STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT IN SOUTH AFRICA

Biodiversity and Ecological Impacts (Terrestrial Ecosystems and Species) - Fynbos Biome

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR GAS PIPELINE DEVELOPMENT

Draft v3 Specialist Assessment Report for Stakeholder Review

FYNBOS BIOME

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ABBREVIATIONS AND ACRONYMS

CBA	Critical Biodiversity Area, numerals 1 and 2 indicate differing conservation importance
CR	Critically Endangered
DEA	Department of Environmental Affairs
ECBCP	Eastern Cape Biodiversity Conservation Plan
EMP	Environmental Management Plan
EN	Endangered
ESA	Ecological Support Area, numerals 1 and 2 indicate differing conservation importance
IDP	Integrated Development Plan
iGas	A company linked to the Central Energy Fund, developer of natural gas resources
LT	Least Threatened
NBA	National Biodiversity Assessment
NEMA	National Environmental Management Act (Act 107 of 1998, as amended)
NP	National Park
NPAES	National Protected Area Expansion Strategy
ONA	Other Natural Area
PA	Protected Area
SANBI	South African National Biodiversity Institute
SDF	Spatial Development Framework
SEA	Strategic Environmental Assessment
spp	Species plural
SWSA	Strategic Water Source Area
TMG	Table Mountain Group
VU	Vulnerable
WCBSP	Western Cape Biodiversity Spatial Plan

1 SUMMARY

The Fynbos Biome forms part of six of the proposed Gas Pipeline Corridor Phases (i.e. 1, 2, 5, 6, 7 and Inland) which, between, them cover almost all the biome.

The Fynbos Biome is globally recognised for its high diversity of plant species with about 7 500 species, 69% of which are endemic and 1 889 are listed as threatened (Raimondo et al., 2009). Many of these species occur in the lowlands which are the logical route for the proposed pipeline. On the inland side and in the drier valleys in the western part of the biome the Fynbos adjoins the Succulent Karoo and in the east the Albany Thicket in low rainfall areas and Grasslands in high rainfall areas. 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. The vegetation in the Fynbos Biome can be divided into three major types: (a) typical Fynbos vegetation on nutrient poor soils; (b) Renosterveld vegetation on more nutrient-rich soils; and (c) Western Strandveld with a dense overstorey of evergreen shrubs and herbaceous species in the gaps. The western part of the biome experiences winter rainfall, the southern part has bimodal (spring, autumn) rainfall and the eastern peaks in spring and summer. This will affect the timing of vegetation re-establishment. Summers are hot and dry in the west with strong, desiccating, south-easterly winds which create conditions of moisture stress, particularly in the north-western part of the biome.

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. Fynbos requires fires at intervals of 10-30 years to maintain biodiversity and ecosystem functioning but fires in arid Fynbos are rare and may not be essential for regeneration. Many species' seeds will only germinate after fires and many species require fires to flower, produce seed and reproduce. Fires occur in and do stimulate regeneration in Renosterveld, but 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. Strandveld rarely burns but can do so under extreme weather conditions and regeneration apparently is not fire-dependent.

All forms of Fynbos are highly susceptible to invasion by alien (introduced) tree species, notably the Australian *Acacia* (wattle), *Hakea* and *Leptospermum* species, and *Pinus* species (pines). Sand-plain Fynbos and Renosterveld are very prone to invasion by alien herbaceous species, particularly grasses but invasions in Strandveld are not well-known. Invasive species control will be an important part of the construction and operational phases.

The diversity and endemism of the terrestrial fauna in Fynbos is not particularly high except for certain groups such as amphibians (60 spp in the Western Cape, 36 endemic and 15 threatened), reptiles (146 spp, 18 threatened), fossorial mammals (moles) and invertebrates (particularly butterflies, dragon flies, long-tongued flies, beetles). **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, 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.

There is a growing body of research on the restoration of Fynbos, but it is still a developing science. There are a couple of guidelines and handbooks for restoration. Research has shown that removing the upper few centimetres of the topsoil, returning it to the site as soon as possible, and the use of treatments to simulate seed-germination can facilitate recovery. Most of the research conducted, and experience that has been gained is in the higher rainfall parts of the biome. There is little research or experience in the arid areas, such as Phase 5, 6 in the west and in the interior valleys in Phase 2, to guide rehabilitation. These areas are at the limits of the climatic tolerance of Fynbos species, so there is a high likelihood of failure at the establishment stage, and recovery after disturbance could be slow. Active restoration will be required but, even then, there is a high risk of failure. 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 for the construction and operational phases.

The high diversity of the Fynbos together with a lack of adequate knowledge of most species' responses to the pipeline construction makes it very difficult to assess the sensitivity with much confidence, especially the impacts of an extensive linear habitat alteration. It also makes it very difficult to assess the effectiveness of the proposed mitigation for many species, especially ground dwelling and/or slow-moving, small bodied animals with narrow distributions and/or specific habitat requirements that are confined to natural or near natural vegetation remnants. Examples would include tortoises, chameleons, small burrowing or slow-moving surface dwelling snakes and potentially many invertebrate species.

Summary of the overall environmental suitability of the proposed Gas Pipeline corridors

Corridor	Overall Suitability	Comment
Phase 1	Low to moderate suitability for gas pipeline development	The coastal lowland areas have a very high concentration of vegetation remnants with a high or very high sensitivity. These remnants typically harbour endemic and threatened plants and fauna. Finding an acceptable route through these will be very difficult. The first 10 km from Ankerlig northwards to Saldanha is difficult because of the West Coast National Park and adjoining sensitive areas. The most feasible option from Saldanha-Ankerlig east to Mosselbay is via the Tulbagh-Ashton valley, but the Nuwekloof Pass will be difficult as will the initial section from Ankerlig or Saldanha into the Swartland. 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.
Phase 2	Low to moderate suitability for gas pipeline development	The coastal lowlands between Mosselbay and Coega have a high density of high and very high sensitivity features. These remnants typically harbour endemic and threatened plants and fauna. Finding an acceptable route through these will be very difficult. The mosaic of Fynbos and Forest between George and Natures Valley and Plettenberg Bay almost certainly rules out a route through this area. 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. Most of this route is through Succulent Karoo and Albany Thicket which are assessed in separate studies.
Phase 5	Low to moderate suitability for gas pipeline development	The coastal lowlands that are the preferred route between Ankerlig-Saldanha and Abrahamvilliersbaai have a high density of high and very high sensitivity features. These remnants typically harbour endemic and threatened plants and fauna. Finding an acceptable route through these will be very difficult. The main pinch point is from the Piketberg through the Sandveld to Graafwater. The route westwards into the Olifants River valley is through high sensitivity areas and difficult terrain.
Phase 6	Low to moderate suitability for gas pipeline development	Fynbos occupies very little of this Phase but the Fynbos that there is, is also characterised by a high density of high and very high sensitivity features. These areas typically harbour endemic and threatened plants and fauna. They are also located on the upper slopes and crests of mountain ranges which makes them unlikely to be selected for the final route.
Phase 7	Moderate to low suitability for gas pipeline development	Fynbos occupies very little of Phase 7 and is mainly confined to the upper slopes and crests of the east-west oriented mountain ranges. None of the Fynbos vegetation types are considered threatened and there appears to be relatively few endemic and threatened plants and fauna. However, there are extensive areas which are shown as high or very high sensitivity in the biodiversity conservation plan.
Phase Inland	Moderate to low suitability for gas pipeline development	Fynbos is confined to the western and extreme south of this Phase and is mainly confined to the upper slopes and crests of the mountain ranges and the Roggeveld escarpment. These features make it is unlikely that the final routing will include Fynbos and the routes will be determined by the sensitivity of the Succulent Karoo, Nama Karoo and Albany Thicket biomes.

2 INTRODUCTION

The Department of Environmental Affairs (DEA) appointed the CSIR to undertake a Strategic Environmental Assessment (SEA) for the Identification of Energy Corridors as well as Assessment and Management Measures for the Development of a Gas Pipeline Network for South Africa. The CSIR, in turn, appointed Dr David Le Maitre to carry out an assessment of the potential impacts of these developments on terrestrial ecosystems in the Fynbos biome.

The purpose of this assessment is to inform decision makers about the potential impacts and facilitate coordination between the authorities responsible for issuing authorisations, permits or consents and so streamlining the environmental authorisation process.

The specific **Terms of Reference** are to provide expert input as a Contributing Author to a Strategic Issue Chapter (specialist assessment report) on the impact on Biodiversity and Ecology (Terrestrial Ecosystems, Flora and Fauna), specifically for the Fynbos Biome.

3 SCOPE OF THIS STRATEGIC ISSUE

This study covers the terrestrial ecosystems of the Fynbos Biome as defined by Mucina and Rutherford (2006) including all the taxa except for birds and bats and amphibians. These taxa were excluded because they are the subject of separate specialist studies and the amphibians which fall under the rivers and wetlands specialist studies. The study also excludes all aquatic ecosystems, including streams, rivers, and wetlands of all kinds whether ephemeral, seasonal or perennial as these are the subject of a separate specialist study. The outputs from the various specialist studies will be integrated by the Integrating Authors listed at the beginning of this report.

3.1 Data Sources

This assessment has made extensive use of the Western Cape Biodiversity Spatial Plan (WCBSP) (Pool-Stanvliet et al., 2017) which covers most of the Biome, the Eastern Cape Biodiversity Conservation Plan (ECBCP, 2017), the 2016 Northern Cape Critical Biodiversity Areas (CBAs) (Holness and Oosthuysen, 2016), and datasets supplied to the CSIR by the South African National Biodiversity Institute (SANBI) in January 2018 (Table 1). The most recent Biodiversity Network (2017[1]) for the Cape Town Metropole has not been used at this stage as the proposed terminal for the Phase 1a and Phase 5 corridors will be located at Ankerlig near Atlantis (near the northern boundary of the metropole) but its information has been included in the WCBSP in a simplified form (Pool-Stanvliet et al., 2017). The information from the City's plan should be used when the detailed pipeline routing options are assessed. The routing of the proposed pipeline in this section of the corridor (i.e. Phases 1 and 5) is also likely to follow the routing proposed in the screening study for this development (CSIR, 2014). Primary data sources used in these studies include a variety of organizations and databases as documented in the respective reports, including many of those listed in the table below. All of the plans used in this assessment conform to the standards for bioregional planning (DEA, 2009).

The datasets also incorporated the best available information on the locations of threatened flora and fauna (Table 1). The WCBSP included threatened plants, mammals, reptiles, amphibians[2], birds, butterflies, dragon and damselflies, and species with management plans (Pool-Stanvliet et al., 2017). The planning process involved selecting priority areas to focus on and could have excluded some species locations as part of the optimisation process. A similar process was used in the generation of the Eastern Cape Biodiversity Conservation Plan (ECBCP, 2017).

[1] https://web1.capetown.gov.za/web1/opendataportal/DatasetDetail?DatasetName=Biodiversity%20network
[2] Some amphibian species are independent of water and thus terrestrial but those species are not included in this assessment

The Northern Cape Biodiversity Conservation Plan included locations of populations of threatened species of plant, butterfly, and reptiles based on data from SANBI, and the province, as CBA1 minimum (Table 1). However, it is important to note that the terrestrial fauna of the Fynbos vegetation types in the Northern Cape have not been well studied and are not as well-known as those in the Western Cape.

In the 2016 Northern Cape Biodiversity Conservation Plan, areas supporting high climate change resilience were included as Ecological Support Areas (ESA) polygons based on data from the National Biodiversity Assessment (NBA) 2011 (Driver et al., 2011) and sourced from SANBI (Table 1). These areas are included in the ESAs and CBAs in the WCBSP based on the Table Mountain Fund Climate Adaptation Corridors (Pence, 2009), edited to exclude all portions within the urban edge (Pool-Stanvliet et al., 2017).

The full set of threatened species locations for all the taxa within the corridors was supplied by SANBI to address this deficiency. The species data were point locations and have been buffered with buffer radiuses of different sizes depending on the likely home range of the particular species. The buffering was done in a way that will not allow the exact location to be determined by species collectors. The radius to use for each taxon was determined by discussions among the specialists involved in this SEA as follows:

- Mammals:
    - 50km buffer for Perissodactyla (Zebras, Rhinos) and the larger Carnivora (African Wild Dogs, Cheetahs, Leopards);
    - 10 km around the larger Artiodactyla (Antelope) – Tsessebe, Bontebok, Roan Antelope, Sable Antelope, Mountain Reedbuck;
    - 2.5km around the Rodentia, Soricomorpha (Shrews) and Afrosoricida (Golden moles)
    - 5km for all other mammals (Hyracoideae (Hyraxes), Lagomorpha (Rabbits, Hares), Macroscelidae (Elephant shrews), Pholidota (Pangolins), Primates, Tubulidentata (Aardvarks))
- For reptiles, amphibians and butterflies a 2.5 km buffer except for crocodiles with a 25 km buffer.
- For the fauna a bounding polygon was also created around the outer boundaries of the localities as a way of defining the range. In practice though this leads to overly wide ranges for species with few occurrence records. As such this information has not been shown in this assessment.
- Plant locations have not been buffered for this assessment because this also results in very extensive areas which are not meaningful. In some cases it is evident that plant threatened plant records are linked to features such as roads (e.g. see Phase 5 map of plant locations Figure 10), perhaps because the species only occurs in the road reserve.

The threatened species that would be most at risk typically occur within remnants of natural vegetation, especially on the lowlands (e.g. Sandveld, Swartland, and Overberg). Whether or not the pipeline would have to be routed through such remnants can only be determined at the next level of assessment and not at this strategic level which can simply emphasise: (a) that there are many species, often recorded from more than one locality; and (b) that it is highly likely that there are more, undocumented occurrences which means that at least all the natural remnants which will be affected must be subject to a thorough impact assessment.

In the case of the large mammals the buffered locations are so large that they appear to occupy the very wide ranges, often collectively spanning most of the corridor. These wide ranges also tend to obscure those of the taxa with smaller ranges. Although the larger mammals will be disturbed during the construction phase, and some species may become trapped in the open trench, they are highly unlikely to be permanently affected by the changes in habitat composition and structure and so are not shown in the maps for each corridor presented in this assessment.

Table 1: Summary of the data sources used in this assessment.

Data title	Source and date of publication	Data Description
Protected Areas	SANBI (2018) supplied for the SEA from the South African Protected and Conservation Areas Database with permission from DEA	Protected Areas classified according to the Protected Areas Act. Broadly as Formal (i.e. government: national, provincial and local authority, World Heritage Sites, Private Nature Reserves and certain forms of Stewardship) and Informal (e.g., Conservancies, some forms of Stewardship Sites). This includes Protected Environments, Biosphere unprotected areas which are part of the outer zone of a Biosphere Reserve
Other Natural Areas	Geoterraimage. 2015. 2013-2014 South African National Land-Cover. Department of Environmental Affairs. Geospatial Data. https://egis.environment.gov.za/.	All untransformed (i.e. natural or near natural) areas based on the 2013-14 land cover
National Protected Areas Expansion Strategy 2010	The 2016 National Protected Areas Expansion Strategy is currently underway. The 2010 data was used as supplied by SANBI for the SEA (based on BGIS data) (SANParks. 2010. National Protected Areas Expansion Strategy: Focus areas for protected area expansion. http://bgis.sanbi.org/).	Areas systematically identified for expansion of the protected areas where direct and visual impacts of the pipeline route and infrastructure would compromise the potential Protected Area value
Listed Threatened Ecosystems of South Africa	DEA (2011). National list of ecosystems that are threatened and in need of protection. Government Gazette No. 34809, Notice No. 1002, 9 December 2011. Supplied by SANBI for the SEA	Gazetted list of threatened ecosystems classified as Critically Endangered, Endangered, or Vulnerable; loss of parts of these ecosystems to development should be avoided or minimised, especially for the first two categories
South African Vegetation Map 2012	Mucina L. & Rutherford, M.C. (eds) (2006). The Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. SANBI, Pretoria.	The 2012 version of this map was downloaded from the BGIS and used to identify the specific vegetation types involved
Land cover / extent of natural remnants	South African National Land Cover 2013-2014, 72 class data set DEA open licence (GTI, 2015)	Used to derive natural vs. not natural habitat classes. A customised version of this dataset with some additional classes was used in the Western Cape Spatial Biodiversity Plan
Western Cape Biodiversity Spatial Plan datasets	(Pool-Stanvliet et al., 2017) Datasets downloaded from the BGIS at municipal level and province-wide CBA and ESA layers obtained from Therese Forsyth of CapeNature.	The most recent biodiversity conservation plan available for the Province and includes all the relevant priority biodiversity areas and ecological infrastructure that require protection. The handbook includes with definitions of all the categories and the land-use constraints.
		Protected Areas of all kinds excluding some forms of Stewardship areas. Private Conservation Areas included Biodiversity Agreements, Natural Heritage and Nature Reserves (private and contract) and Stewardships
		CBA 1 & 2 (terrestrial) for the Western Cape
		ESA 1 (terrestrial) & 2 for the Western Cape
2016 Northern Cape Critical Biodiversity Areas	(Holness and Oosthuysen, 2016) Datasets downloaded from the BGIS	The most recent biodiversity conservation plan available for the Province. This report and map updates, revises and replaces all older systematic biodiversity plans and associated products for the province
		Critical Biodiversity Areas One and Two
		Ecological Support Areas (no sub-categories)
		Protected Areas (no sub-categories)
		Other Natural Areas
Eastern Cape Biodiversity	ECBCP (2017) Eastern Cape Biodiversity Conservation Plan	The most recent biodiversity conservation plan available for the Province. The final report and

Data title	Source and date of publication	Data Description
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	map will replaces all older systematic biodiversity plans and associated products for the province
		Critical Biodiversity Areas 1 and 2
		Ecological Support Areas 1 and 2
		Protected Areas (no sub-categories)
		Other Natural Areas
Critically Endangered, Endangered and Vulnerable species	Mammals (Child et al., 2016), reptiles (Bates et al., 2014), plants (Raimondo et al., 2009), butterflies (Henning et al., 2009; Mecenero et al., 2013)	As prepared by SANBI and by the Endangered Wildlife Trust (mammals) with buffers matched to the species ranges and designed to obscure the detailed locality

3.2 Assumptions and Limitations

This study has focused on the construction and operation of the gas pipeline itself and excludes the associated infrastructure such as the onshore facilities at the landfall and the facilities at the termini of the gas pipeline for distributing the gas (e.g. receiving terminals). It also excludes any other facilities for servicing the line and detecting gas leaks as these should be considered at the detailed engineering stage. Many other aspects such the specific location and impacts of access routes, workers camps, lay down and storage areas, waste disposal or borrow pits cannot be included at this level of assessment.

This desktop assessment of biodiversity sensitivity is based primarily on the most recent provincial conservation planning supplemented with the data supplied by SANBI to the CSIR in January 2018. The CBA, ESA and protected area data were taken from the Western Cape Biodiversity Spatial Plan 2017 for the Western Cape, the 2016 Northern Cape CBA Plans and the draft Eastern Cape Biodiversity Conservation Plan (ECBCP, 2017). This was done so that the assessment could distinguish between CBA 1 and CBA 2 features.

The scale and thus the spatial resolution of the input data used in these plans varied from points for occurrences of species observations or populations through graded data at different special resolutions (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, such as proposing provisional routes, except in a very general sense.

