, Groot and Klein Winterhoekberge-Suurberg inland in the north. The Kammanassie Mountains in the western part of the corridor form a link between the inland and the coastal ranges at the eastern end of the Little Karoo. The mountain ranges with their protected areas have extensive ESA and CBA areas adjoining them (Figure 15). The intensively farmed and developed coastal lowlands from Mosselbay to Plettenberg Bay have a fine-scale mosaic of CBAs including the remnants of these coastal vegetation. The same applies to the Langkloof and the Humansdorp Plains. The complicated mosaic of Fynbos and Forest in the area between Wilderness and Plettenberg Bay will have to be treated as special a unit in the routing assessment should the construction be authorised. The best option is probably the inland through the Little Karoo and Langkloof but the pinch points at the feasible passes from the coast inland are a problem. There are also pinch points between about Joubertina and Kareedouw and between there and the Gamtoos River valley. Another option is to avoid the Langkloof and go via Uniondale, Willowmore and, Steytlerville to Coega.

In the Western Cape portion, the corridor includes 50 vegetation types with 34 of these being Fynbos, 4 Forest, 4 Succulent Karoo and 7 Azonal. Thirteen (38) of the Fynbos vegetation types are threatened based on the WCBSP data. Based on the 2011 Threatened Ecosystems listing, there are six threatened (two CR) Fynbos vegetation types in the Eastern Cape which is 15 of the vegetation types; five of these extend into the Western Cape. Most of these threatened vegetation types are found on the intensively developed coastal lowlands between Mosselbay in the west and Humansdorp in the east. The full range of threatened terrestrial fauna can be found in the CBA areas.

The Cape Mountains are important water sources for the rivers and streams that flow into the adjacent lowland with the Huisrivier-Outeniqua-Tsitsikamma-Kouga and Swartberg all being SWSAs (Nel et al., 2013; 2017). There are also extensive SWSAs for groundwater in this area, including the West Coast aquifer and the Sandveld aquifer, as well as in the inland valleys.

4.2.4.2 Succulent Karoo and Nama Karoo

The arid sections of the propose Phase 2 gas pipeline corridor are bounded by various mountain ranges in the south such as the Swartberg and Baviaanskloof. The arid Karoo plains from Prince Albert in the west to Steytlerville and Jansenville in the east are generally of moderate sensitivity, but there are occasional high to very high sensitivity areas present including the major features such as the Kariega, Sout and Groot Rivers, as well as the transition areas between the plains of the Nama Karoo and the thicket communities present on the slopes and hills of the area. Only few fauna of conservation concern are present across this area, apart from the Black-footed Cat which occurs at a low density across this area as well as the South African Hedgehog, which is known from the eastern margin of this corridor. The mountains are also home to the Near-Threatened Mountain Reedbuck and Grey Rhebok.

4.2.4.3 Albany Thicket

The Albany Thicket in the proposed Phase 2 gas pipeline corridor is rich in high value biodiversity areas and is characterised by a large number of Protected Areas and CBAs. It contains the Baviaanskloof PA, part of the Cape Floral regions World Heritage serial sites, as well as a number CR vegetation types including, Sundays Spekboomveld and Sundays Noorsveld, and comprises the south-western sector of the Maputaland-Pondoland hotspot and the Albany Centre of Endemism (Van Wyk & Smith, 2001) (Figure 15).

4.2.4.4 Grassland

Grassland has a very limited extent in the proposed Phase 2 gas pipeline corridor, with small patches Karoo Escarpment Grassland in the Karoo National Park (north-west of Beaufort West), together with Bedford Dry Grassland towards the eastern side of the corridor.

4.2.4.5 Birds and bats

No bat species of Conservation Importance occur in the proposed Phase 2 gas pipeline corridor. Table 13 presents red data species that occur in the biomes present in the proposed Phase 2 gas pipeline corridor.

Table 13: Red Data bird species likely to be encountered in the proposed Phase 2 gas corridor.

Species	Status	Biome						
		Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Grassland	Forest	Azonal
African Crowned Eagle	VU						✓	
African Finfoot	VU							✓
African Grass-Owl	VU	✓				✓		
African Marsh-Harrier	EN	✓				✓		✓
African Rock Pipit	NT	✓	✓	✓	✓			
Agulhas Long-billed Lark	NT	✓						
Black Harrier	EN	✓	✓	✓		✓		
Black Stork	VU	✓	✓	✓	✓			✓
Black-winged Pratincole	NT	Vagrant						
Blue Crane	NT	✓	✓	✓		✓		✓
Burchell's Courser	VU		✓	✓				✓
Cape Rock-jumper	NT	✓						
Cape Vulture	EN	✓						
Caspian Tern	VU							✓
Chestnut-banded Plover	NT							✓
Damara Tern	CR							✓
Denham's Bustard	VU	✓				✓		
Eurasian Curlew	NT							✓
European Roller	NT	✓			✓			
Great White Pelican	VU							✓
Greater Flamingo	NT	✓	✓	✓				✓
Greater Painted-snipe	NT							✓
Grey Crowned Crane	EN					✓		✓
Half-collared Kingfisher	NT							✓
Hottentot Buttonquail	EN	✓						
Karoo Korhaan	NT	✓	✓	✓				
Knysna Warbler	VU				✓		✓	
Knysna Woodpecker	NT				✓		✓	
Kori Bustard	NT		✓	✓		✓		

Species	Status	Biome						
		Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Grassland	Forest	Azonal
Lanner Falcon	VU	✓	✓	✓	✓	✓	✓	✓
Lesser Flamingo	NT	✓	✓	✓				✓
Ludwig's Bustard	EN		✓	✓				
Maccoa Duck	NT							✓
Martial Eagle	EN	✓	✓	✓	✓	✓		
Pallid Harrier	NT					✓		
Protea Seedeater	NT	✓						
Red-footed Falcon	NT			✓		✓		
Sclater's Lark	NT		✓	✓				
Secretary bird	NT	✓	✓	✓		✓		
Southern Black Korhaan	VU	✓	✓					
Striped Flufftail	VU	✓						
Verreaux's Eagle	VU	✓	✓	✓				
White-bellied Korhaan	VU	✓				✓		
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened								

4.2.4.6 Freshwater ecosystems

Rivers within the proposed Phase 2 gas pipeline corridor are either perennial/permanently-flowing (approximately 45%) or ephemeral/non-perennial (approximately 55%), and are largely characteristic of the Southern Folded Mountains ecoregion, as well as the Great Karoo and the Southern Eastern Coastal Belt ecoregions. Major river systems include the Olifants, Kouga, Doring and Sondags Rivers (Figure 16). A moderate proportion (approximately 41%) of the river habitat in the corridor is currently Threatened (i.e. CR, EN and VU). The rivers are generally in either a natural/good (44 %) or fair (38%) condition, while 17% of the rivers are in either a poor, very poor or critical state.

Wetland habitats within this corridor occupy a fair proportion of the corridor (~8%) comprising up to 133 different wetland types, dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the Albany Thicket and Eastern Fynbos-Renosterveld Sandstone Fynbos regions. The corridor contains one Ramsar wetland, the Wilderness Lakes, which cover 1 300 ha. A small proportion (~5%) of the wetlands in the corridor are characterised as NFEPA wetland. Most notable is that more than 60% of the wetlands of the corridor are associated with the Critically Endangered wetland groups: Albany Thicket Valley (34%), and Lower Nama Karoo (29%).

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 2 pipeline corridor include:

- Urbanization, particularly in towns and cities within the coastal zone, resulting in increased pressure on infrastructure;
- Flow alteration caused by impoundments (e.g. Kouga, Clanwilliam, Darlington), affect downstream aquatic systems (e.g. channel characteristics, riparian vegetation, and instream and floodplain habitats) as well as river continuity
- Increased agriculture and cultivation in this area has caused increased pressure on aquatic ecosystem, through processes such as channel modification, over abstraction of water for irrigation, river bank alteration and contamination of groundwater and rivers through the run-off of fertilizers, pesticides and herbicides. The abstraction of water for the irrigation of crops such as potatoes, grapes, deciduous and citrus fruits within the Olifants catchment, has resulted in extreme pressure on the flow of this system;

- Plantations of alien invasive species have also caused increased pressure on aquatic systems as a result of the decreased flow and lowering of the groundwater table. Kouga and Baviaanskloof form the source of many of the freshwater systems in the Eastern Cape, including a large proportion of the catchments of the Gamtoos, Krom and Seekoei rivers. Invasive alien Acacia, Hakea and Pinus trees pose a serious threat to the conservation of water (the uptake of water of these species is high) and natural vegetation in these mountains;
- Alien trees are also known to accelerate riverbank erosion and reduce in-stream flow. They are also responsible for changes in fire regime and alteration of plant community composition. This is particularly relevant in this region, which experiences high levels of water stress, drought and associated increased fire risk.

Box 16: Red Data aquatic biota likely to be encountered in Phase 2

One Endangered species of Odonata (i.e. *Metacnemis valida*) which occurs in the corridor (status threatened by habitat loss and now only known from two sites on the Kubusi River in the vicinity of Stutterheim) (IUCN, 2017); as well as two Vulnerable and two Near Threatened species. In addition, there are three vulnerable species, and two near-threatened species of Odonata supported in this corridor. The corridor also supports one Critically Endangered fish (i.e. *Pseudobarbus senticeps*: a narrow range endemic species which is restricted to the Krom River system (IUCN, 2017), along with three Endangered, one Vulnerable, one Near Threated and one Data Deficient species. The only Red Listed amphibians that occur within the corridor include the Endangered *Afrixalus knysnae* and *Heleophryne hewitti*. *Afrixalus knysnae* is known from around five locations at low altitudes, on either side of the border between the Eastern Cape and Western Cape Provinces and its EOO is 816 km2, and its AOO is 27 km. (IUCN, 2017) The ghost frog occurring in the Kammanassie Mountains may be Hewitt's ghost frog (*Heleophryne hewitti*), but at this stage this still needs to be confirmed and thus the status updates (Turner and de Villiers, 2017) There are no Red Listed reptiles that are known to occur within the corridor. The corridor supports a reasonable diversity of Red Listed mammals, including the Critically Endangered Riverine Rabbit *Bunolagus monticularis* (see info on status above), as well as one Vulnerable and four Near Threated species.

This corridor supports a low diversity of (up to 7) Red Listed plants. Nevertheless, one is listed as Critically Endangered (i.e. *Cotula myriophylloides*) and another is Endangered (i.e. *Felicia westae*). The other species comprise of two Vulnerable, one Near Threatened, one Data Deficient, and one rare species.

4.2.4.7 Estuaries

In total 26 estuaries (Figure 16) are situated within the Phase 2 corridor, with a combined estuarine habitat area of 7 000 ha (note that the Sundays Estuary overlaps with both the Phase 2 and Phase 7 corridor boundaries and is therefore included in both assessments). Most of the estuaries in the region are not particularly long and extend less than 10 km into the corridor, with the exception of the Sundays (<25 km), Swartkops (<15 km), Klein Brak (<10 km), Swartvlei (<10 km), Goukamma (<10 km), Knysna (<10 km), Keurbbooms (<10 km), Gamtoos (<10 km) and Coega (<10 km).

Only seven estuaries in this corridor are in an excellent or good condition (Categories A to B) – these systems are highly sensitive to change as they will degrade from their near pristine state relatively easily.

The Wilderness/Touws, Swartvlei, Knysna, Keurbooms, Gamtoos, and Swartkops estuaries are of very high biodiversity importance, ranking among the top estuaries in South Africa (Turpie et al., 2002; Turpie and Clark, 2009). The Hartenbos, Groot Brak, Goukamma, Piesang, Kabeljous and Sundays estuaries are also rated as important from a biodiversity perspective.

Thirteen estuaries in the corridor are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). In addition, 13 estuaries are identified as important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). From a habitat diversity and abundance perspective the Hartenbos, Klein Brak, Groot Brak, Wilderness, Swartvlei, Goukamma, Knysna, Piesang, Keurbooms, Kabeljous, Gamtoos, Swartkops, Coega and Sundays estuaries are also considered important as they support sensitive estuarine habitats such as intertidal and supratidal saltmarsh.

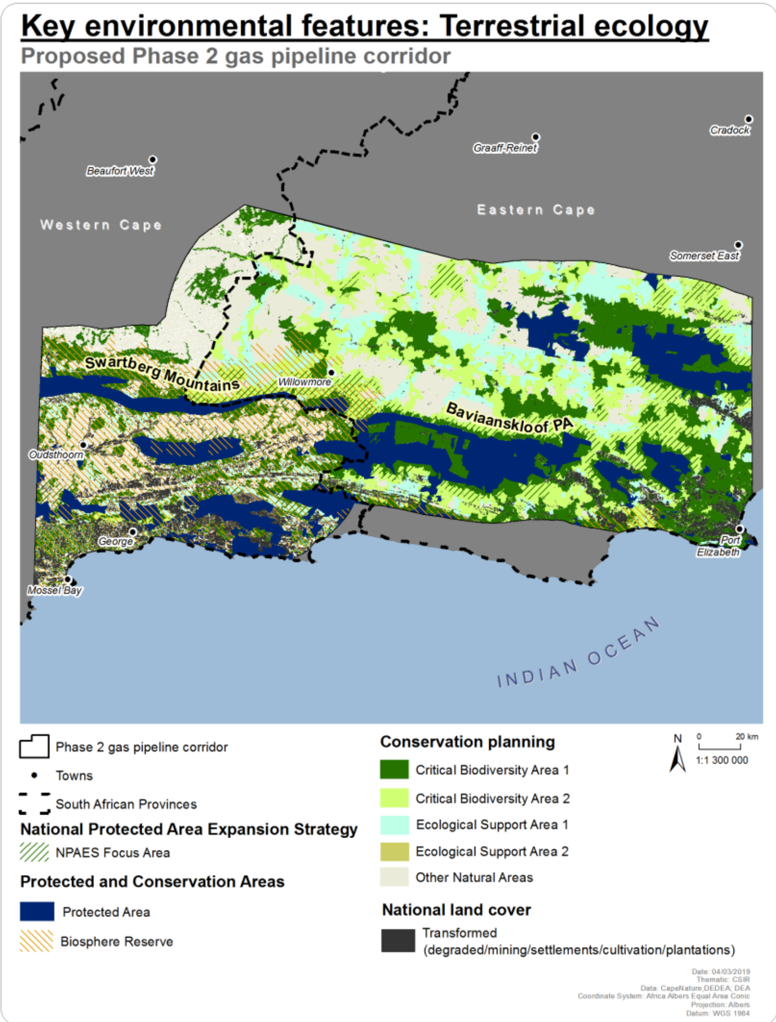


Figure 15: Key environmental features of the proposed Phase 2 gas pipeline corridor.

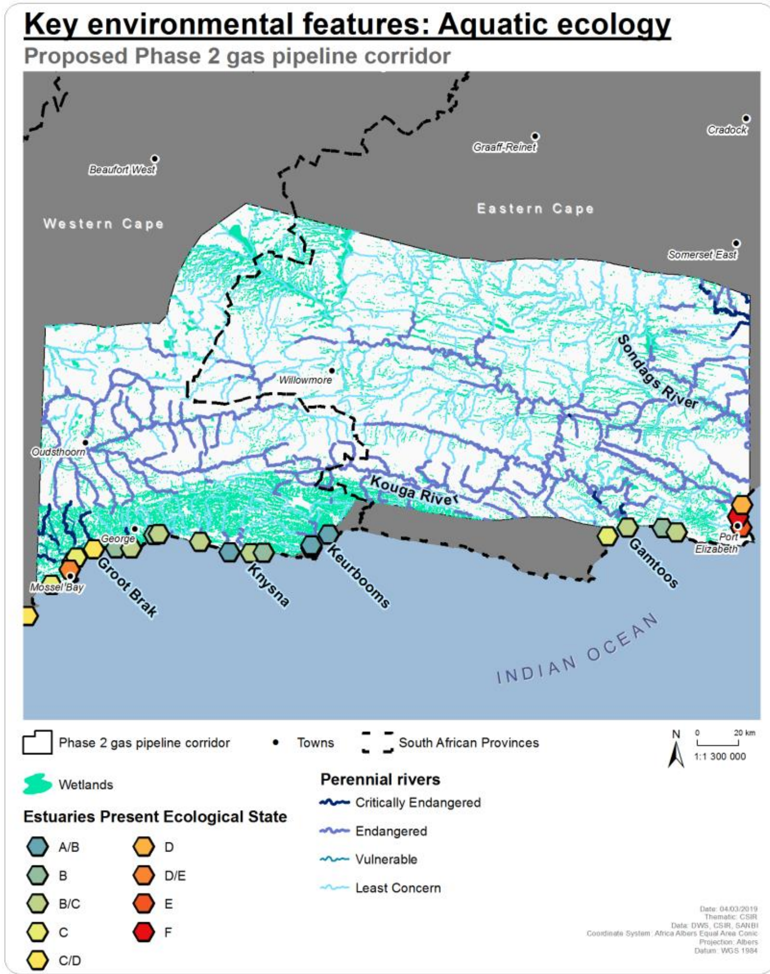


Figure 16: Key aquatic ecosystem features of the proposed Phase 2 gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extent.

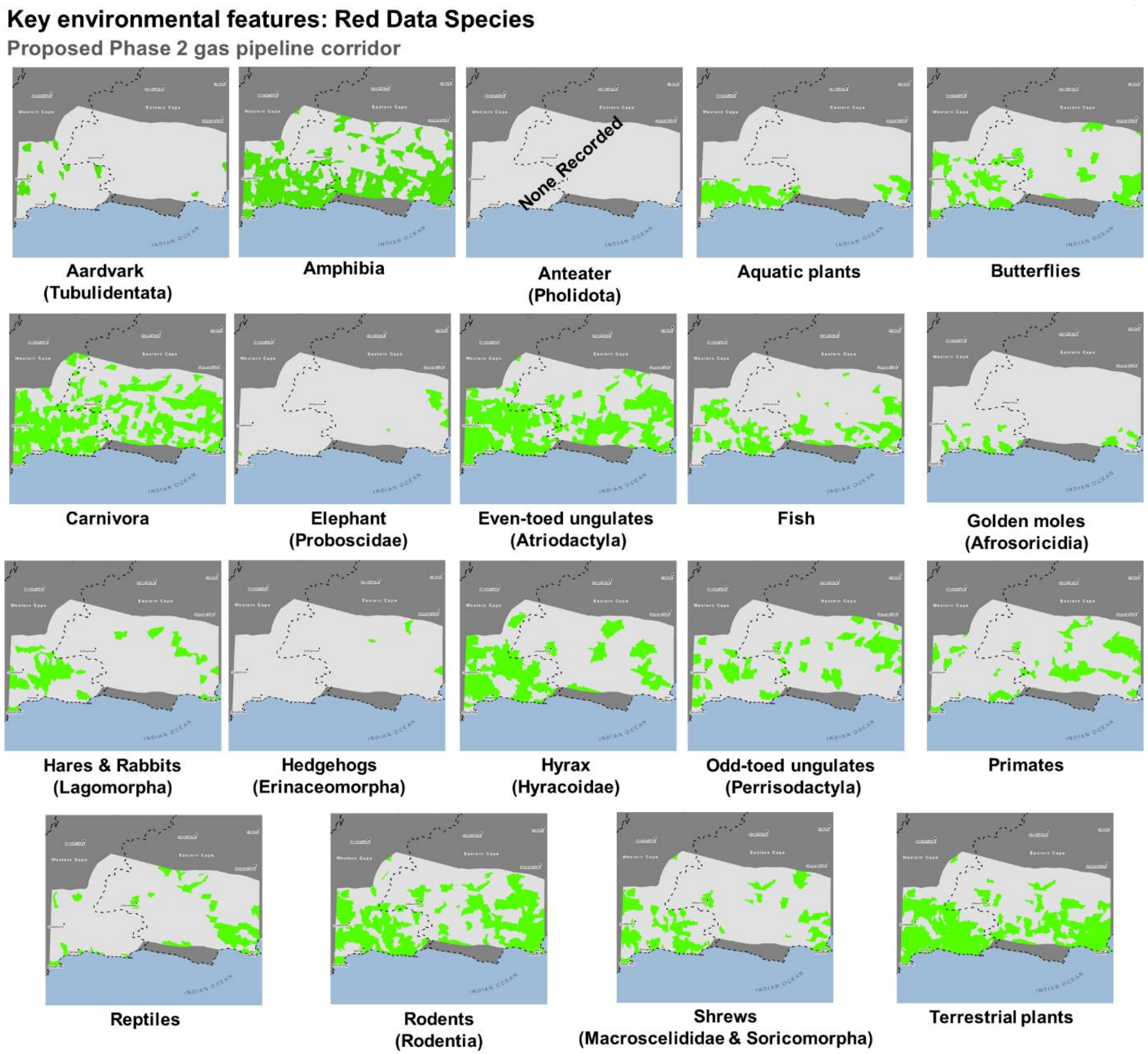


Figure 17: Distribution of recorded Red Data species in the proposed Phase 2 gas pipeline corridor (at quinary catchment scale).

4.2.5 Inland Phase

The proposed Inland Phase gas corridor is situated in the Karoo region from Sutherland to Somerset East (Figure 1). Compared to the other proposed gas pipeline corridors, it is relatively untransformed.

The climate is marked by hot summers and cold winters and the rainfall of about 300-400 mm per year occurs mainly in the winter months.

4.2.5.1 Fynbos

Sixteen Fynbos Biome vegetation types are found in this corridor, with half being Fynbos and half Renosterveld, with one being EN and two VU. About 60 is Roggeveld or Central Mountain or Matjiesfontein Shale Renosterveld. The threatened vegetation types are found mainly in the intensively cultivated Ceres and Kouebokkeveld areas. The Roggeveld escarpment is seen as a key area for the expansion of the Tankwa Karoo NP (Pool-Stanvliet et al., 2017; SANBI, 2009) (Figure 18).

Fires are rare on the Roggeveld Escarpment but more frequent on the northern slopes of the Swartberg and the Bontberg near Touwsriver based on fire occurrence records (Unpublished data, Advanced Fire Information System, Meraka Institute, CSIR).

The diversity and ecology of the Fynbos biome in the Inland Phase corridor is poorly documented and understood. Fires can play a role in regenerating the Renosterveld vegetation (Van der Merwe et al., 2008; van der Merwe and van Rooyen, 2011) but are actively suppressed by the farmers (David Le Maitre, pers. obs.).

The inland mountains, including the Roggeveld are important water source areas at a local scale.

4.2.5.2 Succulent Karoo and Nama Karoo

The inland corridor consists of the plains of the Lower Karoo in the south, which gives way to the Roggeveld and Nuweveld mountain ranges in the north. In general, at a broad level the areas of Lower Karoo are considered less sensitive than the mountains and Upper Karoo in the north. Important features of the Inland Corridor include the Tankwa Karoo National Park in the west, the Roggeveld Mountains which lie within the Roggeveld-Hantam centre of endemism, as well as the Karoo National Park near Beaufort West and the Camdeboo National Park near Graaff-Reinet in the east (Figure 18). Diversity of the rugged northern sections of the inland Corridor is considered high and these areas are considered generally unsuitable for a pipeline. The area from Sutherland across Beaufort West and up towards Loxton and Victoria West is also home to the CR Riverine Rabbit. The open plains to the south of the mountains are however generally of lower diversity with the key biodiversity feature present being the major drainage features such as the Gamka, Buffels, Dwyka, Kariega and Sundays Rivers.

4.2.5.3 Albany Thicket

The proposed Inland Phase gas pipeline corridor area contains many highly sensitive areas due to a number of state Protected Areas including the Camdeboo NP and part of Mountain Zebra NP (Figure 18). It also contains one CR vegetation type, Escarpment Valley Thicket, and part of the Sundays Arid Thicket.

4.2.5.4 Grassland

Grassland has a very limited extent in the proposed Inland Phase gas pipeline corridor, with small patches of Bedford Dry Grassland (Least Threatened) found on the eastern side of the corridor, south of Somerset East.

4.2.5.5 Birds and bats

No bat species of Conservation Importance occur in the proposed Inland Phase gas pipeline corridor. Table 14 presents red data species that occur in the biomes present in the proposed Inland Phase gas pipeline corridor.

Table 14: Red Data bird species likely to be encountered in the proposed Inland Phase gas corridor.

Species	Status	Biome					
		Fynbos	Succulent Karoo	Nama Karoo	Albany Thicket	Grassland	Azonal
Abdim's Stork	NT					✓	
African Finfoot	VU						✓
African Marsh-Harrier	EN	✓				✓	✓
African Rock Pipit	NT	✓	✓	✓		✓	
Black Harrier	EN	✓	✓	✓		✓	
Black Stork	VU		✓	✓			✓
Blue Crane	NT	✓	✓	✓		✓	✓
Burchell's Courser	VU		✓	✓		✓	✓
Cape Rock-jumper	NT	✓					
Caspian Tern	VU						✓
Denham's Bustard	VU					✓	
European Roller	NT				✓	✓	
Greater Flamingo	NT	✓	✓	✓			✓
Half-collared Kingfisher	NT						✓
Karoo Korhaan	NT	✓	✓	✓			
Knysna Woodpecker	NT				✓		
Kori Bustard	NT		✓	✓		✓	
Lanner Falcon	VU	✓	✓	✓	✓	✓	✓
Lesser Flamingo	NT	✓	✓	✓			✓
Ludwig's Bustard	EN	✓	✓	✓		✓	
Maccoa Duck	NT						✓
Marabou Stork	NT	Vagrant					
Martial Eagle	EN		✓	✓	✓	✓	
Protea Seedeater	NT	✓					
Red-footed Falcon	NT			✓		✓	
Sclater's Lark	NT		✓	✓			
Secretary bird	NT	✓	✓	✓		✓	
Southern Black Korhaan	VU	✓	✓				
Tawny Eagle	EN			✓		✓	
Verreaux's Eagle	VU	✓	✓	✓			
Yellow-billed Stork	EN						✓
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened							

4.2.5.6 Freshwater Ecosystems

Rivers within the proposed Inland Phase corridor are mostly ephemeral/non-perennial (95%), and are largely characteristic of the Great Karoo ecoregion, but also form part of the Nama Karoo and Drought Corridor ecoregions. Major river systems include the Dwyka, Kariega and Sondags Rivers (Figure 19). Less than 25% of the river habitat in the corridor is currently Threatened (i.e. CR and EN). The rivers are mostly in a natural/good condition (60%), 34% of rivers are in a fair condition, while 6% are in a poor condition.

Wetland habitats within this corridor occupy a fair proportion of the corridor (~7%), with up to 62 different wetland types dominated by channelled-valley bottom wetlands and depressions that are largely characteristic of the Nama Karoo. There are no Ramsar wetlands within the corridor, and a very small proportion (~1%) of wetlands are classified as NFEPA wetlands. Nevertheless, a significant portion (79%) of the wetlands are associated with CR wetland groups, notably the Lower Nama Karoo (60%) and the Rainshadow Valley Karoo (11%).

Almost the entire (99%) area of the Inland Corridor comprises land that is largely natural, with only a very small proportion transformed by cultivation (1%) and urbanisation (<1%). A very small proportion (3%) of the corridor is protected by a few conservation areas (e.g. Karoo NP and Tankwa Karoo NP). Impacts on freshwater ecosystems from associated land use activities of the transformed landscape are thus relatively localised. More widespread impacts to freshwater systems tend to be linked to livestock farming practices and infestation IAPs. The combined effect of anthropogenic pressures results in both localised and widespread impacts that affect functioning and integrity of freshwater ecosystems.

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Inland Phase pipeline corridor include:

- Weirs and dams (including large water supply dams, e.g. De Hoop, Leeugamka, Vanrynevelspas), which affect instream and riparian habitat continuity, as well as regulate flows downstream;
- Livestock grazing and trampling (including overgrazing, particularly in more rural areas), leading to increased erosion and sedimentation of systems;
- Intensive cultivation immediately adjacent and along the banks of rivers;
- Encroachment and infestation of woody vegetation, including invasive *Tamarix* spp.; and
- Channel incision and headcut erosion, resulting in lowered groundwater table and drying of riparian and wetland habitats.

Box 17: Red Data aquatic biota likely to be encountered in Inland Phase

There are no Red Listed species of Odonata known to occur within the Inland Corridor. Only two Red Listed fish occur within the corridor, namely the Endangered *Pseudobarbus asper*, and the Data Deficient *Sandelia capensis*. There are no Red Listed amphibians and reptiles that are known to occur within the Inland Corridor. The corridor is most notable in terms of supporting significant populations of the Critically Endangered Riverine Rabbit *Bunolagus monticularis*, which is restricted to the semi-arid Karoo, with an estimated EOO of 54,227 km^2 and AOO of 2,943 km^2 (2016 Mammal Red List *Bunolagus monticularis* CR). The Riverine Rabbit inhabits dense, discontinuous scrub vegetation along seasonal river beds and is dependent on soft, deep alluvial spoils along these river courses, for constructing burrows in order to breed. Other Red Listed mammals include the Near Threatened *Serval Leptailurus* and the Near Threatened *Otomys auratus*. This corridor supports the lowest number of Red Listed plants, with only one Vulnerable plant (i.e. *Lachenalia longituba*) and one rare plant (i.e. *Pelargonium denticulatum*) occurring within the corridor.

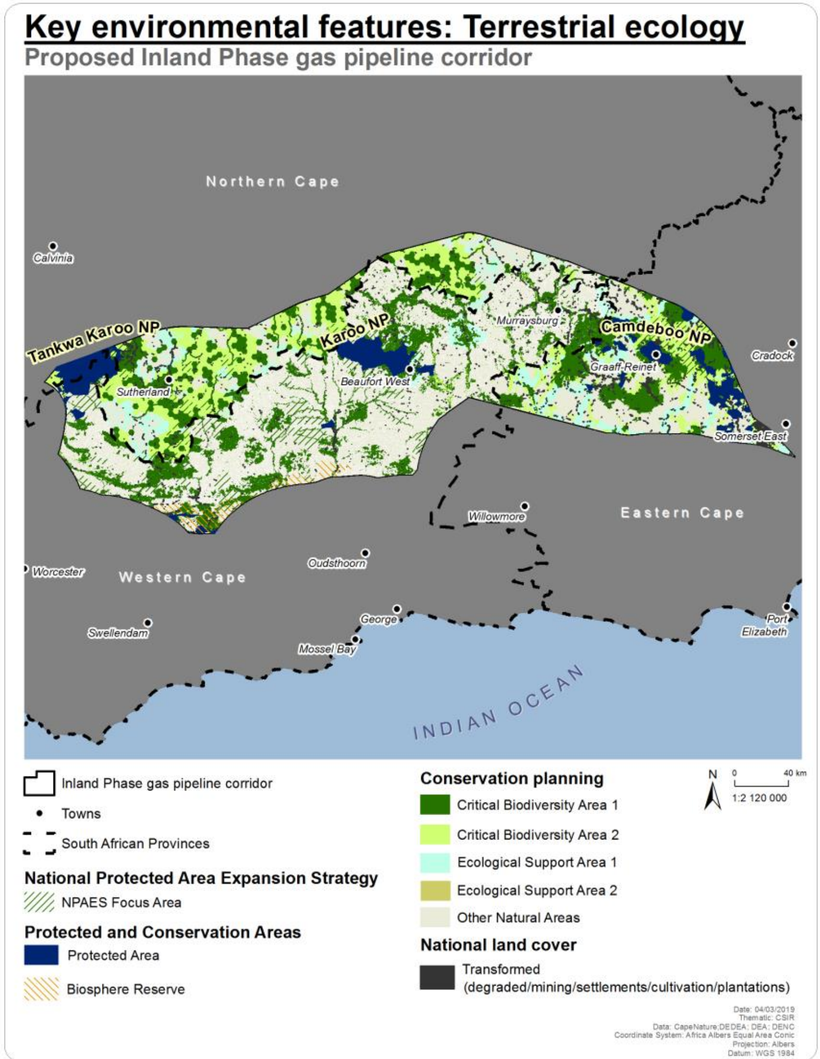


Figure 18: Key environmental features of the proposed Inland Phase gas pipeline corridor.

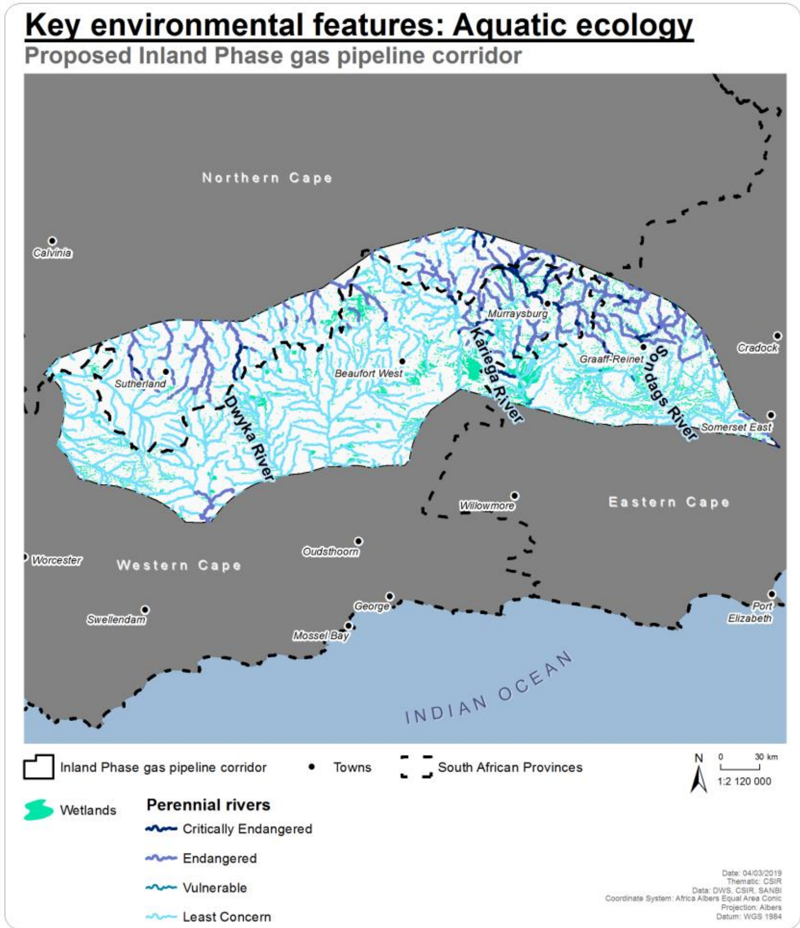


Figure 19: Key aquatic ecosystem features of the proposed Inland Phase gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extent

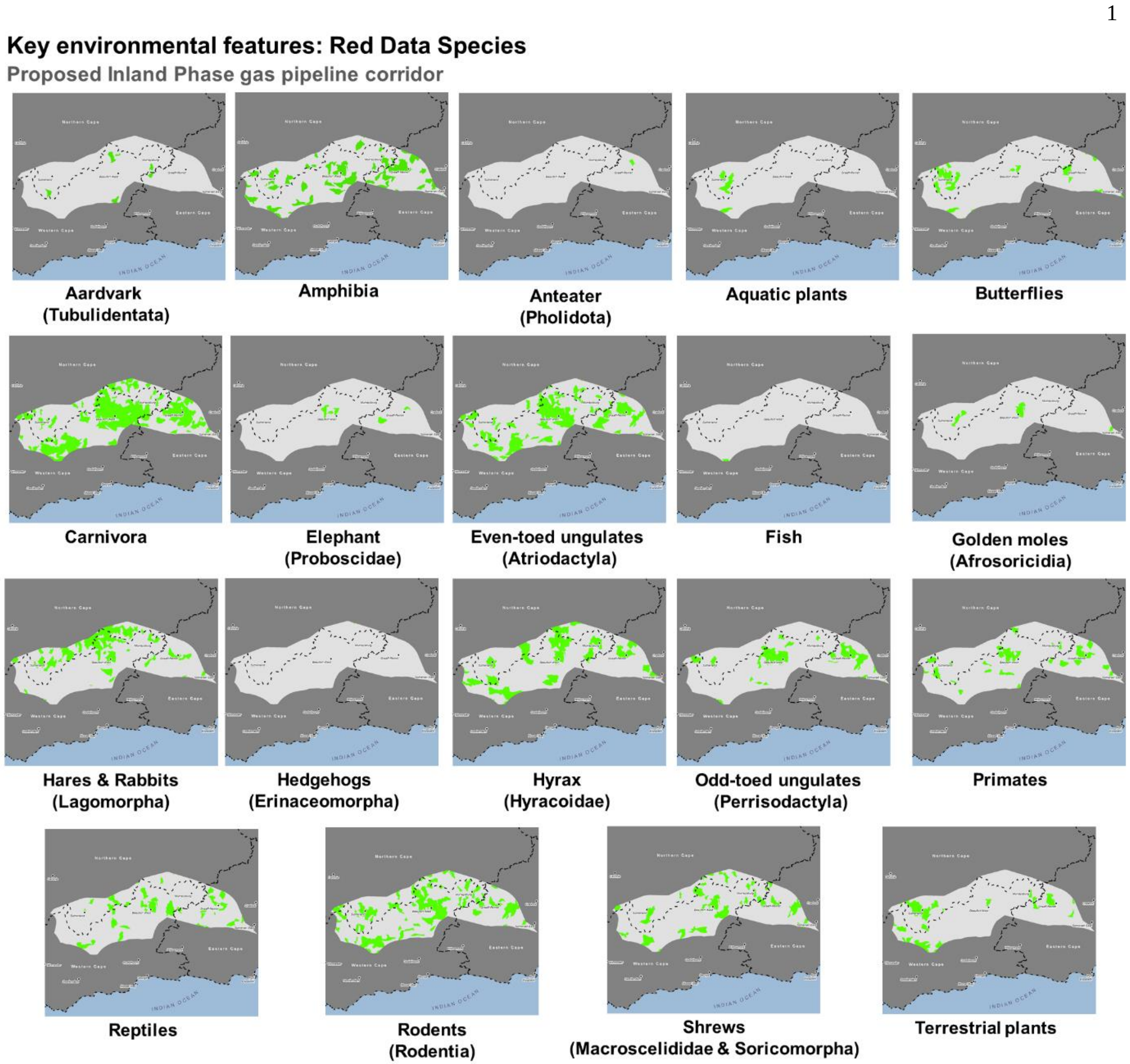


Figure 20: Distribution of recorded Red Data species in the proposed Inland Phase gas pipeline corridor (at quinary catchment scale).

4.2.6 Phase 7

The expansive proposed Phase 7 gas pipeline corridor occupies the eastern coast of South Africa, from Port Elizabeth in the Eastern Cape to Hluhluwe in KwaZulu-Natal (Figure 21 and Figure 23).

The climate of the east coast of southern Africa is controlled by the presence of a high pressure system lying to the east of the sub-continent and intermittently, the area is influenced by low pressure systems arising from the Southern Ocean, particularly during winter. In the late summer, cyclonic systems moving across the Indian Ocean often lead to catastrophic storm events along the coastline (Tinley, 1985).

The northern part of the Eastern Cape tends to be more humid with higher levels of rainfall, with high possibilities of snow in the interior mountain regions during winter. Climate in the KwaZulu-Natal province is subtropical, entailing hot and humid summers and mild winters.

4.2.6.1 Nama Karoo

Only a small patch of Albany Broken Veld in the western section of the proposed Phase 7 gas pipeline corridor. The vegetation type is transitional between the low grassy shrublands of the open plains and the thickets on the slopes of the hills of the area. The majority of species and features of conservation concern within this area are associated with the adjacent areas of thicket, grassland or small pockets of Afromontane forest that occur in moist positions along the mountains of the area.

4.2.6.2 Albany Thicket

The proposed Phase 7 gas pipeline corridor contains a large number of highly sensitive areas mostly due to many state-owned PAs, private nature reserves and game farms. The coastal areas are incised by deep river valleys often with sensitive and endangered vegetation types. It includes important PAs such as Great Fish River and part of Addo Elephant NP, as well as a number of CR vegetation types including Buffels Valley Thicket, Albany Dune, and Albany Thicket, and one EN vegetation type, Sundays Valley Thicket.

4.2.6.3 Grassland and Savanna

The proposed Phase 7 gas pipeline corridor runs through and important Pondoland centre of plant endemism. It has a large number of unique and poorly conserved Grassland and Savanna vegetation types with a large number of endemic species, rare and vulnerable species. Pinch points are not created by conservation areas, but rather by un-conserved or poorly conserved areas of high value and irreplaceable biodiversity.

The nature of the linear structure of the pipeline combined with the altitudinal alignment of vegetation types mean that it may well cut right across almost all areas of a specific vegetation type. This corridor cuts right across three centres of plant endemism.

4.2.6.4 Indian Ocean Coastal Belt

The proposed Phase 7 gas pipeline corridor affects the largest section of the IOCB, which includes a combination of very sensitive unique habitats associated with the Pondoland area and severely degraded and highly urbanised areas such as the greater Durban area.

Between Richards Bay and Hluhluwe, a significant portion of the Isimangaliso Wetland Park associated with Lake St Lucia is located. Outside of this protected area, the landscape is dominated by peri-urban settlement, extensive timber plantations and sugar cane cultivation.

Prominent azonal vegetation includes Swamp Forest (FOa 2) which is largely limited to isolated undisturbed areas in the Richards Bay and St Lucia areas. Extensive Northern Coastal Forests (FOz 7) occur, such as Futululu near Monzi.

Furthermore, the section of the IOCB affected by this corridor includes the lower extent of the Maputaland Coastal Belt (CB 1), the KwaZulu-Natal Coastal Belt (CB 3), Pondoland-Ugu Sandstone Coastal Sourveld (CB 4) and Transkei Coastal Belt (CB 5) major vegetation types. The KwaZulu-Natal south coast and Pondoland area are traversed by a large number of incised coastal and major river systems and undulating valleys. Where not transformed for agricultural purposes, these support Northern Coastal Forest and scarp forest. A prime example is the Umtamvuna River Valley (Umtamvuna Nature Reserve) on the KZN/EC border.

The northern section between Durban and Richards Bay is largely degraded, with the exception of a few pockets of undisturbed and protected habitat, such as the Amatikulu Nature Reserve (Dokodweni/Nyoni area) and The Ongoye Forest, near Mtunzini. The N2 corridor, extensive sugar cane farming and dune mining near Mtunzini are major disturbances within this section of the IOCB.

4.2.6.5 Birds and bats

Bat species of Conservation Importance likely to be encountered in the proposed Phase 7 gas corridor include:

- Short-eared trident bat
- Damara woolly bat
- De Winton’s long-eared bat
- Greater long-fingered bat
- Rendall's serotine
- Large-eared free-tailed bat
- Blasius's horseshoe bat
- Swinny's horseshoe bat
- Light-winged lesser house bat
- Schreber's yellow bat

Table 15 presents red data species that occur in the biomes present in the proposed Phase 7 gas pipeline corridor.

Table 15: Red Data bird species likely to be encountered in the proposed Phase 7 gas corridor.

Species	Status	Biome							
		Albany Thicket	Savanna	Grassland	Nama Karoo	Forest	Indian Ocean Coastal Belt	Fynbos	Azonal
Cape Parrot	EN					✓			
Abdim's Stork	NT		✓	✓					✓
Black Harrier	EN			✓	✓			✓	
Black Stork	VU		✓	✓	✓		✓	✓	✓
Blue Crane	NT			✓	✓		✓	✓	✓
Caspian Tern	VU								✓
European Roller	NT		✓				✓		
Greater Flamingo	NT				✓		✓		✓
Black-rumped Buttonquail	VU		✓	✓			✓		
Damara Tern	CR								✓
Karoo Korhaan	NT				✓			✓	
Lanner Falcon	VU	✓	✓	✓	✓		✓	✓	✓

Species	Status	Biome							
		Albany Thicket	Savanna	Grassland	Nama Karoo	Forest	Indian Ocean Coastal Belt	Fynbos	Azonal
Lesser Flamingo	NT				✓		✓		✓
Bush Blackcap	VU					✓			
Maccoa Duck	NT								✓
Martial Eagle	EN	✓	✓	✓	✓		✓	✓	
Red-footed Falcon	NT			✓	✓				
Secretary bird	NT		✓	✓	✓		✓	✓	
Lappet-faced Vulture	EN		✓						
Verreaux's Eagle	VU		✓	✓	✓			✓	
Marabou Stork	NT		✓						✓
Denham's Bustard	VU		✓	✓			✓		
Orange Ground-Thrush	NT					✓			
Pink-backed Pelican	VU						✓		✓
Half-collared Kingfisher	NT								✓
African Rock Pipit	NT				✓				
Eurasian Curlew	NT								✓
Greater Painted-snipe	NT								✓
Knysna Warbler	VU	✓				✓			
Saddle-billed Stork	EN								✓
Short-tailed Pipit	VU			✓					
Southern Bald Ibis	VU			✓					
Burchell's Courser	VU				✓			✓	✓
Cape Vulture	EN		✓	✓					
Chestnut-banded Plover	NT								✓
Southern Ground-Hornbill	EN		✓						
Tawny Eagle	EN		✓						
Wattled Crane	CR			✓					✓
African Grass-Owl	VU			✓			✓		
Grey Crowned Crane	EN			✓			✓		✓
Pallid Harrier	NT			✓					
White-bellied Korhaan	VU		✓	✓				✓	
White-backed Vulture	CR		✓						
Yellow-billed Stork	EN								✓
Yellow-breasted Pipit	VU			✓✓					
Eastern Bronze-naped Pigeon	EN					✓			
Knysna Woodpecker	NT	✓				✓			
African Crowned Eagle	VU					✓			
African Finfoot	VU								✓
African Pygmy-Goose	VU								✓
Bateleur	EN		✓						
Great White Pelican	VU								✓
Kori Bustard	NT		✓		✓				
Lemon-breasted Canary	NT						✓		
Lesser Jacana	VU								✓
Mangrove Kingfisher	EN						✓		✓
Neergaard's Sunbird	VU						✓		
Ludwig's Bustard	EN				✓				
Rosy-throated Longclaw	NT						✓		
Southern Banded Snake-Eagle	CR						✓		
Swamp Nightjar	VU						✓		
White-headed Vulture	CR		✓						
Southern Black Korhaan	VU							✓	

Species	Status	Biome							
		Albany Thicket	Savanna	Grassland	Nama Karoo	Forest	Indian Ocean Coastal Belt	Fynbos	Azonal
Striped Flufftail	VU			✓					
White-backed Night-Heron	VU								✓
African Broadbill	VU					✓			
Bat Hawk	EN		✓						
Bearded Vulture	CR			✓					
Blue Swallow	CR			✓					
Green Barbet	EN					✓			
Mountain Pipit	NT			✓					
Spotted Ground-Thrush	EN					✓			
White-headed Vulture	CR		✓						
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened									

4.2.6.6 Freshwater ecosystems

Rivers within the proposed Phase 7 gas pipeline corridor flow through a number of ecoregions, notably the South Eastern Uplands, but also the Eastern Uplands, North Eastern Coastal Belt and Eastern Coastal Belt. The rivers are predominantly perennial/permanently-flowing (87%), and major river systems include the Groot-Kei, Mbhashe, Mzimvubu, Mzimkhulu, Mkomazi, uMngeni, Thukela, Mhlatuze, and Mfolozi Rivers (Figure 22). Less than 30% of the rivers are considered to be Threatened (i.e. Critically Endangered, Endangered and Vulnerable). More than 60% of the rivers are in a natural/good condition, 8% are in a fair condition, while 30% are in a poor/very poor condition.