An important assumption in relating qualitative sensitivity classes to the conservation categories (e.g. CBA, ESA) is that their biodiversity value is directly related to their sensitivity to impacts. And that this sensitivity is the same for all such units in all places. While there is a general relationship, a number of factors could influence how specific species or groups of species respond to impacts. For example the specific features or combination of features that result in a taxon or other biodiversity feature being placed in a particular conservation category. For example, a CBA 1 may be there because that area of land has a threatened ecosystem, or contains threatened flora or fauna, or is irreplaceable or a vital link in a climate change movement corridor, or is a combination of some or all of these things. The short, medium and long-term effect of the construction and operation of a gas pipeline through that area on those different features could be very different, even depending on the species involved. The plant species responses differ in many respects for the different vegetation groups that comprise Fynbos. For example Renosterveld plant species may have different responses to disturbance during clearing from Strandveld and both may differ from Fynbos – an example being the roles of fire in regeneration. This means that their sensitivities would differ and cannot be reduced to one single sensitivity rating. In turn, this means that the risk assessment based on the sensitivity is even more subject to uncertainty, and is only relevant to the strategic level of this study. The only way to reduce this uncertainty would be to examine every feature traversed by each of the alternative and assess its sensitivity at the project level for a specific proposed gas pipeline routing. When this line of reasoning is followed through the risk assessment to predicting the outcomes of mitigation, it should be very clear why there is very low confidence in the mitigation component of this study. The existing knowledge is simply not sufficient to have much confidence in the ability to achieve effective mitigation, even when following best practice described in the sections on mitigation. This is not a conclusion that has been reached lightly. Although the recommended approach has been followed and the best available knowledge has been applied, the results must be treated with great circumspection and caution as emphasised in that section.

The feature maps are also merging data captured at very different scales, spatial resolutions and accuracies. For example, there may be species location (point) data, land cover (which is used in some cases to assess ecosystem structure and degree of degradation) at 30x30 m, and vegetation types mapped to a scale of roughly 1 in 250 000 where the boundaries are possibly accurate to 10s of metres or more. These data cannot simply be mixed and used to assess routes with a high degree of confidence without field verification. The extent of the corridors that need to be assessed means that fine-scale features cannot be assessed at this level. All this study can do is a high level screening that identifies where there are concentrations of features and highlights those as areas where route selection will need additional field assessments. Even then, this assessment may miss fine-scale details with features that could make them Very Highly sensitive and to be avoided if at all possible.

This assessment also only focuses on terrestrial ecosystems and their fauna and flora, but aquatic systems are embedded in and threaded through the terrestrial ones and these ecosystems have functional interactions that could be disrupted by the changes caused by the pipeline (Mouquet et al., 2013; Nakano and Murakami, 2001; Samways and Stewart, 1997). There is a separate assessment of aquatic systems but, ideally, the terrestrial and aquatic experts should sit together and come up with an integrated assessment. Only such an integrated assessment by specialists working together can provide the knowledge required to properly assess sensitivity and the risks that pipeline construction and operation would pose.

Although sensitivity maps do reduce the level of detail that needs to be taken into account when making choices, they cannot be the basis for choosing whether to take one alternative route or another. That choice has to be based on a proper assessment of the nature of the underlying features that determine the sensitivity class. Final route selection must entail more detailed field work by specialists to ground-truth and verify these assessments as well as consultation with local experts.

Given these fundamental limitations on what this level of assessment can realistically achieve, any attempt to assess sensitivity and risk feature by feature and corridor by corridor will be of little value and even misleading. It will also require a level of knowledge of these diverse ecosystems that is only available for a few of them and does not exist for most. This assessment has, therefore, adopted a pragmatic approach of structuring the sensitivity assessment around the different vegetation groups and existing knowledge of how they may respond to the pipeline construction and operation under different environmental conditions and what the consequences of that could be.

This assessment relies greatly on the thoroughness of the compilers of these conservation plans, i.e. that they already have taken all the relevant information on conservation features into account in their plans. Based on what they describe in their reports and knowledge of their work, that appears to be a reasonable assumption. However, the datasets are still subject to the limitations described above. This, in turn, means that there are significant limitations and uncertainties in the assessment of the sensitivities and even more so, the risks. In particular, the level of confidence in statements about whether the risks can be mitigated is very low for most species.

As argued above, the variety and heterogeneity of the features being grouped into sensitivity classes already make a single sensitivity rating problematic. When this is combined with the range of environments which these pipelines potentially will traverse, from very low to very high rainfall, with varying rainfall reliability in all kinds of terrain, such a sensitivity rating needs to be interpreted with great caution. It is vital that those who will use this information understand and appreciate these issues when taking it into account in making decisions about the routes of the pipelines.

3.3 Relevant Regulatory Instruments

Table 2: Regulatory instruments relevant to the Fynbos biome.

Instrument	Key objective	Feature
International Instrument		
World Heritage Convention as recognised in the World Heritage Convention Act No 49 of 1999	Recognising that the cultural heritage and the natural heritage are among the priceless and irreplaceable possessions, not only of the Republic, but of humankind as a whole. Acknowledging that the loss, through deterioration, disappearance or damage through inappropriate development of any of these most prized possessions, constitutes an impoverishment of the heritage of all the peoples of the world and, in particular, the people of South Africa.	For natural heritage sites: natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view, geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation, natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty.
National Instrument		
National Environmental Management Act (Act 107 of 1998).	The National Environmental Management Act of 1998 (NEMA), outlines measures that...."prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."	The protection of all natural features, including from inappropriate development.
National Environmental Management: Protected Areas Act, 2003	No development, construction or farming may be permitted in a national park or nature reserve without the prior written approval of the management authority (Section 50 (5)). Also in a 'protected environment' the Minister or MEC may restrict or regulate development that may be inappropriate for the area given the purpose for which the area was declared (Section 5).	Providing for the protection of all natural features in Protected Areas, including from inappropriate development.
National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004)	The National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004) provides for listing threatened or protected ecosystems, in one of four categories: critically endangered (CR), endangered (EN), vulnerable (VU) or protected. Listing Notice 3 (Government Notice R324 of 2017 (2014 EIA Regulations, as amended)) Activity 12 relates to clearing of 300 m^2 or more of vegetation, within Critical Biodiversity Areas.	Providing for the protection of South Africa's unique biodiversity through various measures. Different sorts of activities are listed as environmental triggers which determine the different levels of impact assessment and planning required. They also set out the procedures to be followed for basic or full environmental impact assessments. DEA's intention is to include Strategic Water Source Area requirements in the listing.

Instrument	Key objective	Feature
	The Act and Regulation 598 of 1 August 2014 require the control of listed invasive alien species, including plants on all land.	
National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004) Threatened or Protected Species Regulations, Notice 255 of 2015, Government Gazette No 38600, March 2015	Regulations protecting and regulating the use of threatened species through permits and restrictions on activities.	Provides for the protection and survival of threatened species in the wild, give effect to international obligations to regulate trade, ensure that the utilisation of biodiversity and threatened or protected indigenous species is sustainable.
Conservation of Agricultural Resources Act (Act No. 43 of 1983) 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 is 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.
Mineral and Petroleum Resources Development Act (Act No. 28 of 2002)	The Mineral and Petroleum Resources Development Act governs prospecting, mining, exploration and production in South Africa.	In terms of section 49 of the Act, the Minister may restrict or prohibit the granting of prospecting or mining, exploration or production rights in respect of specified geographical areas if such restriction or prohibition is necessary to promote the sustainable development of South Africa's mineral or petroleum resources.
NEMA - Threatened or Protected Species Regulations of 2013 (ToPS)	Protection of threatened or protected species	The TOPs relates to Section 56 of NEMBA. Species categorised as CR, EN, VU or Protected require permits for activities relating to any form of capture or harvesting of part or all of an organism, possession, propagation or transport.
NEMA EIA 2014 Regulations, as amended (Government Gazette 40772, Government Notice 326 (April 2017))	These regulations provide a list of activities that require environmental authorisation prior to development because they are identified as having a potentially detrimental effect on natural ecosystems, including freshwater ecosystems.	Restricts development and land-use activities depending on the characteristics and attributes of the features.
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. April 2008.	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)	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.
Provincial Instrument		
Nature Conservation Laws Amendment Act of 2000 (an amendment of the 1994 Cape ordinance	Protection and conservation of threatened flora and fauna and provincial conservation areas	This ordinance is applicable in the Western Cape and Northern Cape. It provides measures to protect the natural flora and fauna, lists nature reserves and endangered flora

Instrument	Key objective	Feature
		and fauna
Eastern Cape Nature and Environmental Conservation Ordinance (19/1974)	Protection and conservation of threatened flora and fauna and provincial conservation area. Much of the Eastern Cape legislation relies on the pre-1994 legislation of the Eastern Cape, Transkei and Ciskei.	This Ordinance is applicable to the Eastern Cape. It includes regulations for conservation areas, and enables the protection of wild animals and plants including lists of protected species.
Mountain Catchment Areas Act	To provide for the conservation, use, management and control of land situated in mountain catchment areas, and to provide for matters incidental thereto.	Originally a national instrument but assigned to the Provinces in 1995. Only really used in the former Cape Province. Intended to restrict land-management practices to those that were compatible with maintaining the ecosystem in good condition to protect water source areas. No regulations were ever created to give this intent effect.
Local Government		
Local Government: Municipal Systems Act (Act No. 32 of 2000; RSA, 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 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.

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4 KEY ENVIRONMENTAL ATTRIBUTES AND SENSITIVITIES OF THE STUDY AREAS

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., 2006). 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).

The vegetation types in the Fynbos can be divided into three major types (Bergh et al., 2014; Rebelo et al., 2006) (Figure 1): (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.

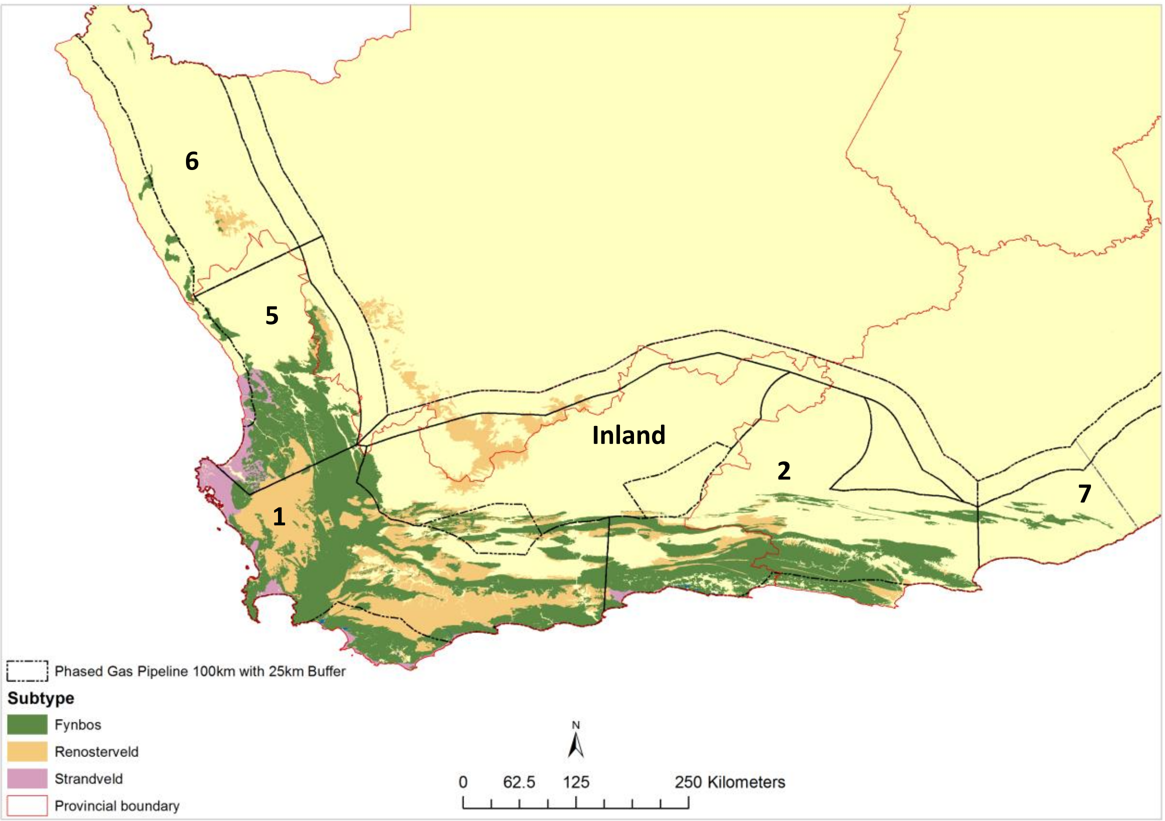


Figure 1: The Fynbos Biome showing the extent of the three main vegetation categories in relation to the Phased Gas Pipeline corridors and their buffers.

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.

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).

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).

Arid Fynbos, as found in corridor Phases 5 and 6, 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.

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 Corridor Descriptions

Only the portions of the proposed Gas Pipeline Phases or corridor sections which include fynbos are assessed (Table 3). The routing of all the pipelines will be such that they are likely to cross faunal migration routes between the coast and interior. They will also cross climate adaptation corridors designed to allow for vegetation movements and migration in response to changes in climatic conditions that are predicted by climate change models (Davis-Reddy and Vincent, 2017; DEA, 2015; Midgley et al., 2006, 2005; Midgley and Thuiller, 2011; Rutherford et al., 1999). These areas are identified as CBAs and are rated as highly sensitive in the sensitivity assessments.

1 Table 3: Summary of the Fynbos biome environmental description for the proposed Gas Pipeline Phases.

Site	Brief description
Phase 1	The corridor covers the southwestern corner of South Africa and is located mainly in the Western Cape, just extending into the Northern Cape at its northern most point. It extends southwards from Cape Columbine along the West Coast to Cape Point, then eastwards to Vleesbaai near Mosselbay, northwards to near Prince Albert, then south-westwards past Ladismith before turning northwest past Touwsriver into the Tanqua Karoo - in this last section it meets the Inland corridor. Then it turns southwest to Hopefield and northwest back to Cape Columbine – this section adjoins Phase 5. In the East it connects with Phase 2. 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 Strategic Water Source Areas (SWSAs) (Nel et al., 2017, 2013). 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 Critically Rare, 14 Endangered and 15 Vulnerable, 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. 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 National Park* (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, and Gouritz) will have to be chosen with care as these are also climate change adaptation corridors. There are some extensive Azonal vegetation types in this corridor but they are mainly wetlands (e.g. the reed beds and salt marshes in the Langebaan Lagoon and the Breede River floodplain) and so fall outside the scope of this assessment. 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., 2017, 2013). 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. 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.

Site	Brief description
Phase 2	This corridor covers the southern or middle portion of the Fynbos Biome between Phase 1 in the west and Phase 7 in the east. It extends from a line roughly between Vleesbaai and Prince Albert in the West (i.e. at Mossgas) to a line between Coega and Somerset-East in the east. The coastal boundary excludes the area between Plettenberg Bay and St Francis and the Tsitsikamma Mountains. The inland boundary is generally inland of the Fynbos Biome and so is not included in this assessment. 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 (Geldenhuys, 1994; Kraaij et al., 2013a). 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. 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. Most of this route is through Succulent Karoo and Albany Thicket whose sensitivity is assessed in separate studies. 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. There are some extensive Azonal vegetation types in the corridor such as river floodplains and the Wilderness Lakes and wetlands which are covered in a separate specialist study. 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., 2017, 2013). 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.
Phase 5	The corridor is situated on the west-coast of South Africa and forms a link between Phase 1 in the south-west and Phase 6 in the north-west. It extends about 220 km from near Piketberg in the Swartland to near Bitterfontein in Namaqualand. 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. 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

Site	Brief description
	as do cultivated areas on the Nieuwoudtville plateau and the Gifberg. 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, 4 Endangered, 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 and every remnant classified as a CBA 1 (Very high sensitivity). 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. The Niewoudtville-Gifberg plateau in the Northern Cape also is an extensive area where all natural vegetation is categorised as CBA 1. 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 SWSA (Nel et al., 2017, 2013). There are also extensive SWSAs for groundwater in this area and in the inland valleys.
Phase 6	This corridor is situated on the arid north-west coast of South Africa. 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 corridor extends about 100 km inland from the West Coast and is about 375 km in length. The southern boundary is near the town of Nuwerus and the northern boundary is the Orange River and border with Namibia. Four biomes are found within the corridor, Succulent Karoo, Nama Karoo, Desert and Fynbos and there are extensive areas of Azonal vegetation along rivers and along coast. 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., 2011). 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 CBA plan, the Kamiesberg Granite Fynbos is considered a CBA1 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.

Site	Brief description
	The northern section of the Stinkfonteinberge Quartzite Fynbos falls within the Richtersveld 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, 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. The Kamiesberg is an important water source area at the local level but not at the national level.
Phase 7	Phase 7 extends eastwards from a line roughly between Coega and 100 km inland towards Somerset east, where it adjoins phase 2, to KwaZulu-Natal. The Fynbos Biome only extends into the western end of this corridor to about 27°E, so that section is the focus of this assessment. Only montane Fynbos occurs in this area, being found on the Suurberg, Swartwatersberg, Grahamstown Height and Kapriviersberge. The climate is variable and can be very hot in summer and very cold in winter with snow falls. The mean annual rainfall is about 500-550 mm with slight peaks in spring and autumn. Only two Fynbos vegetation types shave been mapped in this area: Suurberg Quartzite Fynbos and Suurberg Shale Fynbos the latter being found mainly as patches embedded within the former which is more continuous. Neither is considered threatened. They form complex mosaics with the Grassland Biome in the higher rainfall areas and the Albany Thicket Biome in the lower rainfall areas. Grasses and reeds (Restionaceae) are a prominent component in these vegetation types and seed-regenerating shrubs tend to be found in localised and often rocky patches on southern slopes (Rebelo et al., 2006). The ecology and biodiversity of the Fynbos in these eastern areas is not well documented (Kraaij and Wilgen, 2014; Martin, 1987; Richardson et al., 1984). Fire regimes do play an important role especially in the interfaces with the grasslands where fires can be too frequent for the survival of seed regenerating species (Kraaij et al., 2013c; Kraaij and Wilgen, 2014) but fire season seems to be less important (Heelemann et al., 2008). In some areas fires can be very frequent, for example south of Grahamstown where they reach 6 fires in 16 years. These mountains are locally important as water source areas but not at the national level.
Inland Phase	In the north, this corridor extends from the Tankwa Karoo north-eastwards to just north of Victoria West and then south-eastwards to near Somerset East. In the southwest it adjoins Phase 1 and in the south-east Phase 2. It overlaps with the Fynbos Biome only in the south-west and centre where it adjoins Phase 1 and in the Roggeveld mountains. Fynbos Biome vegetation is found on the inland slopes of the mountains from the Skurweberge to the Swartberg and on the Roggeveld escarpment. 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. 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). Sixteen Fynbos Biome vegetation types are found in this corridor, with half being Fynbos and half Renosterveld, with one being Endangered and two Vulnerable. 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 National Park (Pool-Stanvliet et al., 2017; SANBI, 2009). This is another part of the biome whose diversity and ecology 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 the local level.

4.2 Feature Sensitivity Mapping

This section deals with the biodiversity and conservation features where biodiversity features are those that capture aspects of the biodiversity (e.g. endemic species, threatened species and ecosystems), and conservation features are those that have been developed by people to conserve biodiversity and other natural features (e.g. protected areas). The intention was to include information on the threatened Fynbos species which occur in the corridor so they can be flagged for special attention. However, the lists of names, especially for plants, are so extensive that this provides to be impractical and only the maps with information on high level taxonomic groups are shown.

4.2.1 Identification of feature sensitivity criteria

This assessment has relied primarily on the most recent conservation plans for the areas concerned because 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 (PAs).

In the WCSBP (Pool-Stanvliet et al., 2017), the category CBA is reserved for areas that are required to meet biodiversity targets for species and ecosystem pattern (i.e. composition and spatial distribution) or ecological processes and infrastructure (Table 4). These include Critically Endangered (CR) ecosystems and all areas required to meet ecological infrastructure targets for sustaining the existence and functioning of ecosystems and the delivery of ecosystem services. They also include the corridors required to maintain landscape connectivity and allow communities to respond to climate change. A CBA 1 is for ecosystems in natural or near-natural condition and a CBA 2 comprises ecosystems that are degraded and can and should be restored. The category ESA is used for areas which are important for sustaining the functioning of PAs or CBAs, and can deliver important ecosystem services, and remnants of endangered vegetation types (Pool-Stanvliet et al., 2017). They provide connectivity, and so improve the potential to adaptation to climate change. So they include corridors, water source and groundwater recharge areas, azonal habitats along rivers and around wetlands. Every individual CBA and ESA is provided with a “reason” or rationale which takes one or more features into account. These reasons include threatened vegetation types and vertebrates, ecological processes and specific habitat types. The “reasons” given often include both terrestrial and aquatic systems in the same CBA which makes it difficult to differentiate. Other Natural Areas (ONAs) have not been identified as a priority in the current biodiversity spatial plan but retain most of their natural character, biodiversity and ecological functions and are still important. Rather than include PAs in their CBA classes they were retained as separate, but with land-use practices in the PAs and buffer areas tightly restricted by guidelines in the protected area plan, as prescribed in the NEM: Protected Areas Act (Table 5). In essence this amounts to treating them as having very high sensitivity and equivalent to a CBA 1 and this is what is shown in the sensitivity maps.

The 2016 Northern Cape CBA plan CBAs took four features into account: ecosystem threat status, rarity, endemism and ecosystem process importance (Holness and Oosthuysen, 2016) (Table 4). Threatened species of plant, butterfly, and reptile locations based on data from SANBI and the province were included in the Northern Cape as CBA 1 minimum. All protected areas in the Northern Cape were given a 5 km buffer and National Parks a 10 km buffer based on “Listing Notice 3”[3] under NEMA (Act 107 of 1998) Act (Table 5) and rated CBA 2 minimum (Holness and Oosthuysen, 2016). The PA expansion areas were also categorised as CBA 2. ESAs are areas which are important for sustaining the functioning of PAs or CBAs, deliver important ecosystem services, include special habitats, provide connectivity and thus include corridors for improving resilience to climate change. Other Natural Areas have not been identified as a priority in the current biodiversity spatial plan but retain most of their natural character, biodiversity and ecological functions and are still important.

[3] Environmental Impact Assessment Regulations, Government Notice No. R34 in Government Gazette 40772 of 7 April2017

The Eastern Cape Biodiversity Conservation Plan includes all categories of Protected Areas (State) and Conservation Areas (private) (Table 4) and their buffers (Table 5). State includes Biosphere Reserves, World Heritage Sites, State-owned (National Park, Nature Reserve) and Protected Environments as category PA. Private Nature Reserves (PNR) and *De Facto* PNR were categorised as CBA 2, and DAFF Forest Reserves as CBA 1. National threatened ecosystems (Critically Rare (CR) and Endangered (EN)) were included as CBA 1 and VU types were added to meet targets. Irreplaceable sites and Planning Units selected to meet targets for vegetation types, species points and expert areas were included in the category CBA 1. Best Design sites and Planning Units selected to meet targets for vegetation types, species points and expert areas were included in category CBA 2. Other sites required to complete the network were classed as ESA 1 together with selected cliffs and their buffers, Eastern Cape Corridors, climate change refugia and climate change resilience areas. Some Other sites were made ESA 2 as were some Best Design corridor sites.

The buffering is designed to prevent protected areas becoming surrounded by developments that transform the land, such as extensive cultivation and urban developments. The buffer widths for different protected areas were specified in Listing Notice 3 of the 2014 EIA regulations[3] and have not been altered in any of the subsequent amendments Act (Table 5). The buffering only affects the sensitivity maps as the actual boundaries are shown in the feature maps. Such areas are not necessarily no-go areas for a linear development such as this pipeline but, as with any other CBA areas, they should be avoided, wherever possible, at an early stage of the planning (Sahley et al., 2017).

Table 4: Spatial data used for the sensitivity analysis.

Sensitivity Feature Class	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors
Protected Areas	Data supplied by SANBI in January 2018 from the South African Protected and Conservation Areas Database with permission from DEA	Protected areas divided into sensitivity categories: Very High (National Parks, nature reserves, World Heritage Site core, Special Nature Reserves) High (Mountain Catchment Areas, Protected Environment) Moderate (Nature Reserve and National Park Buffers, Biosphere (unprotected)) Low (not used in this assessment)	All phases assessed in this Fynbos Biome Assessment
	2016 Northern Cape CBA Plan (Holness and Oosthuysen, 2016)	All protected areas in the Northern Cape were given a 5 km buffer and National Parks 10 km (Holness and Oosthuysen, 2016) based on "Listing Notice 3" under NEMA (Act 107 of 1998).	Phase 1, 5, 6 and Inland
	Western Cape Biodiversity Spatial Plan (Pool-Stanvliet et al., 2017)	All protected areas excluding stewardship areas. This dataset was found to be more complete than the dataset provided by SANBI in January 2018	Phases 1, 2, 5, 6 and Inland
	Eastern Cape Biodiversity Conservation Plan	All protected areas as indicated in the draft plan dataset supplied via CSIR January 2018	Phase 2, 7 and Inland
National Protected Areas Expansion Strategy (NPAES) 2010	The 2016 National Protected Areas Expansion Strategy is currently still in progress so the 2010 data was used as supplied by SANBI for the SEA (based on BGIS data)	A modified and expanded version of the 2010 data is included in Northern Cape CBA 2016. The expansion strategy areas were not included in the WCBSP Matzikama Plan so the 2010 NPAES data were used for this part of the corridor. Rated Moderately Sensitive	All phases assessed in this Fynbos Biome Assessment
CBA 1	Western Cape Biodiversity Spatial Plan	In the WCBSP in every Local Municipal dataset every individual CBA is provided with a "reason" which takes one or more features into account.	Phase 1, 2, 5, 6 and Inland

Sensitivity Feature Class	Data Source + Date of Publications	Data Description, Preparation and Processing	Relevant Corridors
	2016 Northern Cape Critical Biodiversity Areas	Northern Cape CBAs took four features into account: ecosystem threat status, rarity, endemism and ecosystem process importance	Phase 1, 5, 6, and Inland
	Eastern Cape Biodiversity Conservation Plan	All state protected areas including Forest Reserves, national threatened ecosystems	Phase 2, 7, and Inland
CBA 2	Western Cape Biodiversity Spatial Plan	See above for WCBSP	Phase 1, 2, 5, 6 and Inland
	2016 Northern Cape Critical Biodiversity Areas	For the Northern Cape the individual CBAs did not include reasons, only the general rules applied in the development of the plan (Holness and Oosthuysen, 2016)	Phase 1, 5, 6, and Inland
	Eastern Cape Biodiversity Conservation Plan	Best Design sites and Planning Units selected to meet targets for vegetation types, species points and areas identified by experts	Phase 2, 7 and Inland
ESA 1	Western Cape Biodiversity Spatial Plan	These areas include ecosystems that range from natural to moderately degraded	Phase 1, 2, 5, 6 and Inland
	Eastern Cape Biodiversity Conservation Plan	Other sites required to complete the network were classed as ESA 1 together with selected cliffs and their buffers, Eastern Cape Corridors, climate change refugia and climate change resilience areas	Phase 2, 7 and Inland
ESA 2	Western Cape Biodiversity Spatial Plan	These areas require restoration; although they are degraded or have little natural cover they should be restored	Phase 1, 2, 5 6 and Inland
	Eastern Cape Biodiversity Conservation Plan	Other sites of conservation importance and best design sites not included above	Phase 2 and 7
ESA	2016 Northern Cape Critical Biodiversity Areas	Did not distinguish between ESA categories or give reasons for specific ESAs	Phase 1, 5, 6 and Inland
ONA	Western Cape Biodiversity Spatial Plan, 2016 Northern Cape Critical Biodiversity Areas and Eastern Cape Biodiversity Conservation Plan	Other Natural Areas (ONAs) are not a priority at present but retain a natural level of biodiversity and ecosystem functions and so impacts should be avoided or minimised in favour of transformed areas.	All phases assessed in this Fynbos Biome Assessment

1

Table 5: Sensitivity rating assigned to important environmental features of the Fynbos biome for all the Corridor sections covered in this assessment.

Corridor	Feature Class	Feature Class Sensitivity	Buffer Distance Sensitivity
All	**Protected Areas Western Cape:**		
	National Parks, Nature Reserves, World Heritage Sites	Very High	High (10 km)[4]
	Mountain Catchment Areas	High	High
	Private Conservation Areas (all types)	Moderate	Moderate (5 km)
	Protected Environment	Moderate	Moderate
	National Protected Area Expansion Strategy	Moderate	Moderate
	National Park Buffer	Moderate	Moderate
	Nature Reserve Buffer	Moderate	Moderate
	Protected Areas Northern Cape (all types)	Very High	High: in the plan all PAs were buffered by 5 km and National Parks by 10 km as CBA2 minimum
	Protected Areas Eastern Cape Biodiversity Conservation Plan:		
	World Heritage Sites, National Park, Nature Reserve, DAFF Forest Reserves	Very High	Not buffered
	Biosphere Reserves, Protected Environments	High	Not buffered
	Private Nature Reserves	Moderate	Not buffered
	Conservation categories from Western Cape Biodiversity Spatial Plan	CBA 1: Very High	Not buffered
		CBA 2: High	Not buffered
		ESA 1 and 2: Moderate	Not buffered
	Conservation categories from 2016 Northern Cape CBA Plan	CBA 1: Very High	Not buffered
		CBA 2: High	Not buffered
		ESA: Moderate	Not buffered
	Conservation categories from Eastern Cape Biodiversity Conservation Plan	CBA 1: Very High	Not buffered
		CBA 2: High	Not buffered
		ESA 1 and 2: Moderate	Not buffered
	Land Cover : Natural Area Land Cover: Transformed	Moderate Low	Not buffered
	Other Natural Areas	Moderate	Not buffered

[4] Environmental Impact Assessment Regulations, No. R. 982, 4 December 2014 as updated in Government Notices 324 to 327 in Government Gazette 40772 of 7 April 2017

4.2.2 Feature maps

The features have been presented in the maps using slightly different approaches because of the way in which they have been represented. In the Western Cape the mapping is very detailed and has a high spatial resolution so that the CBA and ESA features are accurately shown and clear in the maps. In the Eastern and Northern Cape the CBA and ESA mapping was more generalised so that the fine-scale features tend to be masked by the broad swathes that are in these categories. This was not such an important issue in the Northern Cape because the Fynbos only occupies a small proportion of the corridor so the CBA and ESA features have been included. However, they have been excluded from the features maps for the Eastern Cape so that the maps are more easily interpreted. The features maps are presented separately for each Phase (Figures 2-19). For each Phase the first map shows the protection areas and other conservation features, the second map the location of the threatened fauna and the third map the threatened flora.

In the sensitivity maps all the features have been included whether they are protected areas, threated species populations or other important conservation features. This means that the sensitivity maps give a more complete representation of the constraints on the potential routes.

4.2.2.1 Phase 1

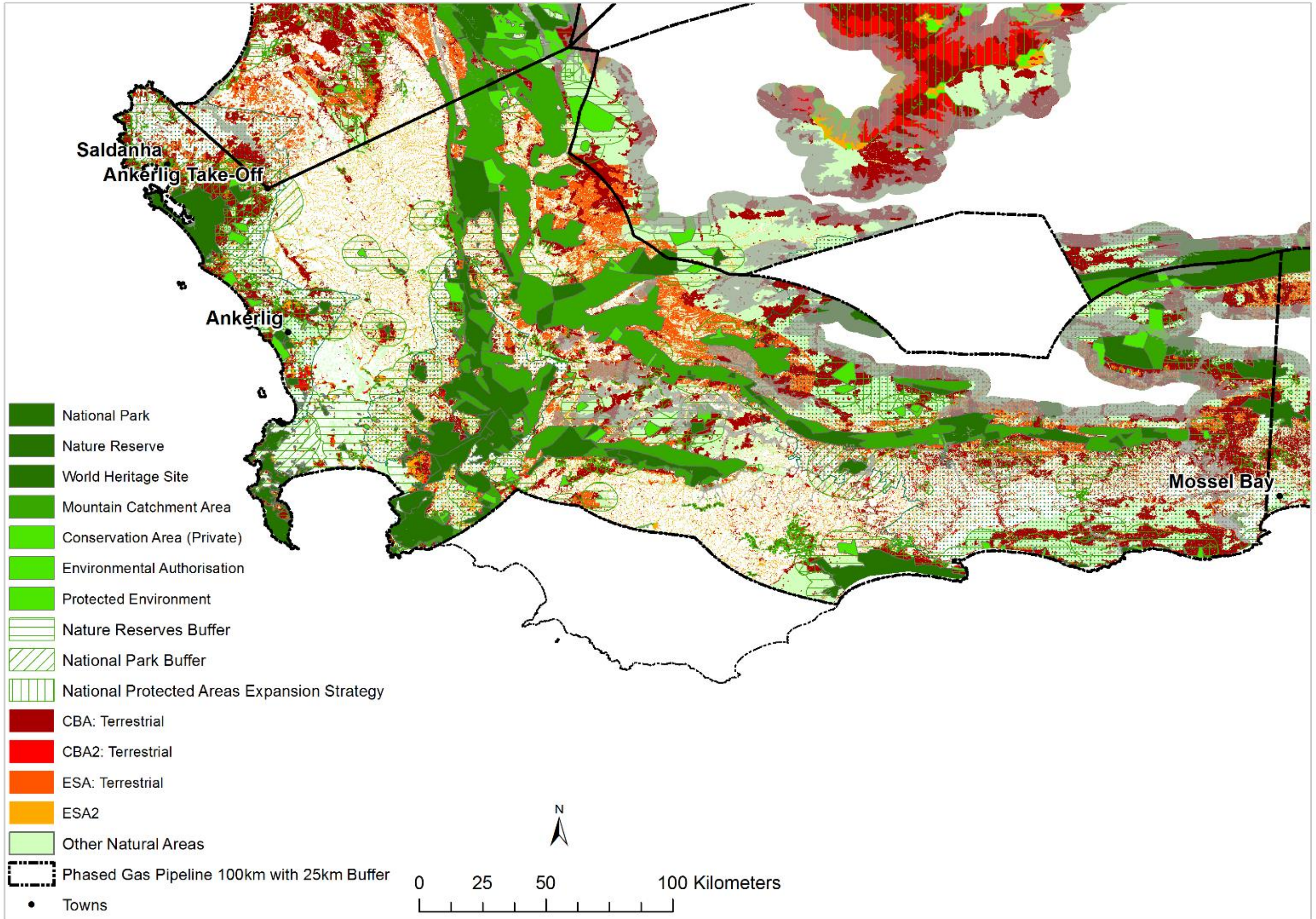


Figure 2: Gas Pipeline Phase 1 – Conservation features showing both the categories of ecosystems (CBA, ESA) and protected areas and their buffers. The Fynbos Biome units have been outlined with a 5 km external buffer in semi-transparent medium grey, and clipped to the corridors and buffers. Areas with the same level of protection status have been given the same shaded of green.

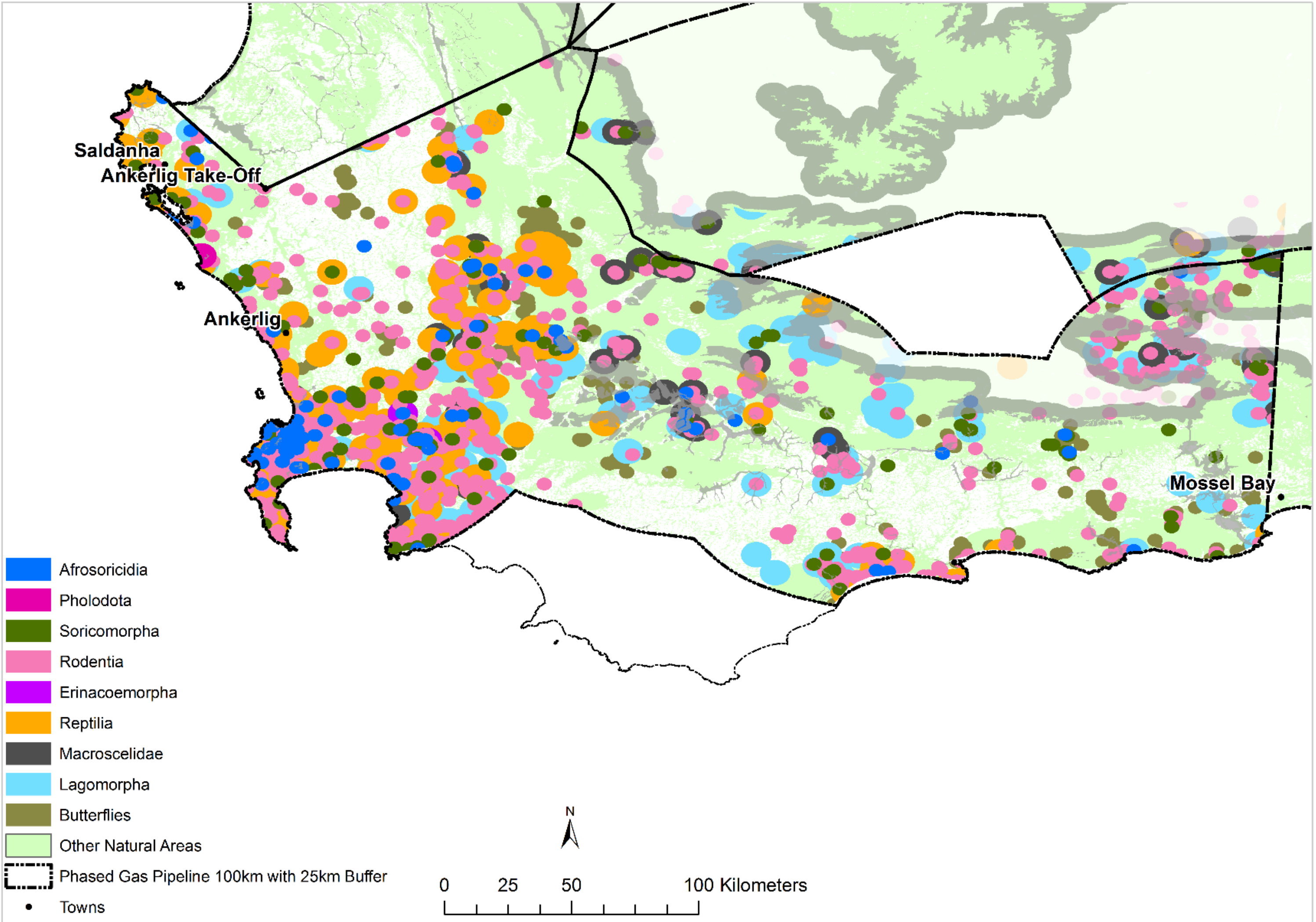


Figure 3: Gas Pipeline Phase 1 - Buffered locations of recorded threatened fauna in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with larger ranges are beneath those with smaller ranges. For information on the buffer radiuses used see the text.