Wetland habitats within this corridor occupy a large proportion of the corridor (~12%) comprising up to 155 different wetland types dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the Subescarpment Grassland region. The supports three Ramsar wetlands, including parts of the St. Lucia System, located in the north eastern corner of the corridor, as well as uMgeni Vlei Nature Reserve (958 ha) and Ntsikeni Nature Reserve (9,200 ha). A moderate proportion (~20%) of the wetlands in the corridor are characterised as NFEPA wetland. A very small proportion (3%) of the wetland habitats are associated with the Endangered Lowveld wetland vegetation (Group 10), while 56% occur within the Vulnerable Lowveld wetland vegetation (Group 11).

Approximately 65% of the Phase 7 Corridor, which stretches across most of the Eastern Cape and KwaZulu-Natal, comprises land that is largely natural, with a fairly large area (6%) degraded by existing land management practices. A small proportion (4%) of the area is protected by a number of small conservation areas, but also larger ones (e.g. Addo Elephant National Park, Hluhluwe-Imfolozi Game Reserve and Isimangaliso Wetland Park). The remaining area is transformed by cultivation (19%), urbanisation and rural settlements (5%) and plantations (5%).

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 7 pipeline corridor include:

- Extensive urbanisation causing transformation and degradation of freshwater ecosystems, notably in the greater Durban area, which continues to expand down? along the coast, as well as Pietermaritzburg and a within numerous of coastal towns south of Durban;
- Water quality impacts and pollution associated with urban areas (e.g. domestic and industrial effluents, failing water treatment infrastructure) and agriculture (e.g. pesticides, herbicides and fertiliser applications), all of which are contaminating receiving aquatic environments;

- Very high (unacceptable) faecal contamination in the uMngeni, Mlazi and Mdloti Rivers, as well as numerous rivers draining the eThekwini Metropolitan and Pietermaritzburg;
- Stormwater runoff from hardened surfaces and sewer reticulation in and around urban areas;
- Altered flows and water quality caused by large impoundments (e.g. Midmar, Albert Falls, Inanda, Goedertrouw and Umtata Dams), inter-basin transfers, which severely affect downstream aquatic systems (e.g. channel characteristics, riparian vegetation, thermal regimes, instream and floodplain habitats), as well as upstream/downstream river continuity;
- Illegal sand mining, as well as and other mining activities, particularly along coastal areas;
- Transformation and alteration of watercourses through canals, diversion structures, weirs, road crossings, flood control berms;
- Cultivation of wetlands and floodplains (notably sugarcane), especially along the coastal region;
- Abstraction of water for large-scale irrigation, as well as streamflow reduction associated with extensive plantations;
- Erosion and degradation, especially linked to overgrazing, which is notable in the more rural areas; and
- Excessive infestation of numerous IAPs, particularly along rivers and around wetlands, as well as instream (e.g. Water Hyacinth).

Box 18: Red Data aquatic biota likely to be encountered in Phase 7

Of the ten species of Red Listed Odonata that are known to occur within the corridor, three are listed as Endangered (i.e. *Chlorolestes apricans, Diplacodes pumila* and *Metacnemis valida*), while five are considered Vulnerable and two near threatened. The corridor also supports up to 15 Red Listed fish, of which seven are Endangered and three are Vulnerable, two are near threatened and three are Date Deficient. Of the 9 Red Listed amphibians that occur within the corridor, one is Critically Endangered (i.e. *Vandijkophrynus amatolicus*), while five are Endangered, one is Vulnerable and two are Near Threatened. *Vandijkophrynus amatolicus* has a severely fragmented population and is known only from the Winterberg and Amathole Mountains, centred on Hogsback. The species has a very narrow EOO is 98 km^2, and there is ongoing decline in the extent and quality of habitat (IUCN, 2017) This corridor supports the highest number of Red Listed reptiles, including two Vulnerable, one Near Threatened and one Data Deficient species. The corridor also supports a high diversity of Red Listed mammals (up to 8 species), including three that are Vulnerable and five that are Near Threatened. This corridor supports a high diversity of (up to 39) Red Listed plants. Of these, two are Critically Endangered (i.e. *Isoetes wormaldii* and *Kniphofia leucocephala*), while six are Endangered, 17 are Vulnerable, 11 are Near Threatened, two are Data Deficient and one is rare.

4.2.6.7 Estuaries

In total 155 estuaries are situated within the Phase 7 corridor, with a combined estuarine habitat area of about 55 100 ha (Figure 22 and Figure 24). Most of the estuaries in the region are not particularly long and extend less than 10 km into the corridor, with the exception of St Lucia (< 30km), Sundays (<25 km), Bushmans (<20 km), Keiskamma (<20 km), Kowie (<15 km), Great Fish (<15 km), Tyolomnqa (<15 km), Great Kei (<15 km), Thukela (<15 km), Mhlathuze (<15 km), Mfolozi (<15 km), Coega (<10 km), Kariega, (<10 km), Kleinemond Wes (<10 km), Mgwalana (<10 km), Bira (<10 km), Nahoon (<10 km), Mbashe (<10 km), Mtamvuna (<10 km), Mzimkulu (<10 km), Matigulu/Nyoni (<10 km), Mlalazi (<10 km), Richards Bay(<10 km) and Nhlabane (<10 km).

Seventy-nine estuaries in this corridor are in an excellent or good condition (Categories A to B). These systems vary from very small to large permanently open systems which are highly sensitive to change as they will degrade from their near pristine state relatively easily.

A total of 14 estuaries in this corridor are of very high biodiversity importance, ranking with the top estuaries in South Africa, namely Kariega, Kowie, Great Fish, Mpekweni, Mtati, Mgwalana, Keiskamma, Great Kei, Mbashe, Mngazana, Mlalazi, Mhlathuze, Mfolozi and St Lucia estuaries (Turpie et al., 2002; Turpie and Clark, 2009). In addition, 37 systems are also rated as important from a biodiversity perspective.

Sixty-one estuaries in the corridor are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). In addition, 53 estuaries are identified as important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017).

From a habitat diversity and abundance perspective 96 estuaries are considered important as they support sensitive estuarine habitats such as mangroves, swamp forest or saltmarsh (intertidal and supratidal).

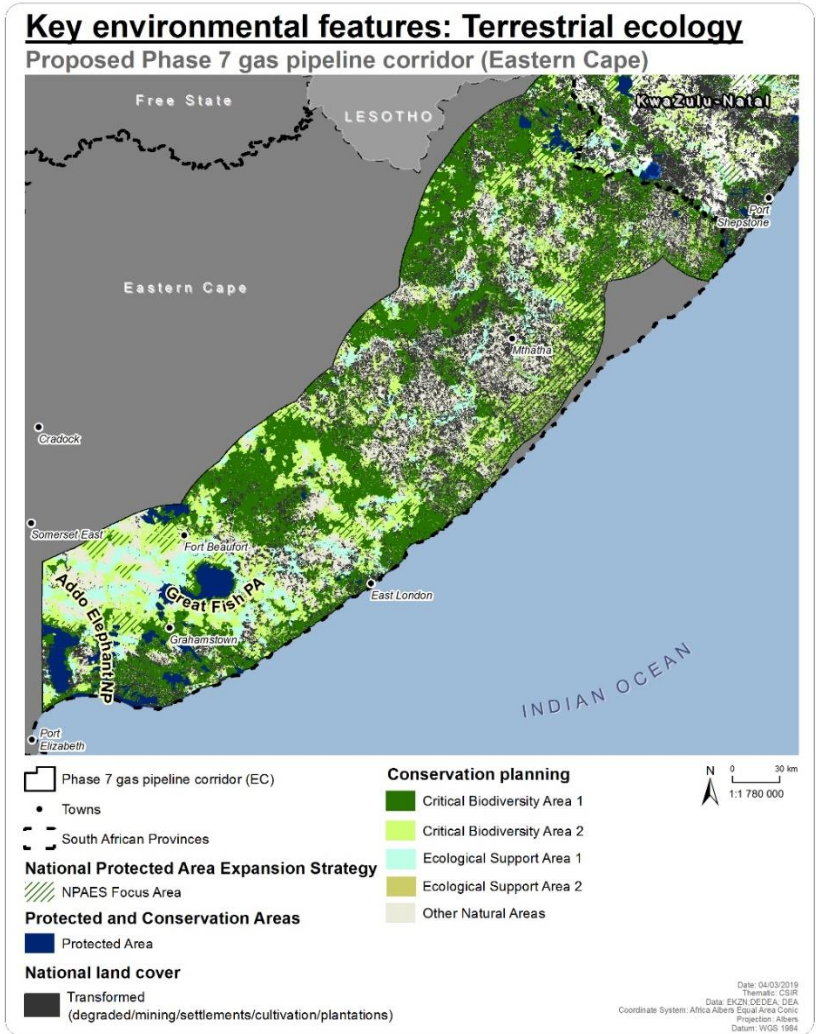


Figure 21: Key environmental features of the proposed Phase 7 gas pipeline corridor (Eastern Cape).

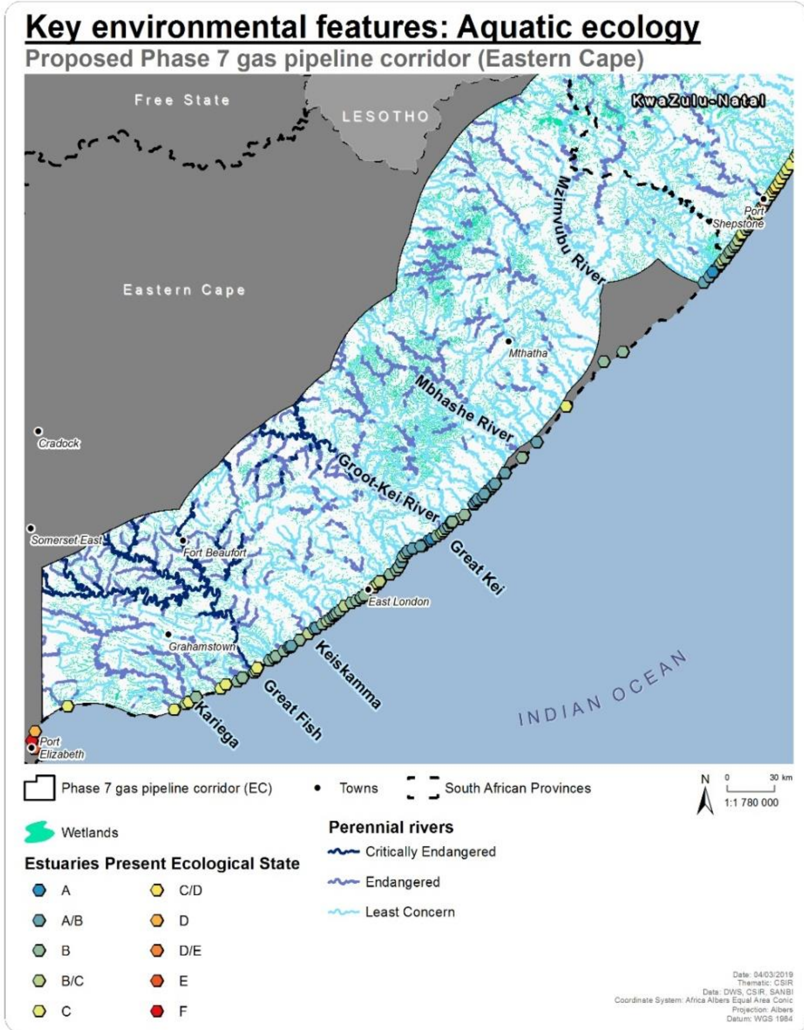


Figure 22: Key aquatic ecosystem features of the proposed Phase 7 gas pipeline corridor (Eastern Cape).

Note: Finer scale features may not be visible at the current map extent

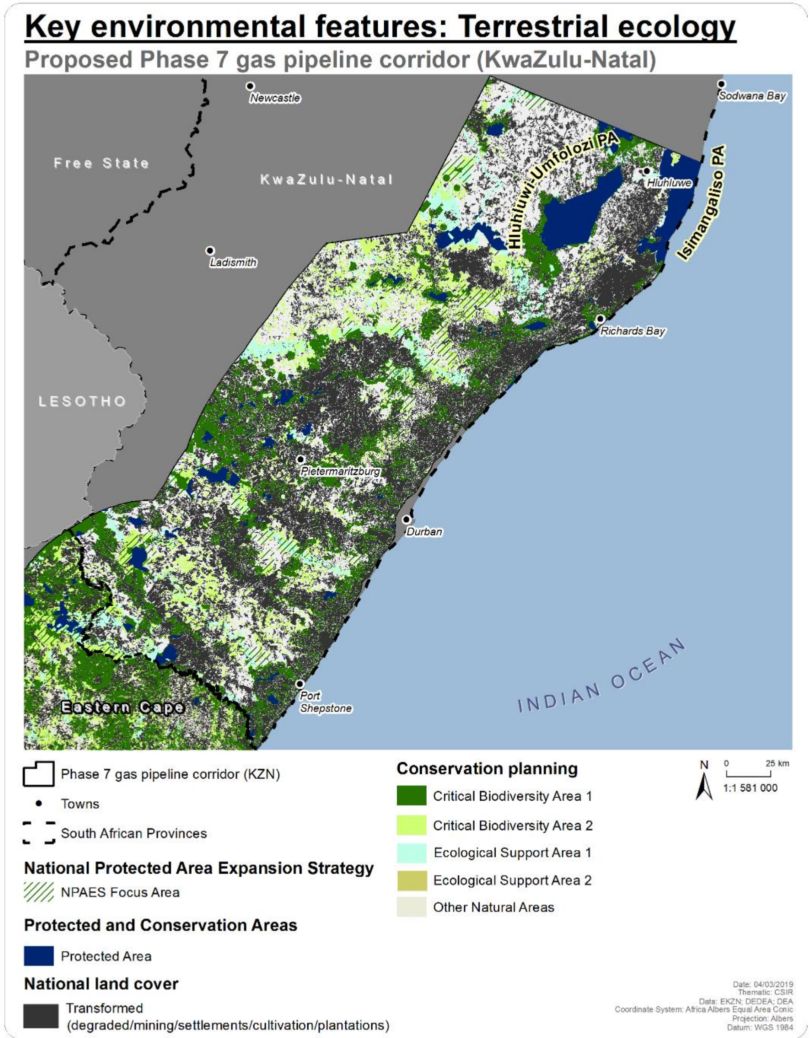


Figure 23: Key environmental features of the proposed Phase 7 gas pipeline corridor (KwaZulu-Natal).

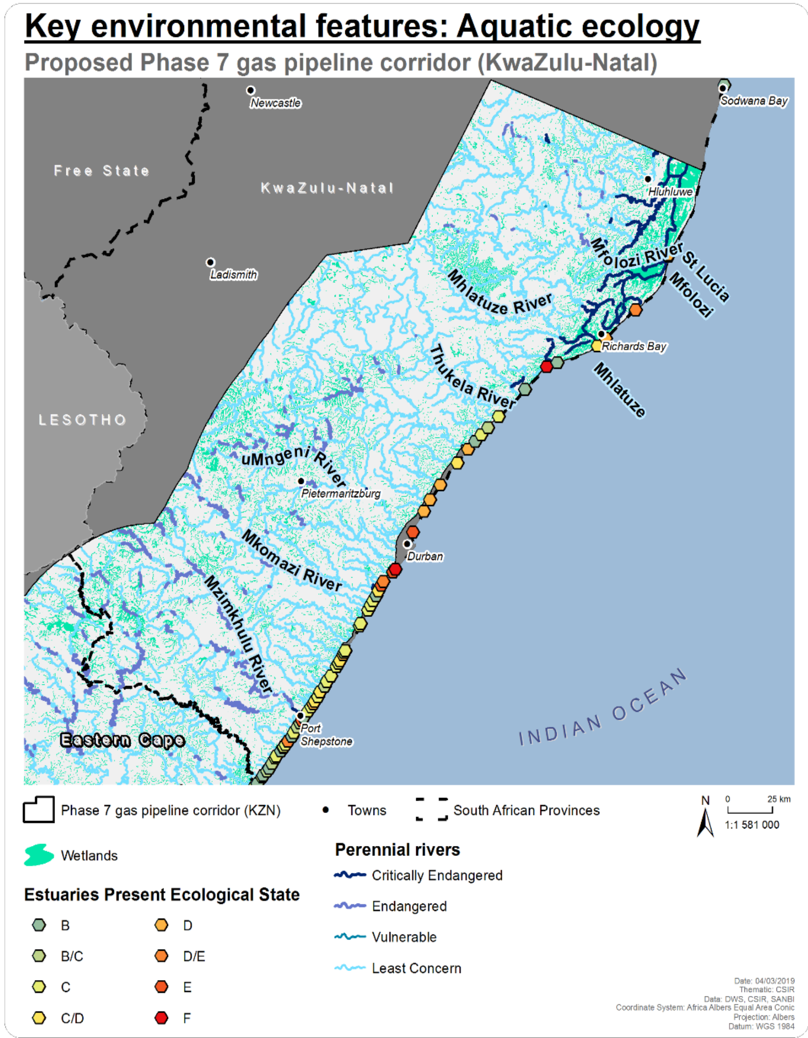


Figure 24: Key aquatic ecosystem features of the proposed Phase 7 gas pipeline corridor (KwaZulu-Natal).

Note: Finer scale features may not be visible at the current map extent

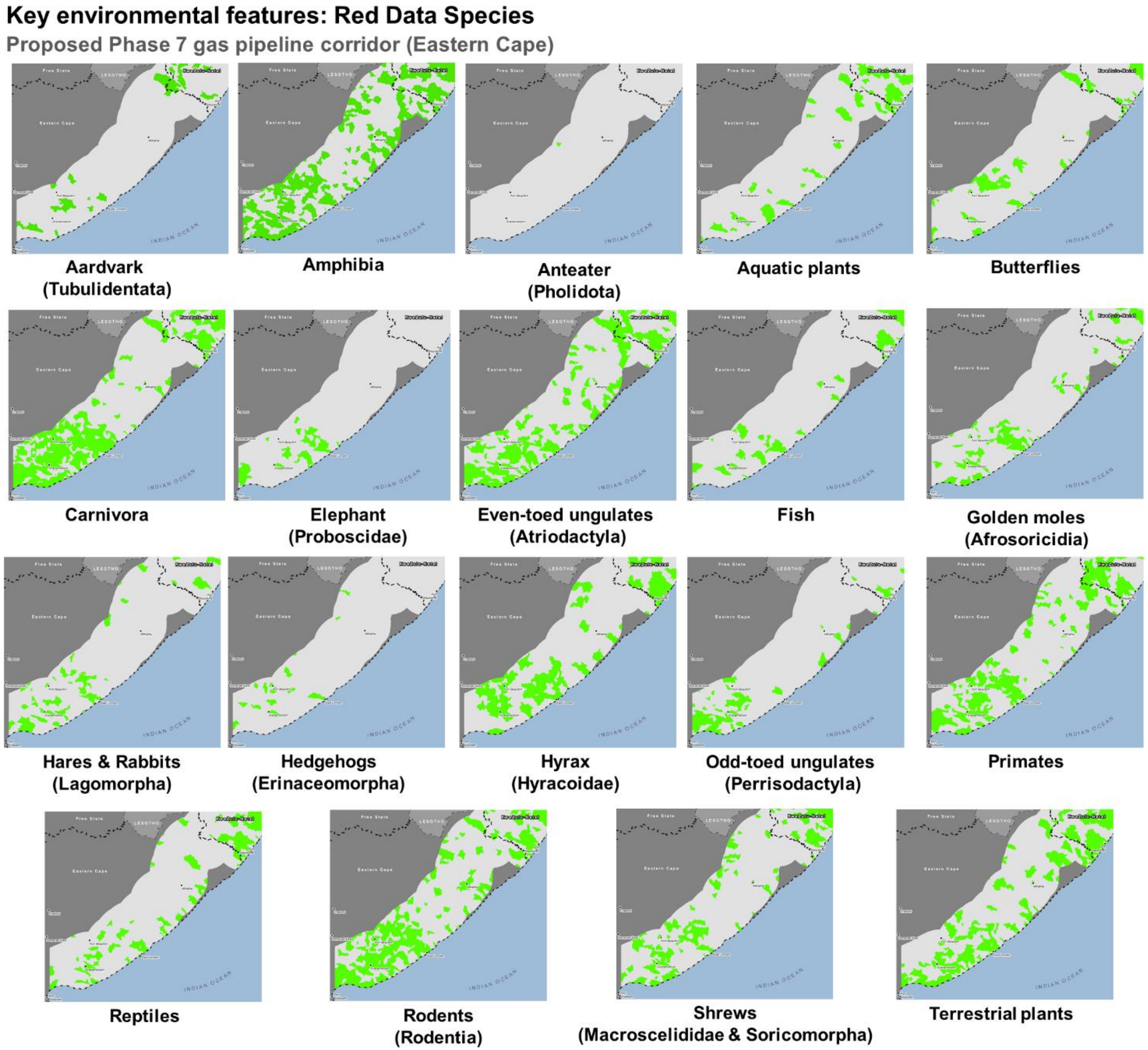


Figure 25: Distribution of recorded Red Data species in the proposed Phase 7 gas pipeline corridor (at quinary catchment scale) (Eastern Cape).

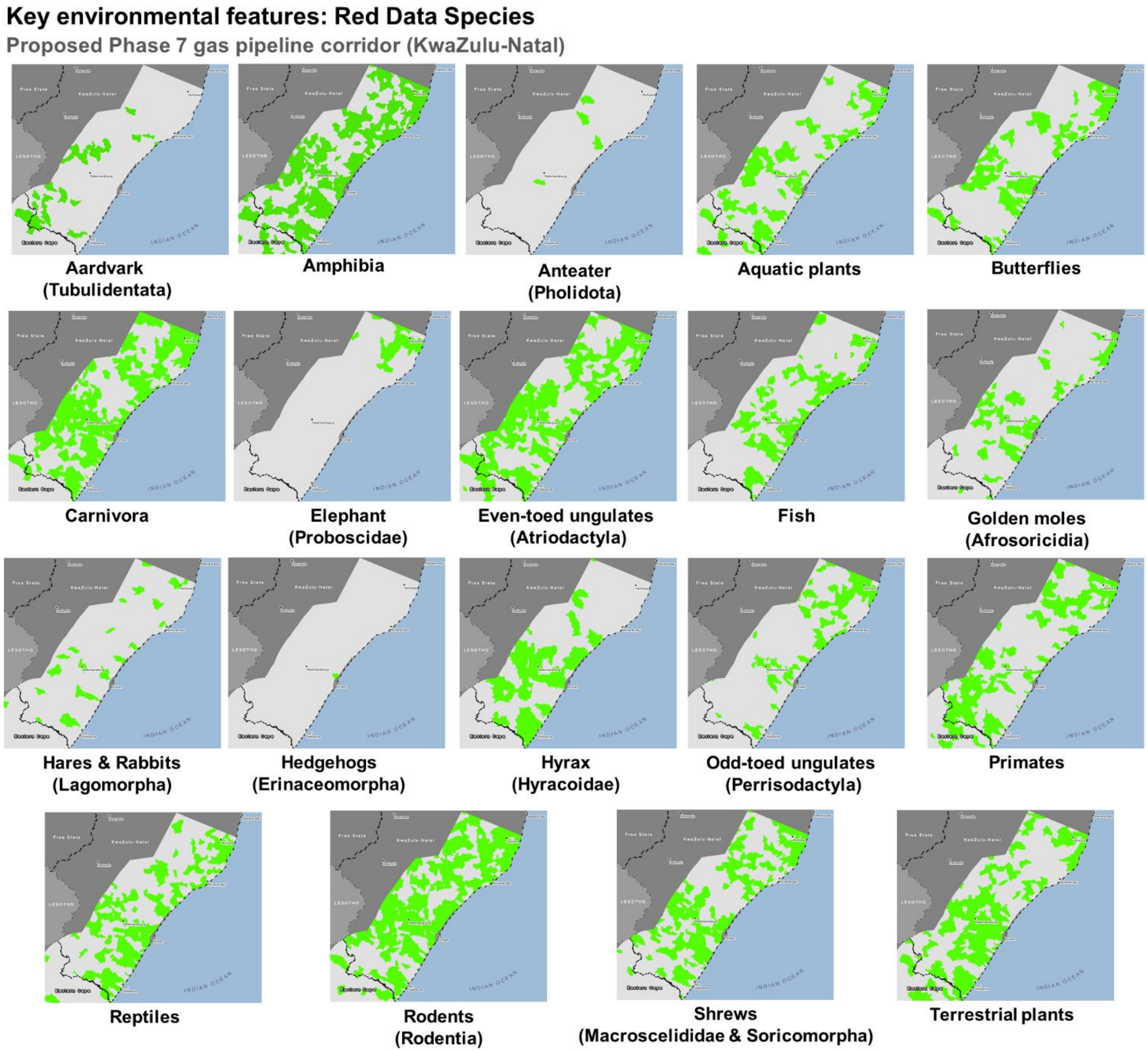


Figure 26: Distribution of recorded Red Data species in the proposed Phase 7 gas pipeline corridor (at quinary catchment scale) (KwaZulu-Natal).

4.2.7 Phase 4

The proposed Phase 4 gas pipeline corridor occupies the eastern coast of South Africa, from Hluhluwe to the Mozambique border (Figure 27).

The climate is subtropical with hot and humid summers and mild winters.

4.2.7.1 Savanna

With the exception of the coastal strip, most of the proposed Phase 4 gas pipeline corridor is Savanna vegetation, and most is in the Maputaland centre of plant endemism. This region has a number of important private and provincial nature reserves that create pinch points. These include Ndumu, Tembe, Mkuzi and the Isimangaliso wetland park (though this is predominantly not Savanna or Grassland).

4.2.7.2 Indian Ocean Coastal Belt

The IOCB within this corridor is made up of the Maputaland Coastal Belt (CB 1) and Maputaland Wooded Grassland (CB 2). Subtropical Freshwater Wetlands and Lowveld Riverine Forest are two significant azonal vegetation types found within this section of the IOCB.

A prominent feature is the Isimangaliso Wetland Park, a significant protected area, Ramsar Site and World Heritage Site. This extends from Maphelane, north of Richards Bay to Kosi Bay and extends inland to the Mkuze Nature Reserve. The bulk of the Isimangaliso Wetland Park, from Lake St. Lucia to Kosi Bay falls within this corridor phase.

4.2.7.3 Birds and bats

Bat species of Conservation Importance likely to be encountered in the proposed Phase 4 gas corridor include:

- Short-eared trident bat
- Damara woolly bat
- Rendall's serotine
- Large-eared free-tailed bat
- Blasius's horseshoe bat
- Swinny's horseshoe bat
- Dent's horseshoe bat
- Light-winged lesser house bat
- Schreber's yellow bat
- Egyptian tomb bat

Table 16 presents red data species that occur in the biomes present in the proposed Phase 4 gas pipeline corridor.

Table 16: Red Data bird species likely to be encountered in the proposed Phase 4 gas corridor.

Species	Status	Biome				
		Savanna	Grassland	Forest	Indian Ocean Coastal Belt	Azonal
Abdim's Stork	NT		✓			✓
African Broadbill	VU			✓		
African Crowned Eagle	VU			✓		
African Finfoot	VU					✓
African Grass-Owl	VU		✓			✓
African Marsh-Harrier	EN	✓	✓		✓	✓
African Pygmy-Goose	VU					✓
African Rock Pipit	NT	✓	✓			
Bateleur	EN	✓				
Black Harrier	EN		✓			
Black Stork	VU	✓	✓		✓	✓
Black-rumped Buttonquail	VU	✓			✓	
Black-winged Pratincole	NT		✓			
Blue Crane	NT		✓		✓	✓
Botha's Lark	EN		✓			
Burchell's Courser	VU		✓			
Bush Blackcap	VU			✓		
Cape Vulture	EN	✓				
Caspian Tern	VU					✓
Chestnut-banded Plover	NT					✓
Denham's Bustard	VU		✓		✓	
Eastern Bronze-naped Pigeon	EN			✓		
Eurasian Curlew	NT					✓
European Roller	NT	✓			✓	
Great White Pelican	VU					✓
Greater Flamingo	NT				✓	✓
Greater Painted-snipe	NT					✓
Grey Crowned Crane	EN		✓		✓	✓
Half-collared Kingfisher	NT					✓
Hooded Vulture	CR	✓				
Lanner Falcon	VU	✓	✓	✓	✓	✓
Lappet-faced Vulture	EN	✓				
Lemon-breasted Canary	NT				✓	
Lesser Flamingo	NT				✓	✓
Lesser Jacana	VU					✓
Maccoa Duck	NT					✓
Mangrove Kingfisher	EN				✓	
Marabou Stork	NT	✓			✓	✓
Martial Eagle	EN	✓	✓		✓	
Neergaard's Sunbird	VU				✓	
Orange Ground-Thrush	NT			✓		
Pallid Harrier	NT		✓		✓	
Pel's Fishing-Owl	EN					✓
Pink-backed Pelican	VU					✓
Red-footed Falcon	NT		✓			

Species	Status	Biome				
		Savanna	Grassland	Forest	Indian Ocean Coastal Belt	Azonal
Rosy-throated Longclaw	NT				✓	
Rudd's Lark	EN		✓			
Saddle-billed Stork	EN					✓
Secretary bird	NT	✓	✓			
Short-tailed Pipit	VU		✓			
Southern Bald Ibis	VU		✓			
Southern Banded Snake-Eagle	CR				✓	
Southern Ground-Hornbill	EN	✓			✓	
Swamp Nightjar	VU				✓	
Tawny Eagle	EN	✓				
Verreaux's Eagle	VU	✓	✓			
Wattled Crane	CR		✓			✓
White-backed Vulture	CR	✓				
White-bellied Korhaan	VU	✓	✓		✓	
White-headed Vulture	CR	✓				
Yellow-billed Stork	EN					✓
Yellow-breasted Pipit	VU		✓			
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened						

4.2.7.4 Freshwater ecosystems

Rivers within the proposed Phase 4 gas pipeline corridor largely form part of the Lowveld and Natal Coastal Plain ecoregions, with a smaller number of river draining off from the Lebombo Uplands. The rivers are either perennial/permanently-flowing (approximately 62%) or ephemeral/non-perennial (approximately 38%). Major river systems include the Phongolo and Mkuze Rivers (Figure 28). Less than 30% of the rivers are considered to be Threatened (i.e. CR, EN and VU). Almost half of the rivers are in a natural/good condition, 36% are in a fair condition, while 16% are in a poor/very poor condition.

Wetland habitats within this corridor occupy a small proportion of the corridor (~4%) comprising up to 47 different wetland types, dominated by floodplain wetlands, particularly within the Indian Ocean Coastal Belt region. The corridor boasts four Ramsar wetlands covering up to 185 000 ha, namely Ndumo Game Reserve, Kosi Bay, Lake Sibaya, and the St. Lucia System. A significant proportion (~51%) of the wetlands in the corridor are characterised as NFEPA wetlands. Most notable is that 65% of the wetland habitats within the corridor are associated with the Endangered Lowveld wetland vegetation (Group 10).

Approximately 72% of the Phase 4 Corridor comprises land that is largely natural, with a significant proportion of the area protected by existing conservation areas (e.g. Isimangaliso Wetland Park, Tembe Elephant Park, Ndumo Game Reserve, Ithala Game Reserve). The remaining area has been largely degraded (~15%) or is transformed by cultivation, plantations, urbanisation and rural settlements. Impacts on freshwater ecosystems caused by land use activities vary across the corridor, however, combined effect has had a significant effect on freshwater ecosystem functioning and integrity.

Box 19: Red Data aquatic biota likely to be encountered in Phase 4

The only Critically Endangered Odonata for South Africa occurs along the Phongolo River in the north-western corner of the Phase 4 Corridor, namely *Chlorocypha consueta*. The Endangered *Diplacodes pumila* also occurs in the corridor along with six species listed as Vulnerable and four species listed as Near Threatened. One Endangered fish, *Silhouettea sibayi* occurs in coastal rivers that flow through the corridor. The corridor also supports two vulnerable species, three Near Threatened and two Data Deficient species of fish. The only Red Listed amphibians that occur within the corridor include the Endangered *Hyperolius pickersgilli* and the Near Threatened *Hemisus guttatus*. The corridor supports two Red Listed reptiles, namely the Hinged Terrapin *Pelusios rhodesianus*, (Vulnerable) which is known from a few water bodies along the coastal region – and *Macrelaps microlepidotus* (Near Threatened), which is found in forests and coastal bush. Up to eight Red Listed mammals occur within the Phase 4 Corridor, including five rodents/shrews, as well as Spotted-necked Otter *Hydrictis maculicollis* (Vulnerable) and Cape Otter *Aonyx capensis* (Near Threatened). This corridor supports a moderate diversity of (up to 24) Red Listed plants, including two that are Endangered (i.e. *Albizia suluensis* and *Mondia whitei*). The majority of the Red Listed plants occurring with the corridor are either Vulnerable (12 species) or Near Threatened (9 species), while one is considered rare.

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 4 pipeline corridor include:

- Extensive urbanisation causing transformation and degradation of freshwater ecosystems, notably in the greater Durban region, which continues to expand up along the coast, as well as Richards Bay;
- Water quality impacts and pollution associated with urban areas (e.g. domestic and industrial effluents, failing water treatment infrastructure) and agriculture (e.g. pesticides, herbicides and fertiliser applications) all of which are contaminating receiving aquatic environments;
- Flow alteration caused by large impoundments (e.g. Pongolapoort Dam), inter-basin transfers, waste water treatment works return flows, and stormwater runoff from hardened surfaces and sewer reticulation, all of which affect downstream aquatic systems (e.g. channel characteristics, riparian vegetation, and instream and floodplain habitats) as well as river continuity;
- Cultivation of wetlands and floodplains (notably sugarcane), especially along the coastal region;
- Illegal sand mining, as well as and other mining activities, particularly in the Richards Bay region;
- Transformation and alteration of watercourses through canals, diversion structures, weirs, road crossings, flood control berms;
- Abstraction of water for irrigation and extensive forestry, which is having a significant impact on groundwater and linked wetlands in the Maputaland region;
- Erosion and degradation, especially linked to overgrazing, which is notable in the more rural areas; and
- Excessive infestation of numerous IAPs, particularly along rivers and around wetlands, as well as instream (e.g. Water Hyacinth).

4.2.7.5 Estuaries

Three estuaries are situated within the Phase 4 corridor, with a combined estuarine habitat area of about 46 200 ha. Note there is overlap with St Lucia lakes system in Phase 7 corridor. Two of the systems in the corridor are very large, with St Lucia extending about 30 km and Kosi extending about 10 km in land (Figure 28). The Mgobezeleni extends less than 10 km inland.

The Mgobezeleni and Kosi estuaries are in an excellent to good condition (Categories A to B). These systems are highly sensitive to change as they will degrade from their near pristine state relatively easily. The St Lucia and Kosi estuarine lake systems are of very high biodiversity importance (Turpie et al., 2002; Turpie and Clark, 2009). All three estuaries in the corridor, St Lucia, Mgobezeleni and Kosi, are identified as national conservation priorities in the National Estuaries Biodiversity Plan (Turpie et al., 2012). St Lucia and Kosi are important fish nurseries that play a critical role in the maintenance and recovery of South Africa's recreational and commercial fish stock (Lamberth and Turpie, 2003; Van Niekerk et al., 2017). From a habitat diversity and abundance perspective the St Lucia, Mgobezeleni and Kosi estuaries are all considered important as they support sensitive estuarine habitats such as mangroves, swamp forest and saltmarsh.

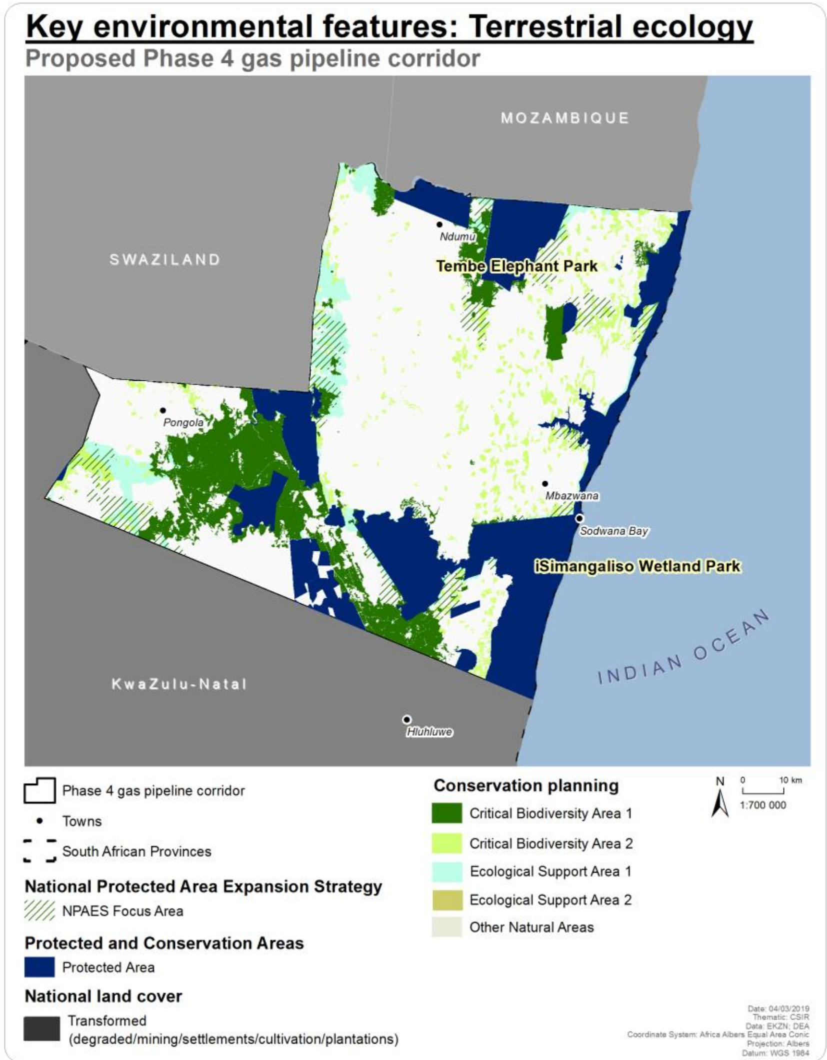


Figure 27: Key environmental features of the proposed Phase 4 gas pipeline corridor.

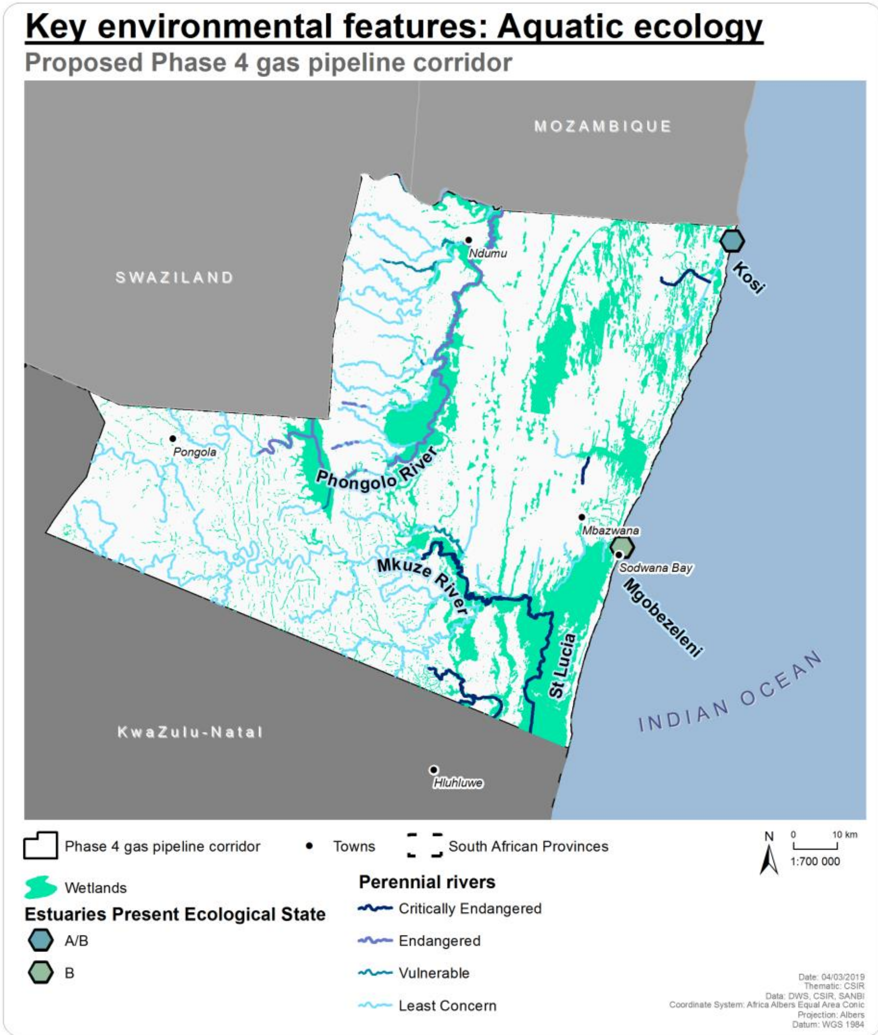


Figure 28: Key aquatic ecosystem features of the proposed Phase 4 gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extent

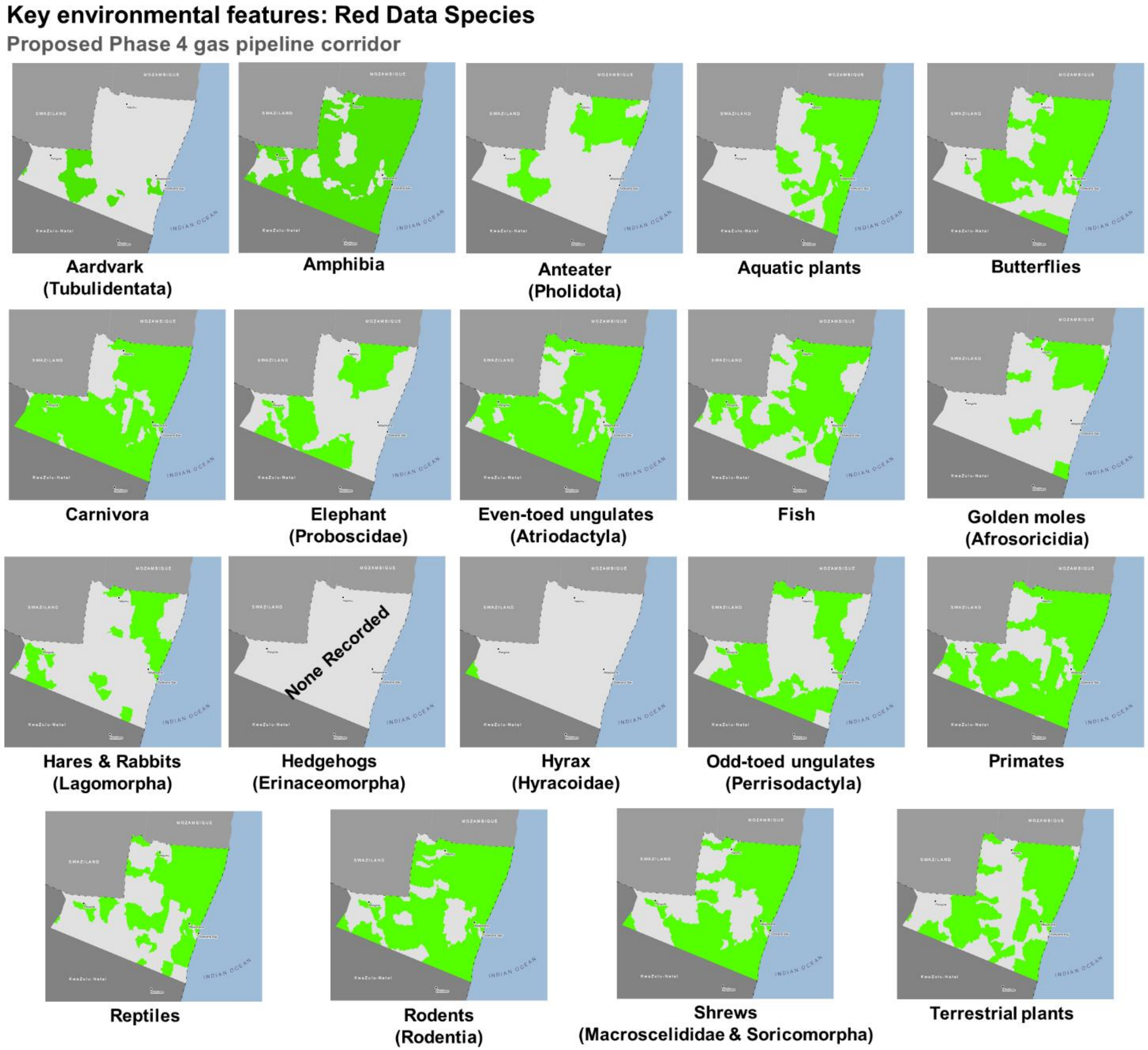


Figure 29: Distribution of recorded Red Data species in the proposed Phase 4 gas pipeline corridor (at quinary catchment scale).

4.2.8 Phase 3

4.2.8.1 Grassland and Savanna

With the exception of the coastal strip this corridor falls almost exclusively within Savanna and Grassland regions, with a few embedded forest patches. There are two key pinch points, the one relates to Savanna biodiversity and a string of game reserves centred on the Hluhluwe–Imfolozi Reserve and Nduna reserve in Zululand and the related Maputaland centre of plant endemism. The second is Grassland areas as the corridor cuts through the Drakensberg mountains. In addition, the northern half of Gauteng is a complex area due to parallel mountain ranges, and the area being an ecotone between the Highveld Grasslands and Savanna bushland regions.

4.2.8.2 Birds and bats

Bat species of Conservation Importance likely to be encountered in the proposed Phase 3 gas corridor include:

- Short-eared trident bat
- Damara woolly bat
- Rendall's serotine
- Greater long-fingered bat
- Large-eared free-tailed bat
- Blasius's horseshoe bat
- Swinny's horseshoe bat
- Dent's horseshoe bat
- Schreber's yellow bat

Table 17 presents red data species that occur in the biomes present in the proposed Phase 3 gas pipeline corridor.

Table 17: Red Data bird species likely to be encountered in the proposed Phase 3 gas corridor.

Species	Status	Biome			
		Savanna	Grassland	Forest	Azonal
African Marsh-Harrier	EN	✓	✓		✓
Abdim's Stork	NT	✓	✓		✓
Black Harrier	EN		✓		
Black Stork	VU		✓		✓
Blue Crane	NT		✓		✓
Caspian Tern	VU				✓
European Roller	NT	✓			
Greater Flamingo	NT	✓	✓		✓
Black-rumped Buttonquail	VU		✓		
Black-winged Pratincole	NT	✓	✓		✓
Botha's Lark	EN		✓		
Lanner Falcon	VU	✓	✓	✓	✓
Lesser Flamingo	NT	✓	✓		✓
Bush Blackcap	VU			✓	
Maccoa Duck	NT				✓
Martial Eagle	EN	✓	✓	✓	✓
Red-footed Falcon	NT		✓		

Species	Status	Biome			
		Savanna	Grassland	Forest	Azonal
Secretary bird	NT	✓	✓		
Lappet-faced Vulture	EN	✓			
Verreaux's Eagle	VU	✓	✓		
Marabou Stork	NT	✓			✓
Denham's Bustard	VU		✓		
Orange Ground-Thrush	NT			✓	
Pink-backed Pelican	VU				✓
Half-collared Kingfisher	NT				✓
African Rock Pipit	NT	✓	✓		
Eurasian Curlew	NT				✓
Greater Painted-snipe	NT				✓
Rudd's Lark	EN		✓		
Saddle-billed Stork	EN				✓
Short-tailed Pipit	VU		✓		
Southern Bald Ibis	VU		✓		
Burchell's Courser	VU		✓		
Cape Vulture	EN	✓	✓		
Chestnut-banded Plover	NT				✓
Southern Ground-Hornbill	EN	✓			
Tawny Eagle	EN	✓			
Wattled Crane	CR		✓		✓
African Grass-Owl	VU		✓		✓
Grey Crowned Crane	EN		✓		✓
Pallid Harrier	NT		✓		
White-bellied Korhaan	VU	✓	✓		
White-backed Vulture	CR	✓			
Yellow-billed Stork	EN				✓
Yellow-breasted Pipit	VU		✓		
Eastern Bronze-naped Pigeon	EN			✓	
Yellow-throated Sandgrouse	NT	✓	✓		
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened					

4.2.8.3 Freshwater ecosystems

Rivers within the proposed Phase 3 gas pipeline corridor are predominantly perennial/permanently-flowing (81%), and drain a number of ecoregions, notably the Highveld ecoregion. Major river systems include the Vaal, Klip and Buffels Rivers (Figure 31). A significant (approximately 71%) proportion of the rivers that drain the corridor are Critically Endangered. Less than 20% of the rivers are considered to be in a natural/good condition, while 50% are in a fair condition, 23% are in a poor condition and 10% are in either a very poor or critical condition.

Wetland habitats within this corridor occupy a significant proportion of the corridor (~17%) comprising up to 127 different wetland types, dominated by channelled-valley bottom wetlands and floodplain wetlands, particularly within the Mesic Highveld Grassland and Sub-escarpment Grassland regions. The corridor supports two Ramsar wetlands, namely Seekoeivlei Nature Reserve (4,754 ha) and the Blesbokspruit (1,858 ha). A small proportion (~8%) of the wetlands in the corridor are characterised as NFEPA wetland. Most notable is that more than 50% of the wetland habitats within the corridor are associated with the Critically Endangered Mesic Highveld Grasslands (Groups 2, 3 and 4).

Approximately 62% of the Phase 3 Corridor comprises land that is largely natural with a further 2% degraded. A very small proportion (2%) of the corridor is protected by a number of small conservation areas, but also larger ones such as the Cradle of Humankind World Heritage Site. A significant area has been transformed by cultivation (~29%), urbanisation in and around Johannesburg (5%), plantations (2%), as well as mining (1%).

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 3 pipeline corridor include:

- Very high (unacceptable) faecal pollution in rivers flowing through Gauteng (e.g. the Jukskei River), largely due to discharge of untreated or poorly treated effluent from malfunctioning/overloaded waste water treatment works, as well as surcharging manholes;
- Unsustainable and rapid urbanisation has resulted in the pollution of most river systems within this region. Pollution of the Vaal itself reached crisis point in January 2018 as a result of the acid mine drainage effluent and raw or partially treated sewage being pumped into the system;
- A high concentration of mining and industrial activity in this area places enormous pressure on the aquatic systems and has caused contamination of these systems though chemical leaching;
- Transformation and damage of wetlands e.g. Klip River wetland, through illegal dumping, high levels of urbanization, poor infrastructure and wastewater treatment works, and erosion through the high volumes of wastewater that flow through the wetland;
- Over-abstraction of water, and various impoundments (construction of dams e.g. the Vaal in particular), place huge pressure on the flow of rivers in this region;
- The effects of agriculture are evident and contribute to the pollution of freshwater resources as a result of run-off of pesticides and fertilizers.

Box 20: Red Data aquatic biota likely to be encountered in Phase 3

Only one notable species of Odonata, considered as vulnerable (i.e. *Lestes dissimulans*) occurs in the corridor. Of the 12 Red Listed fish species that occur within the corridor, one is Critically Endangered (i.e. *Pseudobarbus burchelli*), which is found in the Breede and Tradouw river systems, while two are Endangered, two are Vulnerable, five are Near Threatened and two are Data Deficient. The only Red Listed amphibian that occurs within the corridor includes the Near Threatened *Hemisus guttatus*. There are no Red Listed reptiles that are known to occur within the corridor. The corridor supports the highest number of Red Listed mammals (up to 9 species) of which four are Vulnerable and five are Near Threated. This corridor supports a low diversity of (up to 8) Red Listed plants, but which includes two Endangered species (i.e. *Disa zuluensis* and *Kniphofia flammula*). Other Red Listed species include three Vulnerable and three Near Threatened species.

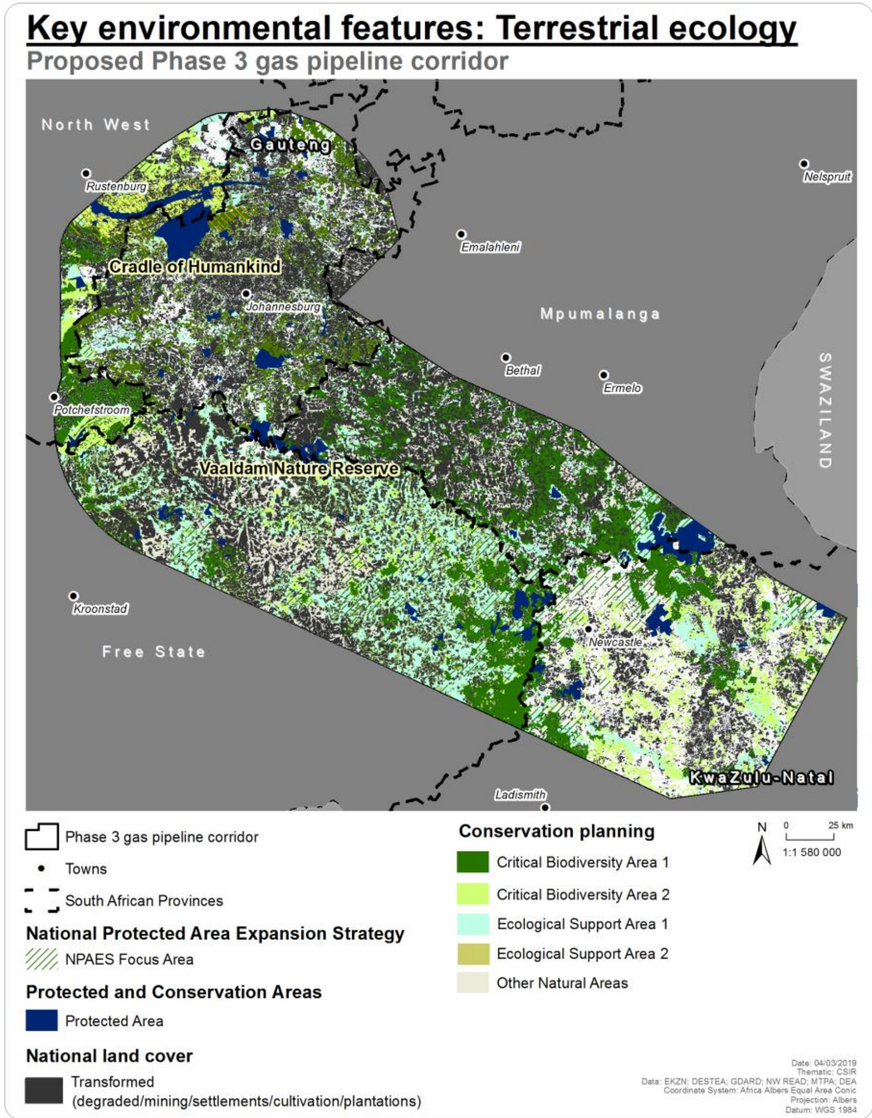


Figure 30: Key environmental features of the proposed Phase 3 gas pipeline corridor.

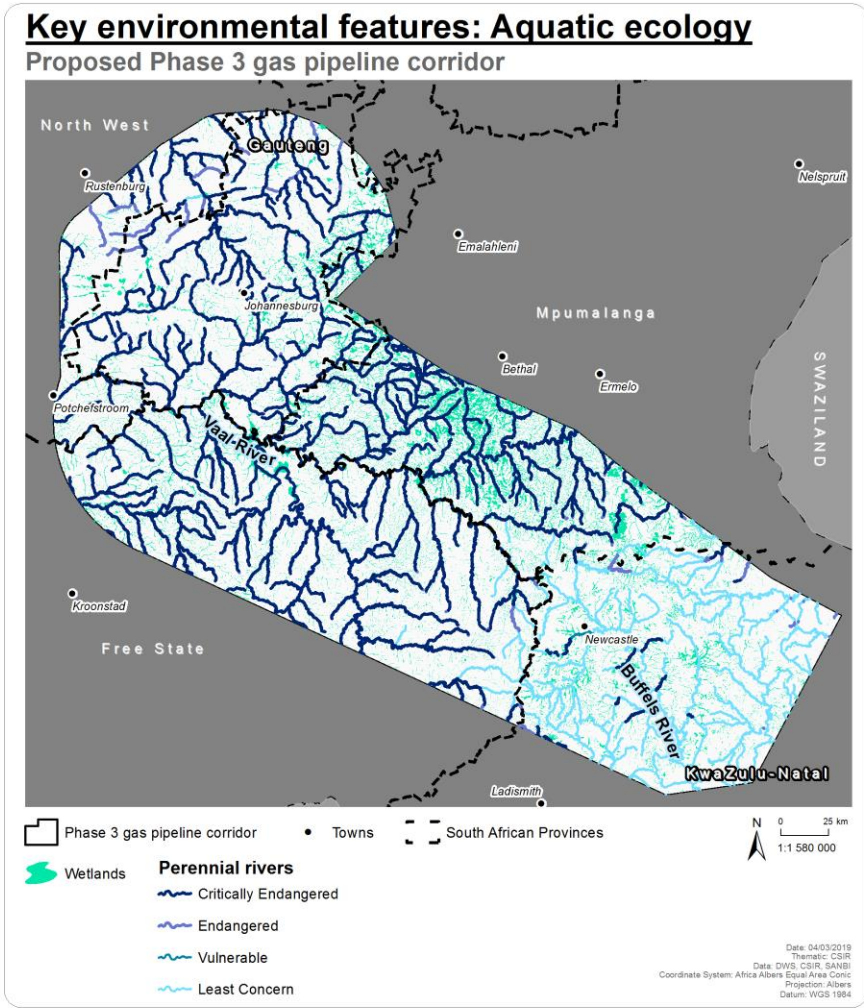


Figure 31: Key aquatic ecosystem features of the proposed Phase 3 gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extent.

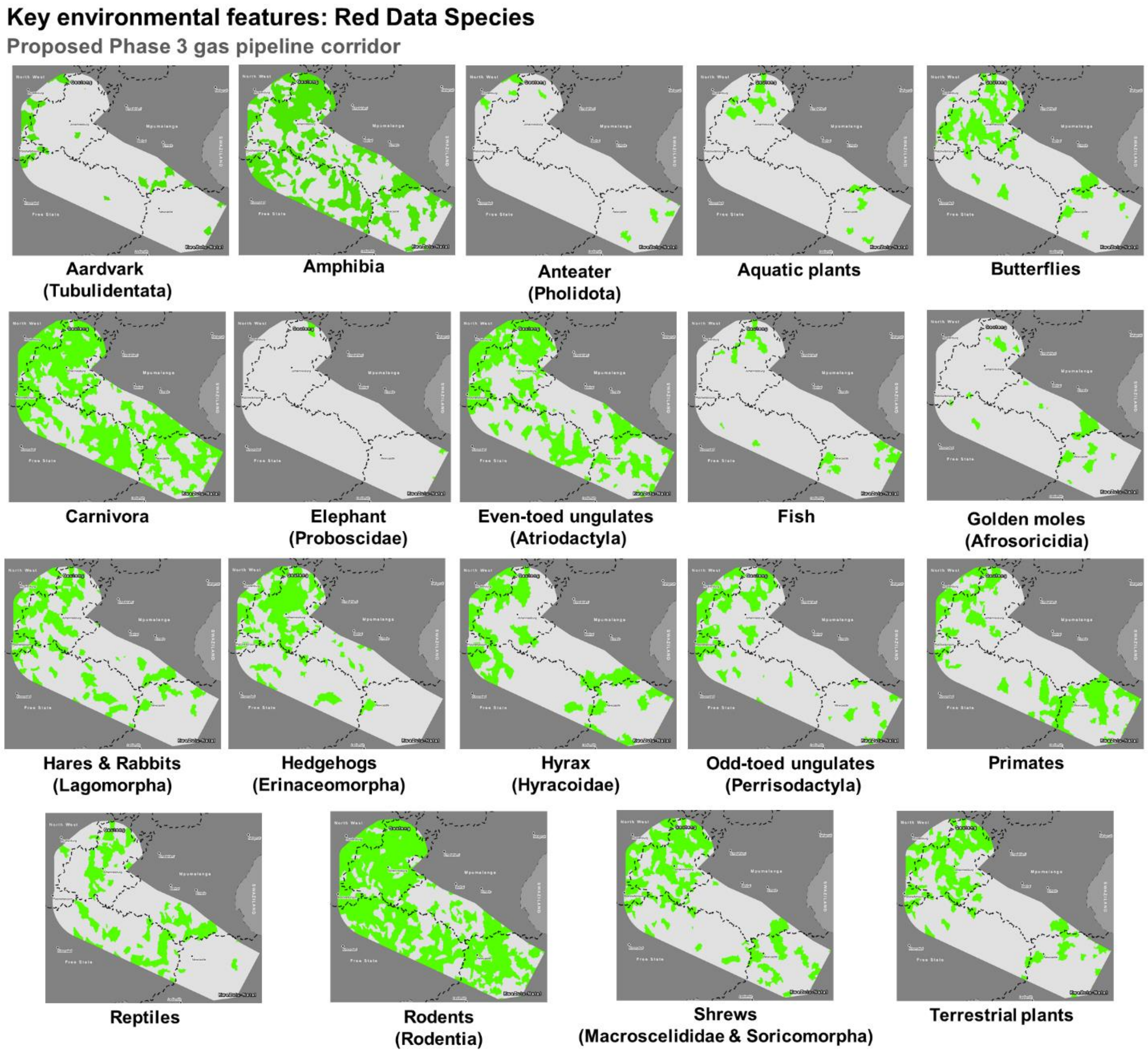


Figure 32: Distribution of recorded Red Data species in the proposed Phase 3 gas pipeline corridor (at quinary catchment scale).

4.2.9 Phase 8

The Kruger National Park can be seen in the north-eastern most corner of the proposed Phase 8 gas pipeline corridor (Figure 33). The number of species records in the KNP indicates that PAs can be expected to be better sampled than surrounding areas (see the Assumptions and Limitations of this assessment in Section 3.1).

4.2.9.1 Grassland & Savanna

This route is almost exclusively through Savanna and Grassland, with a few embedded forest patches. There are a number of critical squeeze points, the first being through the narrow gap below Kruger National Park and associated conservation areas, and the bulge of Swaziland with the Songimvelo and Barberton Nature reserves. There are also a large number of private reserves in this area. The second pinch point is when crossing the Drakensberg escarpment. Forestry patches as well as important Grasslands are encountered in this area.

4.2.9.2 Birds and bats

Bat species of Conservation Importance likely to be encountered in the proposed Phase 8 gas corridor include:

- Short-eared trident bat
- Damara woolly bat
- Greater long-fingered bat
- Rendall's serotine
- Large-eared free-tailed bat
- Blasius's horseshoe bat
- Swinny's horseshoe bat
- Cohen's horseshoe bat
- Light-winged lesser house bat
- Schreber's yellow bat
- Egyptian tomb bat

Table 18 presents red data species that occur in the biomes present in the proposed Phase 8 gas pipeline corridor.

Table 18: Red Data bird species likely to be encountered in the proposed Phase 8 gas corridor.

Species	Status	Biome			
		Savanna	Grassland	Forest	Azonal
Abdim's Stork	NT	✓	✓		✓
Black Harrier	EN		✓		
Black Stork	VU	✓	✓		✓
Blue Crane	NT		✓		✓
Caspian Tern	VU				✓
European Roller	NT	✓			
Greater Flamingo	NT		✓		✓
Black-rumped Buttonquail	VU	✓	✓		
Lanner Falcon	VU	✓	✓		✓
Lesser Flamingo	NT		✓		✓
Bush Blackcap	VU			✓	

Species	Status	Biome			
		Savanna	Grassland	Forest	Azonal
Maccoa Duck	NT				✓
Martial Eagle	EN	✓	✓		
Red-footed Falcon	NT		✓		
Secretary bird	NT	✓	✓		
Lappet-faced Vulture	EN	✓			
Verreaux's Eagle	VU	✓	✓		
Marabou Stork	NT	✓			✓
Denham's Bustard	VU		✓		
Orange Ground-Thrush	NT			✓	
Pink-backed Pelican	VU				✓
Half-collared Kingfisher	NT				✓
Greater Painted-snipe	NT				✓
Saddle-billed Stork	EN				✓
Short-tailed Pipit	VU		✓		
Southern Bald Ibis	VU		✓		
Cape Vulture	EN	✓	✓		
Chestnut-banded Plover	NT				✓
Southern Ground-Hornbill	EN	✓			
Tawny Eagle	EN	✓			
Wattled Crane	CR		✓		✓
African Grass-Owl	VU		✓		
Grey Crowned Crane	EN		✓		✓
Pallid Harrier	NT		✓		
White-bellied Korhaan	VU	✓	✓		
White-backed Vulture	CR	✓			
Yellow-billed Stork	EN				✓
Yellow-breasted Pipit	VU		✓		
African Crowned Eagle	VU			✓	
African Finfoot	VU				✓
African Pygmy-Goose	VU				✓
Bateleur	EN	✓			
Kori Bustard	NT	✓			
Lesser Jacana	VU				✓
White-backed Night-Heron	VU				✓
Bat Hawk	EN	✓			
Blue Swallow	CR		✓		
White-headed Vulture	CR	✓			
African Marsh-Harrier	EN		✓		✓
Black-winged Pratincole	NT		✓		✓
Hooded Vulture	CR	✓			
White-winged Flufftail	CR		✓		✓
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near threatened					

4.2.9.3 Freshwater Ecosystems

Rivers within the proposed Phase 8 gas pipeline corridor are predominantly perennial/permanently-flowing (80%), and flow through ecoregions such as the Highveld, Northern Escarpment Mountains, North Eastern Highlands, and down through the Lowveld. Major river systems include the Olifants, Komati, Crocodile and Sabie Rivers (Figure 34: Key aquatic ecosystem features of the proposed Phase 8 gas pipeline corridor). A significant proportion (approximately 71%) of the rivers are considered to be Threatened (i.e. CR, EN and

VU). Less than 25% of the rivers are in a natural/good condition, majority (47% are in a fair condition, 23% are in a poor condition, while 6% are in a poor condition.

Wetland habitats within this corridor occupy a large proportion of the corridor (~12%) comprising up to 93 different wetland types, dominated by channelled-valley bottom wetlands, and largely characteristic of the Mesic Highveld Grassland region. There are no Ramsar wetlands that occur within the corridor, and a small proportion (~8%) of the wetlands are classified as NFEPA wetland, mostly in the form of channelled-valley bottoms, depressions and seeps. Nevertheless, a significant (75%) of the wetlands are associated with Critically Endangered wetland groups, notably the Mesic Highveld Grassland Group 4 (54%) and Group 3 (9%).

Approximately 65% of the Phase 8 corridor comprises land that is largely natural with a further 2% degraded. A fairly large proportion (16%) of the corridor is protected by conservation areas, including parts of Kruger National Park. The remaining area is mostly transformed by cultivation (~19%) and plantations (11%), and to a lesser extent by urbanisation (3%) and mining (1%).

Existing drivers and pressures currently impacting freshwater ecosystems in the proposed Phase 8 pipeline corridor include:

- Plantations, concentrated in the central highlands, resulting in a number of impacts to freshwater ecosystems (e.g. streamflow reduction particularly dry-season baseflows, increased turbidity and sedimentation, removal of riparian vegetation and buffer zones, IAP infestation, loss of species diversity and abundance);
- Mining related activities (notably for coal resources) resulting in pollution of surface waters caused predominantly by acidification (i.e. acid mine drainage) and other mining-related effluents;
- Run-of-river abstraction and small farm dams for irrigation, which is more pronounced in the western parts of the corridor;
- Urbanisation in and around towns such as Emalahleni, Middleberg, Ermelo and Nelspruit placing increased pressure on water resources, largely due to increased stormwater runoff and decreased water quality from both point and non-point sources linked to residential and industrial areas);
- Very high (unacceptable) faecal pollution in regions such as Witbank/Middleburg and Nelspruit, which is affecting river systems such as the Crocodile and Olifants; and
- Extensive maize cultivation and livestock farming resulting in removal and/or degradation of freshwater habitat.

Box 21: Red Data aquatic biota likely to be encountered in Phase 8

The corridor supports two species of Odonata that are listed as Endangered (i.e. *Ceriagrion suave* and *Diplacodes pumila*), along with three that are Near Threatened. There are also 13 Red Listed fish that are known to inhabit the corridor, including the Critically Endangered *Chiloglanis bifurcus* and *Enteromius treurensi. Chiloglanis bifurcus* is an instream species, endemic to the Inkomati River System and within this system it is restricted to altitudes between 900 metres above sea level (m.a.s.l) to 1200 m.a.s.l. In addition, there are also 3 endangered fish species, one Vulnerable, five Near Threatened, and two Data Deficient. There are no Red Listed amphibians that are known to occur within the corridor. Only one Red Listed reptile occurs within the corridor, namely the Near Threatened *Macrelaps microlepidotus*. The corridor supports a high diversity of Red Listed mammals (up to 7 species), including three that are Vulnerable and four that are Near Threatened. This corridor supports a moderate diversity of Red Listed plants, including one that is Critically Endangered (i.e. *Aloe simii*) and one that is Endangered (i.e. *Disa zuluensis*). The majority of the Red Listed plants occurring with the corridor are either Vulnerable (7 species) or Near Threatened (7 species), while one is Data Deficient and two are rare.

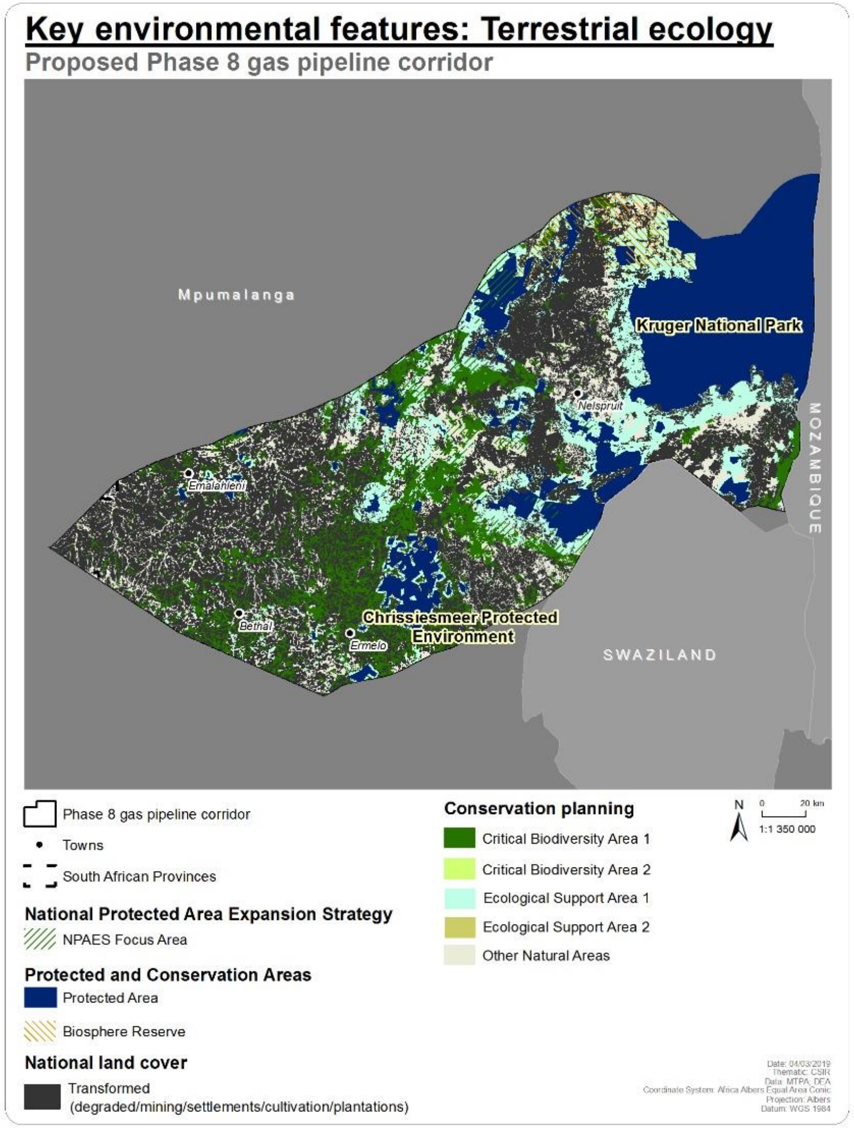


Figure 33: Key environmental features of the proposed Phase 8 gas pipeline corridor.

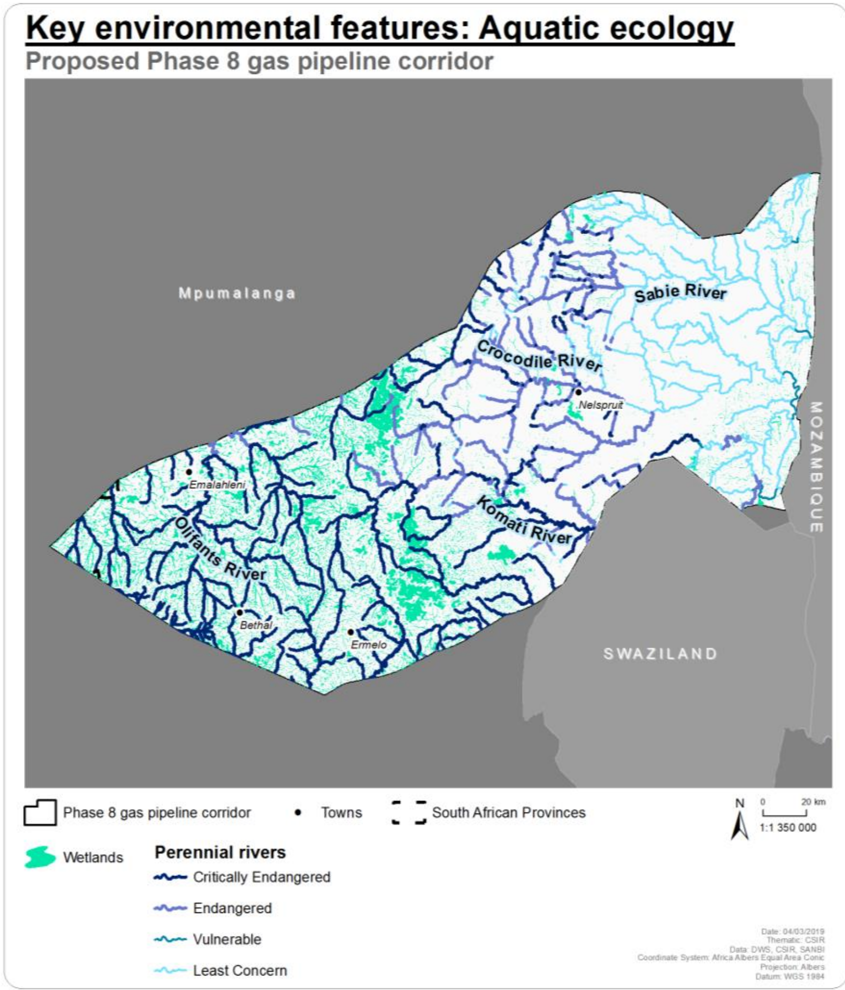


Figure 34: Key aquatic ecosystem features of the proposed Phase 8 gas pipeline corridor.

Note: Finer scale features may not be visible at the current map extent.

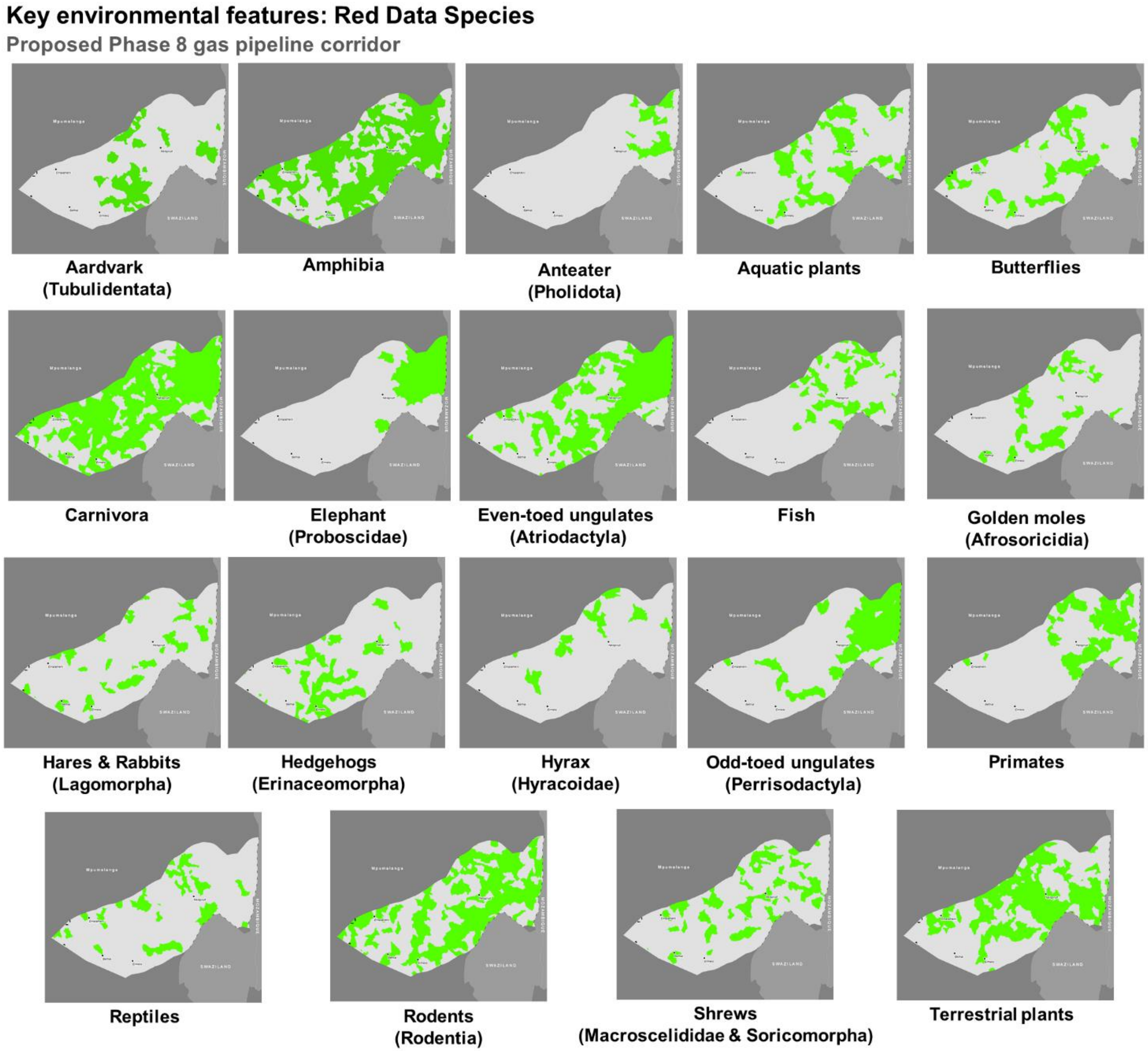


Figure 35: Distribution of recorded Red Data species in the proposed Phase 8 gas pipeline corridor (at quinary catchment scale).

5 SENSITIVITY ANALYSIS

5.1 Identification of feature sensitivity criteria

The data presented in Table 1 - Table 6 (Section 3.2) were used as the point of the departure for the sensitivity analysis. Sensitivities were assigned to various important environmental features and identified buffers (where relevant). The sensitivities of the different biomes may vary, as they are known to have various degrees of resilience and recoverability. For example: rehabilitation may be more easily and successfully achieved in the Savanna and Grassland vegetation types than in Fynbos and Karoo vegetation types.

5.1.1 Desert, Succulent Karoo and Nama Karoo

The biodiversity sensitivity values are adapted from CBA classifications from provincial systematic conservation plans for the Northern, Western and Eastern Cape provinces, as well as relevant specialist experience and previous SEAs conducted in these biomes (Table 19).

Table 19: Sensitivity ratings assigned to important environmental features of the Desert, Succulent Karoo and Nama Karoo biomes in the proposed gas corridor phases (i.e. Phases 6, 5, 1, 2, Inland and 7).

Feature Class	Sensitivity Rating
Conservation planning	
CBA 1	Very High
CBA 2	High
ESA	Low
Protected areas	
PA	Very High
NPAES Focus Area	Medium
Old agricultural fieldsOld Fields Layer	Low
Old agricultural fields + CBAs	Medium
Agricultural fields	Low
Specific Vegetation types	
Azonal wetland related vegetation types	Very High
Azonal non-wetland related vegetation types	High
Vegetation types which have a high abundance of SCC	High
Vegetation types which are considered vulnerable to disturbance (dunes)	High
Threatened ecosystems	
CR	Very High
EN	High
VU	Medium
Species of Conservation Concern	
Quinary catchments where fauna and flora SCC are present	High
SCC Plant Habitats	Very High
Other areas of biodiversity significance	
Specialist identified sensitive areas in Karoo and Desert ecosystems (Todd, personal observations)	High
Areas of biodiversity significance identified in the Shale Gas SEA.	High
PA = Protected Area; CBA = Critical Biodiversity Area; NPAES = National Protected Area Expansion Strategy; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; ESA = Ecological Support Area; SCC = Species of Conservation Concern	

5.1.2 Fynbos

The Fynbos sensitivity analysis relied primarily on the most recent conservation plans for the areas concerned as they already include all the relevant layers of information such as threatened vegetation, threatened vertebrates, protected area expansion strategies and climate adaptation corridors in their CBAs and ESAs and the latest information on the protected areas (Table 20).

Table 20: Sensitivity ratings assigned to important environmental features of the Fynbos biome in the proposed gas corridor phases (i.e. Phases 6, 5, 1, 2, Inland, and 7).

Feature Class	Sensitivity Rating
Protected Areas Western Cape	
- NPs, Nature Reserves, World Heritage Sites	Very High 10 km Buffer[a]: High
- Mountain Catchment Areas	High
- Private Conservation Areas (all types)	Medium 5 km Buffer: Medium
- Protected Environment	5 km Buffer: Medium
- NPAES	5 km Buffer: Medium
- Nature Reserve Buffer	5 km Buffer: Medium
Protected Areas Northern Cape (all types)	Very High
- PA	5 km Buffer[b]: High
- NPs	10 km Buffer[b]: High
Protected Areas Eastern Cape	
- WHS, NP, Nature Reserve, DAFF Forest Reserves	Very High
- Biosphere Reserves, Protected Environments	High
- Private Nature Reserves	Medium
Conservation planning	
- CBA1	Very High
- CBA2	High
- ESA	Medium
- Land Cover : Natural Area	Medium
- Land Cover: Transformed	Low
- Other Natural Areas	Medium
[a] EIA Regulations, No. R. 982, 4 December 2014 as updated in Government Notices 324 to 327 in Government Gazette 40772 of 7 April 2017.	
[b] In the Northern Cape CBA plan all PAs were buffered by 5 km and National Parks by 10 km as minimum.	
NP = National Park; WHS = World Heritage Site; NPAES = National Protected Area Expansion Strategy; PA = Protected Area; CBA = Critical Biodiversity Area; ESA = Ecological Support Area.	

5.1.3 Albany Thicket

The Albany Thicket sensitivity analysis made extensive use of data resources arising from the updated, revised Eastern Cape Biodiversity Conservation Plan (DEDEA, 2017) and the Western Cape Biodiversity Spatial Plan (Pool-Stanvliet et al., 2017) (Table 21).

The inherent fragility of the receiving environment will vary depending on the specific type of biodiversity feature being considered, however, for any given feature a number of contingent factors will influence fragility, typically these will include the slope and rainfall of the site being impacted. For any given impact, receiving environments on steep slopes (> 30 %), and with very high or very low rainfall will be more fragile, and susceptible to cumulative and secondary impacts, such as erosion or poor recovery after rehabilitation. However, this criterion should be considered at finer scales of planning, where for example adjustments to routing paths may be considered based on topography.

Table 21: Sensitivity ratings assigned to important environmental features of the Albany Thicket biome in the proposed gas corridor phases (i.e. Phases 1, 2, Inland, and 7).

Feature Class	Sensitivity Rating
- PA (including Biosphere Reserves, World Heritage Sites, State Owned - SANParks and ECPTA, and Protected Environments)*	Very high
- CA (including Private Nature Reserves, De Facto Private Nature Reserves, and DAFF Forest Reserves)*	High
- CBA 1	Very high
- CBA 2	High
- ESA 1	Medium
- ESA 2	Medium
- Other Natural Areas	Medium
- Non Natural Areas	Low
**Buffers included as used in ECBCP (DEDEAT, 2017).*	
PA = Protected Area; CA = Conservation Area; CBA = Critical Biodiversity Area; ESA = Ecological Support Area.	

5.1.4 Indian Ocean Coastal Belt

For the IOCB areas of high conservation value and existing conservation plans were selected as basis for the sensitivity analysis (Table 22).

Table 22: Sensitivity ratings assigned to important environmental features of the Indian Ocean Coastal Belt biome in the proposed gas corridor phases (i.e. Phases 4 and 7).

Feature Class		Sensitivity Rating
- Coastline		1 km buffer: Very High
- PA		5 km buffer: Very High
- WHS		Very High
- Ramsar Sites		High
- NPAES		Medium
- National Forests		Very High
- Conservation categories from KZN BSP	CBA Irreplaceable	High
	CBA Optimal	Medium
	ESA	Low
- EKZN Wildlife Stewardship areas		Very High
- Conservation categories (ECBCP)	PA	5 km buffer: Very High
	CA	High
	CBA 1	High
	CBA 2	Medium
	ESA 1	Low
	ESA 2	Low
	Other Natural Areas	Low
- Landcover	Modified	Low
	Field Crop Boundaries	Low
- Vegetation	LT	Low
	VU	Medium
	EN	High
	CR	Very High
	Thicket Vegetation	High
- Ecoregion		Medium
- Private Nature Reserves and Game farms	Game Farms Title Deeds	5 km buffer: Medium
	Nature Reserves/Protected Areas	5 km buffer: Medium

Feature Class	Sensitivity Rating
PA = Protected Area; WHS = World Heritage Site; CA = Conservation Area; CBA = Critical Biodiversity Area; ESA = Ecological Support Area; KZ – KwaZulu-Natal; LT = Least Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; ECBCP = Eastern Cape Biodiversity Conservation Plan.	

5.1.5 Grassland and Savanna

The sensitivity of biodiversity and ecological features was based largely on sensitivities as used in Provincial biodiversity conservation plans (Table 23).

Table 23: Sensitivity ratings assigned to important environmental features of the Grassland and Savanna biomes in the proposed gas corridor phases (Phases 2, 3, Inland, 7, 4, and 8).

Feature Class		Sensitivity Rating
PAs: national and provincial parks, forest wilderness, special nature reserves and forest nature reserves		Very High
Coastlines		Very High
All indigenous forests		Very High
CBA (CBA1 for EC)		Very High
CBA 2 EC		High
Threatened ecosystems	CR	Very High
	EN	High
	VU	Medium
Land Cover: Natural Area Land Cover: Modified areas		Low
Game Farms		Medium
SANParks Buffer		High
Protected Environments		High
NPAES focus areas		Medium
Mountain Catchment Areas		High
Biospheres		Medium
Botanical Gardens		Medium
ESA		Medium
PA = Protected Area; CBA = Critical Biodiversity Area; NPAES = National Protected Area Expansion Strategy; EC = Eastern Cape; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; ESA = Ecological Support Area		

5.1.6 Freshwater ecosystems

The sensitivity rating for freshwater ecosystems is a combined rating for rivers, wetlands and freshwater biota (Table 24). The total score for each SQ4 catchment were collapsed into the four sensitivity classes using a quantile data split. This coverage provides an integration of all data pertaining to freshwater biodiversity and ecosystems, and is particularly useful for identifying preferred alignments for gas pipeline infrastructure in order to reduce impacts on freshwater ecosystems and associated biodiversity.

Table 24: Sensitivity ratings assigned to important freshwater features in the proposed gas corridor phases (All Phases).