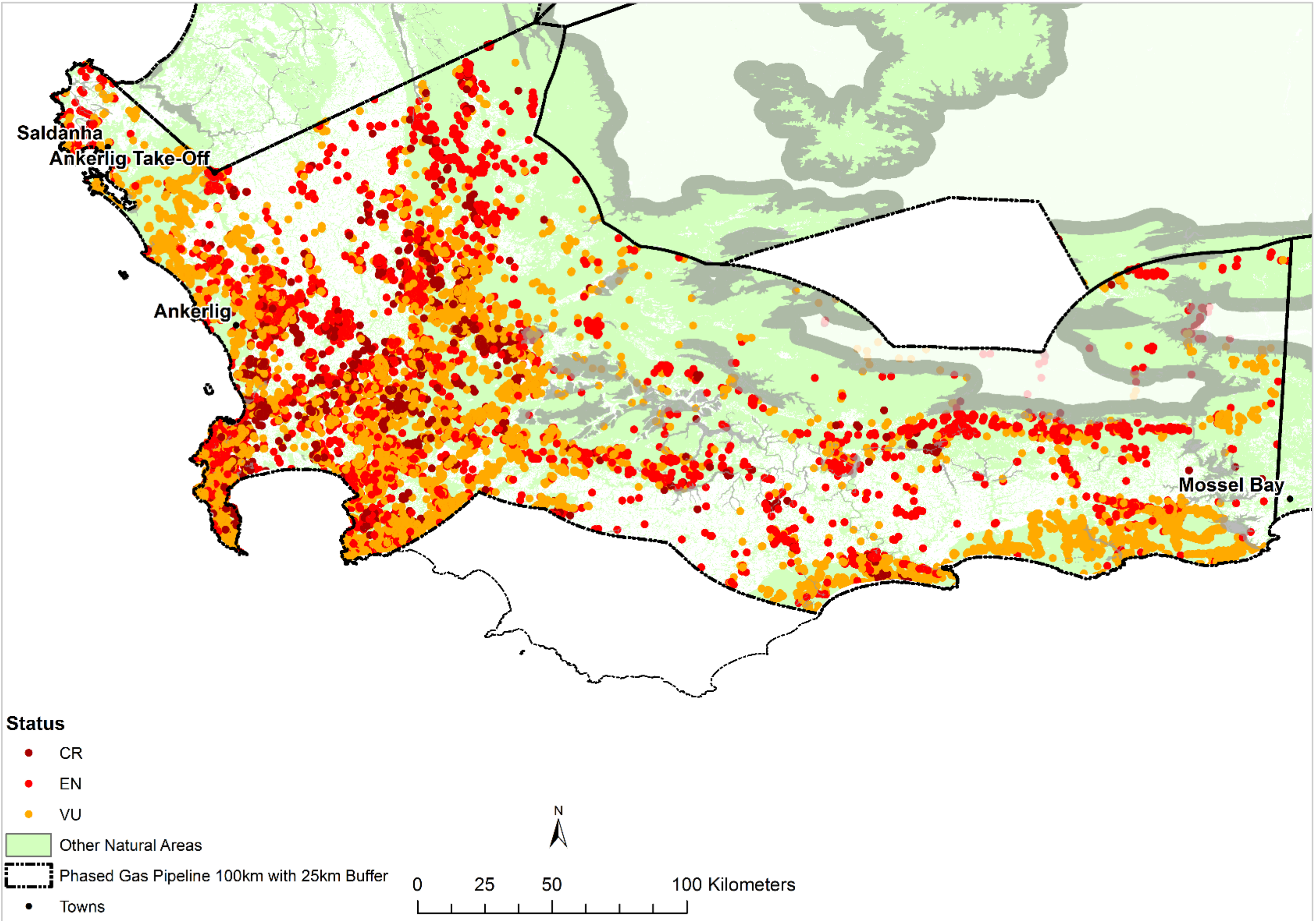


Figure 4: Gas Pipeline Phase 1 - Records of the locations of threatened plant species in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with a higher threat status are overlaid on those with a lower threat status where they overlap.

4.2.2.2 Phase 2

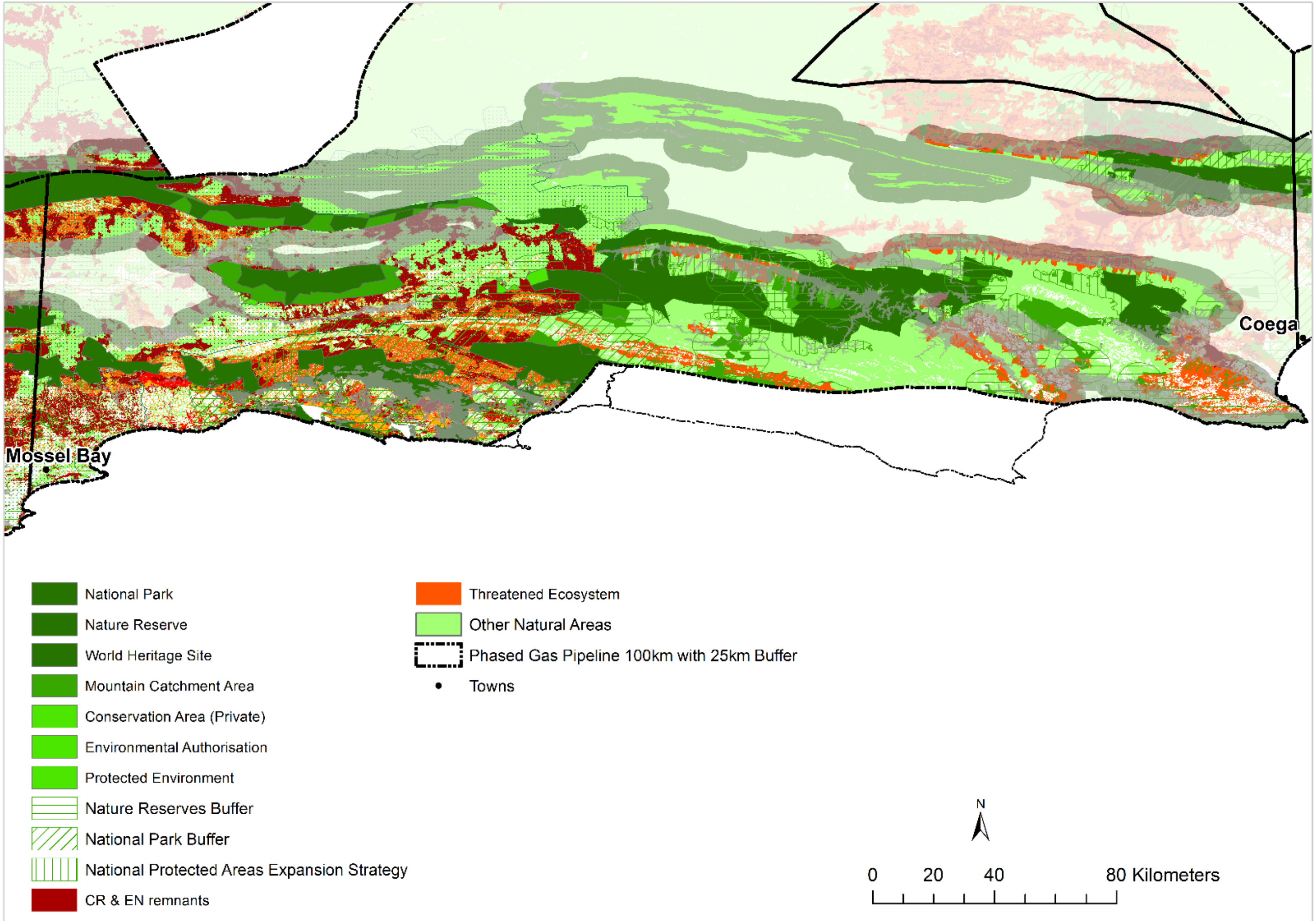


Figure 5: Gas Pipeline Phase 2 - Conservation features showing both the categories ecosystems (CBA, ESA) and protected areas and their buffers. The Fynbos Biome units have been outlined with a 5 km external buffer in semi-transparent medium grey, and clipped to the corridors and buffers. In the Western Cape threatened remnants are shown in deep red (CR, EN) and medium red (VU). Areas with the same level of protection status have been given the same shaded of green.

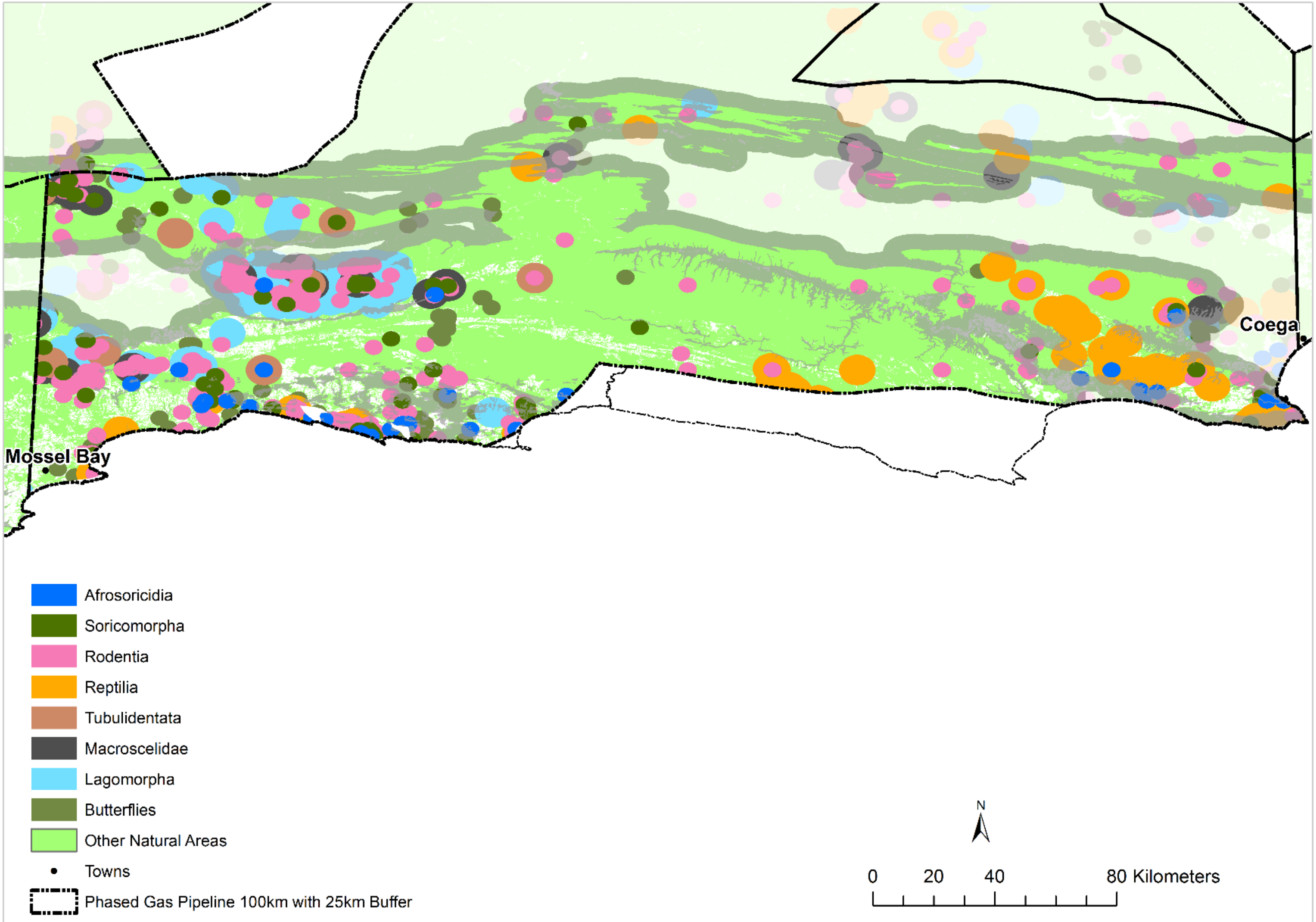


Figure 6: Gas Pipeline Phase 2 - Buffered locations of recorded threatened fauna in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with larger ranges are beneath those with smaller ranges. For information on the buffer radiuses used see the text.

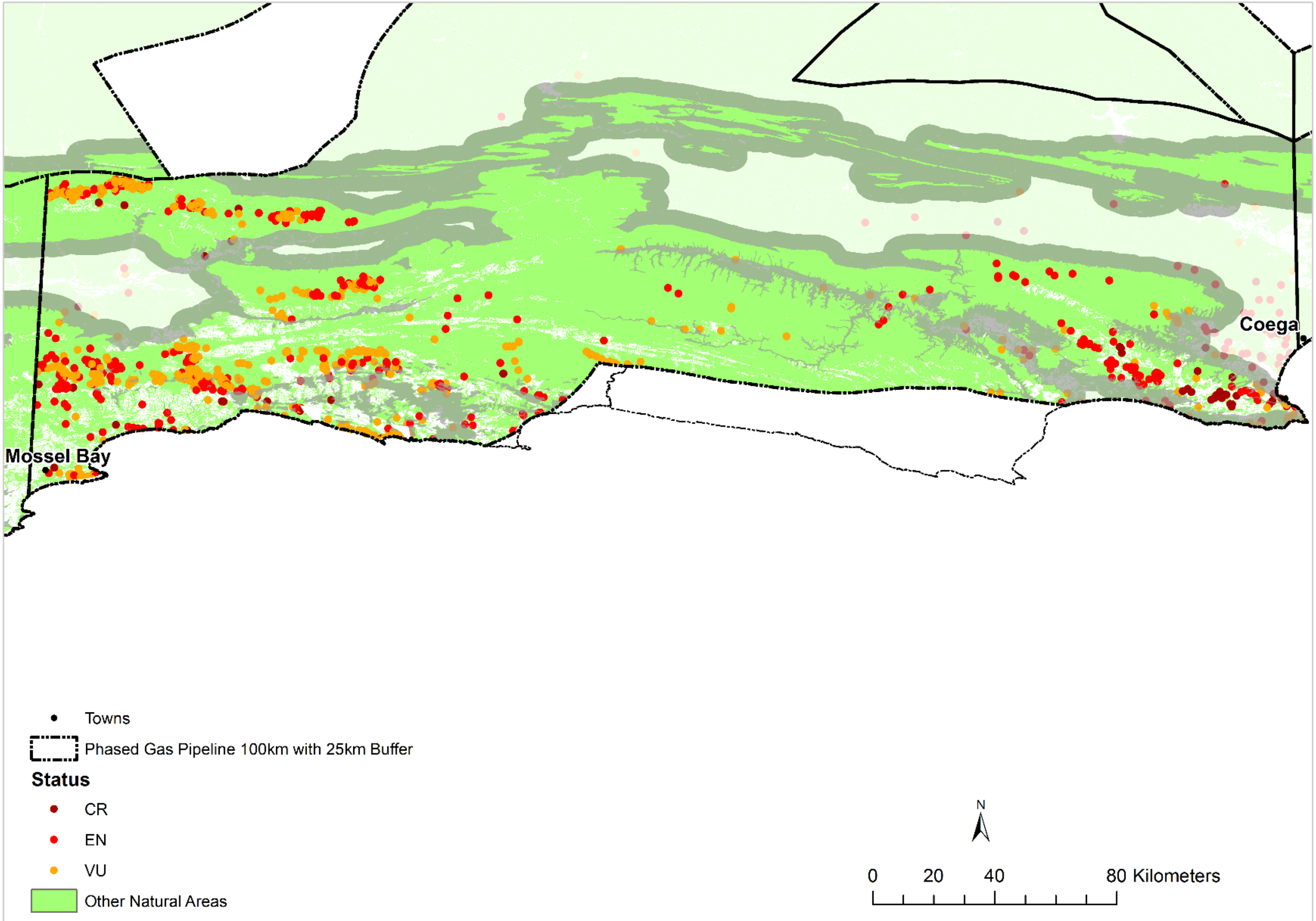


Figure 7: Gas Pipeline Phase 2 - Recorded locations of threatened plant species in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with a higher threat status are overlaid on those with a lower threat status where they overlap.

4.2.2.3 Phase 5

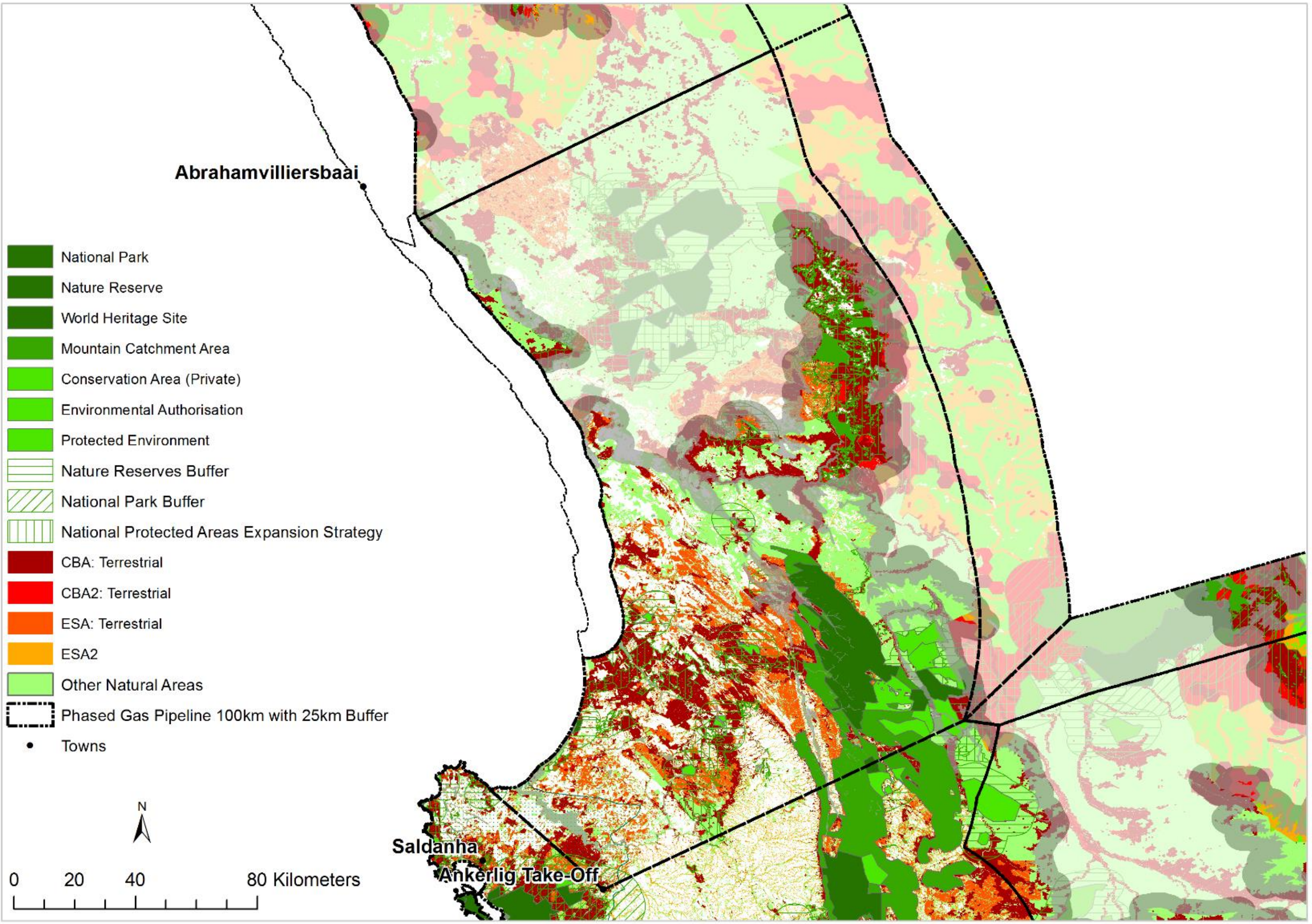


Figure 8: Gas Pipeline Phase 5 - Conservation features showing both the categories ecosystems (CBA, ESA) and protected areas and their buffers. The Fynbos Biome units have been outlined with a 5 km external buffer in semi-transparent medium grey, and clipped to the corridors and buffers. Areas with the same level of protection status have been give the same shaded of green.