Feature Class		Sensitivity Rating
Wetlands: Critically Endangered wetlands and Irreplaceable CBAs (aquatic)		200 m buffer: Very High
Wetlands: Ramsar wetlands, KZN priority wetlands, Endangered or Vulnerable wetlands, Optimal CBA (aquatic)		100 m buffer: High
Wetlands: NFEPA wetlands, Near Threatened wetlands and ESA (aquatic)		50 m buffer: Medium
Wetlands: probable wetland, non-NFEPA wetlands, least threatened wetlands, ONA (aquatic), formally protected aquatic features		32 m buffer: Low
River ecosystems (including instream and riparian habitats)		200 m buffer Very High
		100 m buffer: High
		50 m buffer: Medium
		32 m buffer: Low
Freshwater fauna and flora per quinary catchment	CR Data Deficient	Very High
	EN VU	High
	NT Rare	Medium
	LT	Low
CBA = Critical Biodiversity Area; NFEPA = National Freshwater Ecosystem Priority Areas; KZN = KwaZulu Natal;; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LT = Least Threatened; ESA = Ecological Support Area; ONE = Other Natural Area		

5.1.7 Estuaries

Sensitivity was assigned to a suite of environmental indicators for estuaries (Table 25).

Table 25: Sensitivity ratings assigned to important estuarine features in the proposed gas corridors phases (i.e. Phases 5, 1, 2, 7, and 4).

Sensitivity Indicator	Sensitivity Class
Estuaries in Formal / desired PAs	Very High
Estuaries of high biodiversity importance	Very High
Important nurseries	Very High
Important estuarine habitats	Very High
Natural or near natural condition estuaries	Very High
Estuaries that support species of conservation importance	Very High
Other estuaries	High
Coastal rivers, wetlands and seeps above or adjacent to estuaries	5 km around EFZ: High
Coastal rivers, wetlands and seeps	5 - 15 km buffer around EFZ: Medium
Terrestrial environment	15 km or more from EFZ: Low
PA = Protected Area; EFZ = Estuary Functional Zone	

5.2 Four-Tier Sensitivity Mapping

The sensitivity rating assigned to environmental features in Table 19 - Table 25 are expressed spatially as sensitivity maps in Sections 5.2.1 - 5.2.9 below.

5.2.1 Phase 6

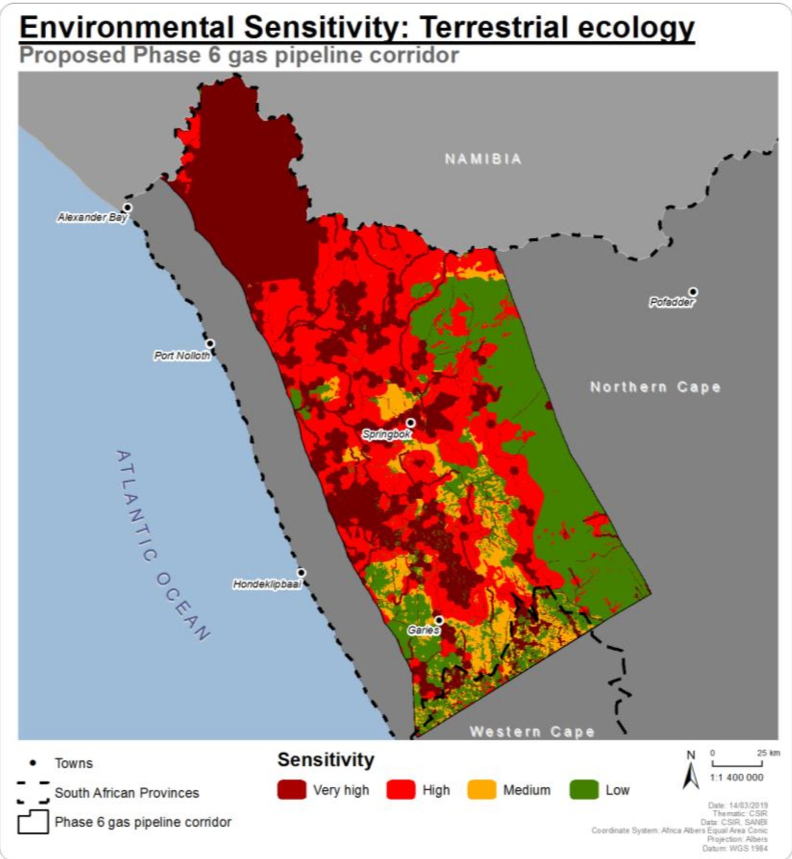


Figure 36: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 6 corridor.

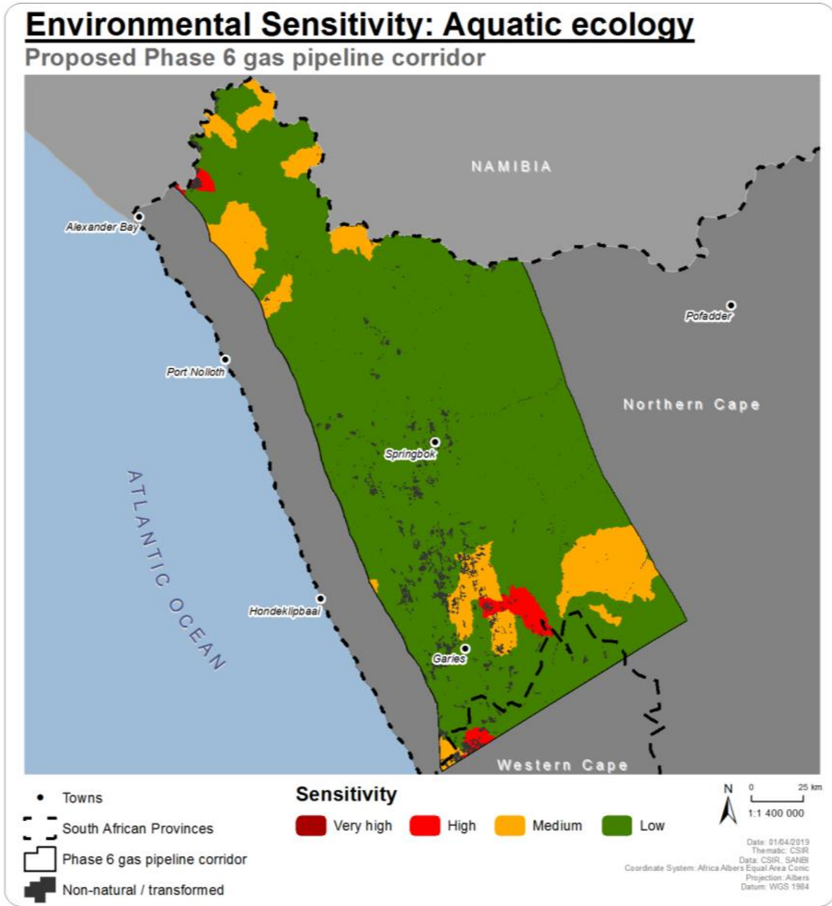


Figure 37: Environmental sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 6 corridor.

5.2.2 Phase 5

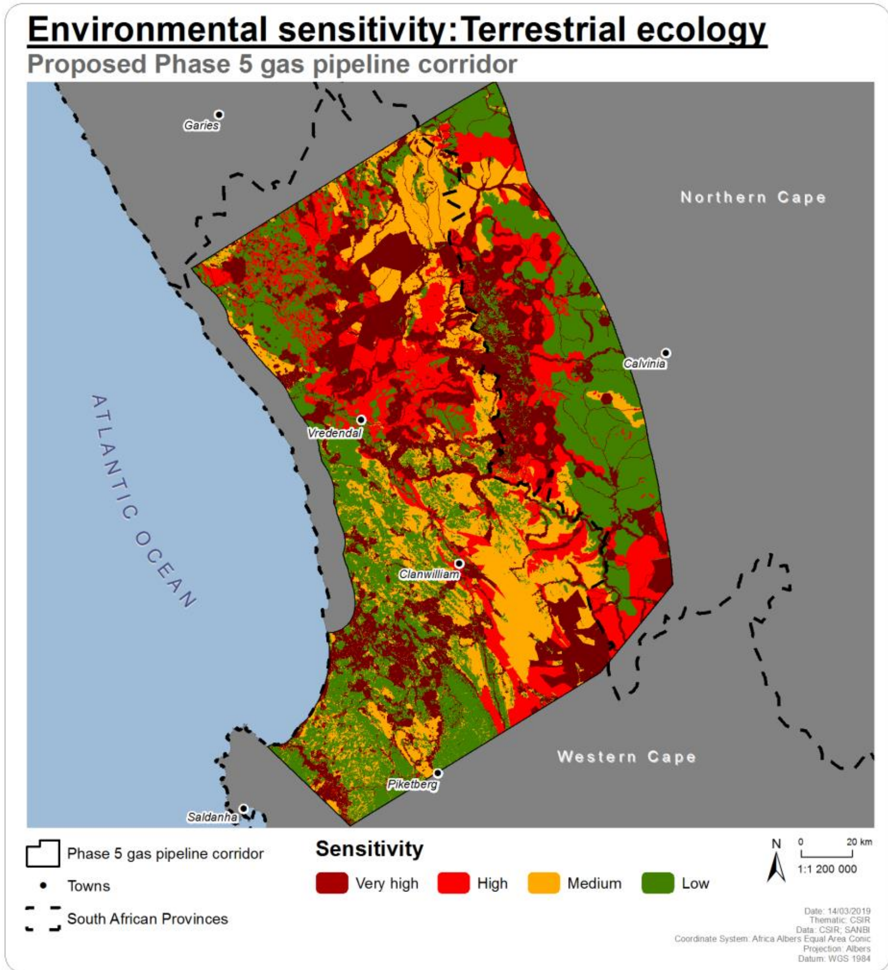


Figure 38: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 5 corridor.

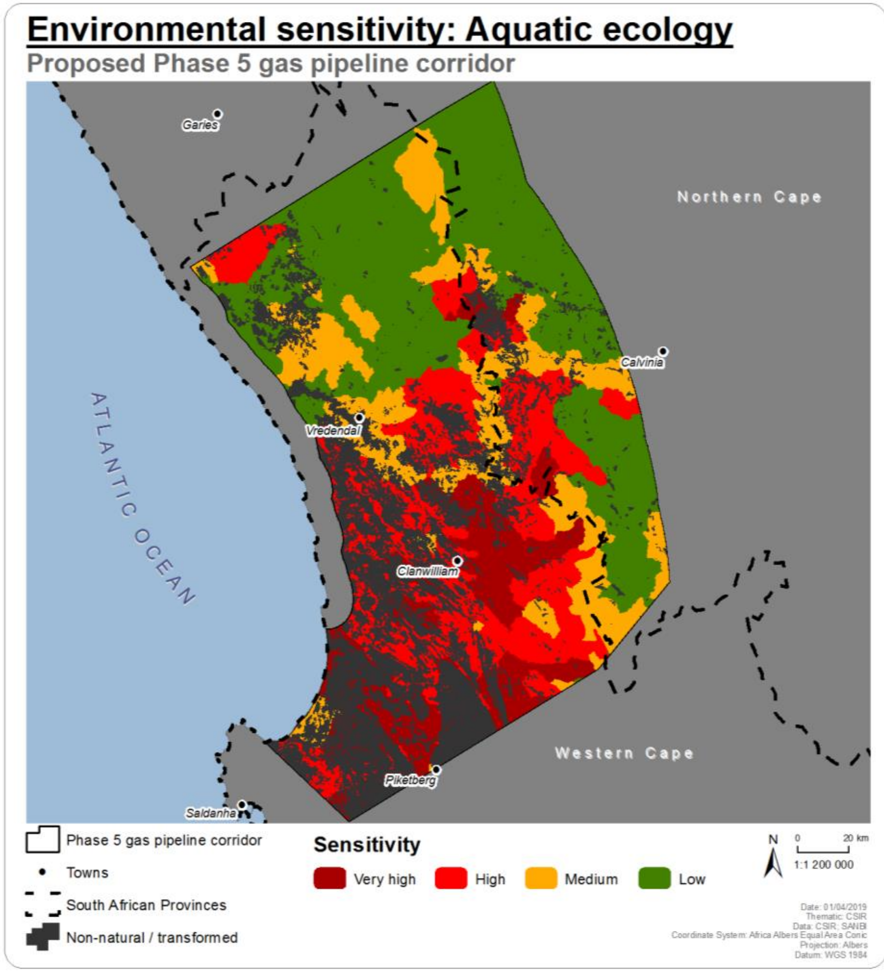


Figure 39: Environmental sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 5 corridor.

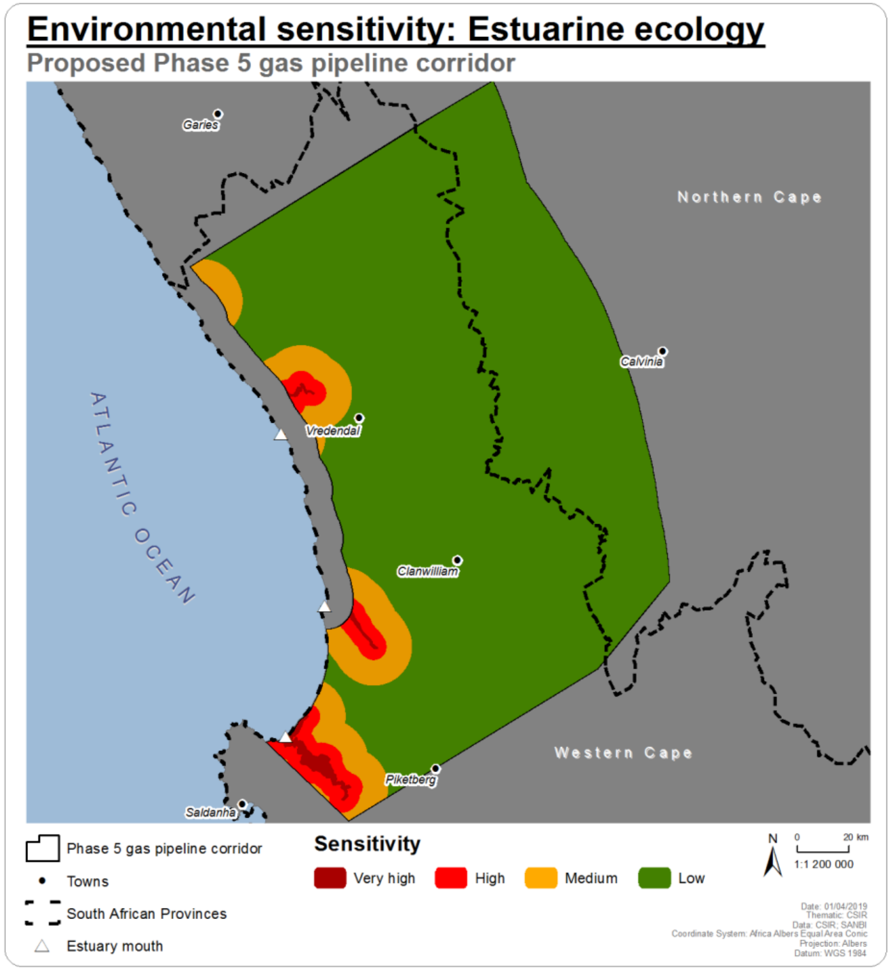


Figure 40: Environmental sensitivity of estuarine ecosystems to proposed gas pipeline development in the Phase 5 corridor.

5.2.3 Phase 1

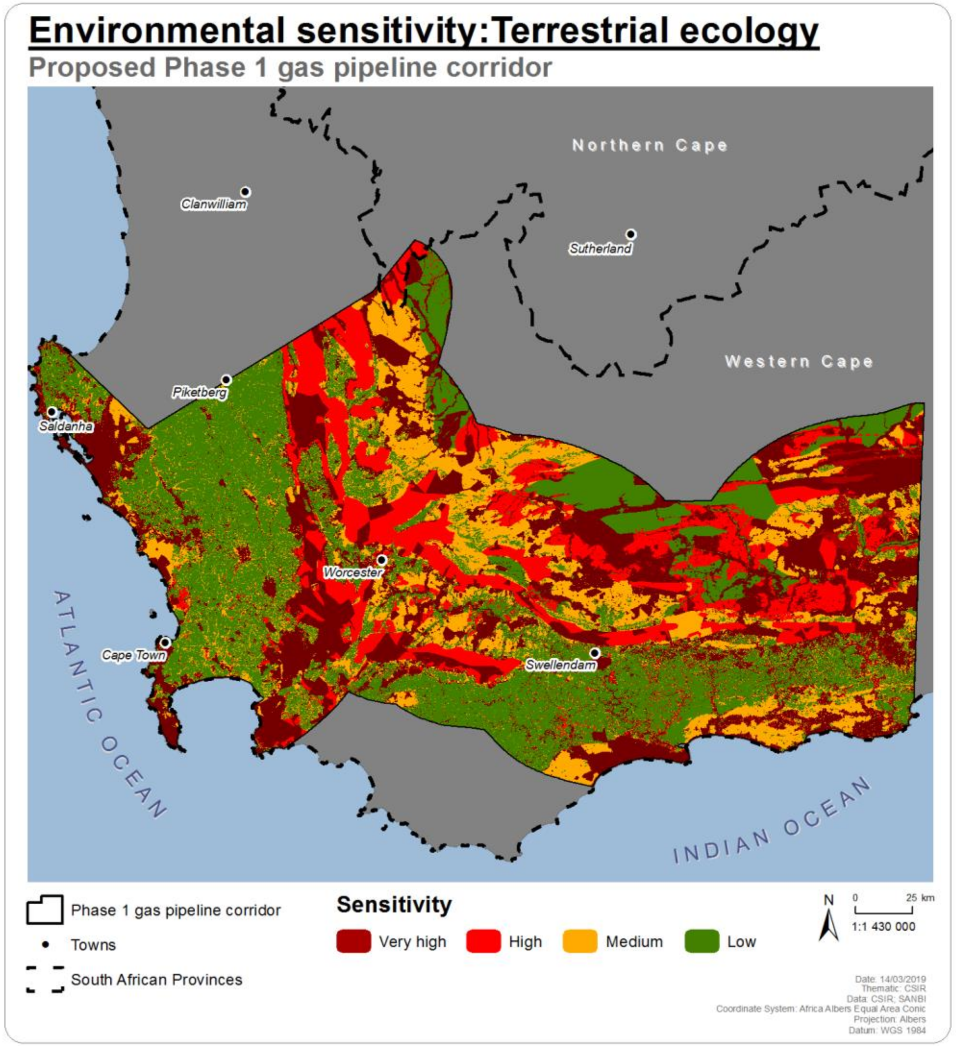


Figure 41: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 1 corridor.

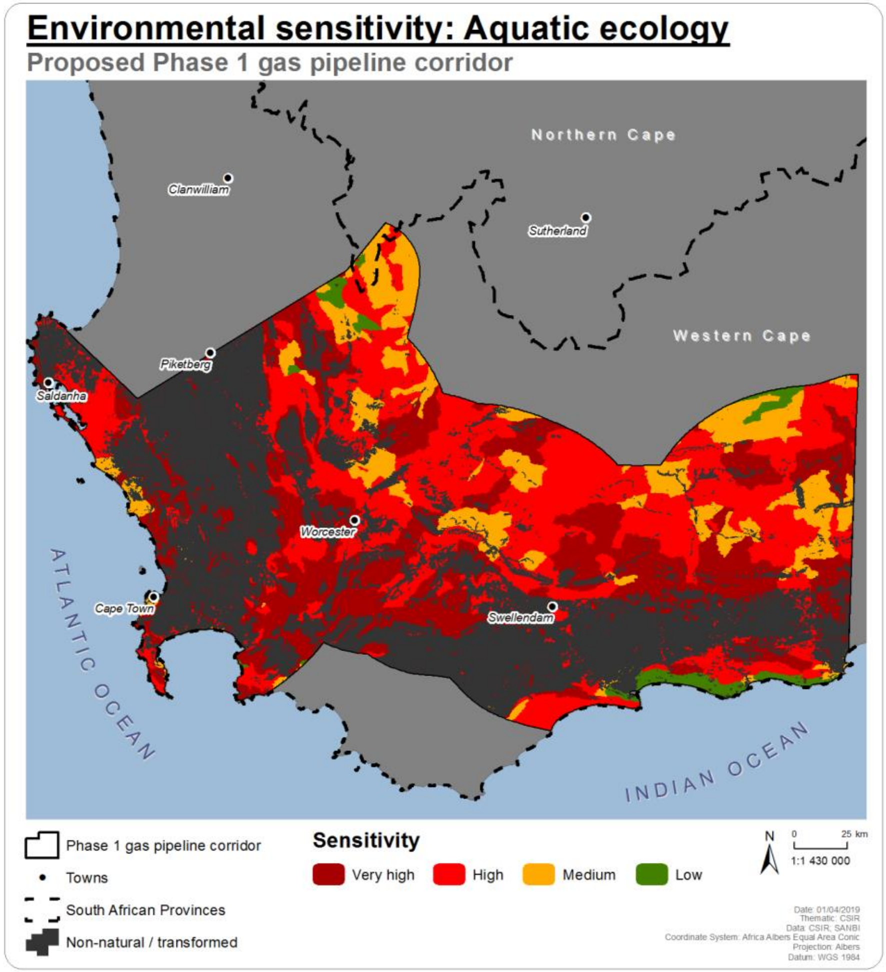


Figure 42: Environmental sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 1 corridor.

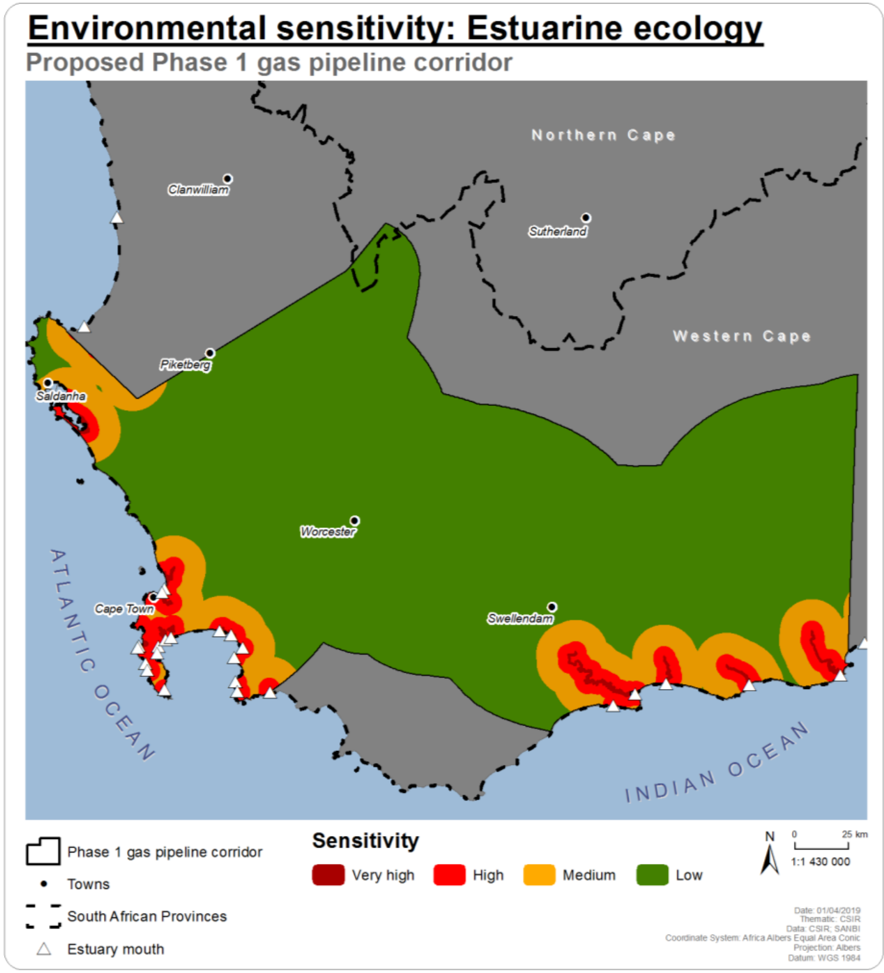


Figure 43: Environmental sensitivity of estuarine ecosystems to proposed gas pipeline development in the Phase 1 corridor.

5.2.4 Phase 2

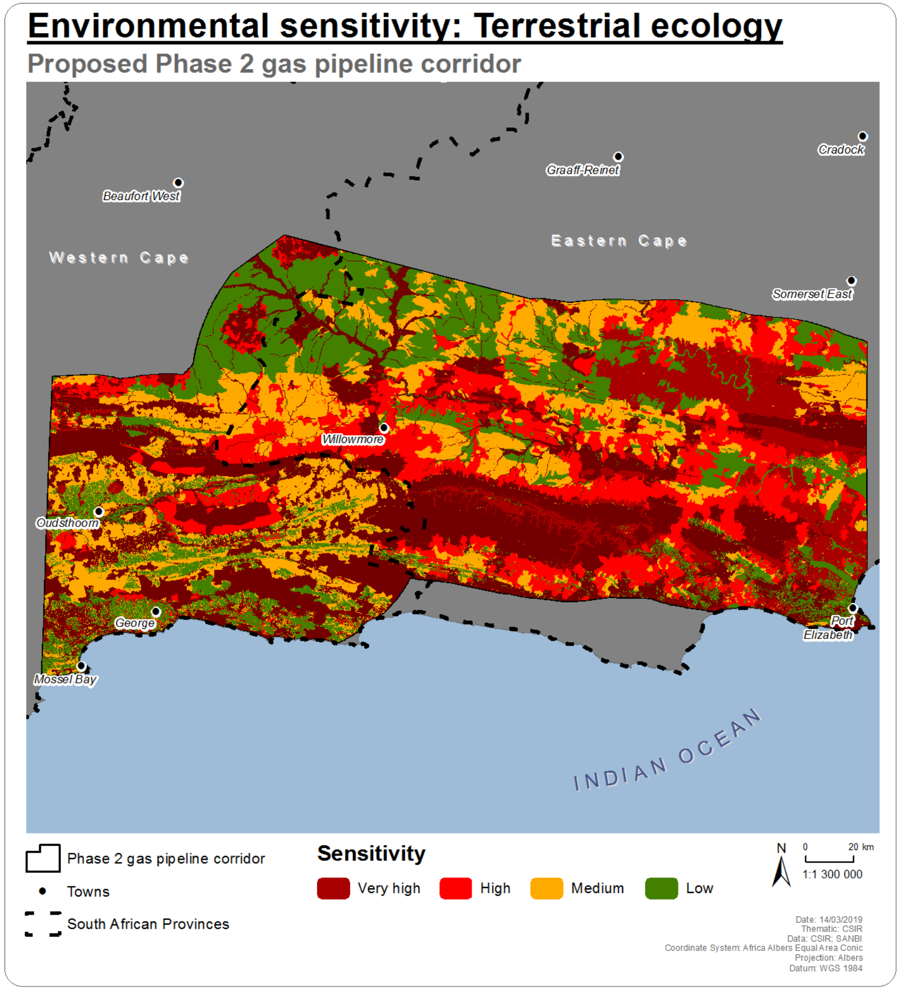


Figure 44: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 2 corridor.

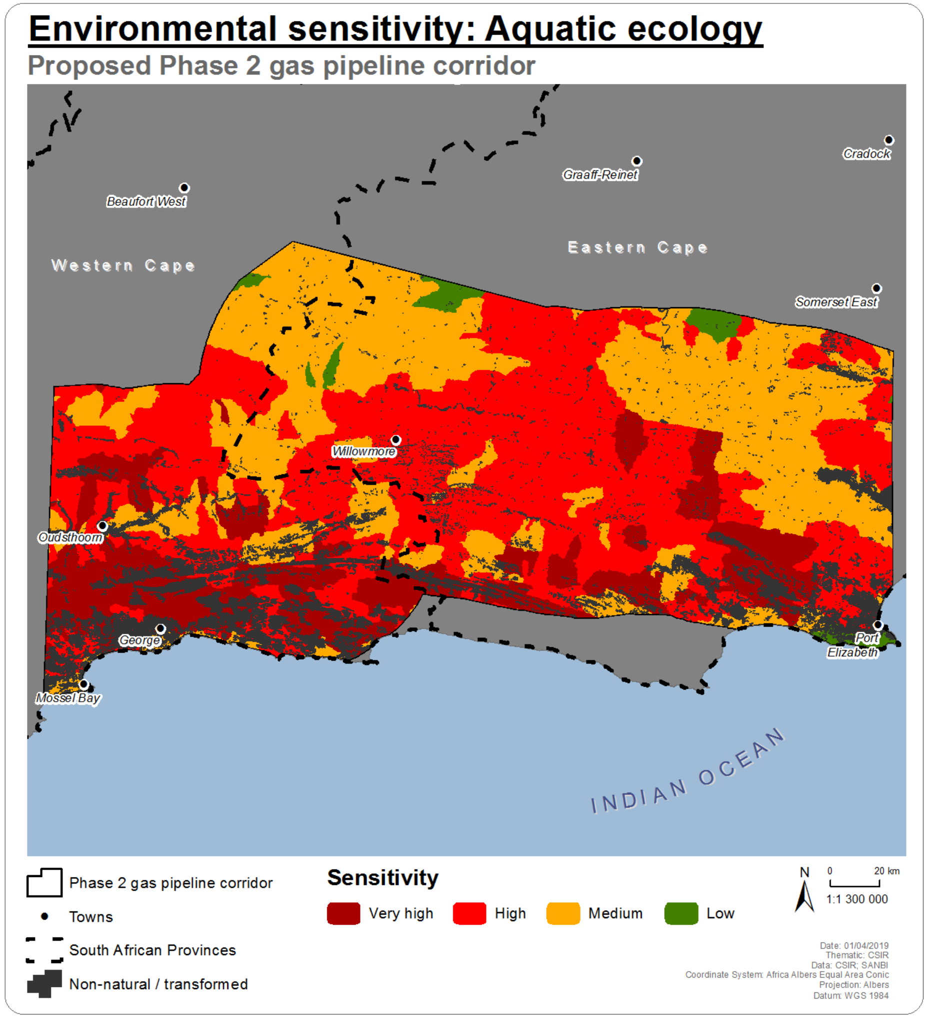


Figure 45: Environmental sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 2 corridor.

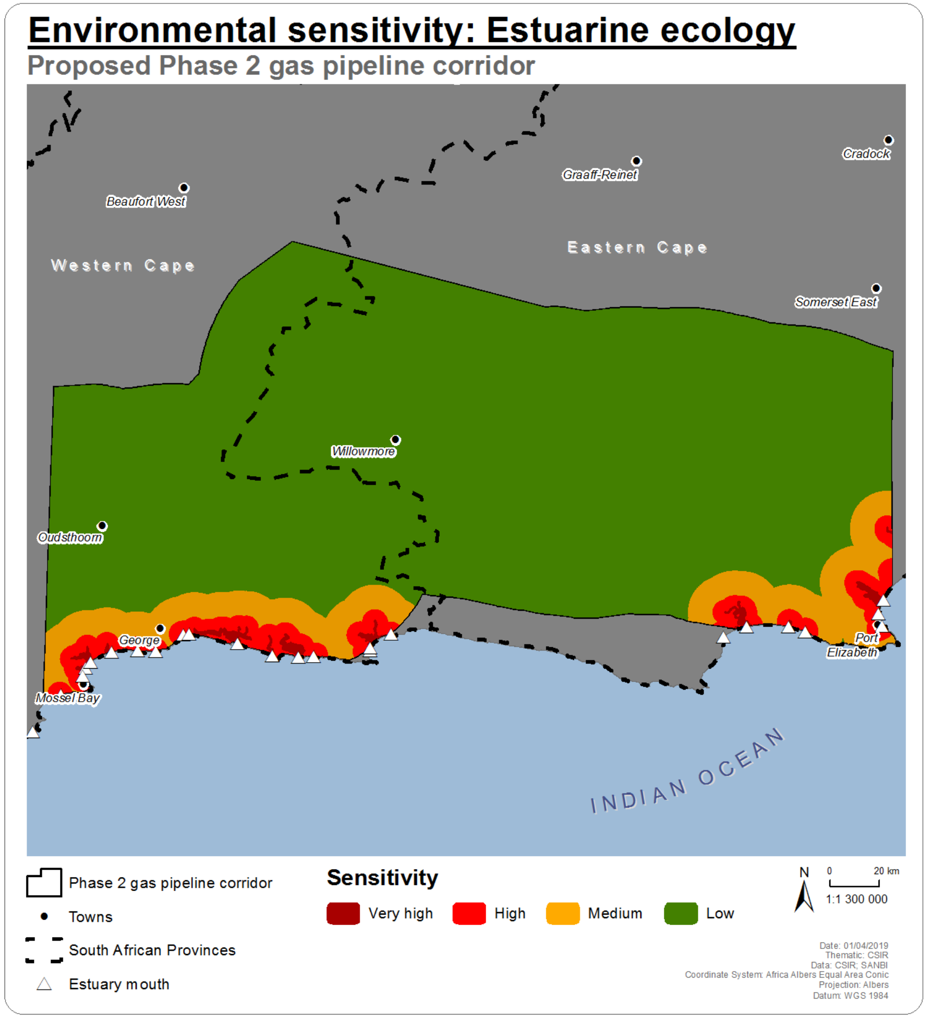


Figure 46: Environmental sensitivity of estuarine ecosystems to proposed gas pipeline development in the Phase 2 corridor.

5.2.5 Inland Phase

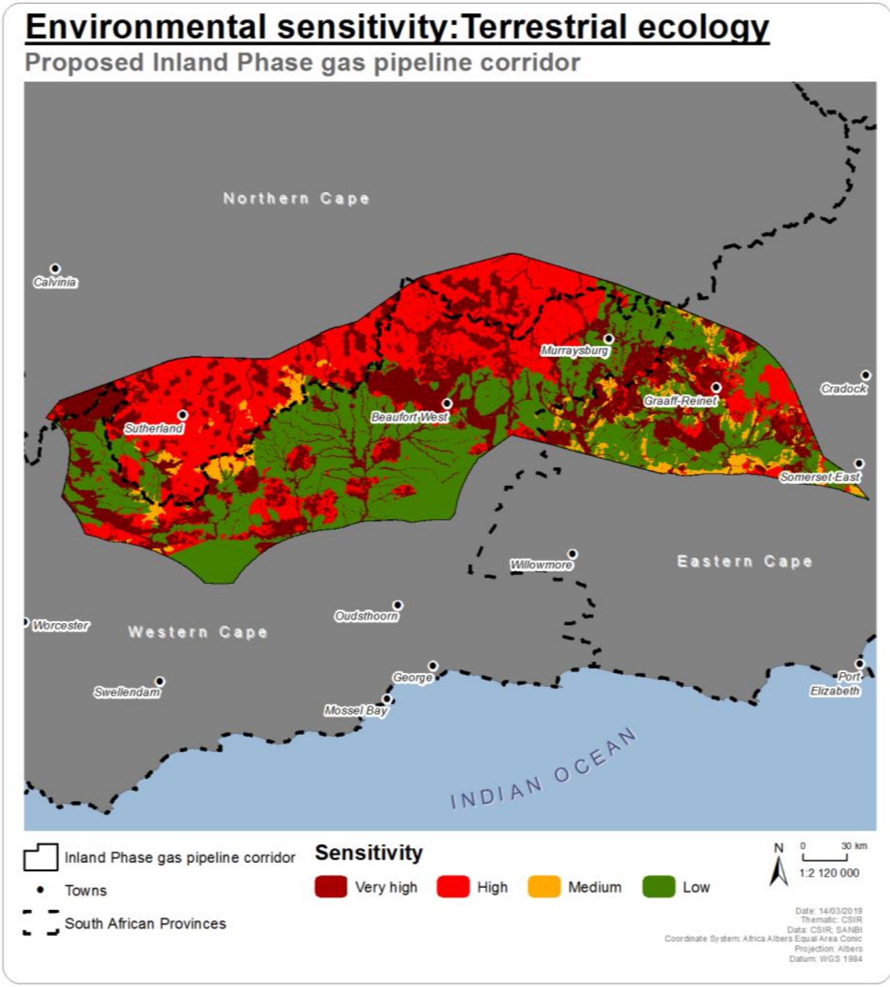


Figure 47: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Inland Phase corridor.

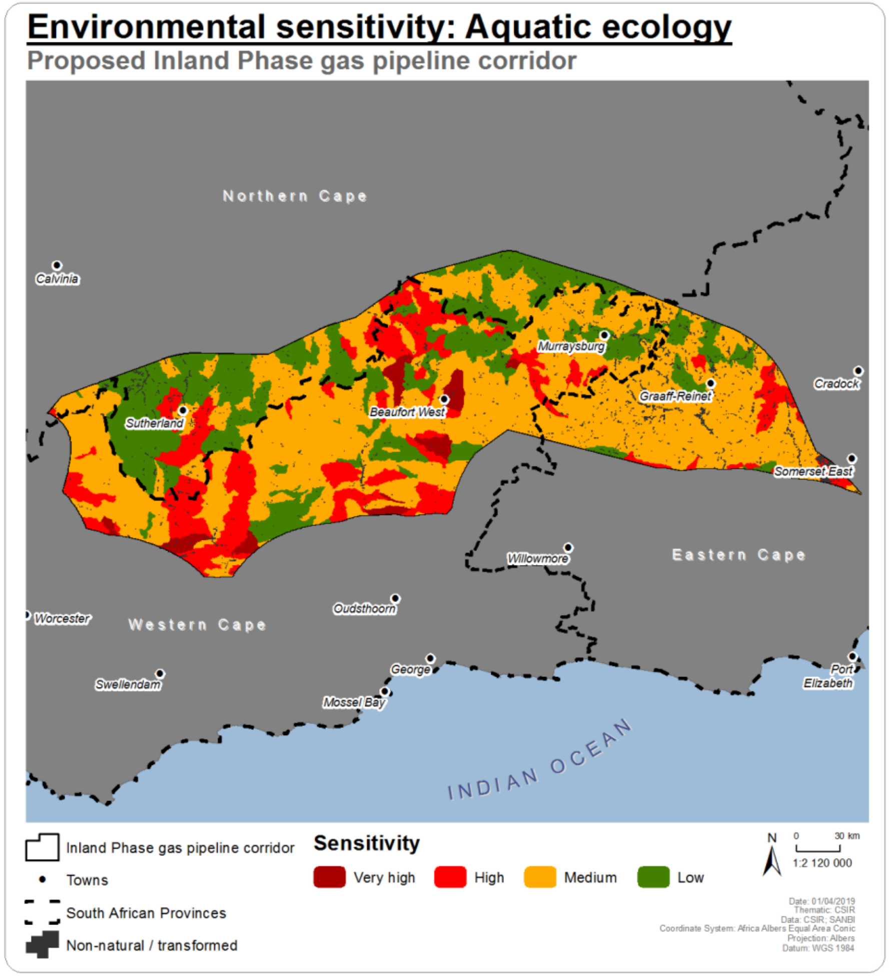


Figure 48: Environmental sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Inland Phase corridor.

5.2.6 Phase 7

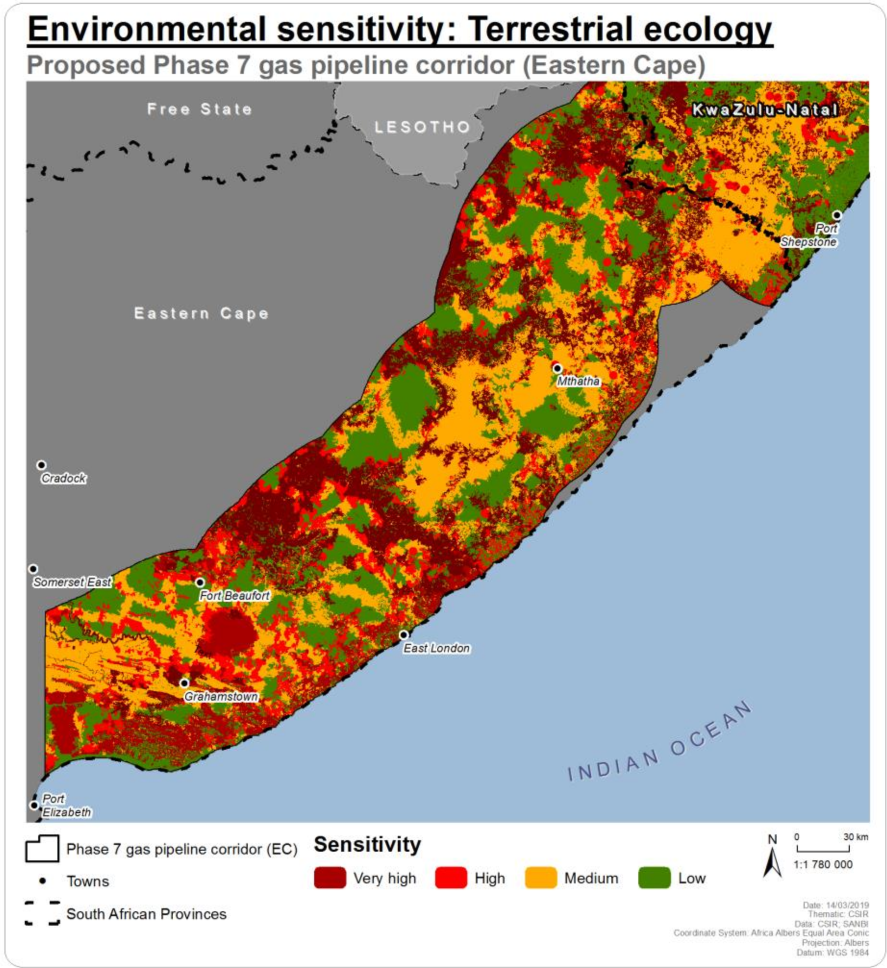


Figure 49: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 7 (Eastern Cape) corridor

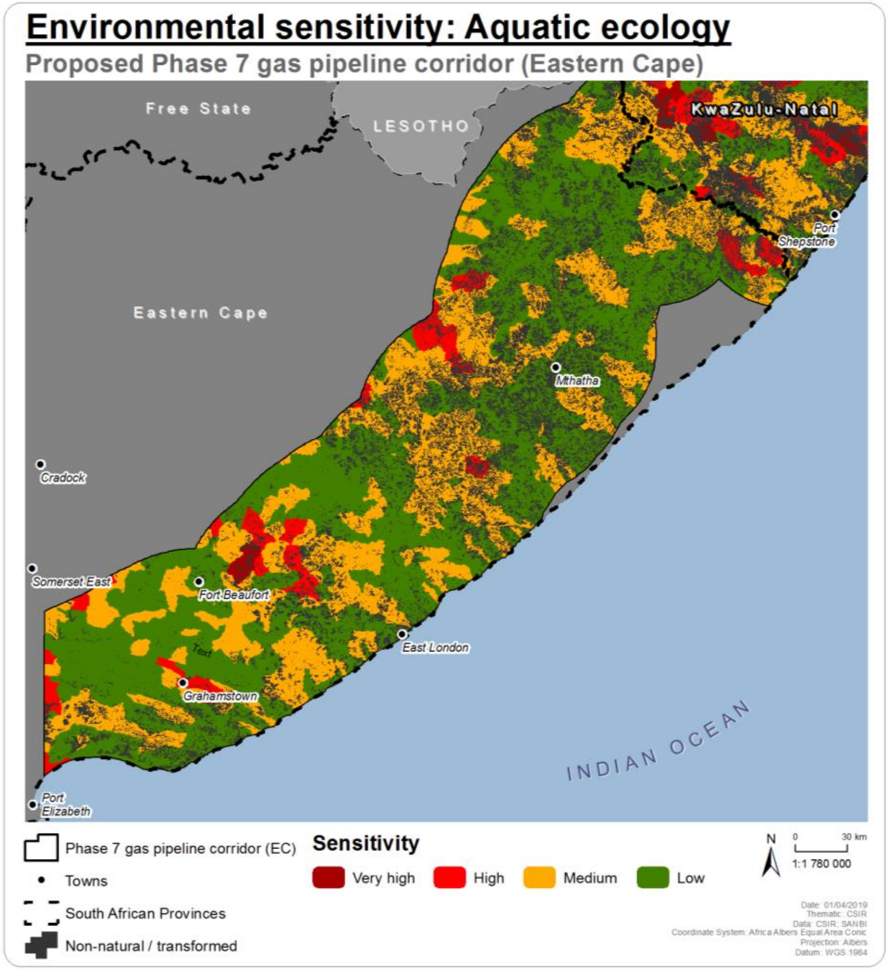


Figure 50: Environmental sensitivity sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 7 (Eastern Cape) corridor.