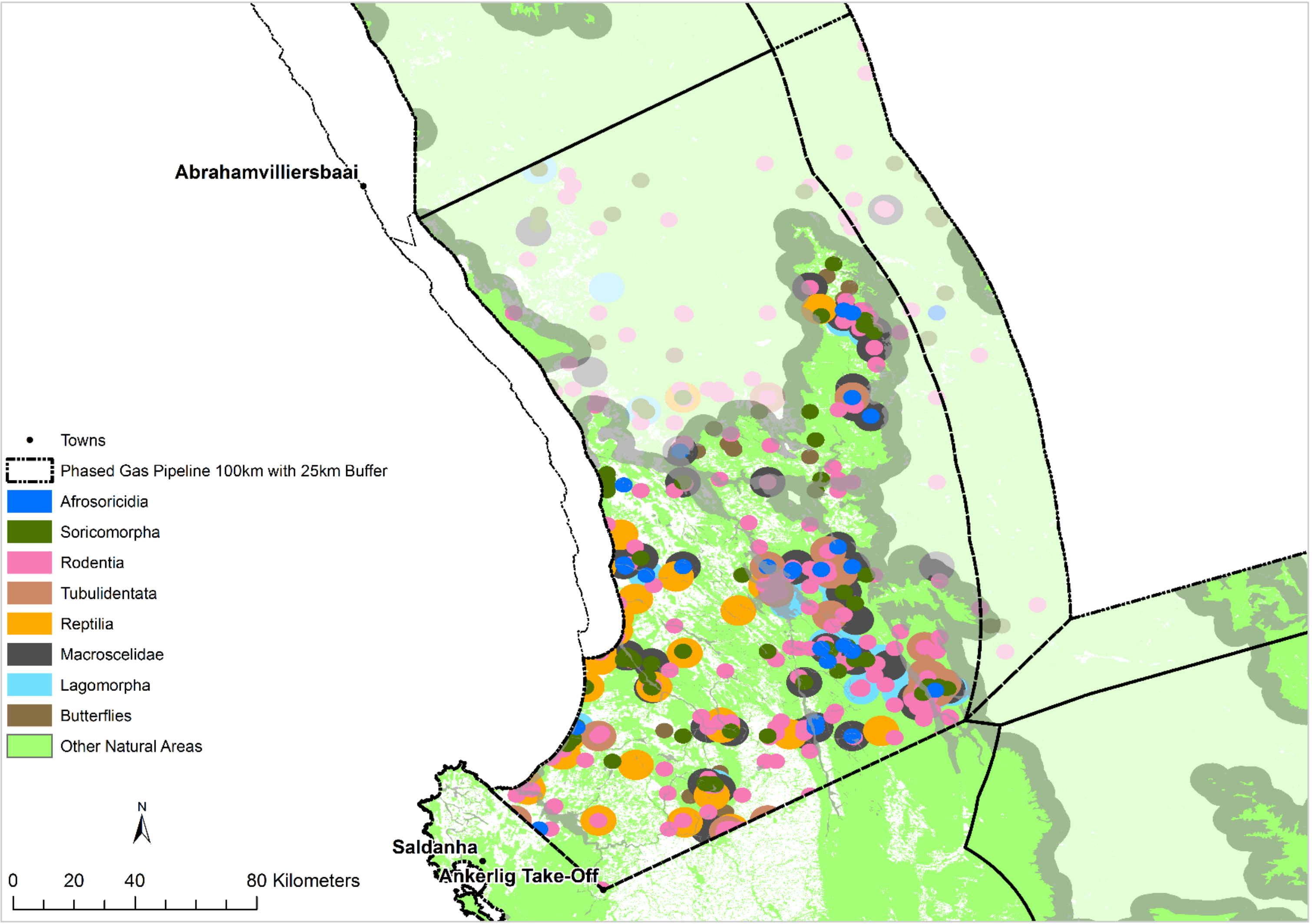


Figure 9: Gas Pipeline Phase 5 - Buffered locations of recorded threatened fauna in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with larger ranges are beneath those with smaller ranges. For information on the buffer radiuses used see the text.

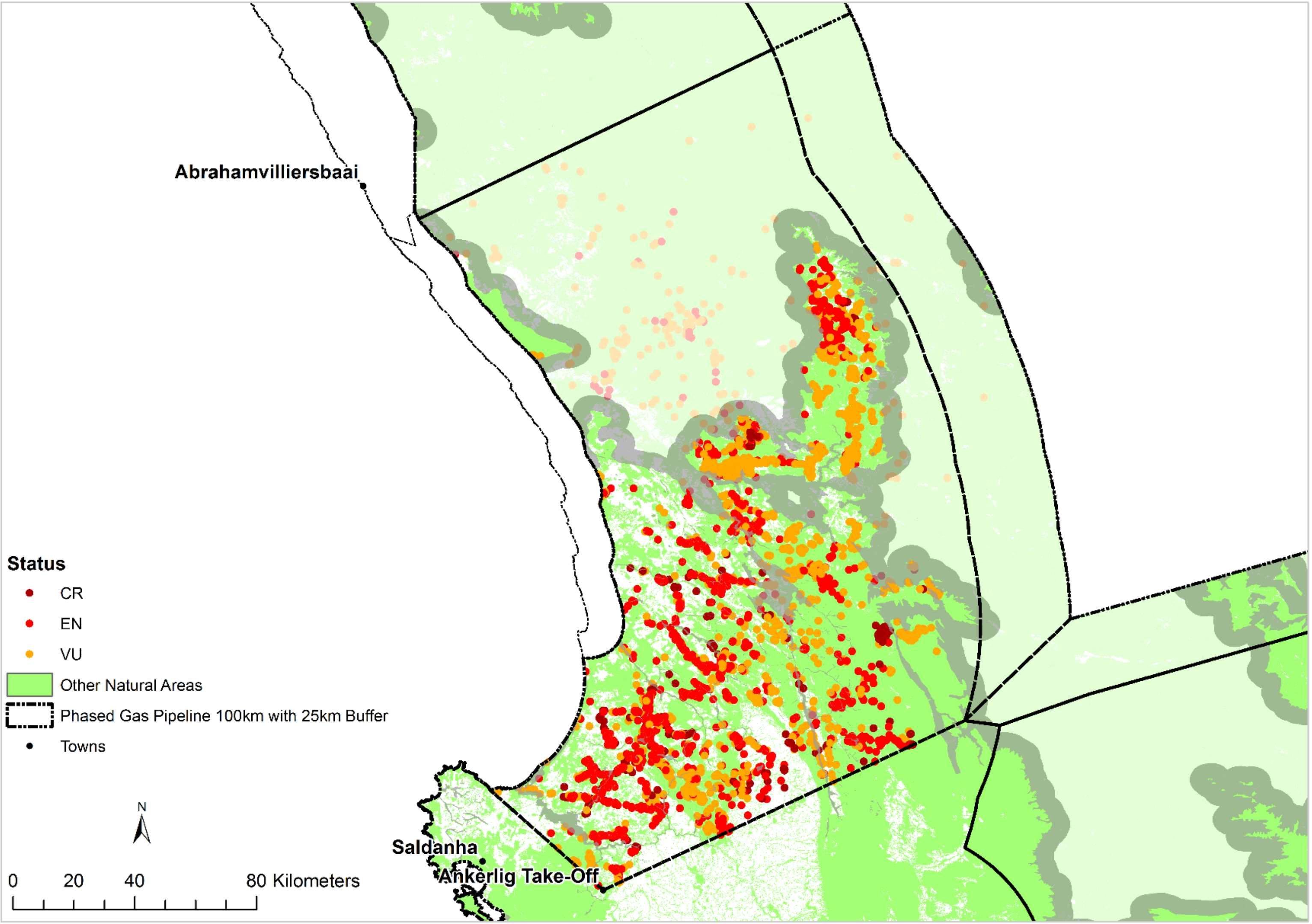


Figure 10: Gas Pipeline Phase 5 - Recorded locations of threatened plant species in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with a higher threat status are overlaid on those with a lower threat status where they overlap.

4.2.2.4 Phase 6

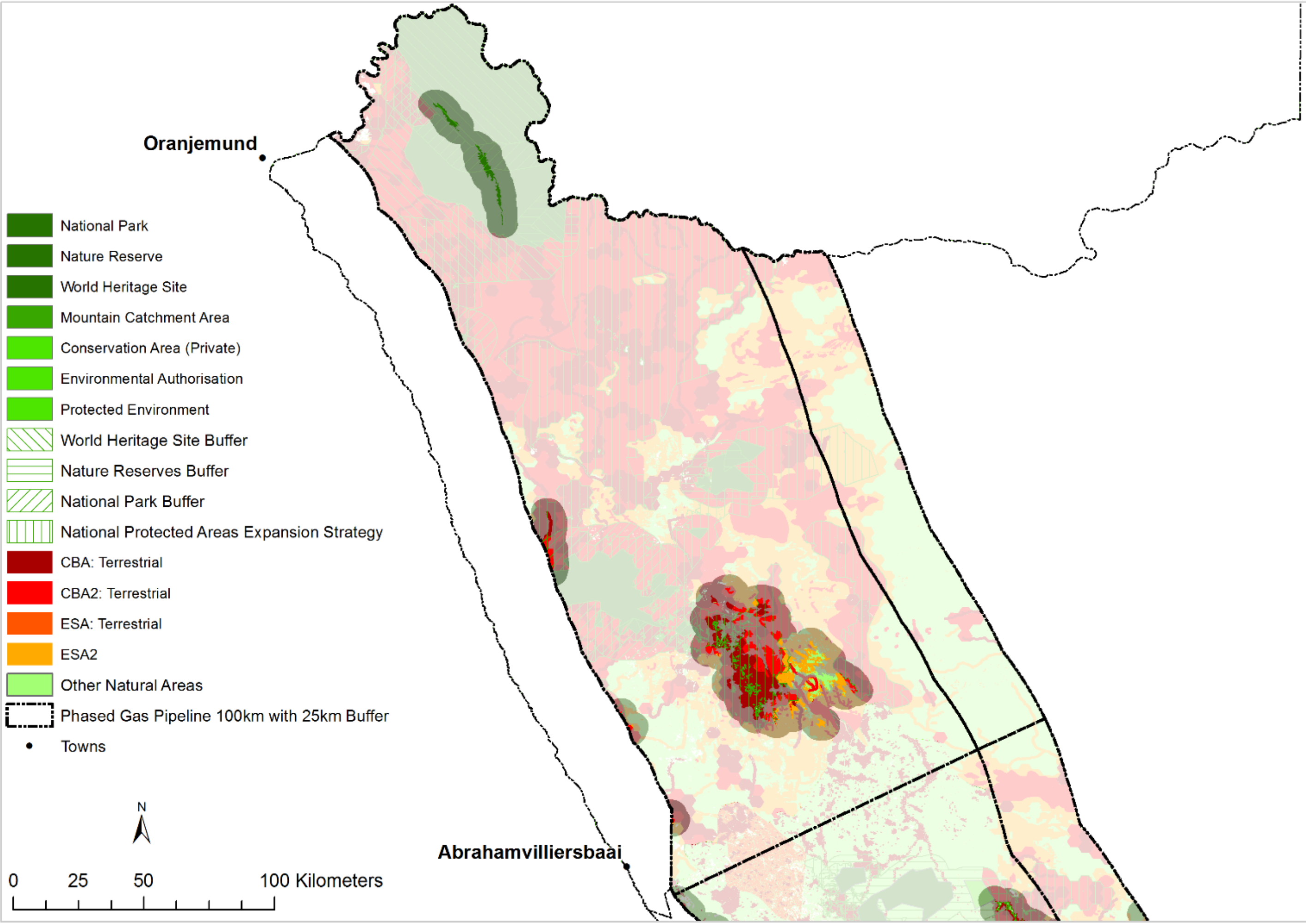


Figure 11: Gas Pipeline Phase 6 - Conservation features showing both the categories of ecosystems (CBA, ESA) and protected areas and their buffers. The Fynbos Biome units have been outlined with a 5 km external buffer in semi-transparent medium grey, and clipped to the corridors and buffers. Areas with the same level of protection status have been given the same shade of green.

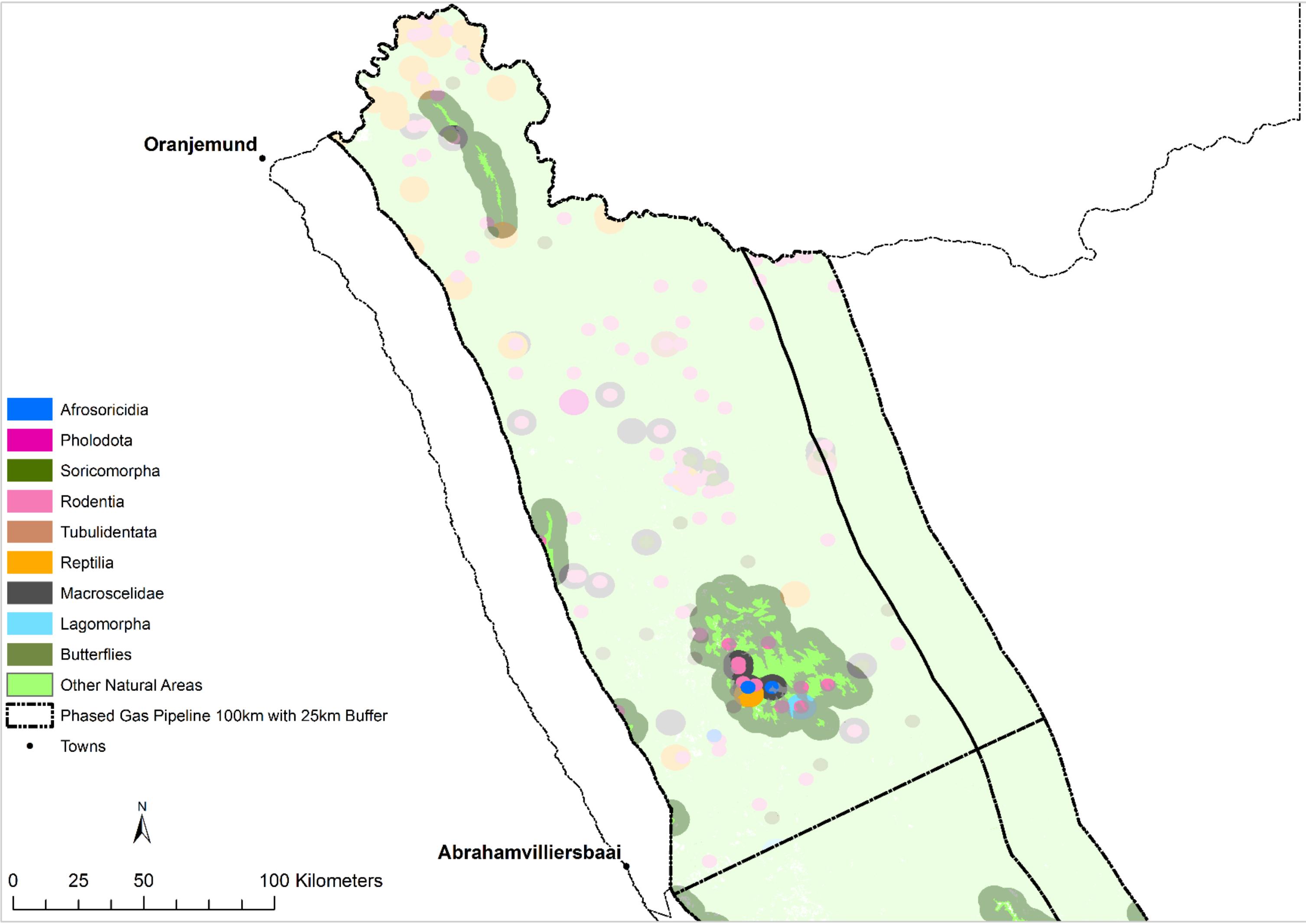


Figure 12: Gas Pipeline Phase 6 - Buffered locations of recorded threatened fauna in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with larger ranges are beneath those with smaller ranges. For information on the buffer radiuses used see the text.

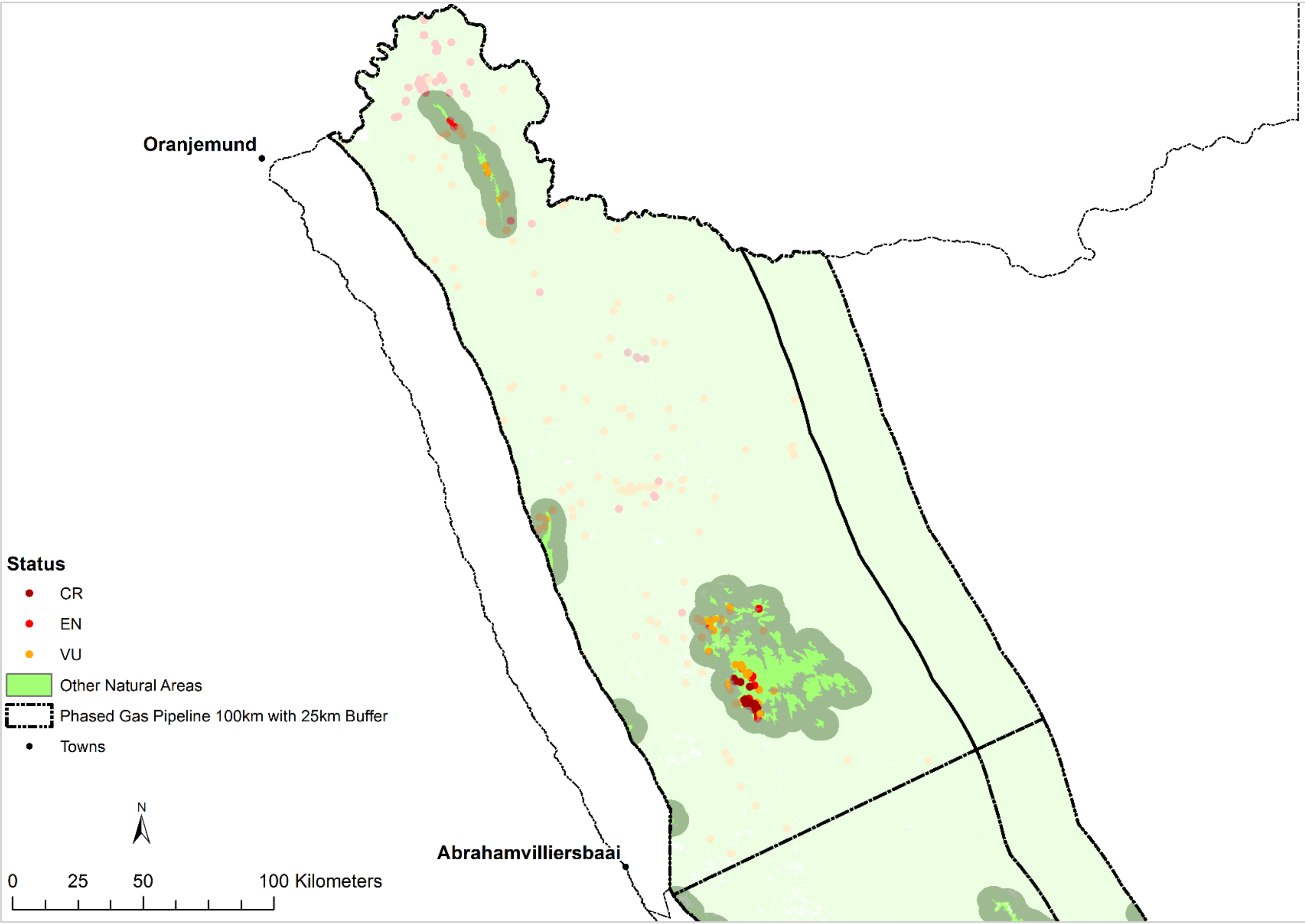


Figure 13: Gas Pipeline Phase 6 - Recorded locations of threatened plant species in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with a higher threat status are overlaid on those with a lower threat status where they overlap.

4.2.2.5 *Phase 7*

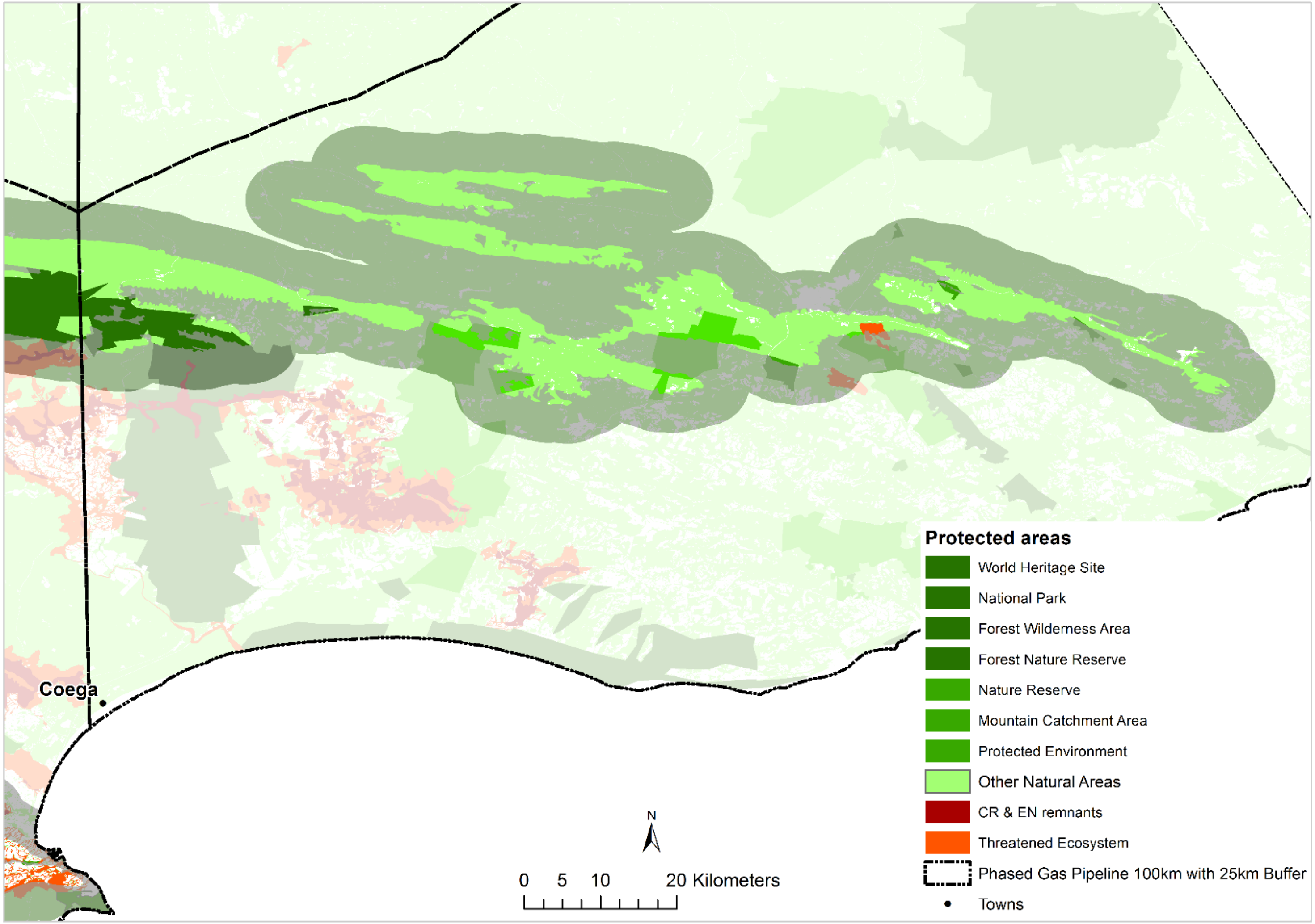


Figure 14: Gas Pipeline Phase 7 - Conservation features showing both threatened ecosystems and protected areas. The Fynbos Biome units have been outlined with a 5 km external buffer in semi-transparent medium grey. Areas with the same level of protection status have been given the same shade of green.

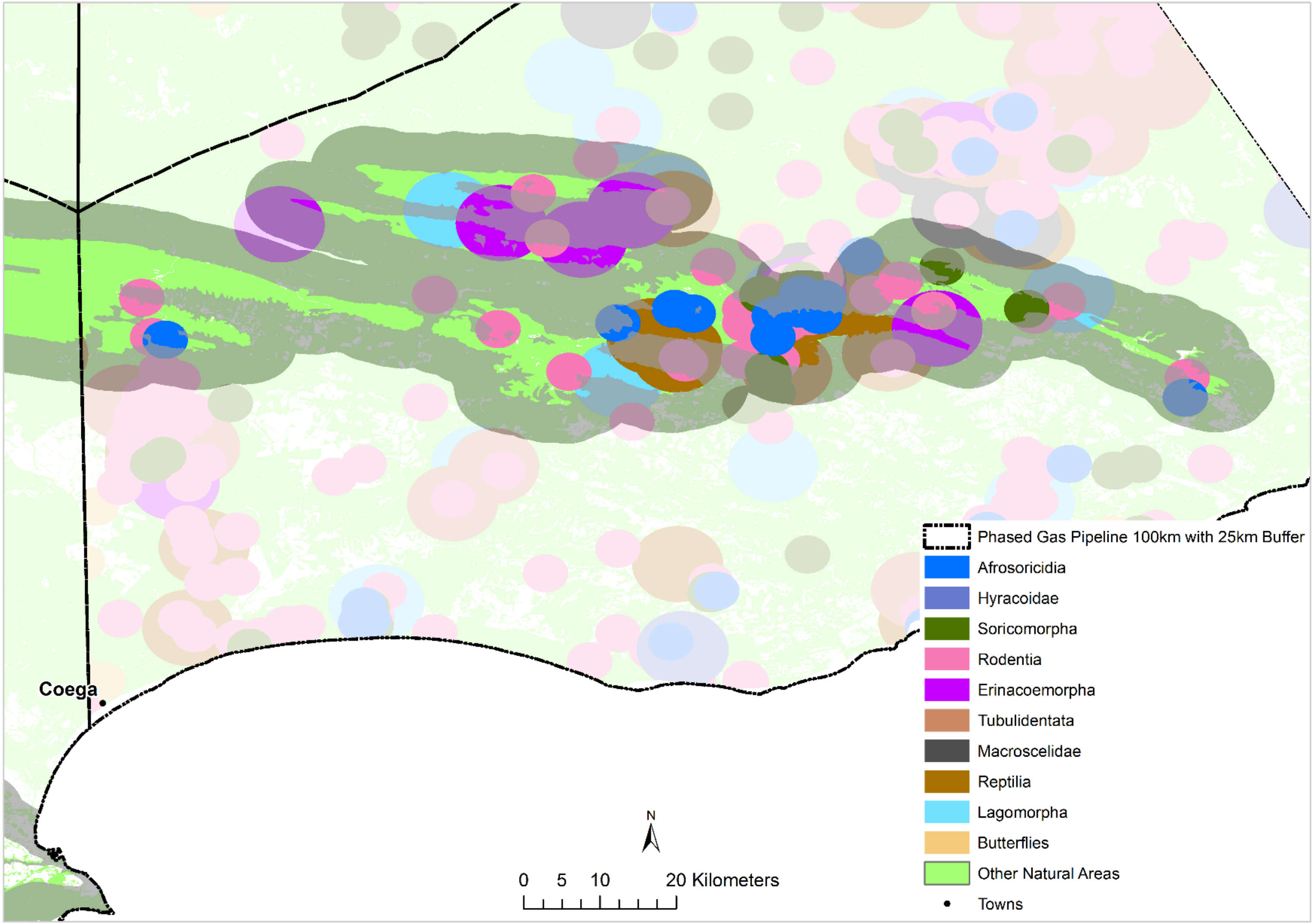


Figure 15: Gas Pipeline Phase 7 - Buffered locations of recorded threatened fauna in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with larger ranges are beneath those with smaller ranges. For information on the buffer radiuses used see the text.

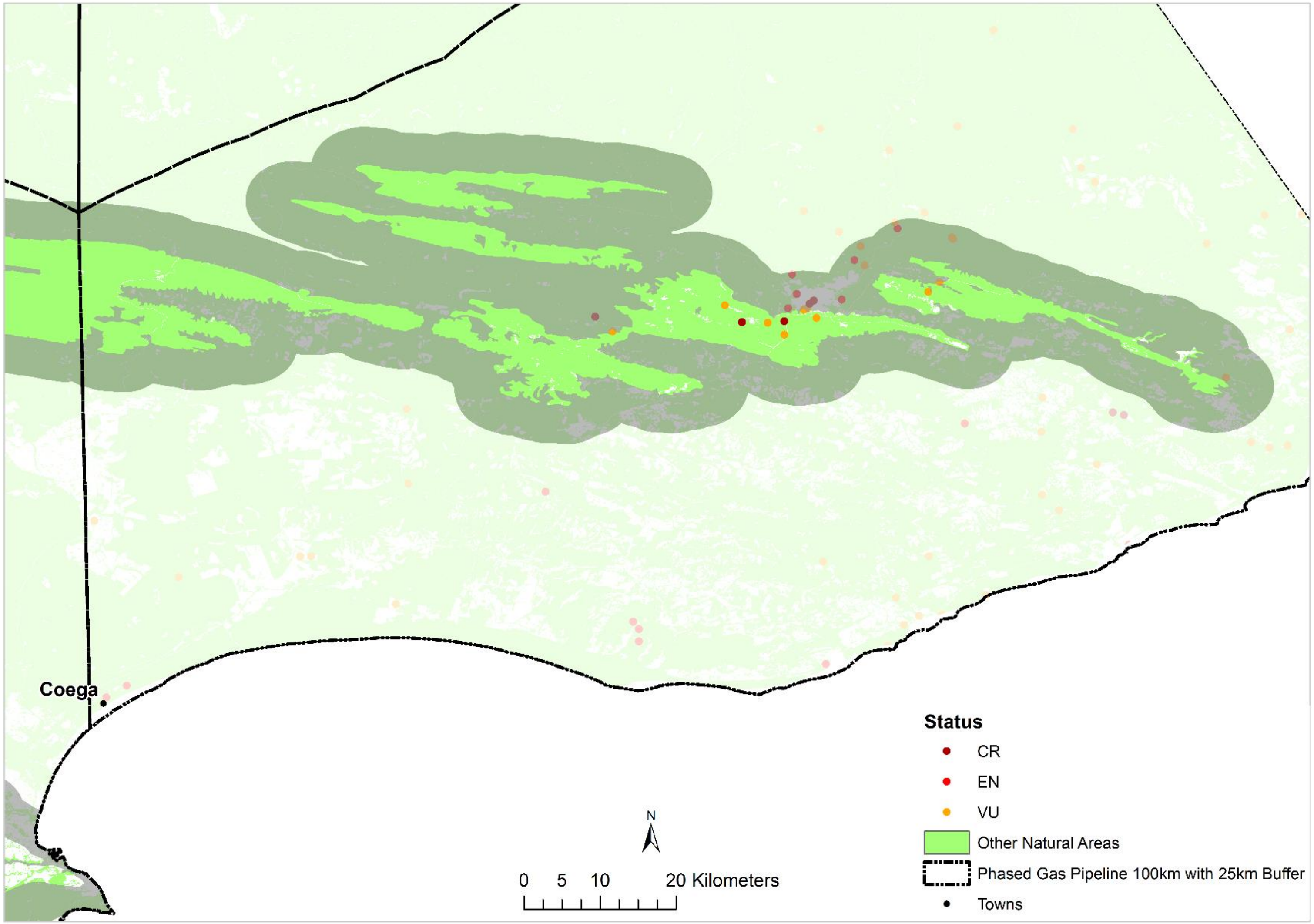


Figure 16: Gas Pipeline Phase 7 - Recorded locations of threatened plant species in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with a higher threat status are overlaid on those with a lower threat status where they overlap.

4.2.2.6 Inland

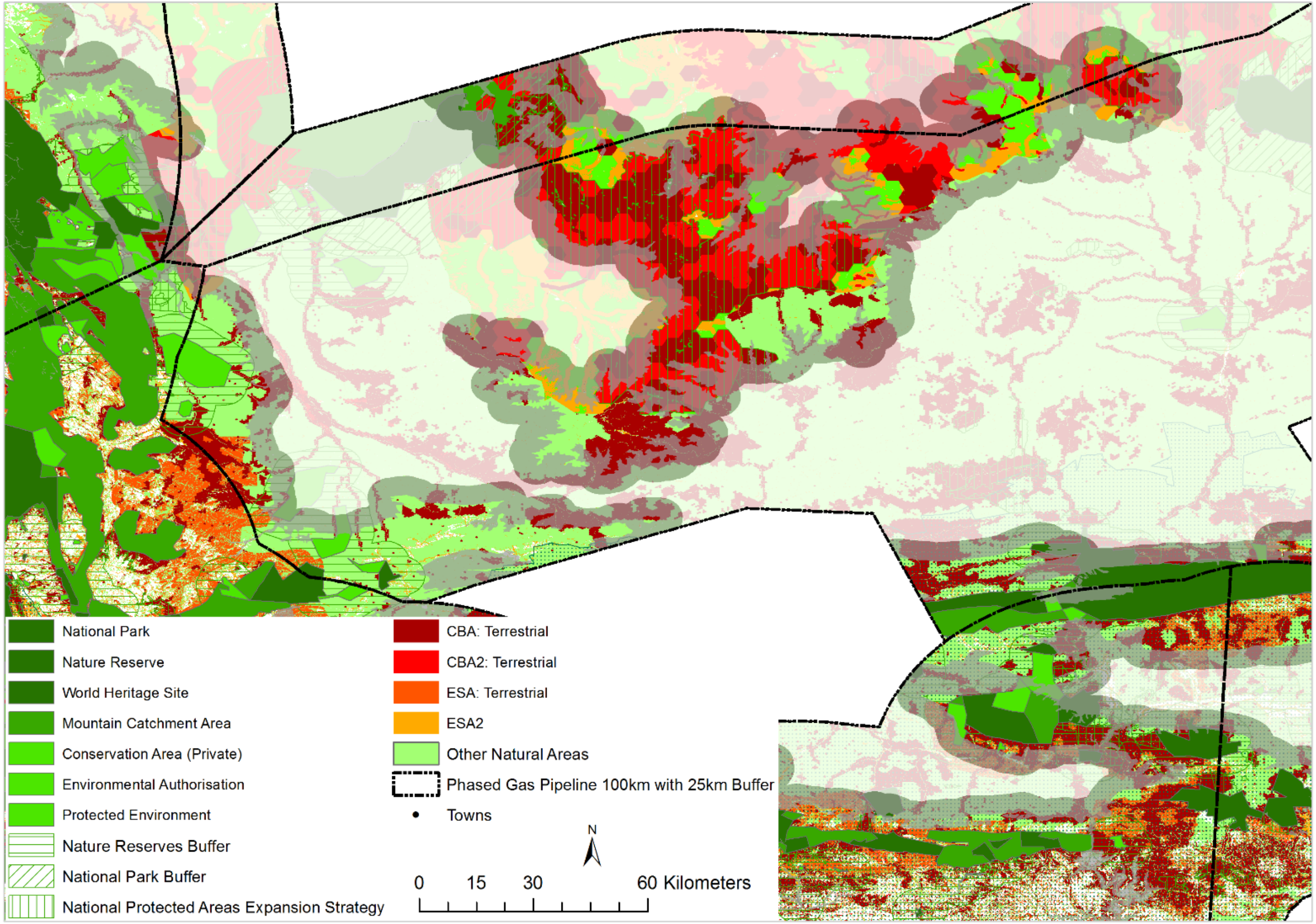


Figure 17: Gas Pipeline Phase Inland - Conservation features showing both the categories ecosystems (CBA, ESA) and protected areas and their buffers. The Fynbos Biome units have been outlined with a 5 km external buffer in semi-transparent medium grey, and clipped to the corridors and buffers. Areas with the same level of protection status have been given the same shade of green.