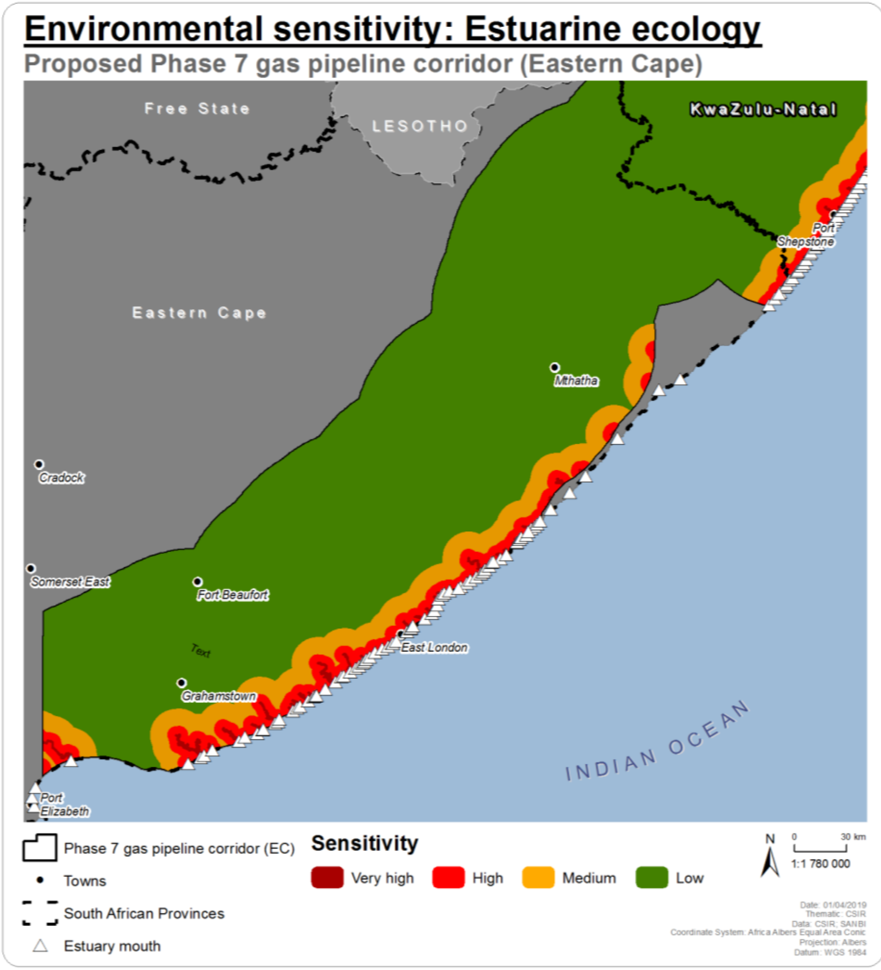


Figure 51: Environmental sensitivity of estuarine ecosystems to proposed gas pipeline development in the Phase 7 (Eastern Cape) corridor.

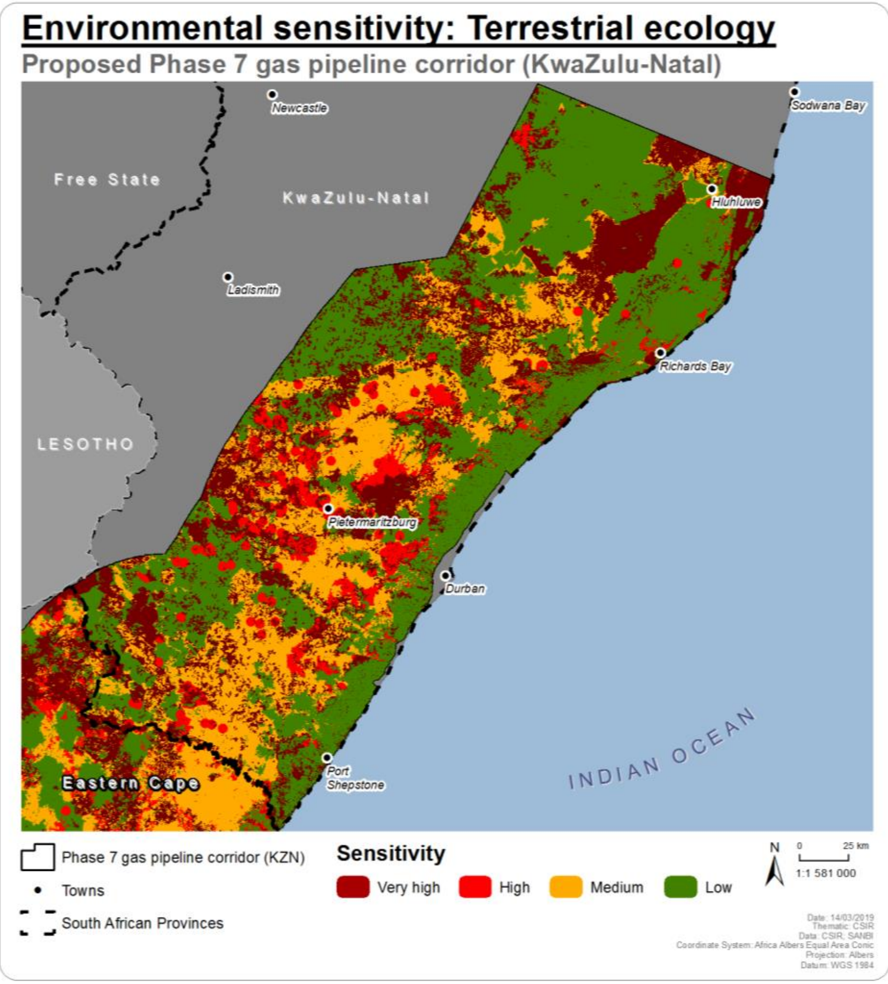


Figure 52: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 7 (KwaZulu-Natal) corridor.

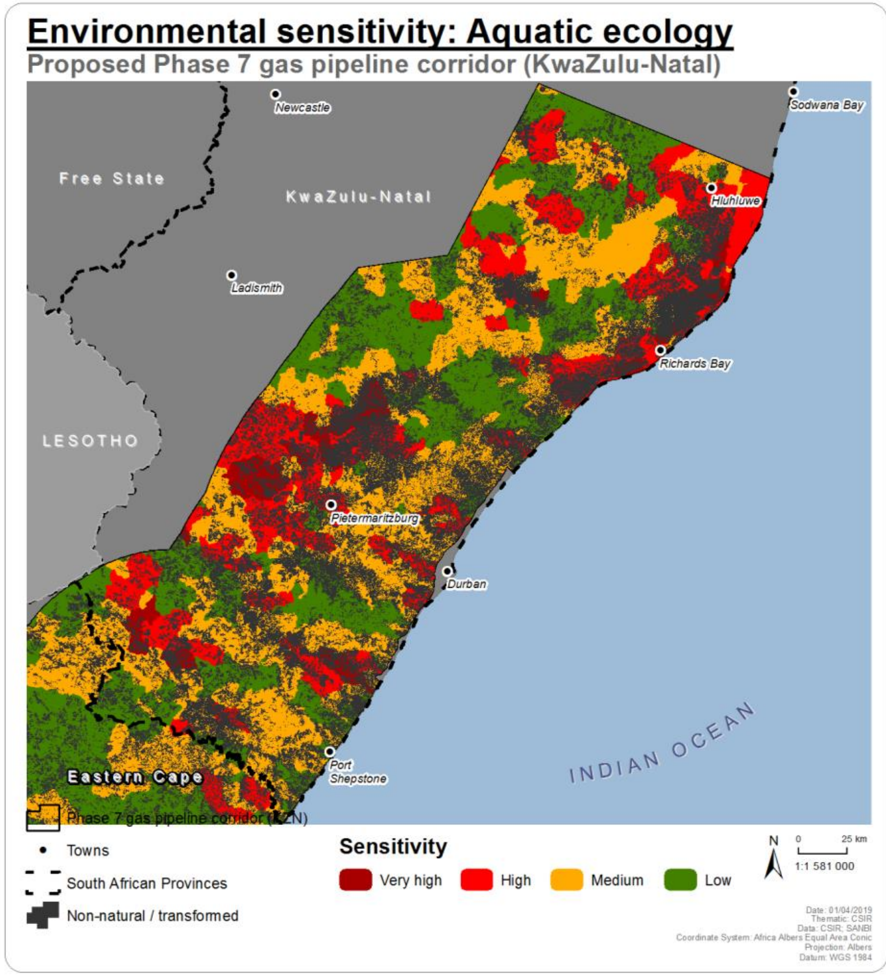


Figure 53: Environmental sensitivity sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 7 (KwaZulu-Natal) corridor.

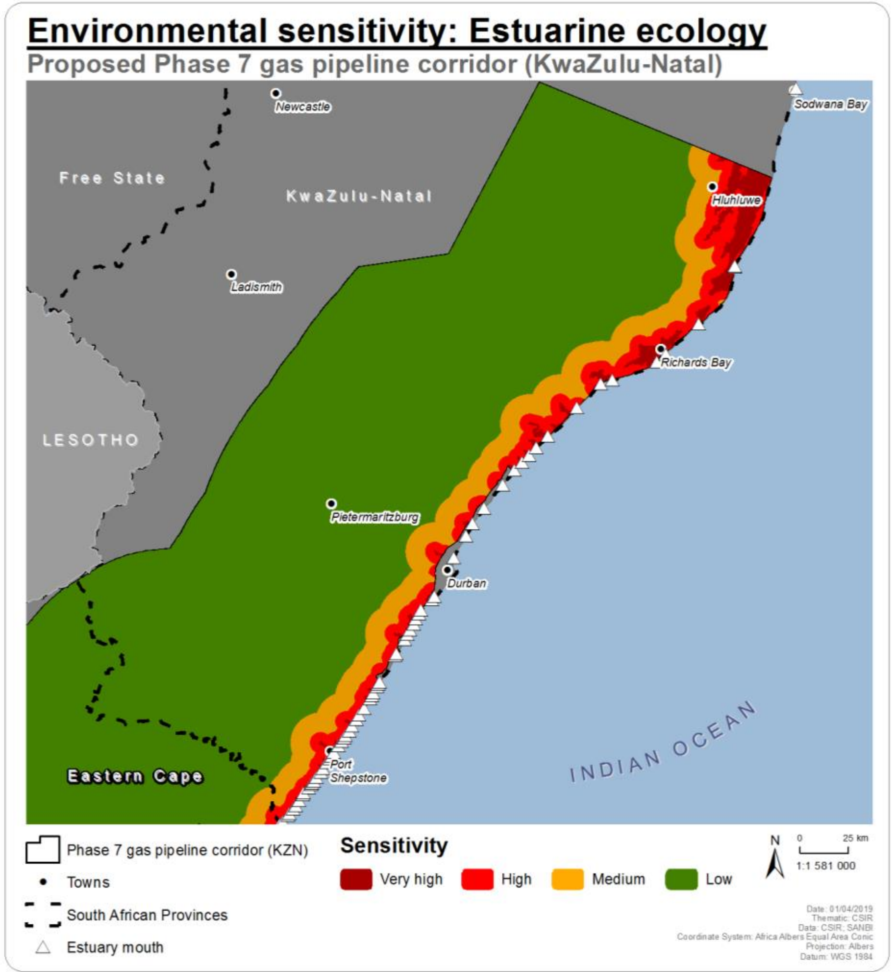


Figure 54: Environmental sensitivity of estuarine ecosystems to proposed gas pipeline development in the Phase 7 (KwaZulu-Natal) corridor.

5.2.7 Phase 4

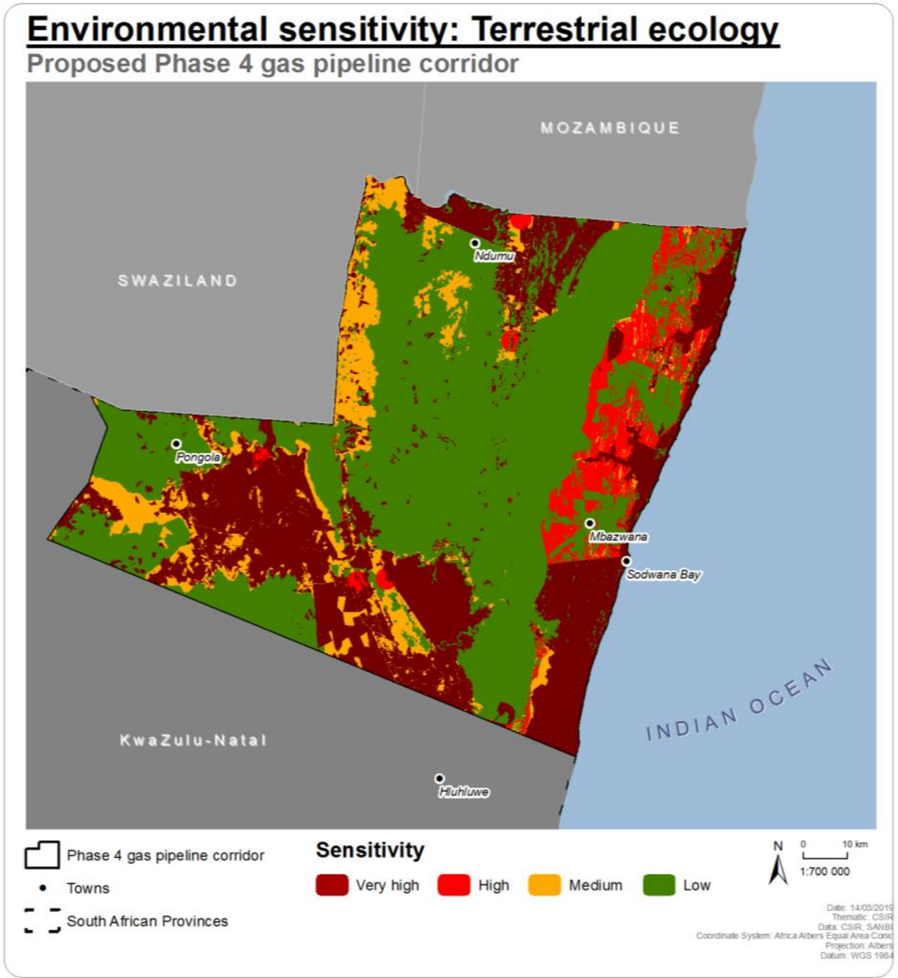


Figure 55: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 4 corridor.

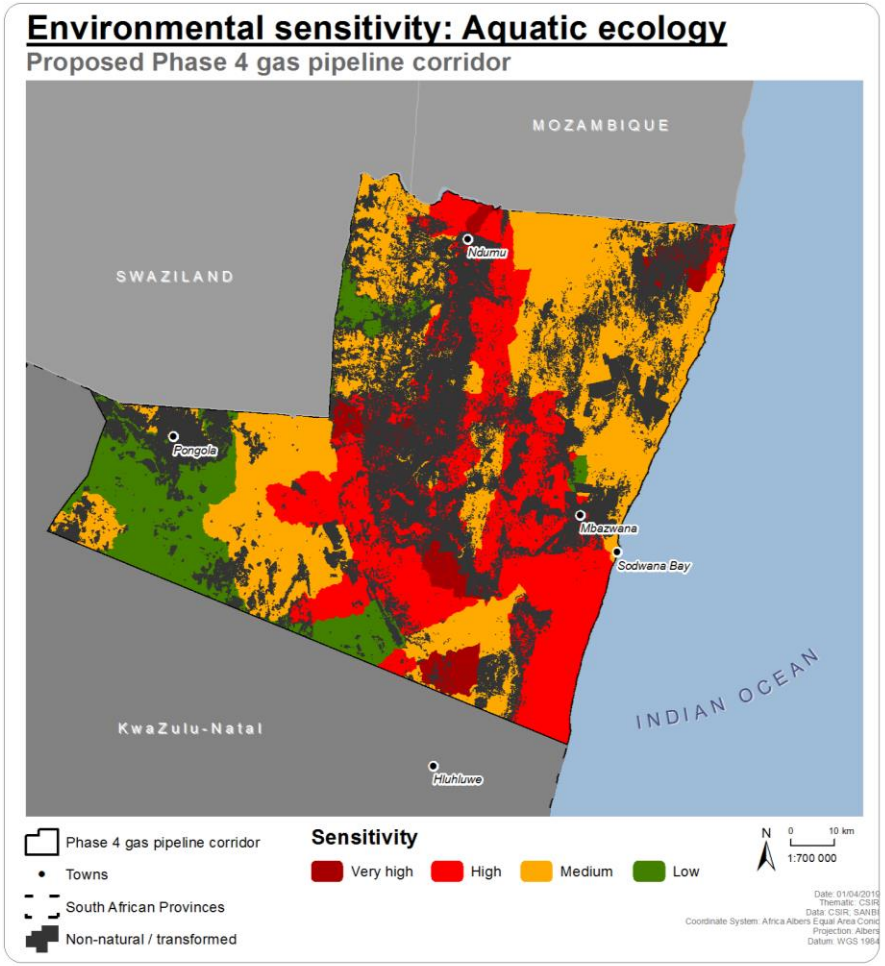


Figure 56: Environmental sensitivity sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 4 corridor.

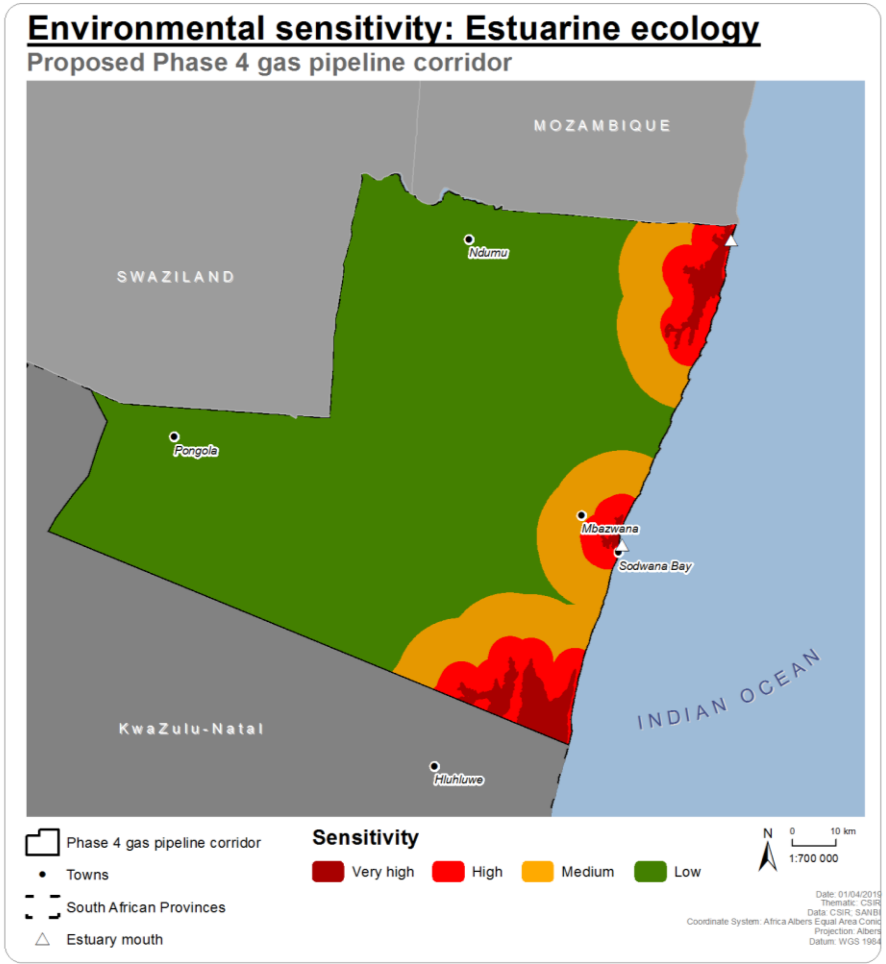


Figure 57: Environmental sensitivity of estuarine ecosystems to proposed gas pipeline development in the Phase 4 corridor.

5.2.8 Phase 3

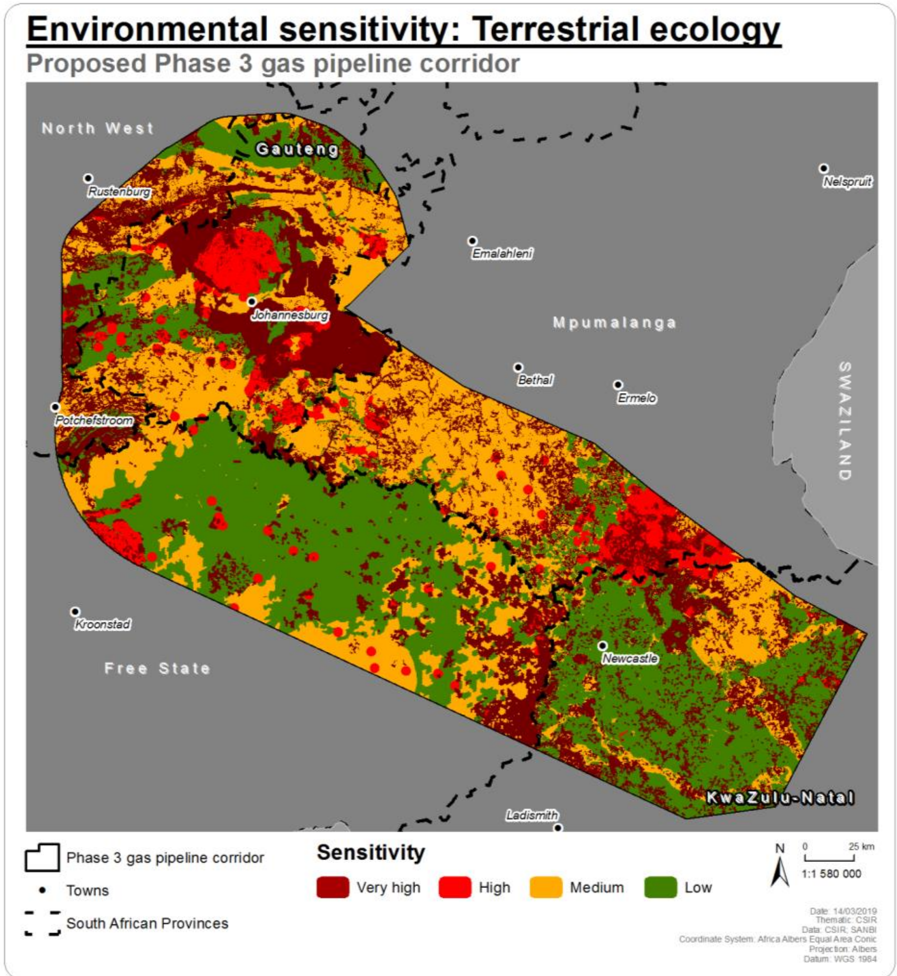


Figure 58: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 3 corridor.

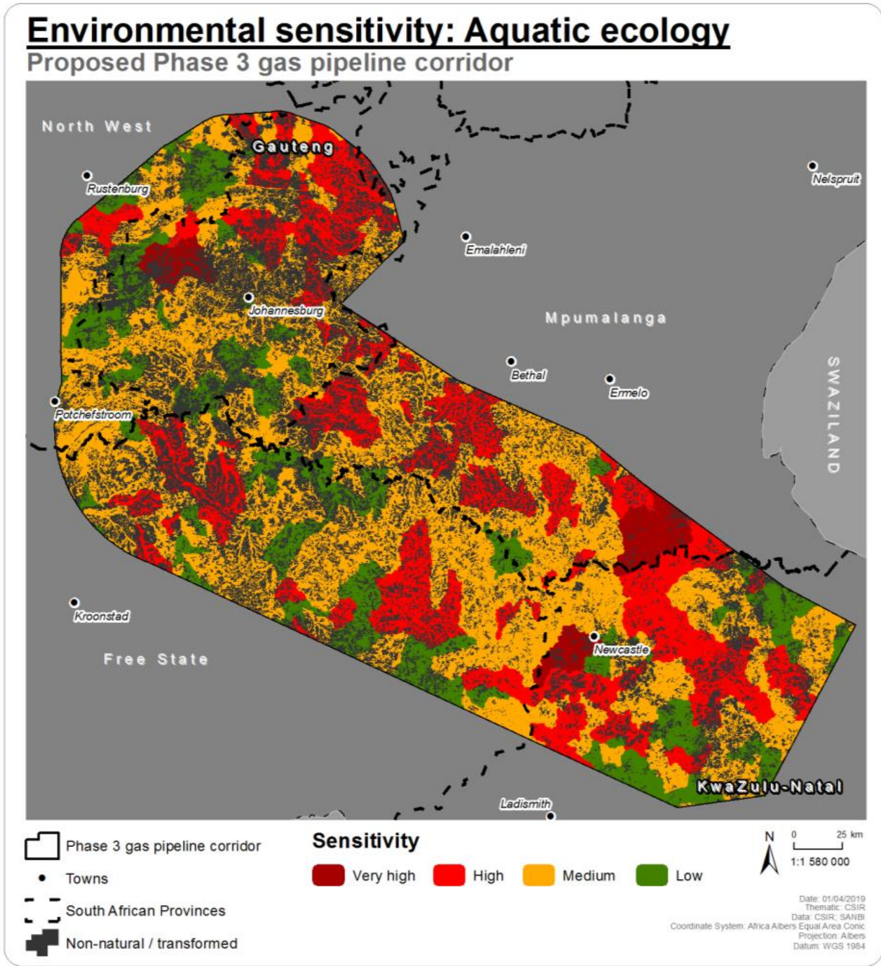


Figure 59: Environmental sensitivity sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 3 corridor.

5.2.9 Phase 8

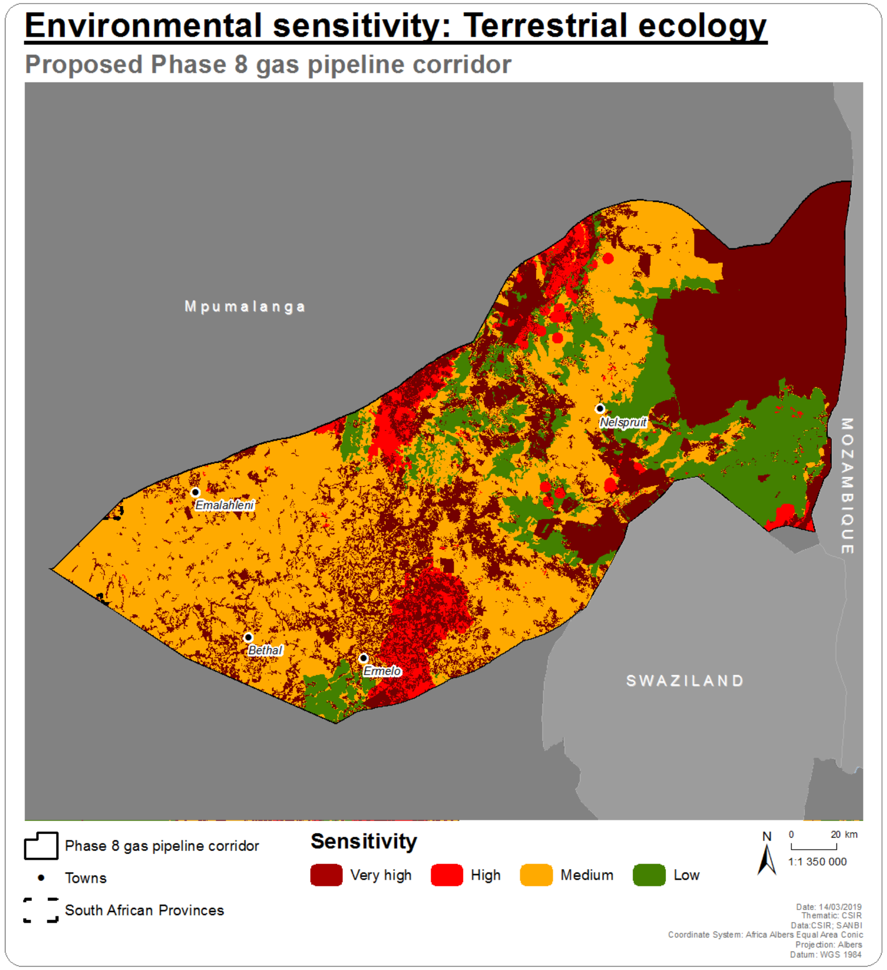


Figure 60: Environmental sensitivity of terrestrial ecosystems to proposed gas pipeline development in the Phase 8 corridor.

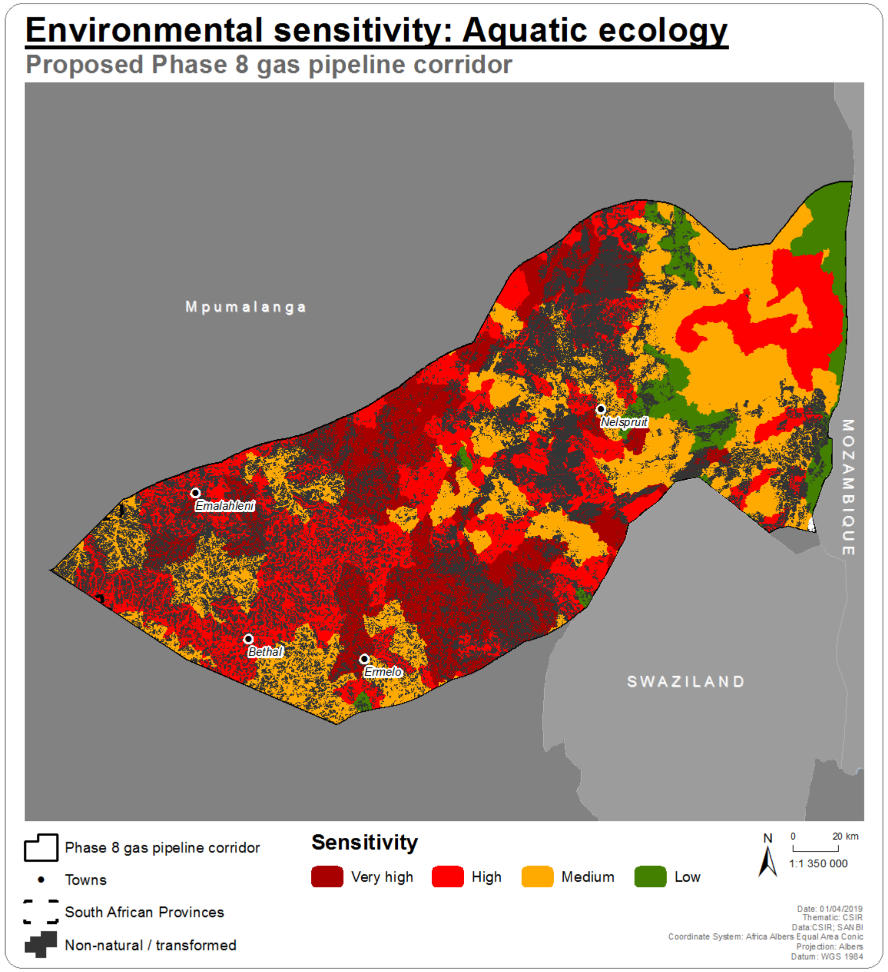


Figure 61: Environmental sensitivity sensitivity per quinary catchment (overlaid with non-natural/transformed landcover) of aquatic ecosystems to proposed gas pipeline development in the Phase 8 corridor.

6 KEY POTENTIAL IMPACTS AND THEIR MITIGATION

The potential impacts of gas pipeline development are summarised as three key impacts to terrestrial ecosystems (Section 6.1) and four key impacts to aquatic ecosystems (Sections 6.2.1 – 6.2.4 - freshwater; Sections 6.2.5 - 6.2.8 - estuaries) (Table 26).

Table 26: Summary of the key impacts from gas pipeline development, and the development phase in which the consequences of the impacts are expected to manifest.

Impact	Phase			
	Planning & design	Construction	Operation & maintenance	Post-closure & rehabilitation
TERRESTRIAL ECOSYSTEMS				
Physical disturbance to soils, fauna and flora	x	x	x	
Establishment and spread of IAPs		x	x	
Ecosystem alteration and loss		x	x	x
AQUATIC ECOSYSTEMS				
Degradation and loss	x	x	x	
Reduction in habitat quality		x	x	
Hydrological alteration		x	x	
Water quality deterioration		x	x	x

The NEMA calls for the widely recognised mitigation hierarchy (avoid, mitigate/manage, rehabilitate, offset) (Figure 62) to be implemented to minimise or negate negative impacts, and maximise positive impacts of infrastructure development.

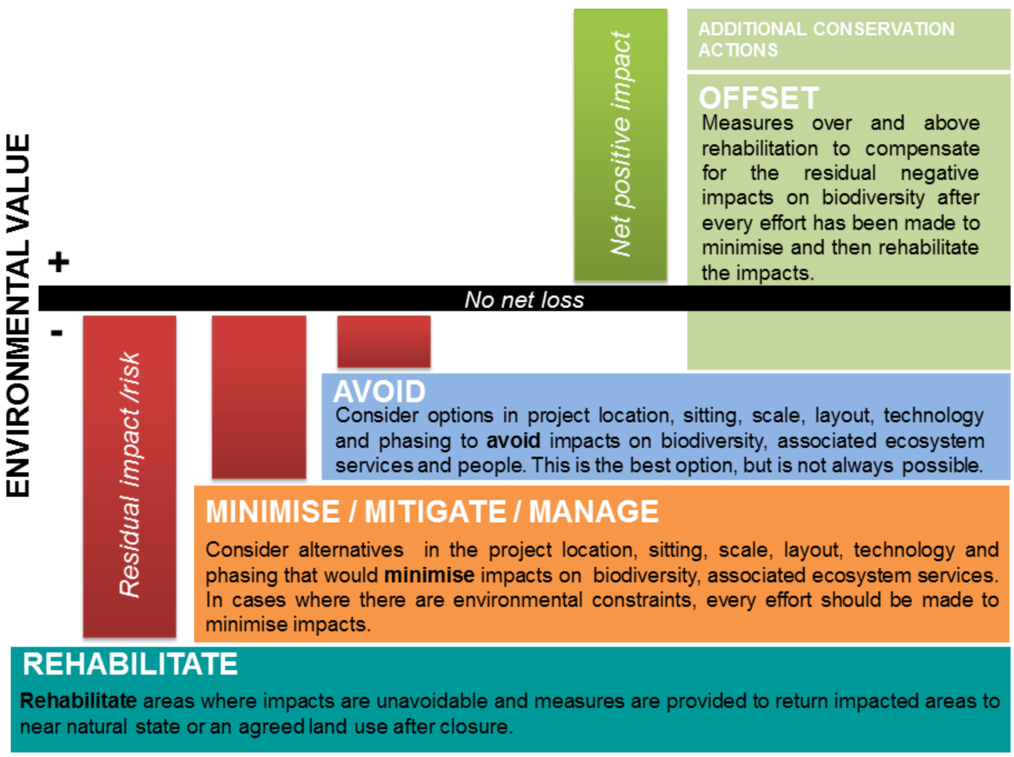


Figure 62: Implementation of the mitigation hierarchy is encouraged to ensure more sustainable and responsible development (after Rio Tinto, 2013).

6.1 Terrestrial ecosystems

6.1.1 KEY IMPACT 1: PHYSICAL DISTURBANCE TO SOILS, FLORA AND FAUNA

6.1.1.1 Drivers and consequences

Physical disturbance to soils, flora and fauna may be caused by the following activities associated with gas pipeline development:

- Arrival and movement of construction and operational personnel, vehicles and heavy equipment en route to and on site;
- Construction activities, including trenching, blasting, and drilling;
- Open trenches;
- Removal and disturbance of vegetation;
- Exclusion of deeper-rooted vegetation from the pipeline route and the access routes;
- Potential oil and fuel spills from equipment and vehicles;
- Gas leaks and explosion, in the event unlikely of infrastructure failure during the operational phase.

The consequences of physical disturbance to soils, fauna and flora include:

- Establishment and invasion by IAPs (also see Key Impact 2, Section 6.1.2);
- Direct loss of foraging habitat and shelter for fauna (also see Key Impact 3, Section 6.1.3);
- Loss of SCC;
- Nuisances which may cause changes to fauna behaviour and movement:
  - Noise;
  - Dust; and
  - Vibration.
- Poaching, collection of plants and animals that are collectable or have indigenous/medicinal uses;
- Entrapment of animals open trenches (which could then have fatal consequences as a result of drowning in pools of collected water, dehydration, or starvation);
- Possible ensnarement of animals or ingestion of materials (e.g. cables), waste and litter (e.g. plastic) that are left on site;
- Road mortalities;
- Reduced movement and mortalities of sub-surface fauna (e.g. moles) due to soil compaction;
- Altered hydrological patterns, drainage and runoff movements;
- Loss of topsoil and changes in terrain morphology;
- Habitat fragmentation;
- Disrupted ecosystem services; and
- Declined ecosystem resilience.

6.1.1.2 Mitigation

Planning and pre-construction

AVOID

- Use of **environmental sensitivity maps** and **least cost path analysis findings** in the routing design;
- **Avoid**, as far as possible, **High and Very High sensitive areas, which may also contain valuable species,** during the route planning;
- **Avoid**, as far as possible, **crossing key migration or movement corridors for fauna** during the route planning;
- **Avoid** any construction on **steep slopes** (>25 degrees); and
- **Avoid areas of high erosion vulnerability** as far as possible.

MINIMISE / MITIGATE / MANAGE

- Design to **use common/shared infrastructure** as far as possible with development in nodes, rather than sprawling development;
- **Undertake specialist assessments:**
    - Where avoidance is not possible, in areas of Moderate to Very High sensitivity undertake specialist faunal and plant species assessments to propose site-specific mitigation or recommend alternatives prior to finalising the route; and
    - Undertake specialist surveys or inspections to establish/confirm whether threatened or endemic species are present in areas of lower sensitivity. If populations of threatened or endemic species are encountered and unavoidable then specialist inputs should be obtained.

Construction

AVOID

- **Avoid the roosts nests and burrows sensitive faunal species** (e.g. porcupines, aardvarks) and **establish sensitivity buffers** where they are in the vicinity;
- **Avoid** construction activities in the **breeding and/or migration seasons** of threatened and important taxa;
- **Avoid unnecessary vegetation clearing**;
- **Prohibit collection of 'fuel wood'** on site;
- **Prohibit poaching of animals, or illegal collection of rare species**. All instances of illegal collection should be reported to the applicable provincial Nature Conservation Authorities;
- **No dogs or other pets** should be allowed on site.

MINIMISE / MITIGATE / MANAGE

- **Undertake construction activities in short phased stretches** and continuously rehabilitate as sections are complete;
- **Minimise the development footprint and physical extent**;
- **Clearly demarcate the construction footprint;**
- **Keep the duration of the activities on-site to a minimum** - complete them in as short a time as possible;
- **Construction activities should take place outside of peak rain seasons** as much as possible;
- **Develop community environmental education programs** to ensure that all staff understand that no plants and animals may be intentionally harmed, killed, poached, or collected. Also **monitor staff behaviour** and **sanction transgressions.**
- Specialist inspection of proposed micro-sited route prior to clearing of vegetation and breaking of ground to **ensure no animal burrows, nests, and roosts are harmed**;
- **Flushing or active capture and removal of key faunal species** from the working area;
- If roads or structures are fenced, **use fencing that allows safe animal movement** through fences;
- **Electrical fences**, if installed, should be erected **at least 30 cm from the ground** or according to relevant norms and standards of Nature Conservation Authorities;
- **Equip open trenches with suitable ramps, ladders or steps** every 50 m so that trapped animals can escape;
- **In areas where there is high animal activity, fine-mesh fences should be laid out around the open section** and secured to minimise the likelihood that animals will fall in;
- Do **daily patrols to rescue trapped animals**;
- **Ensure that rare and endangered species are not buried** under the temporary soil dumps;
- **Use plant rescue to remove and relocate rare plants** in construction footprint;
- **Control dust** to minimise impacts by regulating vehicle speeds and using geotextiles, particularly on soil dumps;
- **Control soil erosion and sediments in runoff** through appropriate drainage and erosion control structures to minimise impacts on rivers and wetlands (e.g. barriers, geotextiles, active rehabilitation);

- **Where the pipeline cuts through unstable soils** (e.g. sodic soils) ensure that adequate interventions are taken to prevent erosion and piping;
- **Take care where the pipeline crosses dynamic swelling and contracting soils** (e.g. vertic soils) ensure that soil movement does not cause damage to the pipeline resulting in further secondary environmental damage;
- **Limit vehicle speeds** to minimise potential collisions with animals and dust creation;
- **Limit night driving**;
- **Use existing roads** as far as possible for access;
- Provide new **roads with run-off structures**;
- **Prevent fuel or oil leaks and make provision to contain them** (e.g. in drip trays) to reduce risk of contamination of surrounding soil and water.

Operations and maintenance

MINIMISE / MITIGATE / MANAGE

- **Limit vehicle speeds** to minimise potential collisions with animals and dust creation;
- **Surveillance and monitoring of potential poaching and illegal species collection** (e.g. snares, debarking, hunting); and
- **Employ all technical measures to reduce the likelihood of infrastructure failure** (e.g. sensors for loss of pressure as well as automatic cut off valves; prevent deep-rooted plant species establishing directly above the pipeline).

Post-construction and rehabilitation

REHABILITATE

- **Return the area to as near natural a state as possible**, with natural processes such as fire being retained;
- **Maintain top soil for later rehabilitation;**
- **Replace soil in the sequence it was extracted** – this should be carried **out within a month of excavation.** This not only limits changes in the soil, but ensures that the exposed area of the trench, a potential trap for animals, is minimised;
- **Retain rootstock of existing vegetation** where possible[3];
- **Rehabilitate using locally indigenous plant species.** Where feasible translocate savage plants. Where not feasible use a seed mix that includes both annuals and perennials;
- **Stabilise all slopes and embankments**;
- **Re-establish ecological connectivity** where fragmentation of key habitats has occurred using landscape design methods (e.g. over and under pass wildlife bridges); and
- **Develop an Open Space Management Plan**, which makes provision for favourable management of the infrastructure and the surrounding area for fauna.

[3] Savanna trees, particularly, have an incredible ability to sprout from felled trees and hence can re-colonise the area much faster than new seedlings.

6.1.2 KEY IMPACT 2: ESTABLISHMENT AND SPREAD OF ALIEN INVASIVE PLANTS

6.1.2.1 Drivers and consequences

Machinery and people can actively introduce and spread IAP propagules[4] on site (e.g. in the form of mud encrusted onto excavators or trucks). Construction materials, especially sand, stone and gravel from quarries can include propagules so all such materials should only be sourced from quarries or borrow pits which are free of invasive species.

Consequences related to the establishment and invasion by IAPs include:

- Alteration, reduction and loss of the effective habitat of a number of indigenous rare or endangered species.

6.1.2.2 Mitigation

Planning and pre-construction

AVOID

- **Incorporate, and budget for, control of invasive species** in environmental management plans for the construction, operation and decommissioning phases of the pipeline;
- **Identify and map IAPs** along and within the planned route prior to construction;
- **Prepare systematic and properly costed plans for invasive species control** for sections of the proposed route;
- **Avoid off road driving**; and
- **Carry out initial control measures prior to the construction.**

Construction

AVOID

- **Avoid unnecessary disturbance** of plant cover and topsoil;
- **Avoid off road driving**; and
- **Do not use soil sources contaminated with IAP seeds** for bedding of the pipe or for construction work.

Box 22: Invasive Alien Plants in the Fynbos Biome

Many of the Fynbos invaders are woody plants which have deep roots and would have to be controlled if they established in the pipeline servitude.

Alien grasses are particularly aggressive invaders in the Sand Fynbos and Renosterveld communities and possibly also the Strandveld communities.

Studies of invasive species control measures have shown that eradication of a species cannot be achieved except in the initial stage of establishment. Therefore, effective control in this context should be that IAP species cover within the pipeline servitude is reduced to, and maintained at, less than 5% canopy cover.

[4] Any parts or life stages of organisms which could enable them to establish new populations.

MINISMISE / MITIGATE / MANAGE

- **Environmental education programmes on IAPs** for staff to assist in the identification of existing and potential invasive species that may affect the servitude;
- **Use existing roads** as far as possible for access;
- **Ensure that machinery is properly cleaned** before being brought onto site and also before moving it from a section of the route where invading species were controlled to a section that is free of invading species;
- **Minimise imports of materials that could contain propagules of invasive species**, particularly plants and/or screening such materials to ensure they are propagule free;
- **Remove IAPs before they set seed** on or in vicinity of construction site; and
- **Dispose of all the cut plant material from site** immediately using carefully considered and suitable methods that are in compliance with relevant legislation and based on consultation with experts, as required.

Operations and maintenance

MINIMISE / MITIGATE / MANAGE

- **Develop and implement an Alien Invasive Species Management Plan**, which makes provision for regular alien clearing and monitoring.
- **Carry out regular surveys to identify invading species**; where they are found, carry out the necessary control operations;
- **Regular** (at least bi-annual) **IAP control** using the most appropriate and specific measures to control exotic species that have established (e.g. herbicides, fire, manual removal).
- **Ensure that appropriate follow-up operations are continued until the invading species are effectively under control;**
- **If and when the pipeline is replaced, then follow the same procedures as for the construction**;
- **Avoid off road driving**; and
- **Keep all livestock out of rehabilitated areas.**

Post-construction and rehabilitation

REHABILITATE

- **Ensure that appropriate follow-up operations are continued until the invading species are effectively under control;**
- **Avoid off road driving;**
- **If/when the gas pipeline is closed ensure that any invasions are controlled as part of the closure processes.** As part of the hand-over process, ensure that the land-owner's responsibility to maintain the cleared areas is acknowledged in writing.

6.1.3 KEY IMPACT 3: ECOSYSTEM ALTERATION AND LOSS

6.1.3.1 Drivers and consequences

Physical disturbance to soils, fauna and flora (Key Impact 1), and IAP establishment and spread (Key Impact 2) can ultimately manifest as ecosystem alteration and loss. It is also associated with the:

- Introduction of non-local genetic stock;
- Exclusion of deeper-rooted vegetation from the pipeline route and the access routes; and
- Partial or complete failure to achieve effective rehabilitation.

Consequences of ecosystem alteration and loss include:

- Changes in local habitat features and ecological processes;
- Changes in habitat suitability for local species;
- Reduction/loss in endemic and rare species populations;

- Transformation of intact habitat within a CBA. CBAs are areas required to meet biodiversity targets for ecosystems, species or ecological processes, as such development in these areas is discouraged;
- Transformation of habitat within an ESA. ESAs are areas that are not essential for meeting biodiversity targets, but play an important role in supporting the ecological functioning in a CBA;
- May affect the suitability of certain areas for inclusion in NPAES;
- Local or global extinction;
- Changes in species movements, abundance and distribution,
- Changes in ecosystem functions, interactions, and resilience;
- Decline in ecosystem services;
- Soil erosion;
- Habitat fragmentation; and
- Exposure of adjacent communities to unfavourable edge effects (susceptibility to invasions by alien species).

6.1.3.2 Mitigation

Planning and pre-construction

AVOID

- **Avoid CBAs** as far as possible;
- **Avoid impact to restricted and specialised habitats** such as cliffs, large rocky outcrops, quartz, pebble patches and rock sheets;
- **Use environmental sensitivity maps and least cost analyses in routing design**;
- Design and layout of infrastructure to **avoid**, as far as possible **highly sensitivity areas**;
- **Conduct ground assessments** and verification before construction;
- **Design to use as much common/shared infrastructure** as possible with development in nodes, rather than spread out; and
- **Avoid**, as far as possible, construction on **steep slopes** (> 25 degrees).

Construction

MINIMISE / MITIGATE / MANAGE

- **Minimise construction in ESAs** as far as possible;
- **Locate temporary-use areas such as construction camps and lay-down areas in previously disturbed areas** as far as possible;
- **Obtain expert inputs on appropriate rehabilitation techniques and species choices** to ensure that ecosystem structure and function recover;
- **Rapidly rehabilitate** the area to pre-construction conditions where possible;
- **Replace top soil (seed bearing soil) as soon as possible;**
- **Control dust** to minimise impacts by regulating vehicle speeds and using geotextiles, particularly on soil dumps.
- **Ensure proper runoff management and erosion control**, especially on steeper slopes.

Operations and maintenance

- **Control dust** to minimise impacts by regulating vehicle speeds and using geotextiles, particularly on soil dumps.

Post-construction and rehabilitation

- **Obtain expert inputs on appropriate rehabilitation techniques and species choices** to ensure that ecosystem structure and function recover;

- **Rapidly rehabilitate** the area to pre-construction conditions where possible;
- **Replace top soil (seed bearing soil) as soon as possible**;
- **Planting of plant stock and reseeding should be timed to maximise the likelihood of successful recruitment** (e.g. do not revegetate after the end of spring);
- **All plant stock and seed must be from local populations,** whenever possible avoid introduction of non-local genetic material;
- **Use material from that section of the route in its rehabilitation** or, where this is not feasible, **from a source community matched as closely as possible**, excluding Very High sensitivity areas; and
- Wherever there is an evident change in the vegetation or community (i.e. between two neighbouring vegetation communities / types), **keep the rehabilitation material for each community's section separate to minimise introduction of non-local genetic stock.**

Box 23: Environmental Offsets

"Environmental / Biodiversity Offsets" are often promoted as a means of redressing the apparent disturbance or "loss" of natural habitat or systems. The benefit and success of offsets has yet to be proven (Bull et al., 2013) and is a debatable topic.

Offsets should not be considered as a first management/mitigation option, and should be avoided unless absolutely necessary.

Calculating, identifying and successfully establishing a suitable offset can be a complex and costly undertaking with no guarantee of success. Other forms of Offsets are also considered by various authorities, including financial contributions and stewardship programmes or partnerships with conservation authorities. Given the strategic importance of the proposed pipeline, the latter option may be the most practical offset strategy, if the offset approach is adopted.

Box 24: Potential impacts to Birds and bats

Birds

The potential negative impacts on **birds** by the proposed gas pipeline can be summarised as:

- Direct mortality due to the destruction of nests in the construction servitude;
- Displacement due to disturbance during the construction of the pipeline and associated infrastructure (compressor/pump stations); and
- Displacement of breeding individuals through habitat transformation.

Although the 50 m wide construction servitude will be revegetated through a process of vegetation rehabilitation and natural colonisation, a 10 m wide servitude will remain to provide access for maintenance. In the case of access roads, the transformation will be permanent. However, where possible, shallow rooted plants/crops can be allowed to re-grow in the 10 m wide servitude. No service road is planned to be built along the pipeline.

Assessment and mitigation measures specific to avifauna

- Nest surveys by a suitably qualified avifaunal specialist to identify all active nests in the servitude and immediately adjacent areas prior to the commencement of the servitude clearing.
- On discovery of a nest, the avifaunal specialist must be provided with a work schedule which will enable him/her to ascertain, if, when and where the breeding birds could be impacted by the clearing activities. Appropriate management measures would need to be implemented, the nature of which will depend on the conservation status of the species and the location of the nest.

Each case will have to be dealt with on an ad hoc basis but could include the following:

- Remove eggs and/or chicks to rehabilitation facility if the nest will be destroyed.
- If the nest falls outside the actual pipeline servitude, the timing of construction activities to avoid the disturbance of the breeding birds.

If the above assessment and mitigation measures are diligently adhered to, the risk that gas pipeline construction poses to avifauna can virtually be eliminated.

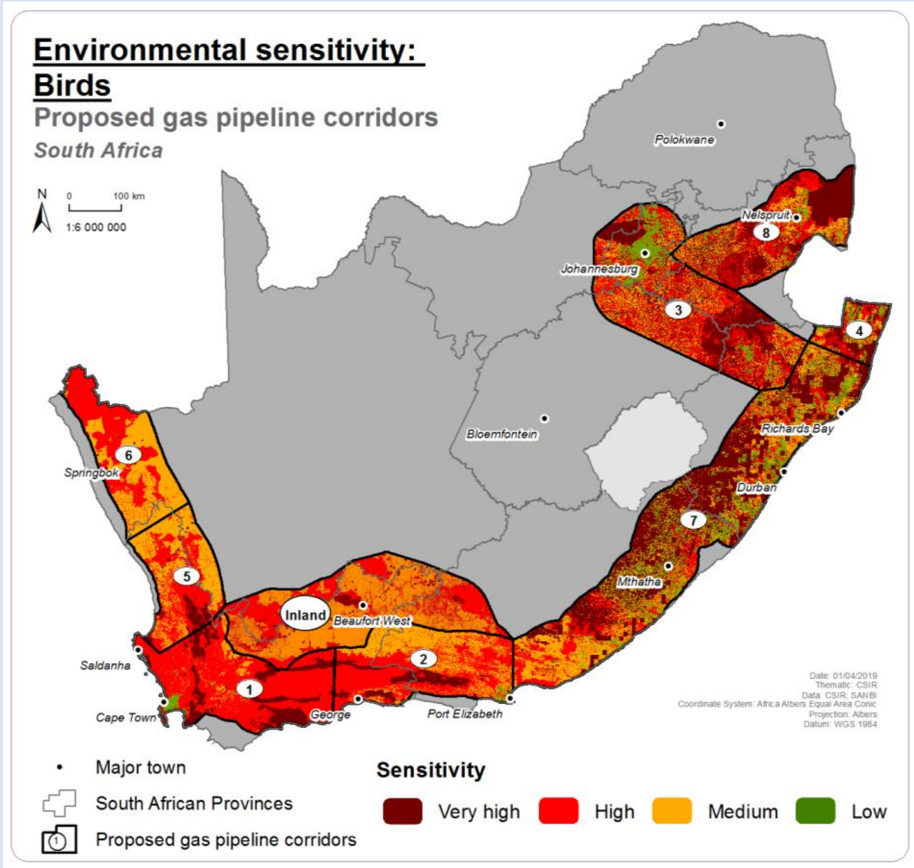


Figure 63: Bird sensitvitiy in the proposed gas pipeline corridors.

Bats

Construction activities, such as trenching, blasting and vehicle movement could cause noise, dust and vibrational disturbances to roosting **bat colonies**, especially during the breeding season from approximately October to March. These may lead to three key impacts to bats:

- Displacement and disturbance;
- Reduced foraging potential of habitats (through dust generation); and
- Reduction in habitat quality through the sedimentation of water bodies.

The best measure to avoid potential negative consequences for bats would be to avoid placing infrastructure in the vicinity of known and potential roosts, especially known large maternity roosts and near areas utilized by bats of conservation of importance. While species differ in their preferences, the following act as ideal habitats for bats to roost:

- Large trees or bush clumps;
- Caves and sinkholes;
- Rock crevices;
- Disused or old mining adits;
- Tunnels; and
- Dwellings/buildings with sufficient roosting space under roofs.

Additionally, bats require adequate surface water for feeding and drinking (Sirami et al., 2013; Lisóon and Calvo, 2014), particularly for insectivorous bats which hunt insects congregating above water bodies or wet soil.

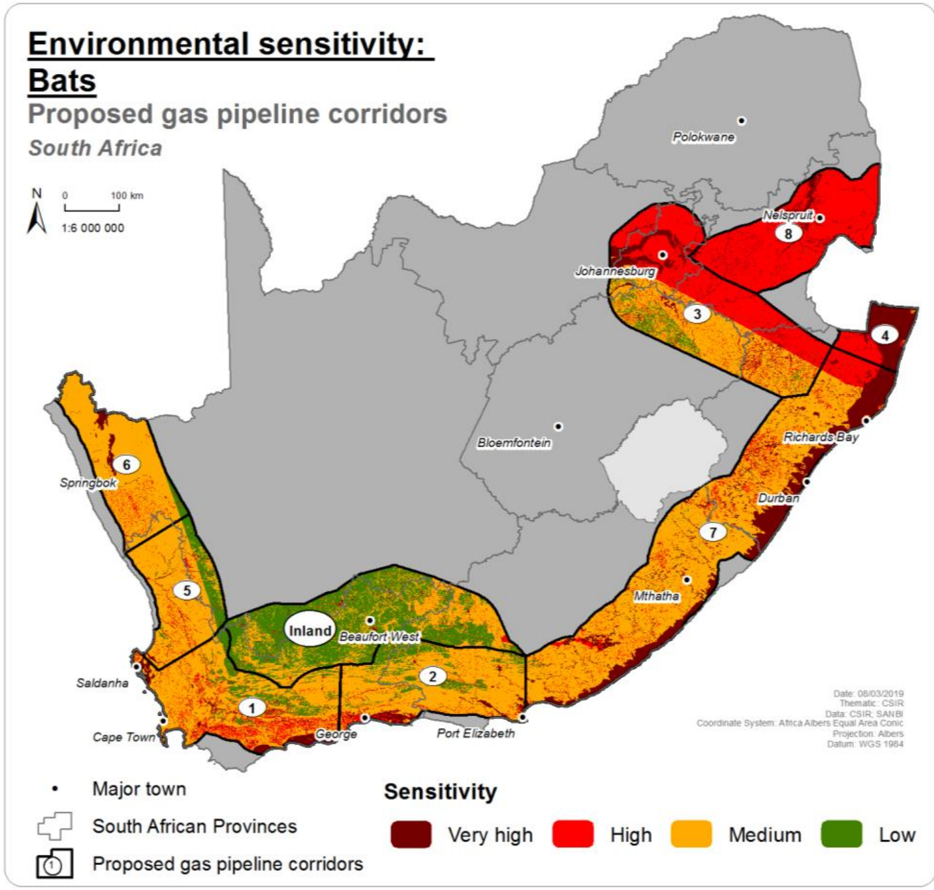


Figure 64: Bat sensitvitiy in the proposed gas pipeline corridors.

6.2 Aquatic ecosystems

6.2.1 KEY IMPACT 4: PHYSICAL DEGRADATION AND LOSS OF FRESHWATER ECOSYSTEMS

6.2.1.1 Drivers and consequences

Physical degradation and loss of freshwater ecosystems may be caused by the following activities associated with gas pipeline development:

- Placement of gas pipelines and pigging stations within ROWs, as well as construction camps, pipeline stockpiles, and access roads within or close to wetlands or rivers (including associated buffer habitat);
- Clearing or trimming of natural wetland or riparian vegetation;
- Clearing / infilling of wetlands and rivers and associated buffer habitat, potentially including threatened/ sensitive ecosystems;
- Workers and machinery operating within or in close proximity to wetlands or drainage lines, and through the establishment of construction camps or temporary laydown areas;
- Noise and vibration from and movement of construction teams and their machinery working within or in close proximity to wetlands and rivers; and
- Excavation of borrow pits for road construction acting as pitfall traps for amphibians and other terrestrial species leading to unnecessary death of species.

Consequences of physical degradation and loss of freshwater ecosystems include:

- Fragmentation of aquatic habitat;
- Soil erosion caused by loss of vegetation cover;
- Disturbance to and fatality of aquatic and semi-aquatic fauna;
- Stimulation of alien vegetation/invasive species;
- Loss of ecological functions and processes, freshwater biota (i.e. fauna and flora), and valuable ecosystem services; and
- Loss of ecosystem resilience and integrity through the disruption of biodiversity patterns and processes.

6.2.1.2 Mitigation

Planning and pre-construction

AVOID

- ➢ Gas pipeline routing to **avoid catchments with a very high sensitivity** as far as possible, and try to avoid catchments with a medium to high sensitivity.
- ➢ **Avoid clearing of sensitive indigenous vegetation,** as far as possible.

MINIMISE / MITIGATE / MANAGE

- ➢ Where highly sensitivity catchments area unavoidable, placement of pipeline infrastructure within these catchments (as well as catchments with a low sensitivity) should **avoid freshwater ecosystems and associated buffers**, which should be determined during route screening, validation and walk-throughs.
- ➢ **Ensure that a Water Use License (WUL) is undertaken where developments will occur within 500 metres of a wetland or 100 metres from a river** to authorise certain activities as per Section 21 of the National Water Act (Act 36 of 1998).
- ➢ **Use existing road networks and river crossings**, as far as possible.
  - ○ Where it is not possible to utilise existing roads, **avoid and/or minimise road crossings through wetlands and rivers** as far as possible.
  - ○ **Ensure that crossings are designed to minimise impacts**, as well as to ensure connectivity and avoid fragmentation of ecosystems, especially where systems are linked to a river channel.

    - **Designs** to consider use of riprap, gabion mattresses, with pipe crossings or culverts.
- **Bank stabilisation measures** (gabions, eco logs, geofabric, sediment fences) are required when wetland or watercourse banks steeper than 1:5 are denuded during construction.

Construction

AVOID

- **All wetlands and watercourses should generally be** avoided (as far as possible) and appropriately demarcated as such.
    - No vehicles, machinery, personnel, construction materials, cement, fuel, oil or waste should be allowed into these demarcated areas without the express permission of and supervision by an on-site Environmental Control Officer (ECO).

MINIMISE / MITIGATE / MANAGE

- **Construction camps, ablution facilities, and temporary laydown areas should be located outside of the recommended buffer areas around wetlands and watercourses** and should be rehabilitated following construction.
- **Trenches/excavations should be backfilled and rehabilitated immediately after the pipes/pigging stations have been installed**, and should be done concurrently as the pipeline construction process progresses along the ROW.
- **Open trenches/excavations should be inspected daily** by an ECO
    - **Implement plans to rescue any vertebrate fauna that have become trapped within a trench/excavation.**
    - **Use low fences that will prevent fauna from entering the ROW**, especially in situations where trenches/excavations remain open for longer periods of time (i.e. a few weeks to several months).
- **All construction activities** (including establishment of construction camps, temporary lay-down areas, construction of haul roads and operation of heavy machinery), should ideally **take place during the dry season** to reduce potential impacts to freshwater ecosystems that are linked to rainfall-runoff.
- **Workers should be made aware** of the importance of not destroying or damaging the vegetation along watercourses and in wetland areas, of not undertaking activities that could result in the pollution of drainage lines or wetlands, and of not killing or harming any animals that they encounter. This awareness should be promoted throughout the construction phase and can be assisted through erecting appropriate signage
- **Fixed point photography to monitor vegetation changes and potential site impacts** occurring during construction phase

Post-construction and rehabilitation

REHABILITATE

- **Determine appropriate site-specific rehabilitation** approaches and methods;
- **Fixed point photography could be used to monitor** long-term vegetation changes and potential site impacts.
- **Active removal of alien vegetation/spraying to be guided by an IAP control programme** with long term monitoring.
- **Continuous erosion control.**

6.2.2 KEY IMPACT 5: REDUCTION IN AQUATIC HABITAT QUALITY

6.2.2.1 Drivers and consequences

Reduction in aquatic habitat quality may be caused by the following activities associated with gas pipeline development:

- Physical (natural wetland or riparian) vegetation clearing or trimming results in exposed soil vulnerable to erosion;
- Sedimentation of water courses and wetlands; and
- Excessive dust generation from road construction and vehicle traffic/haulage leading to impact on surrounding vegetation health and suspended solids/sediment entering nearby watercourses.

The consequences of reduction in aquatic habitat quality include the establishments of IAPs, the loss of ecosystem resilience through the disruption of ecological processes and thus a loss of ecosystem integrity.

6.2.2.2 Mitigation

Construction

AVOID

- **Avoid clearing sensitive vegetation** (especially indigenous vegetation from high and very highly sensitive environments).

MINIMISE / MITIGATE / MANAGE

- **Minimise disturbance to surrounding vegetation** as soon as possible when construction activities are undertaken, as intact vegetation adjacent to construction areas will assist in the control of sediment dispersal from exposed areas.
- **Implement dust suppression methods** (e.g. spraying surfaces with water) to minimise the transport of wind-blown dust.
- **Ensure adequate watercourse crossings** (i.e. culverts of the correct specification) are designed where roads traverse these areas so that the concentration of flow (particularly during high flow conditions) is minimised as far as possible.

Post-construction and rehabilitation

REHABILITATE

- **Roads/crossings not needed after the construction process should be decommissioned and rehabilitated** in accordance with detailed rehabilitation plans.
- **Fixed point photography could be used to monitor** long-term vegetation changes and potential site impacts.
- **Active removal of alien vegetation/spraying to be guided by an IAP control programme** with long term monitoring.
- **Continuous erosion control.**

6.2.3 KEY IMPACT 6: ALTERED HYDROLOGY

6.2.3.1 Drivers and consequences

Hydrological alteration is mainly caused by interrupted surface and/or subsurface water flows, as well as the concentration of water flows due to roads traversing wetlands or rivers.

Flow changes result in degradation of the ecological functioning of aquatic ecosystems that rely on a specific hydrological regime to maintain their integrity, which also leads to geomorphologic impacts within systems.

6.2.3.2 Mitigation

Planning and pre-construction

AVOID

- **Use existing road networks and river crossings**, as far as possible.
    - Where this is not possible, **avoid and/or minimise road crossings through wetlands and rivers as far as possible.**

MINIMISE / MITIGATE / MANAGE

- **Minimise the number of watercourse crossings** for access roads.
- **Ensure adequate watercourse crossings** (i.e. culverts of the correct specification) are designed where roads traverse these areas so that the concentration of flow (particularly during high flow conditions) is minimised as far as possible.

6.2.4 KEY IMPACT 7: WATER QUALITY DETERIORATION

6.2.4.1 Drivers and consequences

Water quality deterioration may be caused by the following activities associated with gas pipeline development:

- Stockpiling of materials and washing of equipment within or in close proximity to wetlands or watercourses;
- Runoff of contaminants such as fuel, oil, concrete, wash-water, sediment and sewage into these ecosystems;
- Application of herbicides.

The consequences of water quality deterioration includes the loss of ecosystem resilience through the disruption of ecological processes and thus a loss of ecosystem integrity. Furthermore, pollution (water quality deterioration) of freshwater ecosystems and potential contamination of groundwater/subsurface drainage may lead to bioaccumulation or poisoning of fauna and flora.

6.2.4.2 Mitigation

Planning and pre-construction

AVOID

- **Use existing road networks and river crossings**, as far as possible.
    - Where this is not possible, **avoid and/or minimise road crossings through wetlands and rivers as far as possible.**

MINIMISE / MITIGATE / MANGE

- **Minimise the number of watercourse crossings** for access roads.
- **Ensure adequate watercourse crossings** (i.e. culverts of the correct specification) are designed where roads traverse these areas so that the concentration of flow (particularly during high flow conditions) is minimised as far as possible.

Construction

AVOID

- **No washing of vehicles and machinery within 30 metres** of the edge of any wetland or watercourse.
- **No fuel storage, refuelling, vehicle maintenance or vehicle depots should be allowed within 30 metres** of the edge of any wetlands, rivers or drainage lines.

- **No effluents or polluted water should be discharged** directly into any watercourse or wetland areas.
- **No spoil material, including stripped topsoil, should be temporarily stockpiled within 30 m of the edge of any wetland or drainage line**.
    - Freshwater ecosystems located in close proximity to construction areas (i.e. within ~30 m) should be inspected on a regular basis by the ECO for signs of disturbance from construction activities, and for signs of sedimentation or pollution. If signs of disturbance, sedimentation or pollution are noted, immediate action should be taken to remedy the situation and, if necessary, a freshwater ecologist should be consulted for advice on the most suitable remediation measures.

MINIMISE / MITIGATE / MANAGE

- **Restrict construction activities** associated with the establishment of access roads through wetlands or watercourses (if unavoidable) **to a working area of ten metres in width either side of the road**.
    - **Clearly demarcate these working areas.**
    - **No vehicles, machinery, personnel, construction material, cement, fuel, oil or waste should be allowed outside of the demarcated working areas.**
- **Refuelling and fuel storage areas, and areas used for the servicing or parking of vehicles and machinery, should be located on impervious bases** and should have bunds around them. Bunds should be sufficiently high to ensure that all the fuel kept in the area will be captured in the event of a major spillage.
- **If construction areas are to be pumped of water (e.g. after rainfall), this water should be pumped into an appropriate settlement area**, and not allowed to flow straight into any watercourses or wetland areas.

Operations and maintenance

AVOID

- **Avoid the use of herbicides within 50 m** of wetlands or rivers.

6.2.5 KEY IMPACT 8: ESTUARINE HABITAT DESTRUCTION.

6.2.5.1 Drivers and consequences

Habitat destruction, and loss of estuarine and riparian habitat (e.g. mangroves, saltmarshes, reeds, swamp forest), may be caused by the following activities associated with gas pipeline development within and around the EFZ:

- Removal of the natural vegetation in and around an estuary during the construction phase;
- Movement of heavy vehicles and machinery during construction within the ROW and the EFZ, riparian area and floodplain; and
- Ongoing vegetation clearing for access roads and the operational servitude.

Consequences of habitat destruction, and loss of estuarine and riparian habitat as a result of the above activities include:

- Degradation and reduction of ecological function and productivity of affected estuaries;
- Reduction of overall estuarine habitat, protection for biota and loss of nursery area;
- Establishment of IAPs (which can further alter estuarine functioning);
- Estuary bank erosion by tidal action and river flow and floods causing destabilisation of the estuary channel, mud- and sand bank habitat;
- Habitat losses may occur from secondary impacts. Increased sedimentation during construction and backfilling of the trench in the estuary could cause drying out of the riparian habitat and loss of estuarine and associated floodplain vegetation;

- Increased soil bulk density, reduced porosity, and reduced hydraulic conductivity due to soil compaction;
- Altered soil chemistry (reflected in soil pH, organic matter and nitrogen content) in the trenched area;
- Population and diversity reduction of estuarine invertebrates, fish and birds. For example, decreased mangrove areas will decrease overall estuarine productivity and abundance of invertebrates, which will affect food availability for fish and birds. This in turn will impact on estuarine nursery function and the productivity for estuarine and coastal fisheries;
- Unpredictable trophic network and knock-on impacts are likely. For example, decreased mangrove areas will decrease overall estuarine productivity and abundance of invertebrates, which will affect food availability for fish and birds;
    - This in turn will impact on estuarine nursery function and the productivity for estuarine and coastal fisheries. In addition, the disturbance of estuarine habitat often results in a change in ecological functioning, and can allow for the introduction of IAPs; which in turn can further negatively impact estuarine functioning.

6.2.6 KEY IMPACT 9: ALTERED ESTUARINE PHYSICAL AND SEDIMENT DYNAMICS

Estuaries are high energy environments and their channel morphology is highly dynamic. Estuarine channels can develop and migrate anywhere within the EFZ under the influence of tidal flows, river inflow and floods.

Stabilising sections of the estuary morphology or floodplain (which are naturally dynamic) through pipeline construction, pipeline installation and operation, as well as placement of pigging stations or block valves can lead to changes in long-term physical and sediment dynamics, i.e. disrupting channel and bed formation, altering sediment structure, changing estuary hydrodynamics, mouth dynamics, and ultimately catchment and marine connectivity. This can lead to altered functioning of a system and ultimately affect biota. Loss of estuarine productivity and connectivity in turn will reduce nursery function and associated fisheries value derived along the South African coast.

Over time migrating estuarine channels will expose pipeline infrastructure, changing flow velocities, and cause ongoing sediment erosion from such sites. This, in turn, can cause sediment deposition and accumulation in other parts of the estuary, causing drying out of the riparian zone, loss of water column habitat and can result in premature mouth closure if the tidal flows are constricted enough. Changes in estuarine physical dynamics will lead to altered estuary productivity and biodiversity.

Stabilizing or constricting natural channel migration will also ultimately increase flood risk to riparian properties as it will prevent estuarine channels from increasing in dimension under high flow and flood regimes. Natural flood attenuation processes in estuaries can therefore be detrimentally impacted. During large floods (1:10 to 1:100 year) most estuaries scour down to -20 to -30 m if not constrained by bed rock. This scour channel is filled in by post-flood sediment. Constructing a hard structure in the EFZ will disrupt this process.

It should also be noted that floods (in the case of estuaries the cumulative flow of the entire catchment) pose a significant risk to pipe failure and the destruction of associated pipe infrastructure. Failure in turn represents a risk of altered estuarine habitat (i.e. hard structures now exists where only soft bedforms should occur) and water quality risk (pollution).

Sediment eroding from a construction site and backfilling of the trench can cause sediment deposition and build-up in other parts of the estuary, causing drying out of the riparian zone, loss of water column habitat and premature mouth closure if the tidal flows become constricted (loss of marine habitat access). Changes in estuarine physical dynamics will lead to altered estuary productivity and biodiversity.

6.2.7 KEY IMPACT 10: DETERIORATION OF ESTUARINE WATER QUALITY

Estuarine water quality may deteriorate as a result of sediment disturbance, the removal of estuarine vegetation, or pollution events, which could result in the following during the construction and operational phases:

- decreased pH as a result of disturbance of the anoxic sediment profiles characteristic of estuaries;
- increased Total Dissolved Solids (TDS);
- increased Total Suspended Solids (TSS);
- increased organic matter content, and
- increased nutrient content.

The changes in estuarine water quality can have knock-on effects on the biota. Increased nutrient loading can cause algal blooms/eutrophication in an estuary, and, in turn, result in anoxia or hypoxia. Increased turbidity in clear water systems in turn can also lead to smothering of primary producers, disrupted predator-prey relationships and fish and invertebrate kills.

Disturbance of estuarine water quality results in a change in ecological functioning, and increases the risk of introduction and establishment of invasive alien species (vegetation, invertebrates and fish). Currently, deteriorating water quality in KZN estuaries is contributing to the establishment of floating invasive macrophytes in pest proportions as well as the spread of the invasive snail *Tarebia granifera* (Appleton et al., 2009, Van Niekerk and Turpie, 2011). Once established invasive species out compete indigenous species and disrupt ecosystem processes.

The likelihood of impacts arising might be reduced as operational impacts will largely be limited to periods when pipeline maintenance is taking place. Some long-term impacts (for example increased suspended solids) might occur as a result of the placement of the pipelines themselves. Similar knock-on effects to the estuarine biota described above might also be expected during the operational phase.

6.2.8 KEY IMPACT 11: ESTUARINE HABITAT FRAGMENTATION AND LOSS OF CONNECTIVITY

Estuaries are highly connected aquatic systems, with river inflow and tidal flows maintaining important circulatory processes and ensuring catchment and marine connectivity. Road infrastructure and construction activities can disrupt processes that support this connectivity, affecting the migration of invertebrates and fish across freshwater-estuarine-marine systems. Estuaries serve as nursery habitats for both estuarine and marine fish, as well as act as migratory destinations or stops for many birds as well.

Thus, road infrastructure and pipeline construction pose a direct (e.g. road through EFZ, pipeline construction cutting through an estuary) and indirect (e.g. prolonged mouth closure due to infilling of open water area) threat to estuarine connectivity and can increase habitat fragmentation.

Permanent roads (mainly associated with pigging stations), the operational servitude and pipeline infrastructure, and maintenance activities associated with long-term operation will disrupt processes that support estuarine connectivity, affecting the migration of invertebrates and fish across freshwater-estuarine-marine systems.

Furthermore, the cumulative impact of pipeline construction on a multitude of estuaries along a stretch of coast and the collective risk it poses to estuarine connectivity and functioning is a concern. While individual impacts may appear insignificant, the cumulative resulting shifts in estuarine physical process, connectivity and production can have unacceptable consequences.

6.2.8.1 Mitigation (for all impacts to estuarine ecosystems)

Planning and pre-construction

AVOID

- **Avoid**, as far as possible:
  - construction or ROW clearance in the EFZ.
  - road infrastructure within the EFZ.
  - pipeline infrastructure such as Pipeline Intelligence Gauge Stations (PIGS) within the EFZ.
  - trenching within the EFZ.
  - pipe jacking within the EFZ as the ground water table is shallow and variable in estuaries and required burial depths cannot be achieved with elevated water tables.
  - pipeline infrastructure within the 1:100 year potential estuarine bed scouring levels.

Construction

MINIMISE / MITIGATE / MANAGE

- **Preserve natural estuarine indigenous vegetation** such as mangroves and saltmarsh.
- **Adopt below ground pipe construction methods** (HDD rather than trenching).

If pipeline infrastructure cannot be avoided within the EFZ, opt for:

- **HDD with pipe buried at bed rock level or to depths of greater than 1:100 year potential bed scouring levels** (estimated to be on average deeper than 20 m, (Personal communication, Prof G Basson, Stellenbosch University, 2018).
- Suspending pipelines over the EFZ, use existing infrastructure where possible, e.g. existing road and rail bridges[5].

Operations and maintenance

MINIMISE / MITIGATE / MANAGE

- **Regular control of IAPs**
- **Monitor the condition of the infrastructure** to ensure that there is no exposed section and ongoing erosion occurring.
- **Should the pipe become exposed, suspend operations, and establish the pipe at greater depths below ground** (using HDD) within 6 months, once sediment engineering studies have been done to confirm new burial depth.
- **Operational staff should be made aware of the sensitivities** of estuarine and freshwater environments.

[5] From a technical and safety perspective it is not feasible to suspend a gas transmission pipeline on an existing road or rail bridge.

Box 25: Rehabilitation of estuarine ecosystems

While disturbances from the construction of the pipeline may not be long-term, the restoration of altered habitat and recovery of invertebrate, fish and bird population can be prolonged (and is not assured). This depends on the overall complexity and health of the systems (Yu et al., 2010). There are no examples in South Africa of successful estuarine restoration following largescale degradation as has occurred in systems such as Nhlabane, Mhlanga, and St Lucia in KwaZulu-Natal. In most cases it has only been possible to restore a degree of functionality as reflected by the overall low estuarine health score.

Box 26: Other potential impacts to consider: conflict with conservation initiatives

The identification of areas outside of the formally protected areas and avoiding other areas of ecological importance in the biome is being identified as an important guideline for the identification of an appropriate route. While such an approach may be a rational one to the identification of such servitude from a contemporaneous perspective, such routing, depending upon where it is located does serve to constrain the expansion and connection of protected areas.

In the declaration of protected areas, it is clear that following the proclamation process, the pipeline and servitude itself will remain the property of a third party with differing management objectives to that of the conservation authority. In practical terms this state would mean that the requirement to maintain the servitude, conduct regular inspections, maintain access and undertake pipeline maintenance will create additional disturbances and constraints that may hinder the management of the protected area. For example, a case in point is the Opathe – Imfolozi corridor (IOCB), which is a long term initiative to link these two reserves for the benefit of land conservation and migration of larger fauna.

To avoid or reduce the likelihood of constraining protected area expansion, where this may apply, the utilisation or adherence to extensive buffer zones around protected areas may be successful mitigation as would the avoidance of placing the servitude between proximal protected areas, where connection and expansion is likely to form a conservation objective. Additionally, where feasible, it may be useful to align vegetation management programmes and objectives along the servitude with that of the conservation authority.

Box 27: The importance and effectiveness of Avoidance

Figure 65 illustrates the importance and effectiveness of using avoidance options as the favoured mitigation option. In this example, a patch of Northern Coastal Forest (near Park Rynie on the KZN South Coast) will be affected by a pipeline following the routings indicated in red. These forest patches will also be affected, but to a lesser degree, by the yellow alignment and completely unaffected by the green route alignment. In this case the forest patch is surrounded by sugar cane and any alignment outside of the forest footprint will significantly reduce the likelihood and consequences of potential impact, as such virually eliminating the risk of direct negative effects.

If avoidance cannot be achieved, other mitigation options may reduce the impacts slightly – such as plant rescue, revegetation and AIP management. Rehabilitation is not an option due to the pipeline being kept clear of deeper-rooted plants. As such, the forest cannot recover and will be permanently lost. This may not necessarily be a serious concern in other vegetation types however, the likelihood of remaining forests being disturbed (outside of protected areas) within the IOCB is considered to be highly likely. For this reason the reliance on rehabilitation based mitigation measures is cautioned, as in many cases they will not effectively mitigate the impact.

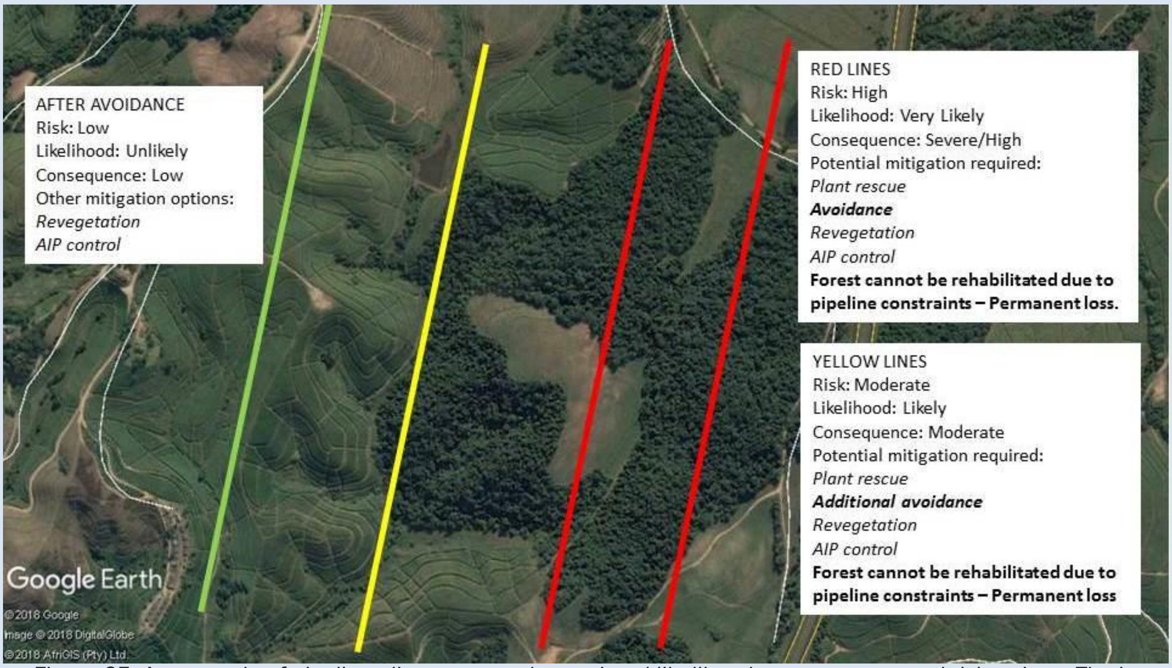


Figure 65: An example of pipeline alignments and associated likelihood, consequence and risk ratings. The image features a likely scenario, where forest habitat will be impacted within the IOCB.

7 RISK ASSESSMENT

7.1 Consequence levels

Table 27 presents the consequence levels assumed for this assessment for terrestrial, freshwater and estuarine ecosystems. This table should be perused when interpreting the risk assessment results (Section 7.2).

Table 27: Levels consequence that may result from impacts caused by gas pipeline development.

Slight	Moderate	Substantial	Severe	Extreme
TERRESTRIAL ECOSYSTEMS				
- No natural habitat is crossed. - <20 % loss of coverage of an isolated natural habitat, forest or azonal vegetation type or any level of clearance of agricultural land, secondary vegetation and exotic vegetation. - No loss of an isolated population and affected individuals can move away freely/trapped individuals can be rescued and survival is a certainty. - Degree of IAP infestation in catchment of footprint = < 0.5 %.	- Natural habitat impacted is of 'Low' sensitivity. - 20 to 40 % loss of coverage of an isolated natural habitat, forest or azonal vegetation type. - No loss of an isolated population but affected individuals have limited opportunity to move away/trapped individuals can be rescued and survival is >50 %. - Degree of IAP infestation in catchment of footprint = 0.5 - 2 % of footprint.	- Any impact of 'Medium' sensitivity habitat caused by project activities. - 40 to 60 % loss of coverage of an isolated natural habitat, forest or azonal vegetation type. - The loss of an isolated natural population where opportunity exists to rescue and relocate more than 50 % of the affected individuals/or the loss of individuals due to the disturbance will be partial/ trapped individuals can be rescued but the potential for survival is 50 %. - Degree of IAP infestation in catchment of footprint = 2 - 5 %.	- Any loss of ' High' sensitivity area caused by project activities. - 60 to 80 % loss of coverage of an isolated natural habitat, forest or azonal vegetation type. - The loss of an isolated natural population where opportunity exists to rescue and relocate up to 50 % of the affected individuals/trapped individuals can be rescued but the potential for survival is <50 %. - Degree of IAP infestation in catchment of footprint = 5 - 10%.	- Any loss of Very High' sensitivity areas caused by project activities. - 80 to 100 % loss of coverage of an isolated natural habitat, forest or azonal vegetation type. - The loss of an isolated natural population where no opportunity exists to save the individuals/trapped individuals cannot be rescued. - Degree of IAP infestation in catchment footprint > 10 %

Slight	Moderate	Substantial	Severe	Extreme
FRESHWATER ECOSYSTEMS				
- No loss of riparian, river and wetland ecosystems - Impacts do not change aquatic systems in way that is discernible - Resource ecostatus class would not change - Limited in extent: Site specific - Readily reversible at any time and/or of short-term duration	- Some degradation in resource status/possible change in class - Some modification of riparian, river and wetland ecosystems - Readily reversible once activity ceased - Impacts will be well within the tolerance levels or adaptive capacity of the users (NWA) relying on the resource	- Marked degradation in resource status - Marked change in riparian, river and wetland ecosystems - Surface water impacts potentially reversible once activity ceases - Beyond the adaptive capacity of the users relying on the resource	- Considerable degradation in resource status - Considerable change in riparian, river and wetland ecosystems - Surface water impacts reversible only with human intervention over decades	- Total loss of riparian and wetland vegetation - Total loss of flora and fauna that inhabit wetland/river ecosystems and adjacent buffer/fringe habitats - Significant degradation in resource status - Resource impacts irreversible and remediation impractical

Slight	Moderate	Severe	Extreme
ESTUARINE ECOSYSTEMS			
- Limited modification in all zones. - Ecosystem attributes largely unmodified and little influence on other uses. - Small changes in natural habitats and biota in the area may occur, but the ecosystem functions are essentially unchanged. - Natural conditions and the resilience and adaptability of biota are not compromised. - Characteristics of the resource are determined by unmodified natural disturbance regimes. - Modification is of a temporary nature.	- Some modification in sensitive zones - Moderate modification in non-sensitive zones. - A loss and change of natural habitat and biota occurs, but the basic ecosystem functions are still predominantly unchanged. - Moderate modification of the abiotic template and exceedance of the resource base occurs of a permanent nature.	- Moderate modification in sensitive zones. - High modification in non-sensitive zones. - Largely modified. A large loss of natural habitat, biota and basic ecosystem functions occurs, with risk of modifying the abiotic template and exceeding the resource base. - Loss of well-being and survival of intolerant biota. Associated increase in the abundance of tolerant species does not assume pest proportions. - Modification is of a permanent nature.	- High modification in sensitive zones. - Extreme modification in non-sensitive zones. - Seriously and critically modified with loss of natural habitat, biota and basic ecosystem functions. - Modification is of a permanent nature.

7.2 Risk assessment results

7.2.1 Terrestrial ecosystems

Table 28: Summary risk assessment of physical disturbance to soils, flora and fauna to biodiversity and ecology in the proposed gas pipeline corridors.

Impact	Study area & topic	Sensitivity Class	Without mitigation			With mitigation		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Key Impact 1: **Physical disturbance to soils, flora and fauna** **(including avifauna habitat)**	All Phases FYNBOS	Very High	Extreme	Very likely	Very high	Severe	Very likely	High
		High	Severe	Very likely	High	Severe	Very likely	High
		Medium	Substantial	Very likely	Moderate	Substantial	Very likely	Moderate
		Low	Moderate	Very likely	Low	Slight	Not likely	Very low
	All Phases ALBANY THICKET	Very High	Extreme	Very Likely	Very high	Severe	Likely	High
		High	Severe	Very Likely	High	Severe	Likely	High
		Medium	Severe	Likely	High	Substantial	Likely	Moderate
		Low	Moderate	Likely	Low	Moderate	Likely	Low
	All Phases IOCB	Very High	Substantial	Very Likely	High	Substantial	Likely	Moderate
		High	Moderate	Likely	Low	Moderate	Likely	Low
		Medium	Slight	Unlikely	Very Low	Slight	Unlikely	Very Low
		Low	Slight	Unlikely	Very Low	Slight	Unlikely	Very Low
	All Phases SAVANNA AND GRASSLAND	Very High	Severe	Very likely	High	Substantial	Very likely	Moderate
		High	Substantial	Very likely	Moderate	Moderate	Very likely	Low
		Medium	Moderate	Very likely	Low	Slight	Very likely	Very low
		Low	Slight	Very likely	Very low	Slight	Very likely	Very low
	All Phases SUCCULENT KAROO, NAMA KAROO, DESERT	Very High	Extreme	Very Likely	Very high	Severe	Very Likely	High
		High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
		Medium	Substantial	Very Likely	Moderate	Moderate	Likely	Low
		Low	Moderate	Very Likely	Low	Slight	Likely	Very low

Table 29: Summary risk assessment of establishment and spread of Alien Invasive Plants to biodiversity and ecology in the proposed gas pipeline corridors.

Impact	Study area & topic	Sensitivity Class	Without mitigation			With mitigation		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Key Impact 2: Establishment and spread of Alien Invasive Plants	All Phases FYNBOS	Very High	Extreme	Very likely	Very high	Severe	Not likely	Moderate
		High	Severe	Very likely	High	Substantial	Not likely	Moderate
		Medium	Substantial	Very likely	Moderate	Moderate	Not likely	Low
		Low	Moderate	Very likely	Low	Slight	Not likely	Very low
	All Phases ALBANY THICKET	Very High	Extreme	Very Likely	Very High	Severe	Likely	High
		High	Severe	Very Likely	High	Substantial	Likely	Moderate
		Medium	Severe	Very Likely	High	Substantial	Likely	Moderate
		Low	Substantial	Very Likely	Moderate	Moderate	Very unlikely	Low
	All Phases IOCB	Very High	Severe	Likely	High	Substantial	Not likely	Moderate
		High	Substantial	Likely	Moderate	Moderate	Not likely	Low
		Medium	Moderate	Likely	Low	Slight	Not likely	Very Low
		Low	Moderate	Likely	Low	Slight	Not likely	Very Low
	All Phases SAVANNA AND GRASSLAND	Very High	Severe	Very likely	High	Moderate	Likely	Low
		High	Substantial	Very likely	Moderate	Moderate	Likely	Low
		Medium	Moderate	Very likely	Low	Slight	Likely	Very low
		Low	Moderate	Very likely	Low	Slight	Likely	Very low
	All Phases SUCCULENT KAROO, NAMA KAROO, DESERT	Very High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
		High	Severe	Very Likely	High	Substantial	Very Likely	Moderate
		Medium	Substantial	Very Likely	Moderate	Moderate	Likely	Low
		Low	Moderate	Likely	Low	Slight	Likely	Very Low

Table 30: Summary risk assessment of ecosystem alteration and loss to biodiversity and ecology in the proposed gas pipeline corridors.