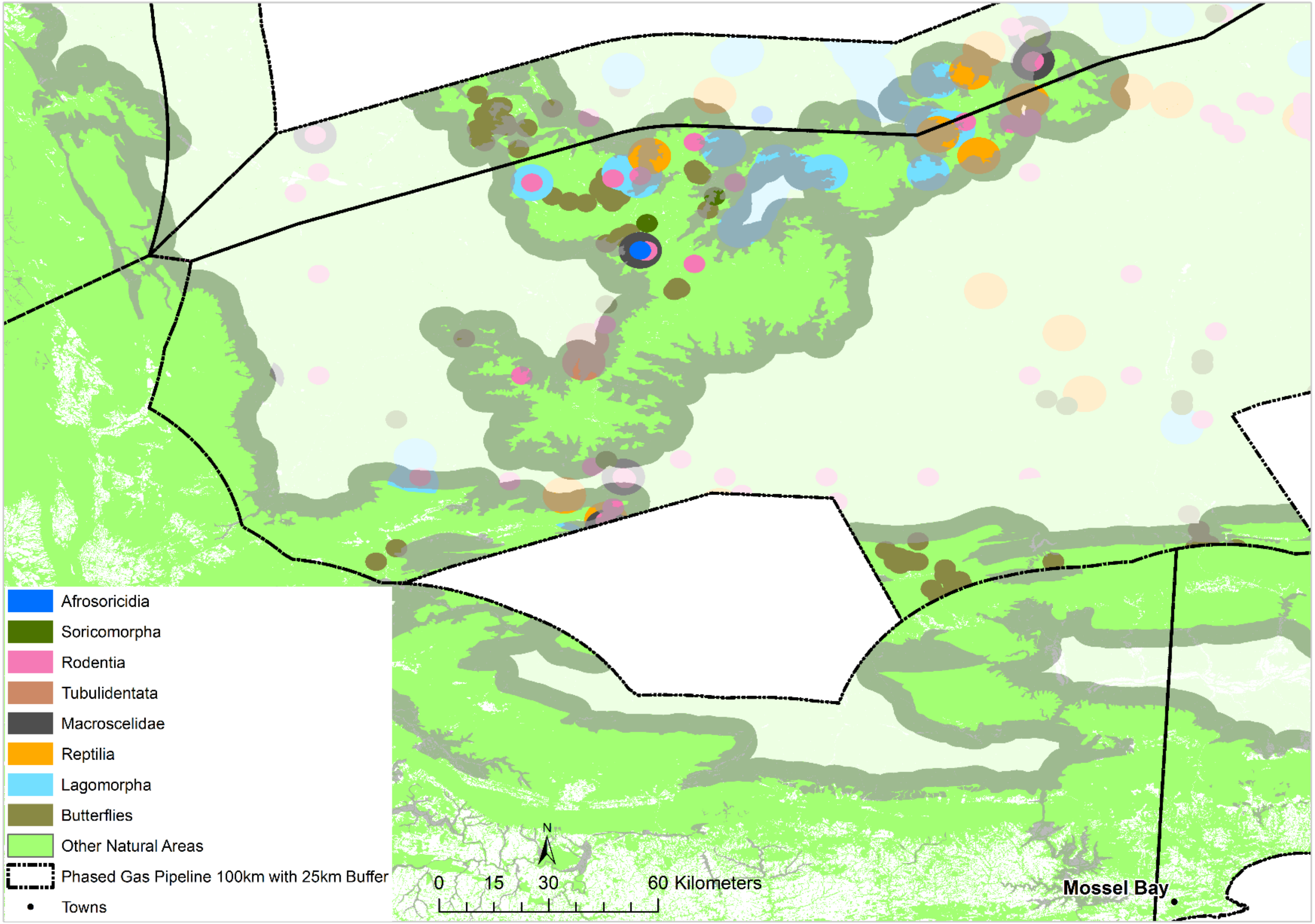


Figure 18: Gas Pipeline Phase Inland - Buffered locations of recorded threatened fauna in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with larger ranges are beneath those with smaller ranges. For information on the buffer radiuses used see the text.

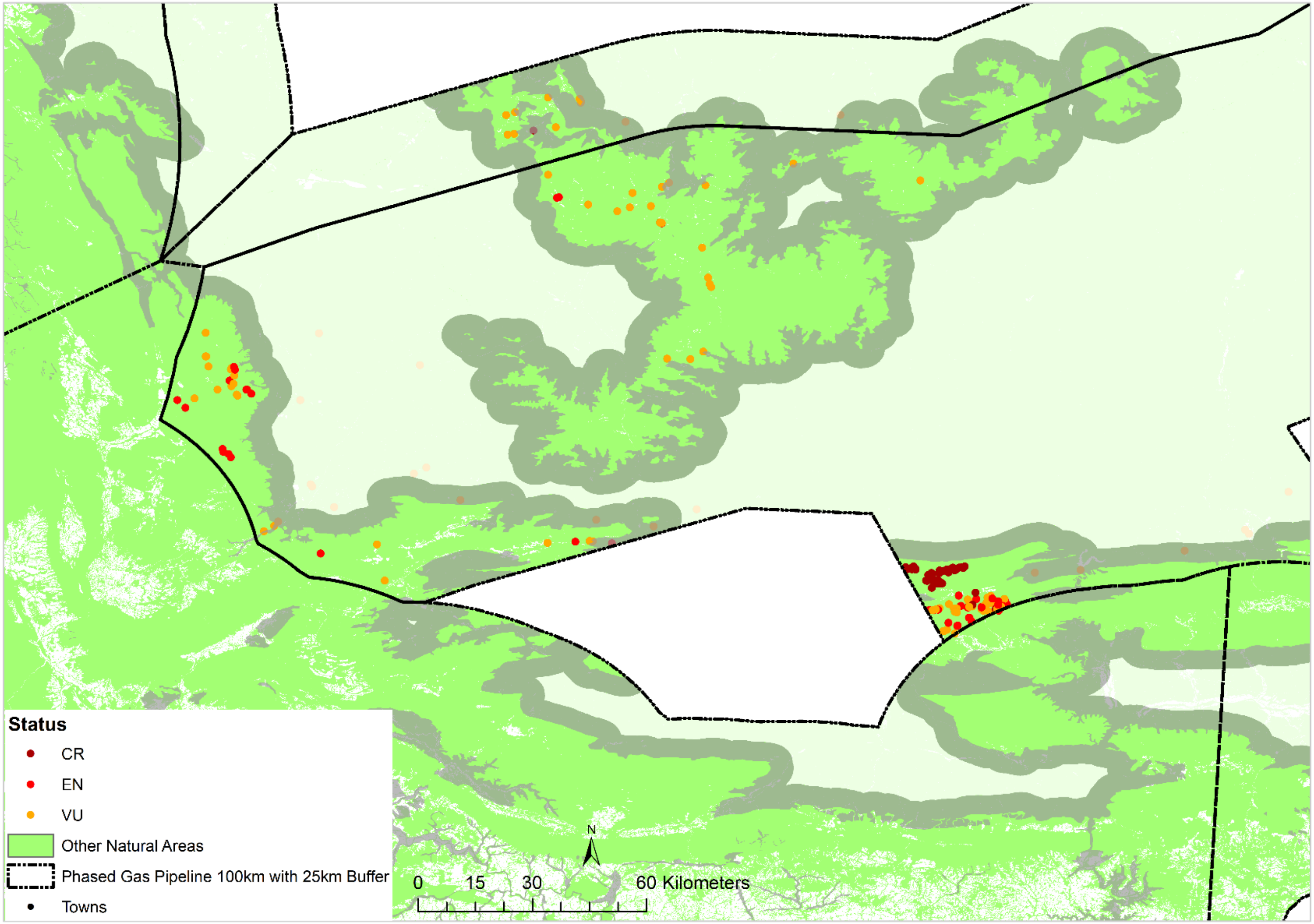


Figure 19: Gas Pipeline Phase Inland - Recorded locations of threatened plant species in the Fynbos Biome within the proposed corridor based on datasets supplied by SANBI. The taxa have been arranged so that those with a higher threat status are overlaid on those with a lower threat status where they overlap.

4.3 Four-Tier Sensitivity Mapping

The sensitivity rating followed the approach suggested for this assessment although there are shortcomings because the method combines quite disparate measures: namely biodiversity feature based values such threatened ecosystems or species, uniqueness, with the current level of protection. Ideally the level of protection and the biodiversity measures should be related, but the original establishment of protected areas was not based on a systematic assessment of the biodiversity value. In many cases the level of protection was determined by land availability or the land was protected for other purposes (e.g. water source protection), or by the views and objectives of the body that was legislating for their protection. The resulting maps, which illustrate the spatial distribution of the relative sensitivity, are potentially misleading because the mapped sensitivity classes are not uniform but heterogeneous. To give a hypothetical example, routing the pipeline through a National Park is seen as inappropriate given that it has the highest level of protection under law and so is rated as Very High sensitivity. But the area of the park through the pipeline is being routed may not include threatened ecosystems or any threatened species. Adjoining the boundary is a threatened ecosystem which might also contain threatened species and be a crucial link (corridor) for species movements and has been rated a CBA 1 and so the sensitivity also is Very High. The pipeline route through the park might be longer than through the CBA 1, so the choice based on them having the same sensitivity would be to route the pipeline through the CBA 1. In this hypothetical example such a decision could well do more harm to biodiversity.

In many cases such sensitivities are estimated based on assigning a numerical value and this is potentially feasible where the features being compared are in some sense commensurate, such as species or ecosystem status or even information on key processes (e.g. movement corridors). However, in this case there are both biodiversity based values - using biodiversity in the broad sense of composition, structure and function from genes to landscapes (Noss, 1996) – that are being combined with the level of statutory protection. In such cases a simple quantitative score is the best because the preferred alternative, a multi-criteria decision making approach, is best done through consultation with other experts and the scope of the present study does not allow for such detailed consultations.

Assigning a sensitivity rating requires an assessment of the vulnerability of the receiving environment to the impact (i.e. the potential magnitude of the loss) and the potential for mitigation to reduce that impact by, for example, reducing the vulnerability. The vulnerability of the feature of interest is, in turn, determined by the characteristics of the impact and those of the feature, including the specific environmental setting and context of that feature. The characteristics of the impact that are important are its timing in relation to key community processes (e.g. in winter versus summer), intensity or severity, extent, duration and likely recurrence interval. The inherent vulnerability to the impact varies between features of different types (e.g. ecosystems, species), the environmental settings (high rainfall or marginal rainfall environment, stable versus erodible soils) and the context (e.g. north versus south-facing slopes, steep versus gentle slope). In this case the sensitivity that is being rated is to the construction and operation of a gas pipeline, which amount to a severe, linearly-extensive impact of relatively short duration and of a similar magnitude everywhere. The main impact during construction phase is due to the clearing of vegetation, access for people, machines and materials, trenching, and initiating rehabilitation. All the stages, bar the rehabilitation, could be accomplished in a period of weeks or days. It is the long-term impacts that really matter in the form of the degree of recovery of the composition and structure of the regenerating community, potentially including invading alien species, and those due to the access tracks, both forming a long line across the landscape.

Figure 20 - Figure 26 present the sensitivity maps for the Fynbos Biome in the proposed gas pipeline phases.

4.3.1 Phase 1

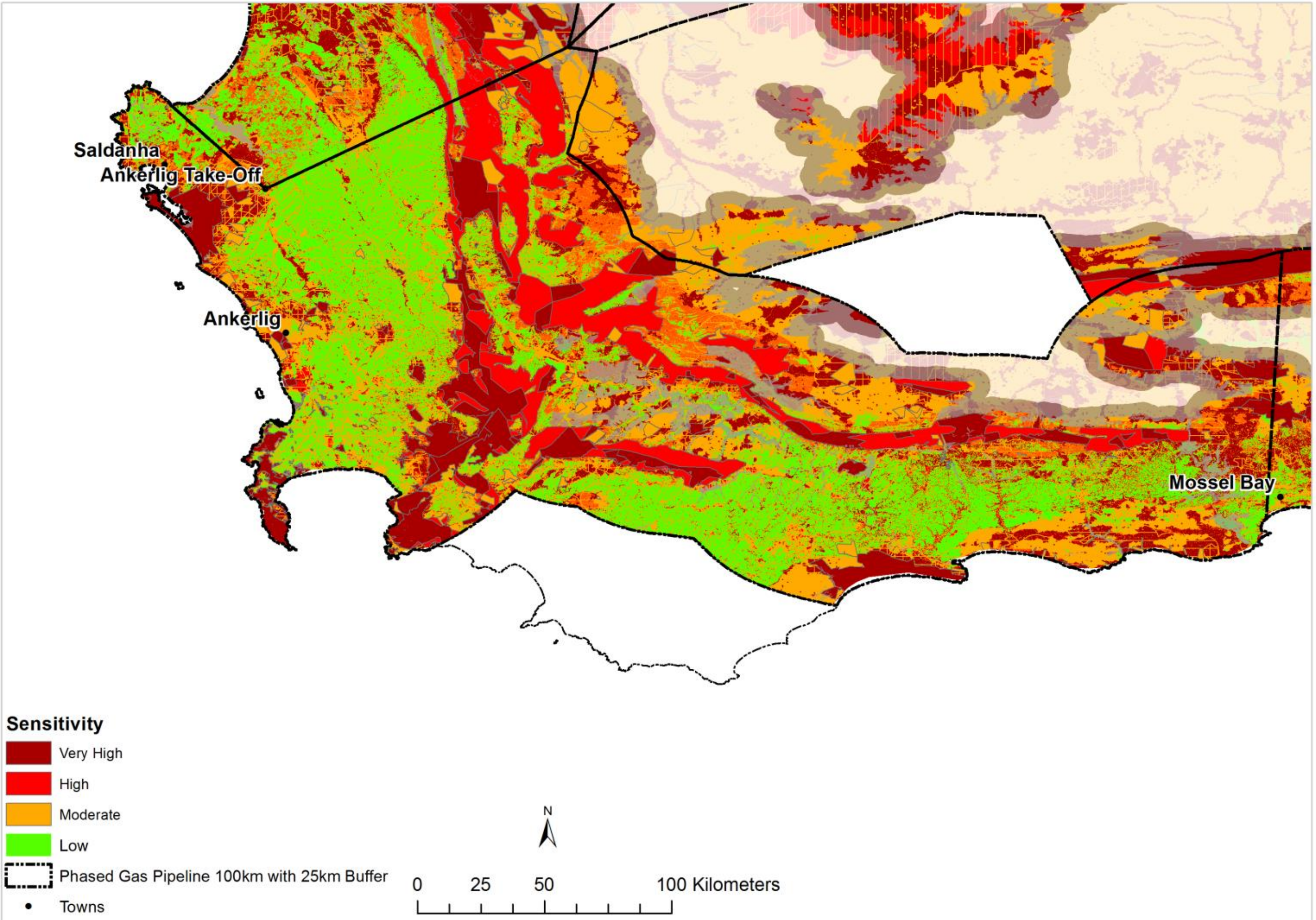


Figure 20: Gas Pipeline Phase 1 - Sensitivity map based on the sensitivity ratings of the biodiversity and conservation features.

4.3.2 Phase 2

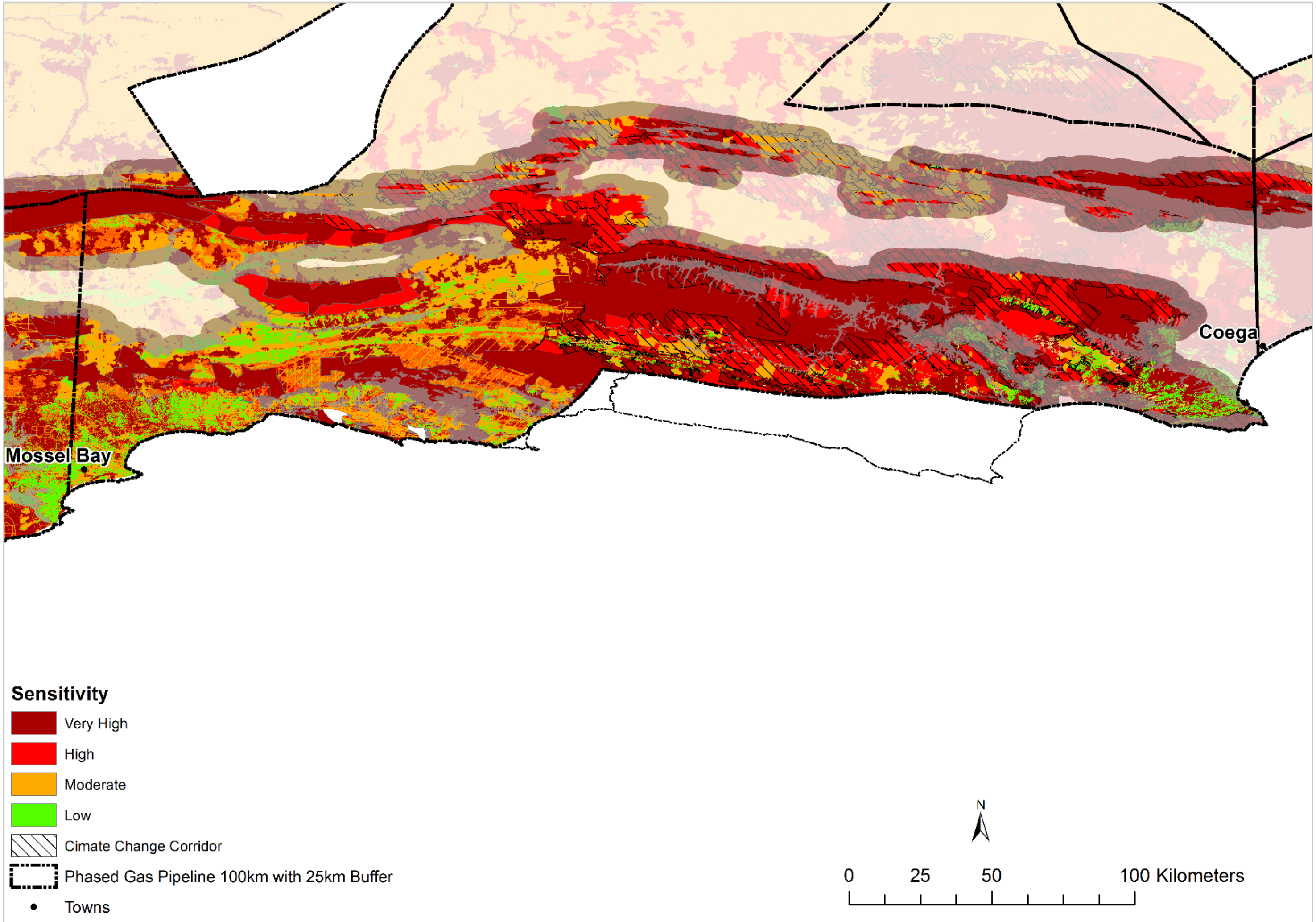


Figure 21: Gas Pipeline Phase 2 - Sensitivity map based on the sensitivity ratings of the biodiversity and conservation features.