Impact	Study area & topic	Sensitivity Class	Without mitigation			With mitigation		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Key Impact 3: Ecosystem alteration and loss	Phases 1, 2, 7 FYNBOS High rainfall areas	Very High	Extreme	Very likely	Very high	Severe	Very likely	High
		High	Extreme	Very likely	Very high	Severe	Very likely	High
		Medium	Severe	Very likely	High	Substantial	Likely	Moderate
		Low	Substantial	Likely	Moderate	Moderate	Likely	Low
	Phases 5, 6, Inland FYNBOS Low rainfall areas	Very High	Extreme	Very likely	Very high	Extreme	Very likely	Very high
		High	Extreme	Very likely	Very high	Extreme	Very likely	Very high
		Medium	Severe	Very likely	High	Severe	Very likely	High
		Low	Severe	Very likely	High	Severe	Very likely	High
	All Phases SAVANNA AND GRASSLAND	Very High	Severe	Very likely	High	Substantial	Very likely	Moderate
		High	Substantial	Very likely	Moderate	Moderate	Very likely	Low
		Medium	Moderate	Very likely	Low	Slight	Very likely	Very low
		Low	Slight	Very likely	Very low	Slight	Very likely	Very low
	All Phases ALBANY THICKET	Very High	Severe	Likely	High	Substantial	Not likely	Moderate
		High	Severe	Likely	High	Substantial	Not likely	Moderate
		Medium	Moderate	Not Likely	Low	Slight	Very unlikely	Very Low
		Low	Moderate	Not Likely	Low	Slight	Very unlikely	Very Low
	All Phases IOCB	Very High	Severe	Likely	High	Severe	Likely	High
		High	Substantial	Likely	Moderate	Substantial	Likely	Moderate
		Medium	Slight	Likely	Very Low	Slight	Likely	Very Low
		Low	Slight	Very Likely	Very Low	Slight	Likely	Very Low
	All Phases SUCCULENT KAROO, NAMA KAROO, DESERT	Very High	Extreme	Very Likely	Very High	Severe	Very Likely	High
		High	Severe	Very Likely	High	Substantial	Likely	Moderate
		Medium	Substantial	Likely	Moderate	Moderate	Likely	Low
		Low	Moderate	Likely	Low	Slight	Not Likely	Very Low

7.2.2 Freshwater ecosystems

Table 31: Summary risk assessment of physical degradation and loss of freshwater ecosystems, reduction in aquatic habitat quality, altered hydrology, and water quality deterioration in the proposed gas pipeline corridors.

Impact	Study area & topic	Sensitivity Class	Without mitigation			With mitigation		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Physical degradation and loss of freshwater ecosystems	All Phases FRESHWATER ECOSYSTEMS	Very High	Extreme	Very Likely	Very High	Severe	Likely	High
		High	Severe	Very Likely	High	Substantial	Likely	Moderate
		Medium	Substantial	Very likely	Moderate	Slight	Not likely	Very Low
		Low	Moderate	Very Likely	Low	Slight	Likely	Very Low
Reduction in aquatic habitat quality	All Phases FRESHWATER ECOSYSTEMS	Very High	Substantial	Likely	Moderate	Moderate	Likely	Low
		High	Substantial	Likely	Moderate	Moderate	Likely	Low
		Medium	Moderate	Likely	Low	Slight	Likely	Very Low
		Low	Moderate	Likely	Low	Slight	Likely	Very Low
Altered hydrology	All Phases FRESHWATER ECOSYSTEMS	Very High	Substantial	Likely	Moderate	Substantial	Not likely	Moderate
		High	Substantial	Likely	Moderate	Moderate	Not likely	Low
		Medium	Moderate	Likely	Low	Slight	Not likely	Very Low
		Low	Slight	Likely	Very Low	Slight	Not likely	Very Low
Water quality deterioration	All Phases FRESHWATER ECOSYSTEMS	Very High	Extreme	Likely	High	Substantial	Likely	Moderate
		High	Severe	Likely	High	Moderate	Likely	Low
		Medium	Substantial	Likely	Moderate	Slight	Likely	Very Low
		Low	Moderate	Likely	Low	Slight	Likely	Very Low

7.2.3 Estuarine ecosystems

Table 32: Summary risk assessment of estuarine habitat destruction, altered physical and sediment dynamics, deteriorated water quality, and habitat fragmentation and loss of connectivity in the proposed gas pipeline corridors.

Impact	Study area & topic	Sensitivity Class	Without mitigation			With mitigation		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Estuarine habitat destruction	Phases 1, 2, 4, 5,7 ESTUARIES	Very High	Extreme	Very likely	Very high	Severe	Very likely	High
		High	Severe	Very likely	High	Moderate	Very likely	Moderate
		Medium	Moderate	Very likely	Moderate	Slight	Very likely	Low
		Low	Slight	Very likely	Low	Slight	Very likely	Low
Altered physical and sediment dynamics	Phases 1, 2, 4, 5,7 ESTUARIES	Very High	Extreme	Very likely	Very high	Extreme	Likely	Very high
		High	Severe	Very likely	High	Severe	Likely	High
		Medium	Moderate	Very likely	Moderate	Moderate	Likely	Moderate
		Low	Slight	Very likely	Low	Slight	Likely	Low
Deterioration of water quality	Phases 1, 2, 4, 5,7 ESTUARIES	Very High	Severe	Very likely	High	Moderate	Likely	Moderate
		High	Moderate	Very likely	Moderate	Slight	Likely	Low
		Medium	Slight	Very likely	Low	Slight	Likely	Low
		Low	Slight	Very likely	Low	Slight	Likely	Low
Habitat fragmentation and loss of connectivity	Phases 1, 2, 4, 5,7 ESTUARIES	Very High	Severe	Very likely	High	Moderate	Likely	Moderate
		High	Moderate	Very likely	Moderate	Slight	Likely	Low
		Medium	Slight	Very likely	Low	Slight	Likely	Low
		Low	Slight	Very likely	Low	Slight	Likely	Low
Note: The estuary risk assessment here assumes the pipeline construction method of Horizontal Directional Drilling (HDD) at shallow depths (< 20 m). Mitigation is unlikely to be possible / effective for isolated open trenches if placed in the EFZ, whilst HDD at depths greater than 20 m reduces the overall risk to estuaries to Moderate / Low. Avoidance of the EFZ greatly reduces/virtually negates risk to estuaries.								

7.3 Limits of Acceptable Change

7.3.1 Terrestrial ecosystems

Limits of acceptable change are driven as much by the values held by society as by ecological theory. But, for threatened species and ecosystems, it is clear from legislation and other measures that society has determined that adverse changes are not acceptable. There are specific policy and legal requirements for species nationally classified as CR, EN, VU and Protected and some provinces have their own lists of protected species with a similar status. These require that the pipeline development should not lead to the destruction of individuals of any CR species, and should set a goal of not destroying any individuals of any endangered or vulnerable species.

There are a number of national and provincial legislative requirements that relate to destruction of threatened ecosystems or habitats of threatened species (see Table 7). No further adverse changes should be allowed in threatened ecosystems assessed as CR or EN, and should be avoided if at all possible in those assessed as VU or which occur in protected areas.

The individual provincial Critical Biodiversity Assessments are the key basis for defining acceptable change for conservation features. They require that CBA1 and CBA2 areas must be avoided if at all possible. If these cannot be avoided appropriate Biodiversity Impact Assessments should be undertaken and mitigation management guidelines followed.

For example, the Western Cape conservation planners have provided some specific constraints for certain activities or developments – pipeline routes are not acceptable in CBA 1s in terms of the land-use guidelines in the WCBSP (Pool-Stanvliet et al., 2017). Similarly, crossing of formal protected areas will only be considered if the pipeline route is aligned with other linear features already in the protected area. These constraints are considered best practice and should be applied in all provinces.

Whilst species destruction or loss is important, the protection of key ecological processes is fundamental to the long-term viability of ecosystems (Driver et al., 2003; Pressey et al., 2003). Changes in disturbance regimes (e.g. fires, extreme rainfall or drought), pollination and other gene flows, gene pools of populations hydrological flows, dispersal and migration, could have detrimental impacts that extend far beyond the actual footprint of the development. The impacts on these processes is also the main reason why the fragmentation of communities, especially dividing remnants by separating them into pieces, by the pipeline route needs to be minimised. As a general rule, the smaller the remnant the more the processes are altered, especially those that maintain species populations (Cowling and Bond, 1991; Heijnis et al., 1999; Sandberg et al., 2016). The result is that fragmentation results in the loss of species, and the smaller the fragment the greater the loss. These losses can trigger further losses, and example being the loss of a pollinator which then results in the loss of plant species it pollinated and so the cascade can continue.

7.3.2 Aquatic Ecosystems

Legislation, policies and guidelines can be used to gauge Levels of Acceptable Change for aquatic ecosystems.

The NWA Preliminary Reserve Determination and Classification provides for setting desired state (“management class”) and measurable targets for water flow (“Reserve”), and water quality, habitat and biota in aquatic ecosystems (“Resource Quality Objectives”). Objectives for physical processes, water quality, habitat and higher biota are set under the NWA. These provide the benchmark conditions to maintain and/or restore aquatic ecosystems – freshwater and estuarine.

Where necessary, a water use licence (WUL) process will be required to authorise certain activities as per Section 21 of the NWA based on the DWS assessment requirements for all wetlands that occur within 500 metres of the gas pipeline development.

7.3.2.1 Water quality

The Water quality guidelines for South Africa provides guidance on limits of acceptable change for fresh- and marine water (DWAF, 1996; DWAF 1995).

7.3.2.2 Estuarine ecosystems

Emerging as most critical in the context of the present assessment is the Recommended Ecological Category, as defined by the NWA, which is set as desired state as part of the National Estuaries Biodiversity Plan (Turpie et al., 2011).

Where any construction or operation will occur within the Very High or High sensitivity areas the following permits may be required:

- Permits are likely to be required for any activities that require the discharge of an effluent into the EFZ under the ICM Act. This will set targets for use specific chemical in marine waters and sediments to protect ecosystems.
- Permits are likely to be required for any activities that may affect listed Endangered and/or Vulnerable species, ToPs, and/or regionally protected fauna and flora.

1 Table 33: Suggested limits of acceptable change for biodiversity and ecosystems.

Variable	Threat Status	Acceptable Change
Vegetation / Ecosystem Types	CR	▪ No nett Loss of Vegetation/Ecosystem Type
	EN	▪ No nett Loss of Vegetation/Ecosystem Type
	VU	▪ No more than 1% of the remaining extent of the vegetation type. ▪ No loss resulting in the vegetation type being elevated to a higher threat status
	NT	▪ No more than 5% of the remaining extent of the vegetation type ▪ No loss resulting in the vegetation type being elevated to a higher threat status
Plant SCC	CR	▪ No nett Loss of plant SCC
	EN	▪ No nett Loss of plant SCC
	VU	▪ No more than 1% of the remaining local population ▪ No loss resulting in a species being elevated to a higher threat status
	NT	▪ No more than 5% of the remaining local population ▪ No loss resulting in a species being elevated to a higher threat status
Fauna SCC	CR	▪ No nett loss of fauna SCC or resulting in a SCC being elevated to a higher threat status. Should sections of the planned Gas Pipeline routes transect the known Extent of Occurrence / distribution of a fauna SCC, a taxon-specific specialist should be appointed to confirm the sensitivity and assess the significance of potential impacts on that SCC. The impact assessment process must prove to the relevant competent authority that the proposed development will not have an unacceptable negative impact on SCC populations, both locally and regionally. Any identified impacts should be avoided or mitigated. All mitigation measures from the specialist study are to be incorporated into the Environmental Management Programme. A South African Council for Natural Scientific Professions (SACNASP) accredited zoologist must conduct the impact assessment in accordance with the NEMA regulations.
	EN	
	VU	
	Data Deficient	
AIP invasion	All sensitivity categories	▪ No invasion of adjacent natural habitats
Soil erosion	All sensitivity categories	▪ No long-term, irreversible soil erosion
Loss of CBAs	CBA1	▪ No loss of irreplaceable CBAs ▪ No loss resulting in it no longer being possible to meet biodiversity targets
Marine and Fresh Water quality		▪ See Water quality guideline for South Africa - http://www.dwa.gov.za/IWQS/wq_guide/index.asp
CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; SCC = Species of Conservation Concern; CBA = Critical Biodiversity Area		

8 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

In addition to the mitigation and management actions recommended in Section 6, the following key best practice guidelines and monitoring requirement recommendations (summarised from the individual specialist investigations attached as annexures to this chapter) need to be taken into account.

8.1 Planning and pre-construction

Avoidance of areas of very high sensitivity, and as far as possible avoiding areas of high sensitivity, has the potential to greatly reduce impacts on terrestrial and aquatic ecosystems and associated fauna and flora.

- The following areas should be avoided as far as possible:
    - Areas of critical biodiversity or conservation importance;
    - Steep slopes where erosion may be more prevalent and inhibit rehabilitation success;
    - Avoid estuaries (EFZ); if unavoidable, establish the appropriate depth for pipeline construction (through HDD) to reduce risk to the environment and the infrastructure on a case-by-case (estuary crossing – by – estuary crossing) basis.
    - Wetlands and watercourses (and their associated buffers).
- Plan the route to follow, as far as possible, existing disturbance corridors.
- Develop robust pre-construction environmental baseline, including identified indicator species as reference for monitoring;
- Where wetlands and watercourses cannot be avoided, a detailed desktop investigation should be followed to determine whether the gas pipeline alignment and development footprint can avoid the actual freshwater ecosystems (i.e. wetland and river habitats) and associated buffers.
- Planning stage avoidance of high-threat status ecosystems, as well as fauna and flora species populations of conservation concern is required.
    - In many areas, the known extent of occurrence (EoO) / distribution range of SCC are not well known and as such, the planning phase should make provision for flexibility in determining the final pipeline alignment to avoid locally sensitive features and populations of SCC.
    - Should sections of the planned gas pipeline route transect the known EoO / distribution of an SCC, a taxon-specific specialist should be appointed to confirm the sensitivity and assess the significance of potential impacts on that SCC.
    - The impact assessment process must prove to the relevant competent authority that the proposed development will not have an unacceptable negative impact on SCC populations, both locally and regionally.
    - Any identified impacts should be avoided or mitigated. All mitigation measures from the specialist study to be incorporated into the EMPr. A SACNASP accredited botanist and zoologist must conduct the impact assessment in accordance with the NEMA regulations.
- The final gas pipeline route should be checked in the field by the appropriate accredited specialists and at the appropriate time of year. In the winter rainfall areas, all fieldwork for flora should take place from late July through to mid-September depending on the exact timing of rainfall. In the summer rainfall areas, fieldwork should take place following good rainfall and growth of the vegetation. In most areas this is usually late summer to early autumn (February to April).
- Pre-construction walk-through and on-site assessment by a SACNASP accredited botanist and zoologist of the final pipeline route is mandatory to identify any features that should be avoided or buffered from impact, and to identify and locate any plant and animal SCC that should be subject to search and rescue prior to construction.
- Where high sensitivity areas cannot be avoided and there is significant habitat loss in these areas, an offset study should be conducted to ascertain whether an offset is an appropriate mechanism to offset the impact on the high sensitivity area. This should include an identification of offset receiving areas as well as an estimate of the required extent of the offset and the degree to which the offset would be able to compensate for the assessed impacts.

8.2 Construction

- Limit disturbance footprint;
- The construction operating corridor should be clearly delimited and demarcated with construction tape or similar markers to limit construction activity and disturbance to the pipeline corridor.
- Temporary lay-down areas should be located within previously transformed areas or areas that have been identified as being of low sensitivity. These areas should be rehabilitated after use.
- Implement sound “housekeeping” of construction activities;
- Proper topsoil storage, for minimal timespans;
- Minimise soil erosion and IAP establishment risk;
- Relocate threatened species based on expert advice;
- Construction activities should only occur in appropriate seasons (e.g. avoid breeding/migrating season of threatened fauna, avoid peak rain seasons);
- Limit the duration of open trenches;
- Regular checks of open trenches to rescue trapped animals;
- Environmental awareness of construction workers;
- Measures should be taken to prevent and limit poaching of fauna and harvesting of flora by construction crews or other people accessing the pipeline route.
- All construction vehicles should adhere to a low speed limit (30km/h for trucks and 40km/h for light vehicles) to avoid collisions with susceptible species such as snakes and tortoises.
- All hazardous materials should be stored in the appropriate manner to prevent contamination of the site. Any accidental chemical, fuel and oil spills that occur at the site should be cleaned up in the appropriate manner as related to the nature of the spill.
- Appoint and involve an ECO to provide oversight and guidance to all construction activities, as well as ensure full consideration and implementation of the Environmental Management Programme.

8.3 Operations and maintenance

- If parts of the pipeline such as compressor stations (which is not part of the scope of the assessment) need to be lit at night for security purposes, this should be done with low-ultraviolet (UV) type lights (such as most Light Emitting Diodes (LEDs)), which do not attract insects.
- If any parts of the pipeline, or any work area in the vicinity of the pipeline need to be fenced, then no electrified strands should be placed within 30 cm of the ground as some species such as tortoises are susceptible to electrocution from electric fences as they do not move away when electrocuted but rather adopt defensive behaviour and are killed by repeated shocks.
- All vehicles accessing the pipeline should adhere to a low speed limit (30 km/h max) to avoid collisions with susceptible species such as snakes and tortoises.
- Oils, fuels and other hazardous materials required for machine and vehicle maintenance and repair are to be securely stored to prevent spill and contamination during operation and maintenance of the gas pipeline infrastructure.
- Access to the pipeline servitude should be restricted to service and maintenance staff and affected landowners.
- Monitor vegetation recovery using photographic methods;
- Ongoing IAP and erosion management.
    - An annual check with follow-up rehabilitation and remediation should be sufficient in most areas. It is important to note that erosion can be severe in semi-arid environments due to the occasional occurrence of heavy showers and the lack of sufficient vegetation cover to protect the soil or slow runoff, with the result that occasional high-risk erosion events can cause large amounts of damage.

8.4 Post-construction and rehabilitation

- Clear rehabilitation targets should be set for each area based on the background perennial vegetation cover.
- All species used in rehabilitation should be locally occurring, indigenous, perennial species. A mixture of different functional type species is recommended.
- No fertilizers or irrigation should be applied during rehabilitation as this is likely to lead to a green flush after rain and failure of perennial species to establish in competition with annuals and ephemerals.
- There should be annual monitoring and follow-up action on IAP occurrence and erosion.
- Undertake rehabilitation processes as soon as possible (i.e. in a rolling manner – after a section of pipeline has been installed).
- Rehabilitation and post-closure measures would be mostly required for ROWs within or in proximity to freshwater ecosystems, as well as for areas degraded by access routes, operation of vehicles/heavy machinery, and infestation of servitudes by IAPs. In general, the following processes/procedures as recommended by James and King (2010):
    - Initiation – to assemble the rehabilitation project team/specialists, identify problem/target areas, establish reference condition and desired states, and define rehabilitation targets and objectives;
    - Planning- to account for constraints, budgeting and timeframes;
    - Analysis – evaluation of alternatives and strategies to achieve the objectives, and to develop preliminary designs and inform feasibility;
    - Implementation – a including detailed engineering designs, construction and inspections; and
    - Monitoring – to establish need for maintenance and repair of interventions, as well as provide feedback regarding success and failure.

Box 28: Environmental rehabilitation in arid areas

Arid areas are very difficult to rehabilitate with a variety of constraints limiting success. In most cases topsoil management is a key factor as the soils deeper down may have a very high pH, be salt- or metal-laden, be very nutrient poor or otherwise inhospitable to plant establishment. Furthermore, in most instances, the restoration of pre-construction levels of diversity is not a realistic goal and the rehabilitation should focus on the establishment of an ecologically functional cover of locally-occurring species to protect the soil and provide some cover for fauna.

A reasonable rehabilitation target for arid areas would be 60% of the vegetation cover of adjacent indigenous vegetation achieved after five years.

8.5 Monitoring requirements

- Populations of key fauna and flora SCC, of which the known extent of occurrence or distribution range was identified and confirmed by a SACNASP accredited botanist and zoologist during the planning (pre-construction) phase and which are being transected by the planned gas pipeline route, should be monitored throughout construction and operation to ensure that these SCC are not being poached or otherwise negatively impacted by the presence and operation of the gas pipeline.
    - Monitoring frequency depends to some extent on the longevity of a specific species, but should also be informed by its threat status and the consequences of not identifying unacceptable negative impacts beforehand.
    - Any identified impacts should be avoided or mitigated. As such, the following basic monitoring schedule is proposed – Pre-construction, Post-construction and every 3-5 years during operation depending on the species.

- The successful establishment and persistence of plant species of high conservation concern translocated during the search and rescue should be monitored for at least five years after construction is completed. An appropriate frequency would be a year after translocation and every second year thereafter.
- Develop robust pre-construction environmental baseline, including identified indicator species as reference for monitoring;
- Biodiversity monitoring programme should consider:
  - Vegetation rehabilitation progress;
  - State of rare/endangered vegetation types within reasonable proximity to the infrastructure;
  - Overland flow patterns of water (runoff), sedimentation and erosion, especially on steep slopes and near watercourses.
- Conduct monitoring of terrestrial ecosystems in spring and autumn seasons;
- Use of Geographic Information Systems, spatial data and aerial photography / satellite imagery is recommended as a key tool for long-term monitoring and management.
- Estuaries:
  - Direct impacts to the EFZ require monitoring of:
    - Hydrodynamics;
    - Sediment dynamics;
    - Water Quality;
    - Macrophytes;
    - Microalgae;
    - Invertebrates;
    - Fish;
    - Birds.
  - Indirect impacts to the EFZ require monitoring of:
    - Water Quality;
    - Microalgae;
    - Invertebrates;
    - Fish.

- Sites/areas where freshwater ecosystems are likely to be affected by gas pipeline development, according to the various phases of development (including rehabilitation), appropriate measures of monitoring should be considered, including:
  - Upstream and downstream biomonitoring to include appropriate indicators/measures of assessing rivers (e.g. diatoms, water quality/clarity, macro-invertebrates using the SASS5 method, instream and riparian habitat using the Index of Habitat Integrity (IHI) method) and wetland habitats (e.g. WET-Health and WET-EcoServices) of a potential impact is recommended at suitable sites to be determined in-field by a specialist.
  - Monitoring/sampling is to be conducted by suitably qualified specialists (e.g. DWS accredited SASS 5 practitioners) with sufficient experience in assessing aquatic ecology and water quality;
  - A single sampling event is recommended prior to construction taking place to serve as a reference condition;
  - Monthly monitoring is recommended for the duration of construction to evaluate trends;
  - Biannual monitoring is recommended thereafter during the operation phase, up to the point in time when the monitoring can establish that the systems are stable;
  - Fixed point photography to monitor changes and long term impacts.

9 GAPS IN KNOWLEDGE

9.1 Desert, Succulent Karoo, Nama Karoo

There is a paucity of baseline information for the Desert, Succulent Karoo and Nama Karoo biomes as the area is generally poorly sampled and species are sparsely distributed. Resultantly, extensive areas will have no records for fauna or flora in the existing biodiversity databases. Areas with generally good records include the national parks, along the main access roads and near to towns and other popular tourist destinations. As a result, all areas should receive detailed baseline data collection in the appropriate season to inform the final pipeline routings.

9.2 Fynbos

There have been very few studies of root systems in Fynbos, Renosterveld and Strandveld plant species but the shrubs, especially the tall shrubs, can have root systems that reach depths of 2-3 m or more (Cramer et al., 2014; Le Maitre et al., 1999; Smith and Higgins, 1992).

Furthermore, there exists insufficient knowledge at present to determine whether or not specific treatments fire should be given as part of the rehabilitation process to stimulate germination of Fynbos species.

9.3 Albany Thicket

The following gaps in knowledge have been identified in terms of the Albany Thicket biome:

- Limited success of techniques of rehabilitation for degraded thicket types;
- Extent, stability and distribution of rare and endangered thicket fauna and flora species;
- Differential responses of sensitive biodiversity features to pre- and post-construction activities, and how best to mitigate;
- Impact of climate change on the drivers of changes impacting on rare vegetation types, particularly in transformed and degraded landscapes of the Albany Thicket biome; and
- Uncertainty around long-term fragmentation impacts of long linear structures on terrestrial fauna.

9.4 Indian Ocean Coastal Belt

Faunal records are limited to primarily, conservation areas and areas where monitoring is safe to undertake e.g. gated residential estates, protected areas. As such, the presence of larger fauna can only effectively be correlated with habitat, rather than observation. This situation clearly skews the data, rendering its use at a fine scale level of spatial analysis, dubious. The data is however useful for supporting the importance of certain intact habitat, where there is a correlation.

Transformation across the IOCB region is both rapid and generally pervasive. Such a state renders the accuracy of such spatial information to be of limited temporal duration. In this regard the importance of site specific evaluations during the impact assessment and detailed planning phases is very high.

9.5 Grassland and Savanna

Location of specific sites with rare and threatened species is based on relatively crude assessments that are not of sufficient detail for detailed route planning and would require onsite inspections. In many cases the location of rare and threatened species is recorded at the level of a ¼ degree square (1:50 000 map sheet). In many cases the species is likely to occur only within specific habitat types within this broad location and specialist input will be required. Development of habitat specific location maps could increase the usability of this data in the future.

Core to this assessment is the use of the provincial biodiversity plans. This assessment is therefore subject to all the gaps in knowledge that underpinned the provincial plans.

9.6 Avifauna

The potential impact of pipeline developments on avifauna in South Africa is not as well studied as for example the impacts of powerline networks or wind energy. The reasons for that could be that the impacts on avifauna may on average not be as significant as those associated with powerlines and wind energy.

Areas where the lack of knowledge is a constraint are the following:

- It is unclear how some Red Data species will react to the disturbance associated with the construction of pipelines and associated infrastructure - more scientifically verifiable knowledge of the disturbance thresholds of these species would improve predictive capabilities.
- The population sizes of many Red Data species are not well known. The impact of nestling mortality on the population is therefore difficult to assess.

9.7 Bats

- No publicly available studies investigating the impacts of gas pipeline development on bats. Potential adverse effects based on other human-induced landscape-level changes can be inferred only.
- Bat roost data is limited to data voluntarily supplied by bat specialists and published literature. The co-ordinates provided by some of the published sources are old and/ or they are only provided in degrees and minutes, therefore there are potentially accuracy concerns.
- It would be more accurate to map “Area of Occurrence” (AoO) rather than “Extent of Occurrence” (EoO) for species of conservation importance, but this level of detail was beyond the scope of this high level SEA.

9.8 Freshwater ecosystems

The following gaps in knowledge are presented as follows in terms of influencing the freshwater assessment:

- The study was developed using available spatial data covering freshwater habitats and species, and these datasets are not exhaustive across the entire study area. Species occurrence data in particular is only based on known records, and thus does not necessarily account for the true distribution of species. Furthermore, occurrence data for certain taxonomic groups is poorly represented, particularly in certain corridors (e.g. Odonata within the Phase 6 and Inland corridors, as well as in large parts of the Phase 3 and 7 corridors).
- Complete data of wetland habitat that includes characterisation of wetland condition and HGM units, was not available for the purpose of determining threat status of wetlands based on HGM type. The conservative approach that was adopted in based on the threat status derived for the broader-scale wetland vegetation groups.
- Species-level data and conservation assessments is limited for certain taxanomic groups, notably aquatic invertebrates. Thus, in the case of invertebrates (excluding Family: Odonata), only family-level data was used.
- This study does not make use of any ground-truthing and verification as a means to validate system importance and sensitivity, and therefore assumes that the data obtained is accurate and representative of the on-the-ground situation. The precautionary approach is to ensure that ground-truthing and infield assessments will be required once the gas pipeline alignments have been established (including alternatives), especially in the more sensitive areas. This will be particularly important to ensure that the extent/boundary of freshwater habitats (including the adjacent buffer zones), as well as the presence of conservation important species, is confirmed firstly, then avoided and/or appropriately managed.
- As with any large-scale project the likelihood for cumulative impacts developing are potentially great, especially when considering the knock-ons effects that gas development could have on

other developments that in-turn also may impact on freshwater systems. This study obviously does not account for full extent of cumulative impacts linked both directly gas development (e.g. gas-to-power and storage facilities) and indirectly (through other developments that respond to the distribution of gas as a source of power.

9.9 Estuarine ecosystems

The most critical information gap for the purposes of confident assessment of estuarine impacts relates to the site specific sedimentary processes occurring within each potentially affected estuary. Without this detailed estuary-specific sediment process understanding it is difficult to assess likelihood and consequences of impacts arising from planned structures across and under estuaries. Most important in this regard are issues relating to planned pipelines obstruction to flows during floods and causing long-term estuary bed transformation and infilling. Estuarine physical processes are highly dynamic requiring detailed information over long planning horizons, e.g. understanding the impacts of a 1:100 year flood.

Once a specific project has been determined (based on market demand and the securing of a source of gas), the following detailed information is required at each system in the event an estuary is crossed. This information would be required prior to the construction of the gas pipeline, to inform the depth of HDD, e.g. 20m below bed level and for the actual site specific assessments.

- Estuary bathymetry of the entire system corrected to mean sea level (not just at the crossing site);
- Information on the sediment structure (i.e. sediment core samples taken to bed rock or at a minimum 20 m depth at small to medium sized systems and at a depth of > 20 m at estuaries with a high MAR);
- Estimates of daily sediment loads from the catchment;
- Hourly flood hydrographs of the 1:5, 1:10, 1:20, 1:50 and 1:100 year flood to determine the scouring potential at each system;
- Detailed flood and sediment modelling to determine the degree to which the estuary may scour below its current bed during a flood (before infilling occurs again).

10 REFERENCES

Acocks, J. P. H. 1953. Veld types of South Africa. *Memoirs of the Botanical Society of South Africa,* 28:1–192.

Adams, J, Fernandes, M, & Riddin, T. 2018. Chapter 6: Estuarine Habitat extent and trend. South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol4/A (Draft Report).

Allsopp, N. 1999. Effects of grazing and cultivation on soil patterns and processes in Namaqualand. *Plant Ecology*, 142: 179–187.

Anderson, B., Allsopp, N., Ellis, A.G., Johnson, S.D., Midgley, J.J., Pauw, A., Rodger, J.G. 2014. Biotic interactions. In: Allsopp, N., Colville, J.F., Verboom, G.A. (*Eds*.), Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region. Oxford University Press, Oxford, UK, pp. 224–247.

Appleton, C.C., Forbes, A.T. & Demetriades, N.T. 2009. The occurrence, bionomics and potential impacts of the invasive freshwater snail *Tarebia granifera* (Lamarck, 1822) (Gastropoda: Thiaridae) in South Africa. *Zoologische Medelingen Leiden,* 83(4):525-536.

Armstrong, A. Personal communications regarding invertebrates in grasslands with SC Bundy, November 2017

Atkinson, D. 2007. People-centred environmental management and municipal commonage in the Nama Karoo. *Development of Southern Africa*, 25(4): 707–724.

Badía, D., López-García, S., Martí, C., Ortíz-Perpiñá, O., Girona-García, A. and Casanova-Gascón, J. 2017. Burn effects on soil properties associated to heat transfer under contrasting moisture content. *Science of the Total Environment*, 601:1119-1128.3

Basson, G.R. 2018. Short discussion on scouring levels of South African estuaries. Personal communication. Stellenbosch University.

Basson, GR, Bosman, DE & Vonkeman JK. 2017. Proposed new uMfolozi River N2 Road Bridge. Hydrodynamic modelling of scour and hydrodynamic forces. Stormwater Hydraulics, STIAS, 10 Marais Road, Stellenbosch University

Bates, M.F., Branch, W.R., Bauer, A.M., Burger, M., Marais, J., Alexander, G.J. and De Villiers, M.S. (Eds.). 2014. Atlas and Red List of the Reptiles of South Africa, Lesotho and Swaziland. Suricata Series No. 1. South African National Biodiversity Institute, Pretoria.

Beck, J.S., Kemp, A., Theron, A.K., Huizinga, P. & Basson, G.R. 2004. Hydraulics of estuarine Sediment Dynamics in South Africa: Implications for Estuarine Reserve Determination and the Development of Management Guidelines. WRC Report No. 1257/1/04. Pretoria, South Africa.

Bergh, N.G., Verboom, G.A., Rouget, M., Cowling, R.M., 2014. Vegetation types of the Greater Cape Floristic Region. In: Allsopp, N., Colville, J.F., Verboom, G.A. (Eds.), Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region. Oxford University Press, pp. 1–25.

Blignaut, J., de Wit, M., Milton, S., Esler, K., Le Maitre, D., Mitchell, S., Crookes, D., 2013. Determining the economic risk/return parameters for developing a market for ecosystem goods and services following the restoration of natural capital: A system dynamics approach. Volume 1. Main Report. Report No. 1803/2/13, Water Research Commission, Pretoria.

Boehm, A.B., Ismail, N.S., Sassoubre, L.M. & Andruszkiewicz, E.A. 2017. Oceans in Peril: Grand Challenges in Applied Water Quality Research for the 21st Century. *Environmental Engineering Science,* 34: 3-15.

Bond, W.J. & Slingsby, P., 1990. Collapse of an ant-plant mutualism: the Argentine ant, Iridomyrmex humilis, and myrmecochorous Proteaceae. *Ecology,* 65:1031–1037.

Bond, W.J., Vlok, J. & Viviers, M., 1990. Variation in seedling recruitment of Cape Proteaceae after fire. *Journal of Ecology*, 72:209–221.

Borja, A., Elliott, M., Snelgrove, P.V.R., Austen, M.C., Berg, T., Cochrane, S., Carstensen, J., Danovaro, R., Greenstreet, S., Heiskanen, A., Lynam, C.P., Mea, M., Newton, A., Patricio, J., Uusitalo, L., Uyarra, M.C. & Wilson, C. 2017. Bridging the Gap Between Policy and Science in Assessing the Health Status of Marine Ecosystems. *Frontiers in Marine Science,* 4:32.

Bradshaw, P.L., Cowling, R.M. 2014. Landscapes, rock types, and climate of the Greater Cape Floristic Region. In: Allsopp, N., Colville, J.F., Verboom, G.A. (Eds.), Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region. Oxford University Press, pp. 26–46.

Breen, C.M., Quinn, N.W. and Mander, J.J. 1997. Wetlands conservation and management in southern Africa: Summary of the SADC wetlands conservation survey reports. IUCN ROSA. Harare.

Bromilow, C. 2010. Problem Plants and Alien Weeds of South Africa. 3rd ed. Briza Publications, Pretoria.

Bull, J.W., Suttle KB, Gordon, A., Avinder, N., Singh, J., & Milner, G. 2013. Biodiversity offsets in theory and practice. Fauna & Flora International. *Oryx*, 1–12.

Carrick, P.J., Erickson, T.E., Becker, C.H., Mayence, C.E., Bourne, A.R. 2015. Comparing ecological restoration in South Africa and Western Australia: the benefits of a 'travelling workshop. *Ecological Management & Restoration*, 16:86–94.

Carrick, P.J., Krüger, R. 2007. Restoring degraded landscapes in lowland Namaqualand: Lessons from the mining experience and from regional ecological dynamics. *Journal of. Arid Environments*, 70:767–781.

Child M.F., Roxburgh L, Do Linh San E, Raimondo D, Davies-Mostert H.T. (Eds.). 2016. The Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa.

Colloty, B.M., Adams, J.B. & Bate, G.C. 2002. Classification of estuaries in the Ciskei and Transkei regions based on physical and botanical characteristics. *South African Journal of Botany,* 68: 312-321.

Colville, J.F., Potts, A.J., Bradshaw, P.L., Measey, G.J., Snijman, D., Picker, M.D., Procheş, Ş., Bowie, R.C.K., Manning, J.C. 2014. Floristic and faunal Cape biochoria: do they exist? In: Allsopp, N., Colville, J.F., Verboom, G.A. (*Eds*.), Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region. Oxford University Press, Oxford, UK, pp. 73–92.

Cooper, J.A.G. 2001. Geomorphological variability among microtidal estuaries from the wave-dominated South African coast. *Geomorphology*, 40: 99-122.

Cowan, G.I. 1995. Wetlands of South Africa. Department of Environmental Affairs and Tourism. Pretoria.

Cowling, R.M. 1983. Phytochorology and vegetation history in the south-eastern Cape, South Africa. *Journal of Biogeography*, 10: 393-419.

Cowling, R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. *Bothalia* 15: 175–227.

Cowling, R.M. and Roux, P.W. 1987. The Karoo Biome: a preliminary synthesis. Part 2 – Vegetation and history. FRD, Pretoria.

Cowling, R.M., Bond, W.J. 1991. How small can reserves be? An empirical approach in Cape Fynbos, South Africa. *Biological Conservation*, 58:243–256.

Cowling, R.M., Esler, K.J. and Rundel, P.W. 1999. Namaqualand, South Africa – an overview of a unique winter-rainfall desert ecosystem. *Plant Ecology,* 142: 3–21.

Cramer, M.D., West, A.G., Power, S.C., Skelton, R., Stock, W.D. 2014. Plant ecophysiological diversity. In: Allsopp, N., Colville, J.F., Verboom, G.A. (*Eds*.), Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region. Oxford University Press: Oxford. pp. 248–272.

Cramer, S. 2016. Uranium Mining Threatens the Karoo. Available at http://karoospace.co.za/uranium-mining-threatens-the-karoo/

CSIR (Council for Scientific and Industrial Research). 2017. Protecting South Africa's strategic water source areas. https://www.csir.co.za/protecting-south-africa%E2%80%99s-strategic-water-source-areas. Date accessed: Feb. 2019.

Davies, B. & Day, J. 1998. *Vanishing Waters*. University of Cape Town Press, Cape Town, South Africa.

DEA (Department of Environmental Affairs) 2012. South African Water Quality Guidelines for coastal waters. Volume 2: Guidelines for recreational use.

DEA. 2019. Renewable Energy Data Release Schedule 2019 – 2020. Directorate: Enterprise Geospatial Information Management (EGIM), Department of Environmental Affairs (DEA), Pretoria. Available at https://egis.environment.gov.za/.

Dean, W.R.J. 2002. Distribution patterns and habitat of avifauna in the thicket biome. Terrestrial Ecology Research Unit Report No. 41. 32pp. University of Port Elizabeth

Dean, W.R.J. and Milton, S.J. 2019. The dispersal and spread of invasive alien Myrtillocactus geometrizans in the southern Karoo, South Africa. *South African Journal of Botany,* 121: 210–215.

Dean, W.R.J., Seymour, C.L. and Joseph, G.S. 2018. Linear structures in the Karoo, South Africa, and their impacts on biota. *African Journal of Range and Forage,* Science 35:3-4, pp223-232.

DEDEAT (Department of Economic Development, Environmental Affairs and Tourism) 2017. Eastern Cape Biodiversity Conservation Plan Handbook. Department of Economic Development and Environmental Affairs (King Williams Town). Compiled by G. Hawley, P. Desmet and D. Berliner. Draft version, December 2017.

Desmet, P.G. and Cowling, R.M. 1999. The climate of the Karoo, a functional approach. In: Dean, W.R.J. and Milton, S.J. (Eds.). The Karoo: Ecological Patterns and Processes. Cambridge University Press, Cambridge.

Dettinger, M.D. & Diaz, H.F. 2000. Global Characteristics of Stream Flow Seasonality and Variability. *Journal of Hydrometeorology,* 1: 289-310.

Driver, A., Cowling, R.M., Maze, K. 2003. Planning for Living Landscapes Perspectives and Lessons from South Africa. Center for Applied Biodiversity Science, Conservation International, Washington DC.

Driver, A., Sink, K.J., Nel, J.L., Holness, S.H., Van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P.A., Harris, L. and Maze, K. 2012. National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecosystems. Synthesis report. South African National Biodiversity Institute & Department of Environmental Affairs, Pretoria.

DWAF (Department of Water Affairs and Forestry) 1995. South African water quality guidelines for coastal waters. Pretoria: Department of Water Affairs. Available at http://www.dwa.gov.za/IWQS/wq_guide/index.asp.

DWAF. 1996. South African water quality guidelines for fresh water. Pretoria: Department of Water Affairs. Available at http://www.dwa.gov.za/IWQS/wq_guide/index.asp

Emanuel, B.P., Bustamante, R.H., Branch, G.M., Eekhout, S. & Odendal, F.J. 1992. A zoogeographic and functional approach to the selection of marine reserves on the west coast of South Africa. *South African Journal of Marine Science,* 12: 341-354.

Esler, K.J., Milton, S.J. 2006. Towards best practice in management of road, powerline and rail reserves. Stellenbosch.

Esler, K.J., Milton, S.J., Dean, W.R.J. 2010. Karoo Veld - Ecology and Management. Briza Press, Pretoria.

Esler, K.J., Pierce, S.M., de Villiers, C. 2014. Fynbos: Ecology and Management. Briza Publications, Pretoria.

Fairbanks, D.H.K., Thompson, M W M., Vink, D. E., Newby, T. S., van den Berg H.M. and Everard, D. A. 2000. The South African land-cover characteristics database: a synopsis of the landscape. *South African Journal of Science,* 96:69-82.

Fey, M., Hughes, J., Lambrechts, J., Milewski, A., Mills, A. 2010. Soils of South Africa. Cambridge University Press: Cambridge.

Forman, R. T. T., & Godron, M. 1986. Landscape ecology. pp. 121–155. New York: Wiley

Gaertner, M., Fisher, J., Sharma, G., Esler, K. 2012a. Insights into invasion and restoration ecology: Time to collaborate towards a holistic approach to tackle biological invasions. NeoBiota 12, 57.

Gaertner, M., Nottebrock, H., Fourie, H., Privett, S.D.J., Richardson, D.M. 2012b. Plant invasions, restoration, and economics: Perspectives from South African fynbos. Perspect. Plant Ecol. Evol. Syst. 14, 341–353.

Geldenhuys, C.J. 1994. Bergwind fires and the location pattern of forest patches in the southern Cape landscape, South Africa. J. Biogeogr. 21, 49–62.

Gillanders, B.M. 2005. Using elemental chemistry of fish otoliths to determine connectivity between estuarine and coastal habitats. *Estuarine, Coastal and Shelf Science,* 64: 47-57.

Griffiths, M.H., 1997. Management of South African dusky kob Argyrosomus japonicus (Sciaenidae) based on per-recruit models. *South African Journal of Marine Science*, 18: 213-228.

Hall, S.A., Newton, R.J., Holmes, P.M., Gaertner, M., Esler, K.J. 2017. Heat and smoke pre-treatment of seeds to improve restoration of an endangered Mediterranean climate vegetation type. *Austral Ecology*, 42:354–366.

Harrison, T. D. 2002. Preliminary assessment of the biogeography of fishes in South African estuaries. *Marine and Freshwater Research*, 53: 479-490.

Hayes, A.Y. and Crane, W. 2008. Succulent Karoo Ecosystem Programme, Phase 2 (2009 – 2014). Consolidation and Securing Programme Sustainability. A Strategic Plan of Action for South Africa. Supported by the Critical Ecosystem Partnership Fund and South African National Biodiversity Institute. pp 1-41.

Heelemann, S., Krug, C.B., Esler, K.J., Reisch, C., Poschlod, P. 2012. Pioneers and Perches? Promising Restoration Methods for Degraded Renosterveld Habitats? *Restoration Ecology*, 20: 18–23.

Heelemann, S., Procheş, Ş., Porembski, S., Cowling, R.M. 2010. Impact of graminoid cover on postfire growth of nonsprouting Protea seedlings in the eastern Fynbos Biome of South Africa. *African Journal of Ecology*, 49:51–55.

Heelemann, S., Proches, S., Rebelo, A.G., Van Wilgen, B.W., Porembski, S., Cowling, R.M. 2008. Fire season effects on the recruitment of non-sprouting serotinous Proteaceae in the eastern (bimodal rainfall) fynbos biome, South Africa. *Austral Ecoogy,* 33:119–127.

Heijnis, C.E., Lombard, A.T., Cowling, R.M., Desmet, P.G. 1999. Picking up the pieces: A biosphere reserve framework for a fragmented landscape - The Coastal Lowlands of the Western Cape, South Africa. *Biodiversity & Conservation*, 8:471–496.

Henderson, L. 2001. Alien weeds and invasive plants. Plant Protection Research Institute Handbook No. 12. Agricultural Research Council: Pretoria.

Hoffman, M.T & Cowling, R.M. 1990. Desertification in the lower Sundays River Valley, South Africa. *Journal of Arid Environments*, 19: 105–117.

Hoffmann, M. T., Skowno, A., Bell, W., and Mashele, S. 2018. Long-term changes in land use, land cover and vegetation in the Karoo drylands of South Africa: implications for degradation monitoring, *African Journal of Range & Forage Science*, 35(3-4), 209-221

Hoffmann, M. T., Todd, S., Ntshona, Z. and Turner, S. 2014. Land degradation in South Africa. Collection. University of Cape Town.

Hoffmann, M.T. and Ashwell, A. 2001. Nature divided: land degradation in South Africa. University of Cape Town Press, Cape Town.

Hoffmann, M.T., Carrick, P.J., Gillson, L and West, A.G. 2009. Drought, climate change and vegetation response in the succulent Karoo, South Africa. *South African Journal of Science,* 105: 54–60.

Hoffmann, M.T., Cousins, B., Meyer, T., Petersen, A. and Hendricks, H. 1999. Historical and contemporary land use and the desertification of the Karoo. In: Dean, W.R.J. and Milton, S.J. (Eds.). The Karoo: Ecological Patterns and Processes. Cambridge University Press, Cambridge.

Holmes, P.M. & Cowling, R.M. 1997. Diversity, composition and guild structure relationships between soil-stored seed banks and mature vegetation in alien plant-invaded South African fynbos shrublands. *Plant Ecology*, 133:107–122.

Holmes, P.M. & Richardson, D.M., Van Wilgen, B.W. & Gelderblom, C. 2000. Recovery of South African fynbos vegetation following alien woody plant clearing and fire: implications for restoration. *Austral Ecology*, 25:631–639.

Holmes, P.M. 2005. Results of a lucerne old-field restoration experiment at the Fynbos-Karoo interface. *South African Journal of Botany*, 71:326–338.

Holmes, P.M. 2008. Optimal ground preparation treatments for restoring lowland Sand Fynbos vegetation on old fields. *South African Journal of Botany,* 74:33–40.

Holness, S. & Oosthuysen, E. 2016. Critical Biodiversity Areas of the Northern Cape : Technical Report. Northern Cape Department of Environment and Nature Conservation, Kimberley.

Holness, S., Driver, A., Todd, S., Snaddon, K., Hamer, M., Raimondo, D., Daniels, F., Alexander, G., Bazelet, C., Bills, R., Bragg, C., Branch, B., Bruyns, P., Chakona, A., Child, M., Clarke, R.V., Coetzer, A., Coetzer, W., Colville, J., Conradie, W., Dean, R., Eardley, C., Ebrahim, I., Edge, D., Gaynor, D., Gear, S., Herbert, D., Kgatla, M., Lamula, K., Leballo, G., Lyle, R., Malatji, N., Mansell, M., Mecenero, S., Midgley, J., Mlambo, M., Mtshali, H., Simaika, J., Skowno, A., Staude, H., Tolley, K., Underhill, L., van der Colff, D., van Noort, S. and von Staden, L. 2016. Biodiversity and Ecological Impacts: Landscape Processes, Ecosystems and Species. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (Eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

IUCN (International Union for Conservation of Nature). 2017. The IUCN Red List of Threatened Species. Available at: http://www.iucnredlist.org/

IUCN. 2012. 2001 IUCN Red List Categories and Criteria version 3.1. Second edition. International Union for Conservation of Nature, Gland, Switzerland. 32 pp.

IUCN. 2018. The IUCN Red List of Threatened Species. Version 2018-1. <http://www.iucnredlist.org>.

Jacobs, K. and Jangle, R. 2008. Karoo Ecosystem Management Plan: Western Cape. Unpublished, The Nature Conservation Corporation, Cape Town.

James, C.S. & King, J.M. 2010. Ecohydraulics for South African Rivers: A Review and Guide. Water Research Commission, WRC Report No. TT 453/10. The publication of this report emanates from a project entitled: South African Handbook on Environmental River Hydraulics. WRC Project No. K5/1767.

James, J.J. & Carrick, P.J. 2016. Toward quantitative dryland restoration models. *Restoration Ecology*, 24:S85–S90.

Jezewski, W.A., Pyke, P.D. & Roberts, C.P.R. 1984. Estuarine and Lake Freshwater Requirements. Department of Water Affairs and Forestry, Pretoria, South Africa. Technical Report No TR123.

Jonas, Z. 2004. Land use and its impacts on the Succulent Karoo. Master's Thesis. Department of Botany, Leslie Hill Institute for Plant Conservation, University of Cape Town, Rondebosch.

Jürgens, N. 2006. Desert Biome. In: Mucina, L. and Rutherford, M.C. (Eds.). The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria, pp. 301–323.

Khavhagali, V.P. 2010. Importance, threats, status and conservation challenges of biodiversity in Northern Cape. *The Grassland Society of Southern Africa*, 10(4): 14–17.

Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. 2006. World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift*, 15(3):259-263.

Kotze, D.C. & Breen, C.M. 1994. Agricultural land-use impacts on wetland functional values. Water Research Commission, Pretoria, WRC Report no. 501/3/94.

Kotze, D.C., Breen, C.M. & Quinn, N.W. 1995. Wetland losses in South Africa. *In*: Cowan, G.I. (*Ed*) Wetlands of South Africa. Department of Environmental Affairs and Tourism. Pretoria.

Kraaij, T. 2010. Changing the fire management regime in the renosterveld and lowland fynbos of the Bontebok National Park. *South African Journal of Botany,* 76:550–557

Kraaij, T., Baard, J.A., Cowling, R.M., van Wilgen, B.W., Das, S. 2013a. Historical fire regimes in a poorly understood, fire-prone ecosystem: eastern coastal fynbos. *International Journal of Wildland Fire*, 22:277.

Kraaij, T., Cowling, R.M., van Wilgen, B.W. 2013b. Lightning and fire weather in eastern coastal fynbos shrublands: seasonality and long-term trends. *International Journal of Wildland Fire,* 22:288–295.

Kraaij, T., Cowling, R.M., van Wilgen, B.W., Schutte-Vlok, A. 2013d. Proteaceae juvenile periods and post-fire recruitment as indicators of minimum fire return interval in eastern coastal fynbos. *Applied Vegetation Science*, 16:84–94.

Kraaij, T., Wilgen, B.W. Van, 2014. Drivers, ecology, and management of fire in fynbos. In: Allsopp, N., Colville, J.F., Verboom, G.A. (*Eds*.), Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region. Oxford University Press, Oxford, UK, pp. 47–72.

Krug, C.B. 2004. Practical guidelines for the restoration of renosterveld. Conservation Ecology Department, University of Stellenbosch.

Kruger, F.J., Bigalke, R.C. 1984. Fire in fynbos. In: Booysen, P.D., Tainton, N.M. (Eds.), Ecological Effects of Fire in South African Ecosystems. Springer-Verlag, Berlin, pp. 67–114.

Krupek, A., Gaertner, M., Holmes, P.M., Esler, K.J. 2016. Assessment of post-burn removal methods for Acacia saligna in Cape Flats Sand Fynbos, with consideration of indigenous plant recovery. *South African Journal of Botany*, 105:211–217.

Lamberth, S.J. & Turpie, J.K. 2003. The role of estuaries in South African fisheries: economic importance and management implications. *African Journal of Marine Science*, 25: 131-157.

Le Maitre, D., O'Farrell, P., Milton, S., Atkinson, D., De Lange, W., Egoh, B., Reyers, B., Colvin, C., Maherry, A., and Blignaut, J. 2009. Assessment and Evaluation of Ecosystem Services in the Succulent Karoo Biome. Report prepared by CSIR for the Succulent Karoo Ecosystem Programme (SKEP) Coordination Unit, SANBI.

Le Maitre, D.C., Forsyth, G.G., Dzikiti, S and Gush, M.B. 2016. Estimates of the impacts of invasive alien plants on water flows in South Africa. *Water SA,* 42(4):659–672.

Le Maitre, D.C., Gaertner, M., Marchante, E., Ens, E.-J., Holmes, P.M., Pauchard, A., O'Farrell, P.J., Rogers, A.M., Blanchard, R., Blignaut, J., Richardson, D.M. 2011. Impacts of invasive Australian acacias: implications for management and restoration. *Diversity and Distributions*, 17:1015–1029.

Le Maitre, D.C., Kruger, F.J., Forsyth, G.G. 2014. Interfacing ecology and policy: Developing an ecological framework and evidence base to support wildfire management in South Africa. *Austral Ecology*, 39:424–436.

Le Maitre, D.C., Scott, D.F., Colvin, C. 1999. A review of information on interactions between vegetation and groundwater. *Water SA,* 25:137–152

Le Maitre, D.C., Seyler, H., Holland, M., Smith-Adao, L., Nel, J.L., Maherry, A. and Witthüser, K. 2018. Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater. Report No. TT 743/1/18, Water Research Commission, Pretoria.

Lisóon, F. and Calvo, J.F. 2014. Bat activity over small ponds in dry Mediterranean forests: Implications for conservation. *Acta Chropterologica* 16(1): 95-101.

Lloyd, J.W. 1999. Nama Karoo. In: J. Knobel (Ed). The magnificent natural heritage of South Africa. Sunbird Publishing, Cape Town, South Africa. pp 84–93.

Lloyd, J.W., Van den Berg, E.C., Palmer, A.R. 2002. STEP Project. Patterns of transformation and degradation in the Thicket Biome. ARC Report No. GW/A/2002/30.

Lovegrove, B. 1993. The living deserts of southern Africa. Fernwood Press, Cape Town.

Low, A.B. & Rebelo A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Lynch, S.D. 2004. Development of a raster database of annual, monthly and daily rainfall for Southern Africa. WRC Report 1156/1/04, Water Research Commission, Pretoria, South Africa, pp 78.

McAuliffe, J.R., Hoffmann, M.T., McFadden, L.D., Bell, W., Jack, S., King, M.P. and Nixon, V. 2018. Landscape patterning created by the southern harvester termite, Microhodotermes viator: Spatial dispersion of colonies and alteration of soils. *Journal of Arid Environments*, 157: 97–102.

McAuliffe, J.R., Hoffmann, M.T., McFadden, L.D., Jack, S. Bell, W. and King, M.P. 2019. Whether or not heuweltjies: Context-dependent ecosystem engineering by the southern harvester termite, Microhodotermes viator. *Journal of Arid Environments,* (in press).

McCracken, D. 2008. Saving the Zululand Wilderness: An Early Struggle for Nature Conservation. Jacana.

Mills, A.J., O'Connor, T.M., Bosenberg, D.W., Donalson, J., Lechmere-Oertel, R.G., Fey, M.V. & Sigwela, A. 2003. Farming for carbon credits: implications for land use decisions in South African rangelands. *In*: Seventh International Rangeland Congress. Durban, South Africa. Pp.1458 – 1554.

Milton, S. 2009. The basis for sustainable business in the Karoo: Bringing ecological and economic issues together. Paper presentation. Karoo Development Conference and Expo, Graaff-Reinet, Eastern Cape.

Milton, S. J., Zimmermann, H. G. and Hoffmann, J. H. 1999. Alien plant invaders of the Karoo: attributes, impacts and control. In: Dean, W.R.J. and Milton, S.J. (Eds.). The Karoo: Ecological Patterns and Processes. Cambridge University Press, Cambridge.

Milton, S.J. and Dean, W.R.J. 2012. Mining in the Karoo – Environmental Risks and Impacts. Paper presentation at the Karoo Development Conference, Beaufort West.

Minter, L.R. 2004. Atlas and red data book of the frogs of South Africa, Lesotho, and Swaziland. Animal Demography Unit, University of Cape Town.

Mirimin, L., Macey, B., Kerwath, S., Lamberth, S., Bester-van der Merwe, A., Cowley, P., Bloomer, P. and Roodt-Wilding, R., 2016. Genetic analyses reveal declining trends and low effective population size in an overfished South African sciaenid species, the dusky kob (Argyrosomus japonicus). *Marine and Freshwater Research*, 67: 266-276.

Mitchell, F. 2002. Shoreland buffers: Protecting water quality and biological diversty (New Hampshire). Lewis Publishers. Boca Raton.

Mucina, L. and Rutherford, M. C. (*Eds).* 2006. The Vegetation of South Africa, Lesotho and Swazland. Pretoria: Strelitzia.

Mucina, L., Rutherford, M.C., Palmer, A.R., Milton, S.J., Scott, L., Lloyd, J.W., Van der Merwe, B., Vlok, J.H.J., Euston-Brown, D.I.W., Powrie, L.W. and Dold, A.P. 2006a. Nama Karoo Biome. In: Mucina, L. and Rutherford, M.C.

(Eds.). The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria, pp. 221–299.

Mucina, L., Jürgens, N., Le Roux, A., Rutherford, M.C., Schmiedel, U., Esler, K., Powrie, L.W., Desmet, P.G. and Milton, S.J. 2006b. Succulent Karoo Biome. In: Mucina, L. and Rutherford, M.C. (Eds.). The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria, pp. 221–299.

Mucina, L., Geldenhuys, C.J., Rutherford, M.C., Powrie, L.W., Lotter, M.C., Von Maltitz, G.P., Euston-Brown, D.I.W., Matthews, W.S., Dobson, L., McKenzie, B. 2006c. Afrotemperate, Subtropical and Azonal Forests. In: Mucina, L., Rutherford, M.C. (Eds.), The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria, pp. 585–615.

Musil, C.F., Milton, S.J., Davis, G.W. 2005. The threat of alien invasive grasses to lowland Cape floral diversity: an empirical appraisal of the effectiveness of practical control strategies. *South African Journal of Science*, 101: 337–344.

Ndhlovu, T., Milton, S. and Esler, K.J. 2015. Effect of Prosopis (mesquite) invasion and clearing on vegetation cover in semi-arid Nama-Karoo rangeland, South Africa. *African Journal of Range and Forage Science*, Vol. 33:1 pp 11-19

Ndhlovu, T., Milton-Dean, S.J. and Esler, K.J. 2011. Impact of Prosopis (mesquite) invasion and clearing on the grazing capacity of semiarid Nama Karoo rangeland, South Africa. *African Journal of Range and Forage Science,* Vol. 28:3 pp 129–137.

Nel, J.L. & Driver, A. 2012. South African National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component. Stellenbosch: Council for Scientific and Industrial Research. CSIR Report Number: CSIR/NRE/ECO/IR/2012/0022/A.

Nel, J.L., Colvin, C., Le Maitre, D., Smith, J., Haines, I. 2013. Defining South Africa's Water Source Areas. Report No. CSIR/NRE/ECOS/ER/2013/0031/A, Natural Resources and the Environment, CSIR, Stellenbosch and WWF-SA.

Nel, J.L., Le Maitre, D.C., Roux, D.J., Colvin, C., Smith, J.S., Smith-Adao, L.B., Maherry, A., Sitas, N. 2017. Strategic water source areas for urban water security: Making the connection between protecting ecosystems and benefiting from their services. Ecosyst. Serv. 28, 251–259.

Noroozi, J., Talebi, A., Doostmohammadi, M., Rumpf, S.B., Linder, H.P. and Schneeweiss, G.M. 2018. Hotspots within a global biodiversity hotspot - areas of endemism are associated with high mountain ranges. Scientific Report. Nature 8:10345, pp 1–10.

O'Connor, T.G. and Bredenkamp G.J. 1996. Grasslands. In Cowling, R. M., Richardson, D., & Pierce, S. M. (*Eds*) Vegetation of Southern Africa. Cambridge, UK: Cambridge University Press.

Palmer, A.R. and Hoffmann, M.T. 1997. Nama-Karoo. In: Cowling, R.M., Richardson, D.M. and Pierce, S.M. (Eds.). Vegetation of southern Africa. Pp 167-188. Cambridge University Press, Cambridge.

Passmore, N. & Carruthers, V. 1995. South African Frogs. A Complete Guide Published by Witwatersrand University Press.

Pauw, M.J. 2011. Monitoring Ecological Rehabilitation on a Coastal Mineral Sands Mine in Namaqualand, South Africa. Conservation Ecology and Entomology, University of Stellenbosch, Stellenbosch.

Poff, N.L. & Ward, J.V. 1989. Implications of Streamflow Variability and Predictability for Lotic Community Structure: A Regional Analysis of Streamflow Patterns. *Canadian Journal of Fisheries and Aquatic Sciences,* 46: 1805-1818.

Pool-Stanvliet, R., Duffell-Canham, A., Pence, G., Smart, R. 2017. Western Cape Biodiversity Spatial Plan Handbook 2017. CapeNature and Department of Environmental Affairs and Development Planning, Western Cape Government, Cape Town.

Pressey, R.L., Cowling, R.M., Rouget, M. 2003. Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. *Biological Conservation*, 112: 99–127.

Rahlao, S.J., Milton, S.J., Esler, K.J., Van Wilgen, B.W. and Barnard, P. 2009. Effects of invasion of fire-free arid shrublands by a fire-promoting invasive alien grass (Pennisetum setaceum) in South Africa. *Austral Ecology*, 34: pp920–928.

Raison, R.J. 1979. Modification of the soil environment by vegetation fires, with particular reference to nitrogen transformations: a review. *Plant and soil*, 51(1): 73-108.

Ray, G.C. 2005. Connectivities of estuarine fishes to the coastal realm. *Estuarine, Coastal and Shelf Science,* 64: 18-32.

Rebelo, A.G., Boucher, C., Helme, N., Mucina, L., Rutherford, M.C., Smit, W.J., Powrie, L.W., Ellis, F., Jan, J.N., Scott, L., Radloff, F.G.T., Steven, D., Richardson, D.M., Ward, R.A., Procheş, Ş.M., Oliver, E.G.H., Manning, J.C., Mcdonald, D.J., Janssen, J.A.M., Walton, A., Roux, A., Skowno, A.L., Simon, W., Hoare, D.B. 2006. Fynbos Biome. In: Mucina, L., Rutherford, M.C. (Eds.), The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria, pp. 52–219.

Reddering, J.S.V., Rust, I.C. 1990. Historical changes and sedimentary characteristics of southern African estuaries. *South African Journal of Science* 86: 425-428.

Reyers B, Fairbanks DHK, van Jaarsveld AS & Thompson MW. 2001. Priority areas for the Conservation of South African Vegetation: a coarse filter approach. *Diversity and Distributions,* 17:79-95.

Richardson, D.M., Van Wilgen, B.W., Le Maitre, D.C., Higgins, K.B. & Forsyth, G.G. 1994. A Computer-Based System for Fire Management in the Mountains of the Cape Province, South-Africa. International Journal of Wildland Fire, 4: 17–32.

Rio Tinto. 2013. Suistainable Development. http://www.riotinto.com/documents/ RT_SD_report_2013.pdf.

Rundel, P.W. and Cowling, R.M. 2013. Biodiversity of the Succulent Karoo. In: Levin, S.A. (Eds.) Encyclopedia of Biodiversity, Second Edition. Volume 1, pp. 485-490. Waltham, MA: Academic Press.

Rutherford, M.C., Powrie, L.M. and Schultze, R.E. 1999. Climate change in conservation areas of South Africa and its potential impact on floristic composition: a first assessment. *Diversity and Distributions*, 5: 253–262

Ruwanza, S., Gaertner, M., Esler, K.J., & Richardson, D.M. 2013. The effectiveness of active and passive restoration on recovery of indigenous vegetation in riparian zones in the Western Cape, South Africa: A preliminary assessment. *South African Journal of Botany*, 88:132–141.

SANBI (South African National Biodiversity Institute). 2017. Technical guidelines for CBA Maps: Guidelines for developing a map of Critical Biodiversity Areas & Ecological Support Areas using systematic biodiversity planning. First Edition (Beta Version), June 2017. Compiled by Driver, A., Holness, S. & Daniels, F. SANBI: Pretoria.

SANBI. 2012. Updated vegetation Map of South Africa, Lesotho and Swaziland.

SANBI. 2009. National Protected Area Expansion Strategy Resource Document. South African National Biodiversity Institute, Department of Environmental Affairs, Pretoria.

SANBI. 2011. National List of Threatened Ecosystems. Available at http://bgis.sanbi.org/.

Sandberg, R.N., Allsopp, N., Esler, K.J. 2016. The use of fynbos fragments by birds: Stepping-stone habitats and resource refugia. *Koedoe: African Protected Area Conservation and Science*, 58(1):1-10.

Scholes, R. J. 1997. Savanna. *In* Cowling, R. M., Richardson, D., & Pierce, S. M. (*Eds*) Vegetation of Southern Africa. Cambridge, UK: Cambridge University Press.

Schulze, R.E. & Lynch, S.D. 2007. Annual Precipitation. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. WRC Report 1489/1/06, Section 6.2. Water Research Commission, Pretoria, RSA.

Schulze, R.E. & Maharaj, M. 2007. Rainfall Seasonality. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. WRC Report 1489/1/06, Section 6.5. Water Research Commission, Pretoria, RSA.

Sirami, C., Jacobs, D.S. and Cumming, G.S. 2013. Artificial wetlands and surrounding habitats provide important foraging habitat for bats in agricultural landscapes in the Western Cape, South Africa. *Biological Conservation* 164: 30–38.

Smith, A.B. 1999. Hunters and herders in the Karoo landscape. In: Dean, W.R.J. and Milton, S.J. (Eds.). The Karoo: Ecological Patterns and Processes. Cambridge University Press, Cambridge.

Smith, R.E. & Higgins, K.B.1992. The root systems of three species of Protea shrubs in the Jonkershoek valley, Cape Province. South African Journal of Plant and Soil, 7: 238–240.

South Africa. 2011. National Environmental Management: Biodiversity Act: National list of ecosystems that are threatened and in need of protection. Government Gazette, 558(34809): 1 – 544, December 9.

Stuart-Hill G.C. 1992. Effects of elephants and goats on the Kaffrarian succulent thicket of the Eastern Cape, South Africa. *Journal of Applied Ecology*, 29: 699–710.

Taljaard, S., Snow, G., Gama, P., & Van Niekerk, L. 2009. Verification of a conceptual model of water quality for small temporarily open/closed estuaries: East Kleinemonde Estuary*, South Africa. Marine and Freshwater Research,* 60: 234-245.

Taylor M. R. and Peacock, F. 2018. State of South Africa's Bird Report 2018. Johannesburg: BirdLife South Africa.

Tinley K.L. 1975. Habitat physiognomy, structure and relationships. *University of Pretoria Publications New Series,* 97: 67–77

Tinley, K.L. 1985. Coastal dunes of South Africa. National Scientific Programmes Unit: CSIR.

Todd, S. 2008. Options for Invasive Grass Management in the Nieuwoudtville Wildflower Reserve. Prepared for Indigo Development and Change, Nieuwoudtville.

Todd, S.W., Hoffmann, M.T., Henschel, J.R., Cardoso, A.W., Brooks, M. and Underhill, L.G. 2016. The Potential Impacts of Fracking on Biodiversity of the Karoo Basin, South Africa. In: Glazwewski, J. and Esterhuyse, S. (Eds.). Hydraulic Fracturing in the Karoo: Critical Legal and Environmental Perspectives. First edition. Juta Press. Pp 278–301.

Turner, A.A. & De Villiers, A.L. 2017. Amphibians. *In*: Turner, A.A. (*Ed*). Western Cape Province State of Biodiversity 2017. CapeNature Scientific Services, Stellenbosch.

Turner, A.A. (*Ed*). 2017. Western Cape Province State of Biodiversity 2017. CapeNature Scientific Services, Jonkershoek, Stellenbosch

Turner, R.K., van den Bergh, J.C.J.M. & Brouwer, R. 2003. Managing wetlands: An ecological economics approach. Edward Elgar, Cheltenham, UK.

Turpie, J.K. & Clark, B. 2009. Development of a Conservation Plan for temperate South African estuaries on the basis of biodiversity importance, ecosystem health and economic costs and benefits. CAPE programme.

Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S., & Van Niekerk, L. 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA,* 28: 191-206.

Turpie, J.K., Forsythe, K.J., Knowles, A., Blignaut, J., Letley, G. 2017. Mapping and valuation of South Africa's ecosystem services: A local perspective. *Ecosystem Services*, 1–14.

Turpie, J.K., Heydenrych, B.J., Lamberth, S.J. 2003. Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. *Biological Conervation*, 112:233–251.

Tyser, R. W., & Worley, C. A. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National-Park, Montana (USA). *Conservation Biology*, 6:253–262.

University of Cape Town (UCT). 2018a. MammalMap Database. Animal Demography Unit. Available at http://vmus.adu.org.za/

UCT. 2018b. ReptileMap Database. Animal Demography Unit. Available at http://vmus.adu.org.za/

UCT. 2018c. ScorpionMap Database. Animal Demography Unit. Available at http://vmus.adu.org.za/

UCT. 2018d. FrogMap Database. Animal Demography Unit. Available at http://vmus.adu.org.za/

Valette, J.-C., gomendy, V., Maréchal, J., Houssard, C. & Gillon, D. 1994. Heat transfer in soil during very low-intensity experimental fires: the role of duff and soil moisture content. *International Journal of Wildland Fire*, 4(4): 225-237.

Van der Merwe, H., van Rooyen, M.W. 2011. Vegetation trends following fire in the Roggeveld, Mountain Renosterveld, South Africa. South African J. Bot. 77, 127–136.

Van der Merwe, H., Van Rooyen, M.W., Van Rooyen, N. 2008. Vegetation of the Hantam-Tanqua-Roggeveld subregion, South Africa. Part 1: Fynbos Biome related vegetation. *Koedoe* 50.

Van Jaarsveld, E. 1987. The succulent riches of South Africa and Namibia. Aloe 24:45-92.

Van Niekerk, L. and Turpie, J.K. (*Eds*). 2012. National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch. Available at: http://bgis.sanbi.org/nba/project.asp.

Van Niekerk, L., Adams, J.B., Bate, G.C., Forbes, N., Forbes, A., Huizinga, P., Lamberth, S.J., MacKay, F., Petersen, C., Taljaard, S., Weerts, S., Whitfield, A.K. & Wooldridge, T.H. 2013. Country-wide assessment of estuary health:

An approach for integrating pressures and ecosystem response in a data limited environment. *Estuarine, Coastal and Shelf Science,* 130: 239-251.

Van Wilgen, B.W., Forsyth, G.G., de Klerk, H., Das, S., Khuluse, S., Schmitz, P. 2010. Fire management in Mediterranean-climate shrublands: a case study from the Cape fynbos, South Africa. *Journal of Applied Ecology*, 47:631–638.

Van Wilgen, B.W., Govender, N., Forsyth, G.G. & Kraaij, T. 2011. Towards adaptive fire management for biodiversity conservation: Experience in South African National Parks. *Koedoe,* 53:a982.

Van Wilgen, B.W., Reyers, B., Le Maitre, D.C., Richardson, D.M. and Schonegevel, L. 2008. A biome-scale assessment of the impact of invasive alien plants on ecosystem services in South Africa. Journal of Environmental Management 89: pp336 –349.

Van Wyk A.E. & Smith G.F. 2001. Regions of Floristic Endemism in Southern Africa. Umdaus Press, Hatfield.

Van Wyk, A.E. and Smith, G.F. 2001. Regions of floristic endemism in southern Africa. A review with emphasis on succulents. Umdaus Press, Hatfield

Veldtman, A., Dippenaar-Schoeman, A.S., Samways, M.J., Veldtman, R., & Du Plessis, D., 2017. Arthropods. *In*: Turner, A.A. (*Ed*). Western Cape Province State of Biodiversity 2017. CapeNature Scientific Services, Stellenbosch.

Vernon, C.J. 1999. Biogeography, endemism and diversity of animals in the Karoo. In: Dean, W.R.J. and Milton, S.J. (Eds.). The Karoo: Ecological Patterns and Processes. Cambridge University Press, Cambridge.

Visser, V., Wilson, J.R.U., Canavan, K., Canavan, S., Fish, L., Le Maitre, D., Nänni, I., Mashau, C., O'Connor, T., Ivey, P., Kumschick, S., Richardson, D.M. 2017. Grasses as invasive plants in South Africa revisited: Patterns, pathways and management. *Bothalia* 47, 29 pages.

Vlok J.H.J. & Euston-Brown D.I.W. 2002a. Report by biological survey component for conservation planning for biodiversity in the thicket biome. Unpublished report, Regalis Environmental Services, Oudtshoorn.

Vlok, J.H.J. & Euston-Brown, D.I.W. 2002b. The patterns within, and the ecological processes that sustain, the subtropical thicket vegetation in the planning domain for the Subtropical Thicket Ecosystem Planning (STEP) Project. Terrestrial Ecology Research Unit Report No. 40. University of Port Elizabeth.

Vlok, J.H.J., Euston-Brown, D.I.W. & Cowling, R.M. 2003. Acocks' Valley Bushveld 50 years on: new perspectives on the delimitation, characterization and origin of thicket vegetation. South African. *Journal of Botany*, 69: 27–51.

Vorwerk, P.D., Froneman, P.W., Paterson, A.W., Strydom, N.A. & Whitfield, A.K., 2008. Biological responses to a resumption in river flow in a fresh water deprived, permanently open southern African estuary. *Water SA,* 34: 597-604

Walker, C., Milton, S.J., O'Connor, T.G., Maguire, J.M. and Dean, W.R.J. 2018. Drivers and trajectories of social and ecological change in the Karoo, South Africa. African Journal of Range and Forage Science 35:3-4, pp157-177.

Watkeys, M.K. 1999. Soils of the arid south-western zone of Africa. Dean, W.R.J. and Milton, S.J. (Eds.). The Karoo: Ecological Patterns and Processes. Cambridge University Press, Cambridge.

Whitfield, A. & Elliott, M. 2011. Ecosystem and Biotic Classifications of Estuaries and Coasts. In: Wolanski E and McLusky DS (*Eds*.) *Treatise on Estuarine and Coastal Science*, Vol 1. Academic Press, Waltham, pp. 99-124.

Whitfield, A.K. 1992. A characterization of southern African estuarine systems. *Southern African Journal of Aquatic Sciences*, 18: 89-103.

Whitfield, A.K. 1998. Biology and ecology of fishes in Southern African estuaries. *Icthyological Monograph of the J.L.B. Smith Institute of Ichthyology,* 2: 1-223.

Williamson, G. 2010. Richtersveld – The Enchanted Wilderness. 2nd Ed. Umdaus Press, Hatfield. ISBN 978-919766-47-8, pp1–260.

Wilson, J.R., Gaertner, M., Griffiths, C.L., Kotzé, I., Le Maitre, D.C., Marr, S.M., Picker, M.D., Spear, D., Stafford, L., David, M., Wilgen, B.W. Van, Wannenburgh, A. 2014. Biological invasions in the Cape Floristic Region: history, current patterns, impacts, and management challenges. In: Allsopp, N., Colville, J., Verboom, G.A. (Eds.), Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region. Oxford University Press: Cape Town, pp. 273–298.

Woodhall, S. 2005. Field guide to the butterflies of South Africa. Struik.

Xiao, J., Wang, Y. F., Shi, P., Yang, L., & Chen, L. D. 2014. Potential effects of large linear pipeline construction on soil and vegetation in ecologically fragile regions. *Environmental Monitoring and Assessment*, 186(11): 8037–8048. https://doi.org/10.1007/s10661-014-3986-0.

Yamamoto, S. 1996. Gap regeneration of major tree species in different forest types of Japan. *Vegetatio*, 127(2):203-213.

Yu, X., Wang, G., Zou, Y., Wang, Q., Zhao, H. & Lu, X. 2010. Effects of pipeline construction on wetland ecosystems: Russia-China oil pipeline project (Mohe-Daqing section) *Ambio*, 39: 447-450.

11 SPATIAL DATA SOURCES

Animalia fieldwork database. Obtained from Werner Marais in July 2013.

Bates, M.F., Branch, W.R., Bauer, A.M., Burger, M., Marais, J., Alexander G.J., et al. (*Eds*). Atlas and red data list of the reptiles of South Africa, Lesotho and Swaziland, p. 423, SANBI: Pretoria (Suricata series; no. 1).

Bats KZN fieldwork database. Obtained from Leigh Richards and Kate Richardson in July 2017.

BLSA (BirdLife South Africa). 2015a. Nest localities of Southern Bald Ibis. https://www.birdlife.org.za/.

BLSA. 2014. White-winged Flufftail confirmed sightings 2000 – 2014. https://www.birdlife.org.za/.

BLSA. 2015b. Important Bird and Biodiversity Areas of South Africa. https://www.birdlife.org.za/.

BLSA. 2018a. A list of potential Bush Blackcap, Spotted Ground-Thrush and Orange Ground-Thrush breeding habitat. https://www.birdlife.org.za/.

BLSA. 2018b. Yellow-breasted Pipit core distribution mapping. https://www.birdlife.org.za/.

BLSA. 2018c. Rudd's Lark core distribution mapping. https://www.birdlife.org.za/.

BLSA. 2018d. Botha's Lark core distribution mapping. https://www.birdlife.org.za/.

Burgess et al. 2004. Terrestrial ecoregions of Africa and Madagascar: A conservation Assessment. Island Press: Washington DC.

Burgess, N., Hales, J.D., Underwood, E., Dinerstein, E., Olson, D., Itousa, I., Schipper, J., Ricketts, T. & Newman, K. 2004. Terrestrial ecoregions of Africa and Madagascar: A conservation Assessment. Island Press: Washington DC.

CapeNature. 2017. Western Cape Biodiversity Spatial Plan 2017. http://bgis.sanbi.org/.

CapeNature. 2018. Red Data bird nest localities in the Western Cape. https://www.capenature.co.za/

CGS (Council for Geoscience). 1997. 1: 1M geological data.

Child, M.F., Roxburgh, L., Do Linh San E., Raimondo, D. & Davies-Mostert, H.T. (*Eds*). 2016. The 2016 Red List of Mammals of South Africa, Swaziland and Lesotho. SANBI & EWT: South Africa.

CoCT (City of Cape Town). 2016. City of Cape Town Biodiversity Network. http://bgis.sanbi.org/.

Coetzer, W. 2017. Occurrence records of southern African aquatic biodiversity. Version 1.10. The South African Institute for Aquatic Biodiversity. https://doi.org/10.15468/pv7vds

Collins, N., (2017). National Biodiversity Assessment (NBA) 2018. Wetland Probability Map. https://csir.maps.arcgis.com/apps/MapJournal/index.html?appid=8832bd2cbc0d4a5486a52c843daebcba#

CSIR (Council for Scientific and Industrial Research). 2015. Information on various Red Data species nests obtained from the Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa.

DAFF. 2014. Field Crop Boundaries. Available at: http://bea.dirisa.org/resources/metadata-sheets/WP03_00_META_FIELDCROP.pdf

DAFF (Department of Agriculture, Forestry, and Fisheries). 2016. National Forest Inventory. https://www.daff.gov.za/daffweb3/Branches/Forestry-Natural-Resources-Management/Forestry-Regulation-Oversight/Forests/Urban-Forests/Forestry-Maps.

David Jacobs fieldwork database. Obtained from David Jacobs in May 2018.

DEA (Department of Environmental Affairs). South African Government Gazette. National Environmental Management: Biodiversity Act: National list of ecosystems that are threatened and in need of protection. Government Gazette, 558(34809). http://bgis.sanbi.org/.

DEA. 2018a. South African Protected Areas Database (SAPAD) Data. Q2, 2018.

DEA. 2018b. South African Conservation Areas Database (SACAD) Data. Q2, 2018.

DEDEAT (Department of Economic Development, Environmental Affairs and Tourism) 2017. Eastern Cape Biodiversity Conservation Plan. Draft version, December 2017.

DESTEA (Department of Department of Economic, Small Business Development, Tourism and Environmental Affairs). 2015. Free State Biodiversity Plan. http://bgis.sanbi.org/.

DWS (Department of Water and Sanitation). 2009. Working copies of sub-quaternary catchments for delineation of management areas for the National Freshwater Ecosystem Priority Areas (NFEPA) in South Africa project - 2009 draft version. http://www.dwa.gov.za/iwqs/gis_data/.

DWS. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx.

DWS. 2015. Invertebrate Distribution Records. Department of Water and Sanitation RQIS-RDM, Pretoria. http://www.dwa.gov.za/iwqs/biomon /inverts/invertmaps.htm/ and http://www.dwa.gov.za/iwqs/biomon/inverts/ invertmaps_other.htm/

EWT (Endangered Wildlife Trust). 2006a (as supplemented by more recent unpublished data). Nest database for cranes, raptors and vultures. Endangered Wildlife Trust.

EWT. 2006b (as supplemented by more recent unpublished data). List of eagle nests on Eskom transmission lines in the Karoo.

Ezemvelo KZN Wildlife, 2013. Bearded Vulture nest sites in KwaZulu – Natal Maloti-Drakensberg Vulture Project, Dr Sonja Krűger.

Ezemvelo KZN Wildlife. 2016 KwaZulu-Natal Biodiversity Sector Plans. http://bgis.sanbi.org/.

Ezemvelo KZN Wildlife. 2018. Blue Swallow breeding areas.

GDARD (Gauteng Department of Agriculture and Rural Development). 2011. Gauteng CPlan Version 3.3. http://bgis.sanbi.org/.

Geoterraimage. 2015. 2013-2014 South African Natioanl Land-Cover. Department of Environmental Affairs. https://egis.environment.gov.za/.

Henning, G.A., Terblanche, R.F. and Ball, J.B., 2009. South African red data book: butterflies

Herselman, J.C. and Norton, P.M. 1985. The distribution and status of bats (Mammalia: Chiroptera) in the Cape Province. Annals of the Cape Province Museum (Natural History) 16: 73-126.

Holness et al. 2016. Biodiversity and Ecology. In: Scholes et al. (*Eds*). Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

Inkululeko Wildlife Services fieldwork database. Obtained from Kate MacEwan in March 2018.

IUCN (International Union for the Conservation of Nature). 2017. The IUCN Red List of Threatened Species, 2017. http://www.iucnredlist.org/

Kleynhans, C.J., Thirion, C. & Moolman, J., 2005. A level I river ecoregion classification system for South Africa, Lesotho and Swaziland. Pretoria: Department of Water Affairs and Forestry.

Mecenero S, Ball JB, Edge DA, Hamer ML, Henning GA, Kruger M, Pringle EL, Terblanche RF, Williams MC (Eds). 2013. Conservation assessment of butterflies of South Africa, Lesotho and Swaziland: Red List and Atlas. Saftronics, Johannesburg and Animal Demography Unit, Cape Town.

MGHP (Mabula Ground Hornbill Project). 2018. Potential nesting areas of Southern Ground Hornbills. http://ground-hornbill.org.za/

Minter, L.R. 2004. Atlas and red data book of the frogs of South Africa, Lesotho, and Swaziland. Avian Demography Unit: UCT.

MTPA (Mpumalanga Tourism & Parks Agency). 2014. Mpumalanga Biodiversity Sector Plan. http://bgis.sanbi.org/.

NC DENC (Northern Cape Department of Environment and Nature Conservation). 2016. Critical Biodiversity Areas of the Northern Cape. http://bgis.sanbi.org/.

Nel, J.L. and Driver, A. 2012. South African National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component. Stellenbosch: Council for Scientific and Industrial Research. CSIR Report Number: CSIR/NRE/ECO/IR/2012/0022/A.

Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L. and Nienaber, S. 2011. Technical Report for the National Freshwater Ecosystem Priority Areas project. Pretoria: Water Research Commission, WRC Report No. K5/1801.

NW READ. (North West Province Rural, Environment and Agriculture Department). 2015. North West Terrestrial Critical Biodievrsity Areas. http://bgis.sanbi.org/.

Raimondo, D., Staden, L.V., Foden, W., Victor, J.E., Helme, N.A., Turner, R.C., Kamundi, D.A. and Manyama, P.A., 2009 (as updated in 2018). Red list of South African plants 2009, 2018 update. South African National Biodiversity Institute.

Ramsar Convention. 1971. Convention on Wetlands of International Importance especially as Waterfowl Habitat. https://www.ramsar.org/

Rautenbach, I.L. 1982. Mammals of the Transvaal. No. 1, Ecoplan Monograph. Pretoria, South Africa.

Samways, M.J. & Simaika, J.P. 2016. Manual of Freshwater Assessment for South Africa: Dragonfly Biotic Index. SANBI: Pretoria: Suricata 2, p. 224.

SANBI (South African Biodiversity Institute). 2012 Vegetation Map of South Africa, Lesotho and Swaziland. http://bgis.sanbi.org/.

SANBI. 2018. Updated vegetation Map of South Africa, Lesotho and Swaziland. http://bgis.sanbi.org/.

SANBI. 2014. Mpumalanga Highveld Wetlands. http://bgis.sanbi.org/.

SANBI. 2018. Interim findings of the National Biodiversity Assessment (work in progress). As available.

SANParks (South African National Parks). 2010. National Protected Areas Expansion Strategy: Focus areas for protected area Expansion. http://bgis.sanbi.org/.

Skowno et al. 2015. Terrestrial and Aquatic Biodiversity Scoping Assessment. In: Van der Westhuizen, et al. (*Eds.*). 2015. Strategic Environmental Assessment for Wind and Solar Photovoltaic Energy in South Africa. Department of Environmental Affairs, 2015. CSIR Report Number: CSIR/CAS/EMS/ER/2015/0001/B. Stellenbosch. Available athttps://redzs.csir.co.za/wp-content/uploads/2017/04/ Wind-and-Solar-SEA-Report-Appendix-C-Specialist-Studies.pdf

TNC (The Nature Conservancy). 2009. Terrestrial ecoregions. http://maps.tnc.org/gis_data.html

Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S., & Van Niekerk, L. 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA,* 28: 191-206.

Turpie, J.K., Wilson, G. & Van Niekerk, L. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

UCT (University of Cape Town). 1997. The Southern African Bird Atlas 1 (SABAP1). Animal Demography Unit, UCT.

UCT. 2007 - present. The Southern African Bird Atlas 2 (SABAP2). Animal Demography Unit, UCT.

Van Niekerk, .L, Taljaard, S., Ramjukadh, C.-L. Adams, J.B., Lamberth, S.J., Weerts, S.P., Petersen, C., Audouin, M., Maherry, A. 2017. A multi-sector Resource Planning Platform for South Africa's estuaries. Water Research Commission Report No K5/2464.

Van Niekerk, L. & Turpie, J.K. (*Eds*). 2012. National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch. http://bgis.sanbi.org/nba/project.asp.

Van Niekerk, L., Adams, J.B., Bate, G.C., Forbes, N., Forbes, A. Huizinga, P., Lamberth, S.J., MacKay, F., Petersen, C., Taljaard, S., Weerts, S., Whitfield, A.K. & Wooldridge, T.H. 2013. Country-wide assessment of estuary health:

An approach for integrating pressures and ecosystem response in a data limited environment. *Estuarine, Coastal and Shelf Science,* 130: 239-251.

Van Niekerk, L., Taljaard, S., Adams, J.B., Fundidi, D., Huizinga, P., Lamberth, S. J., Mallory, S., Snow, G.C., Turpie, J.K., Whitfield, A.K. & Wooldridge, T. H. 2015. Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa. Water Research Commission Report No K5/2187.

VulPro & Endangered Wildlife Trust. 2018. The national register of Cape Vulture colonies.

VulPro. 2017. National vulture restaurant database. http://www.vulpro.com/.

Wingate, L. 1983. The population status of five species of Microchiroptera in Natal. M.Sc. Thesis, University of Natal.

Addendum 1: List of estuaries present in the proposed gas pipeline development corridors.

Proposed Phase 5 gas pipeline corridor

- Olifants
- Verlorenvlei
- Groot Berg

Proposed Phase 1 gas pipeline corridor

- Langebaan
- Houtbaai
- Schuster
- Elsies
- Zeekoei
- Sir Lowry's Pass
- Buffels (Oos)
- Breë
- Gourits
- Rietvlei/Diep
- Wildevoëlvlei
- Krom
- Silvermine
- Eerste
- Steenbras
- Palmiet
- Duiwenhoks
- Sout (Wes)
- Bokramspruit
- Buffels Wes
- Sand
- Lourens
- Rooiels
- Klipdrifsfontein
- Goukou (Kaffirkui

Proposed Phase 2 gas pipeline corridor

- Blinde
- Hartenbos
- Maalgate
- Wilderness
- Knysna
- Keurbooms
- Gamtoos
- Baakens
- Coega (Ngcura)
- Gericke
- Klein Brak
- Gwaing
- Swartvlei
- Noetsie
- Matjies
- Van Stadens
- Papenkuils
- Sundays
- Tweekuilen
- Groot Brak
- Kaaimans
- Goukamma
- Piesang
- Kabeljous
- Maitland
- Swartkops

Proposed Phase 7 gas pipeline corridor

- Coega
- Bushmans
- Kowie
- Kleinemond Wes
- Great Fish
- Mtati
- Gqutywa
- Keiskamma
- Tyolomnqa
- Ross' Creek
- Mcantsi
- Hlozi
- Ngqenga
- Hlaze
- Gqunube
- Cunge
- Kwenxura
- Haga-haga
- Sundays
- Kariega
- Rufane
- Kleinemond Oos
- Old Womans
- Mgwalana
- Ngculura
- Ngqinisa
- Shelbertsstroom
- Ncera
- Gxulu
- Hickman's
- Buffalo
- Nahoon
- Kwelera
- Cintsa
- Nyara
- Mtendwe
- Boknes
- Kasuka
- Riet
- Klein Palmiet
- Mpekweni
- Bira
- Mtana
- Kiwane
- Lilyvale
- Mlele
- Goda
- Mvubukazi
- Blind
- Qinira
- Bulura
- Cefane
- Mtwendwe
- Quko

- Morgan
- Cwili
- Great Kei
- Gxara
- Ngogwane
- Qolora
- Ncizele
- Timba
- Kobonqaba
- Nxaxo/Ngqusi
- Cebe
- Gqunqe
- Zalu
- Ngqwara
- Sihlontlweni/Gcin
- Nebelele
- Qora
- Jujura
- Ngadla
- Shixini
- Nqabara/Nqabarana
- Mbashe
- Xora
- Mtata
- Mngazana
- Mzimvubu
- Sikombe
- Kwanyana
- Mtolane
- Mnyameni
- Mpahlanyana
- Mpahlane
- Mzamba
- Mtentwana
- Mtamvuna
- Zolwane
- Sandlundlu
- Ku-Boboyi
- Tongazi
- Kandandhlovu
- Mpenjati
- Umhlangankulu
- Kaba
- Mbizana
- Mvutshini
- Bilanhlolo
- Uvuzana
- Kongweni
- Vungu
- Mhlangeni
- Zotsha
- Boboyi
- Mbango
- Mzimkulu
- Mtentweni
- Mhlangamkulu
- Damba
- Koshwana
- Intshambili
- Mzumbe
- Mhlabatshane
- Mhlungwa
- Mfazazana
- Kwa-Makosi
- Mnamfu
- Mtwalume
- Mvuzi
- Fafa
- Mdesingane
- Sezela
- Mkumbane
- Mzinto
- Mpambanyoni
- Mahlongwa
- Mkomazi
- Ngane
- Umgababa
- Msimbazi
- Lovu
- Little Manzimtoti
- Manzimtoti
- Mbokodweni
- Sipingo
- Mgeni
- Mhlanga
- Mdloti
- Tongati
- Mhlali
- Mvoti
- Mdlotane
- Nonoti
- Zinkwasi
- Thukela
- Matigulu/
- Nyoni
- Siyaya
- Mlalazi
- Mhlathuze
- Richards Bay
- Nhlabane
- Mfolozi
- St Lucia

<u>Proposed Phase 4 gas pipeline corridor</u>

- St Lucia
- Mgobezeleni
- Kosi