4.3.3 Phase 5

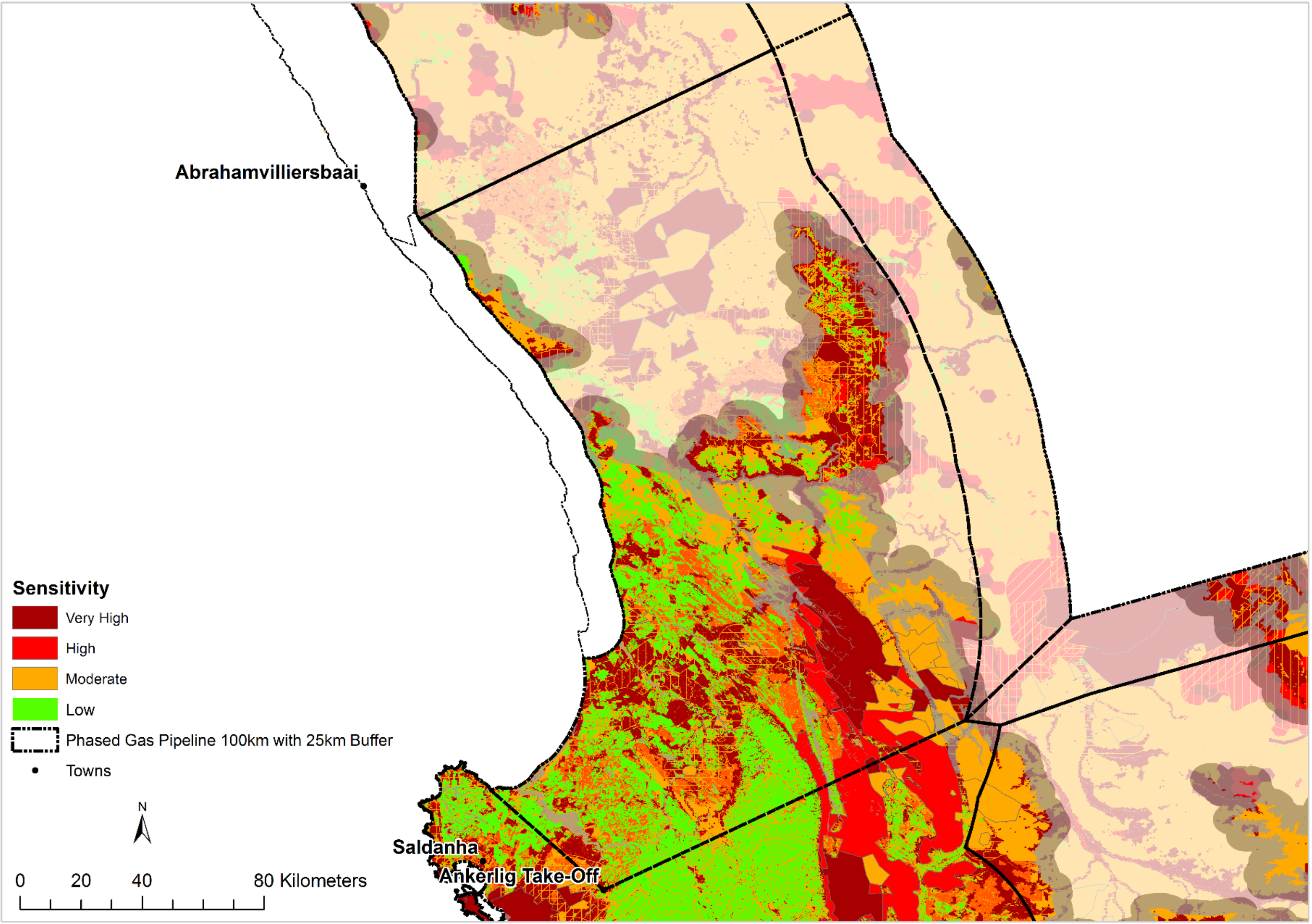
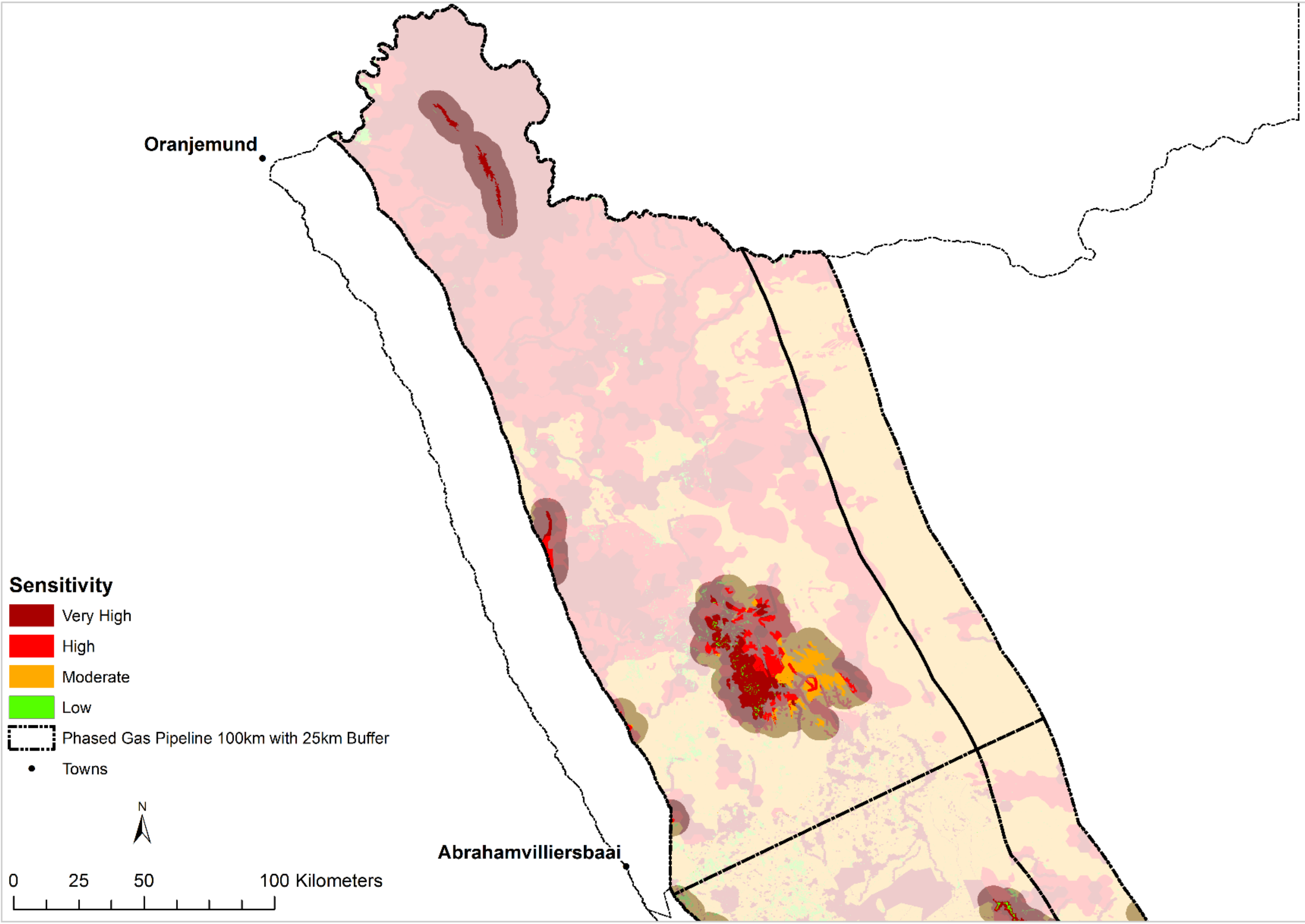


Figure 22: Gas Pipeline Phase 5 - Sensitivity map based on the sensitivity ratings of the biodiversity and conservation features.

1 ### 4.3.4 Phase 6



2
3 Figure 23: Gas Pipeline Phase 6 - Sensitivity map based on the sensitivity ratings of the biodiversity and conservation features.

4.3.5 Phase 7

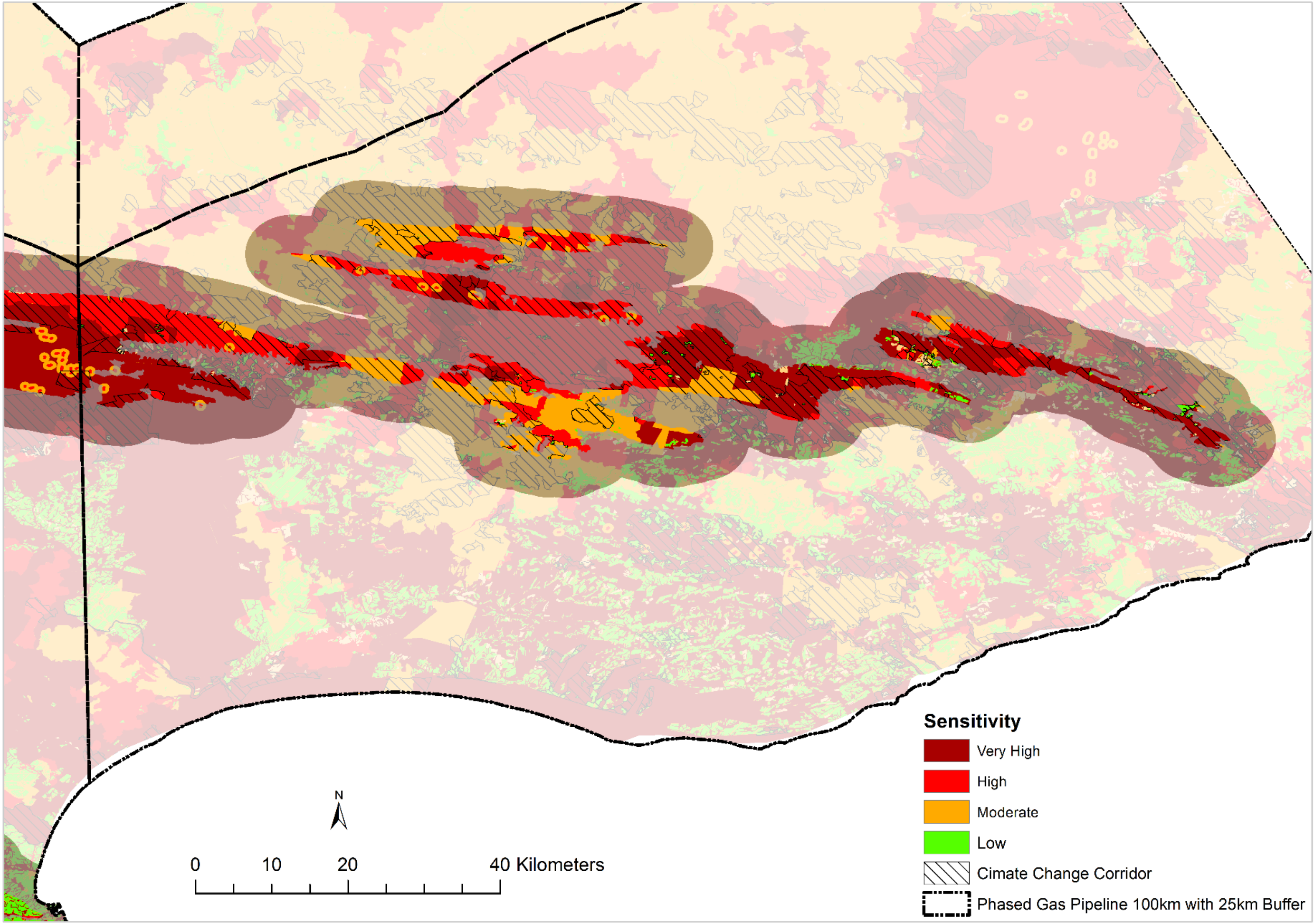


Figure 24: Gas Pipeline Phase 7 - Sensitivity map based on the sensitivity ratings of the biodiversity and conservation features.

4.3.6 Inland

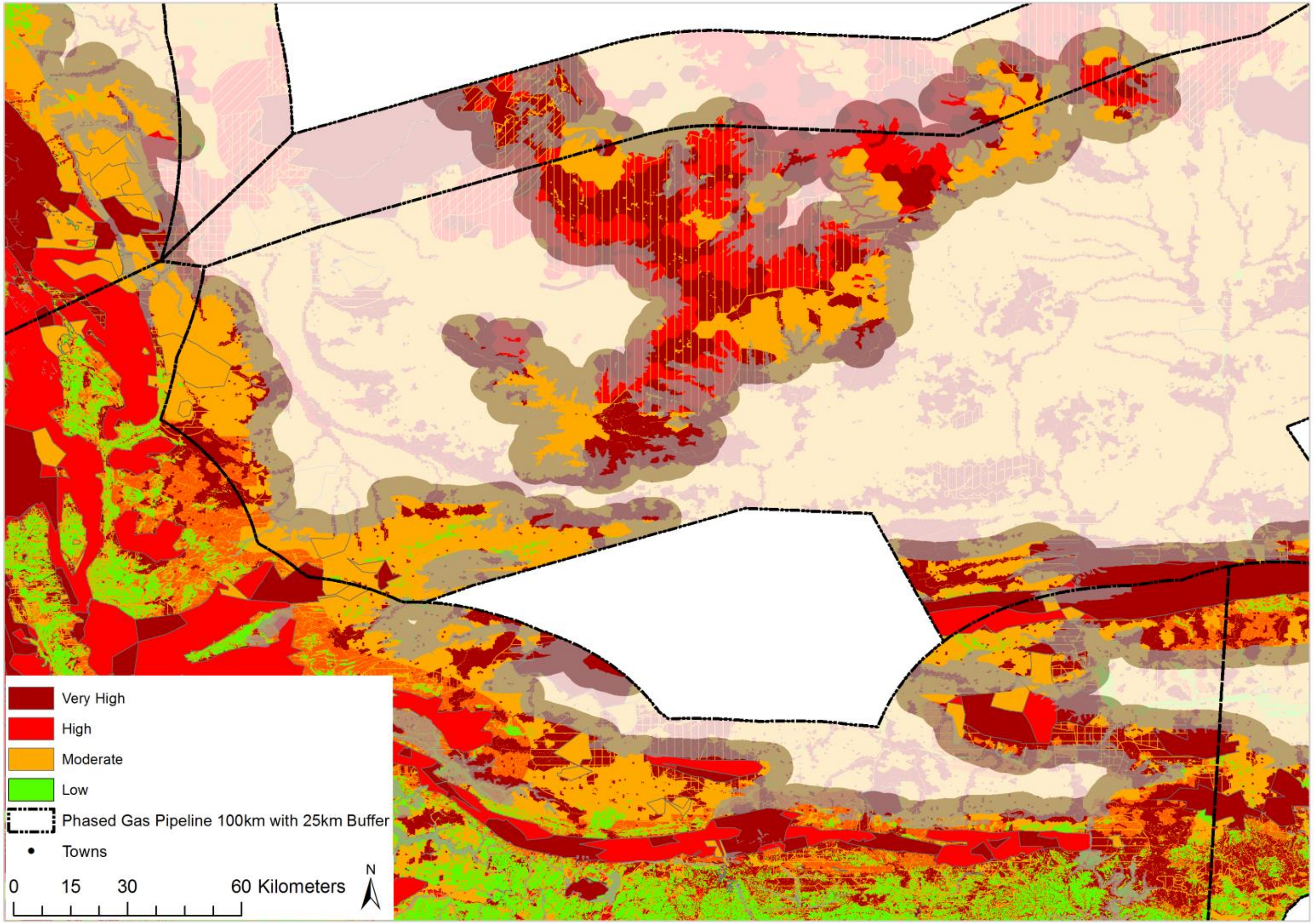


Figure 25: Gas Pipeline Phase Inland - Sensitivity map based on the sensitivity ratings of the biodiversity and conservation features.

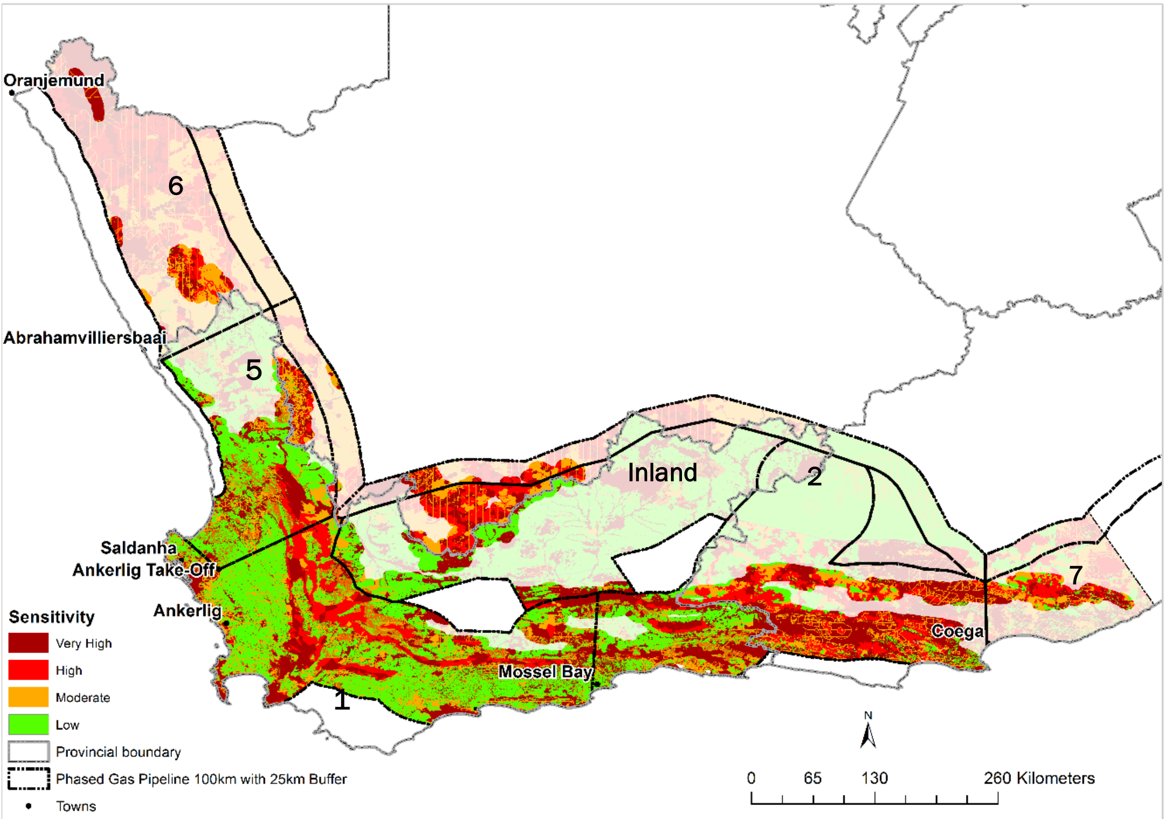


Figure 26: Sensitivity map for the Fynbos Biome based on the underlying biodiversity and conservation features.

Abrahamvilliersbaai has been identified as a key point for a land fall for the marine pipeline from the gas fields off the western coastline of South Africa. The route north to the Orange River (Phase 6) could easily be routed to avoid the limited areas of Fynbos in this section of the corridor with the actual route depending on the sensitivity of the conservation features in the Succulent Karoo. The route southwards (Phase 5, 1) is more constrained although possible routes to Saldanha and Ankerlig have already been assessed (CSIR, 2014). The critical areas lie in the southern section of Phase 5 and the adjacent area Phase 1. The high concentration of Very Highly sensitive CBA 1 features in this area, which included remnants of threatened ecosystems, threatened species and movement corridors means that any route will entail significant impacts. Essentially there are two options, one more or less parallel to the coast and one routed inland of the Piketberg, and the screening study preferred the coastal routing.

All the options for the route from the Ankerlig Take-Off to Mossel Bay (Phase 1) are problematic. They will all involve crossing the mountain ranges that extend from Piekenierskloof to Cape Hangklip. The most obvious one is to use the break formed by the Klein Berg River valley to cross over into the Tulbagh-Ashton valley and from there via Bonnievale into the eastern Overberg. All the other options also involve narrow passes and crossing higher mountain ranges. Much of this route would pass through a mosaic of Renosterveld and Succulent Karoo and route options would have to be assessed jointly.

From Mossel Bay to Coega (Phase 2) the: (a) the coast to mountain concentration of Very Highly and Highly sensitive conservation features in the Fynbos Biome, (b) the mosaic of the Fynbos and Forest Biomes, and (c) the intensive development between George and Nature's Valley, essentially rule out a coastal route. An inland route via the southern Klein Karoo and Langkloof is an easier option but there are significant conservation features and no easy routes over the mountains into the Little Karoo.

The Fynbos Biome east of Coega (Phase 7) is confined to the mountains and higher lying areas and routing through this part of the biome would depend primarily on whether it provides an alternative to the constraints of the conservation features in the Albany Thicket.

The Inland Phase corridor does offer an alternative route inland of the Cape folded mountain ranges but would involve traversing additional mountain ranges both to get inland and then to get back to the coast. Relatively little Fynbos occurs in this Phase and so the routing would be determined primarily by the sensitivity of the conservation features in the Succulent and Nama Karoo Biomes.

5 KEY POTENTIAL IMPACTS AND THEIR MITIGATION [UNDER GAS PIPELINE DEVELOPMENT]

The construction of the pipeline will involve the stages set out in the diagram below (Figure 27) beginning with the surveying and marking out of the route, lay down areas and other facilities, followed by clearing and preparation of the access route for the pipe transport vehicles and other machines. Next will be the pipe stringing, pipe bending, alignment and welding, trenching and pipe laying. Last comes the backfilling, vegetation restoration and establishment of the permanent access route for maintenance.

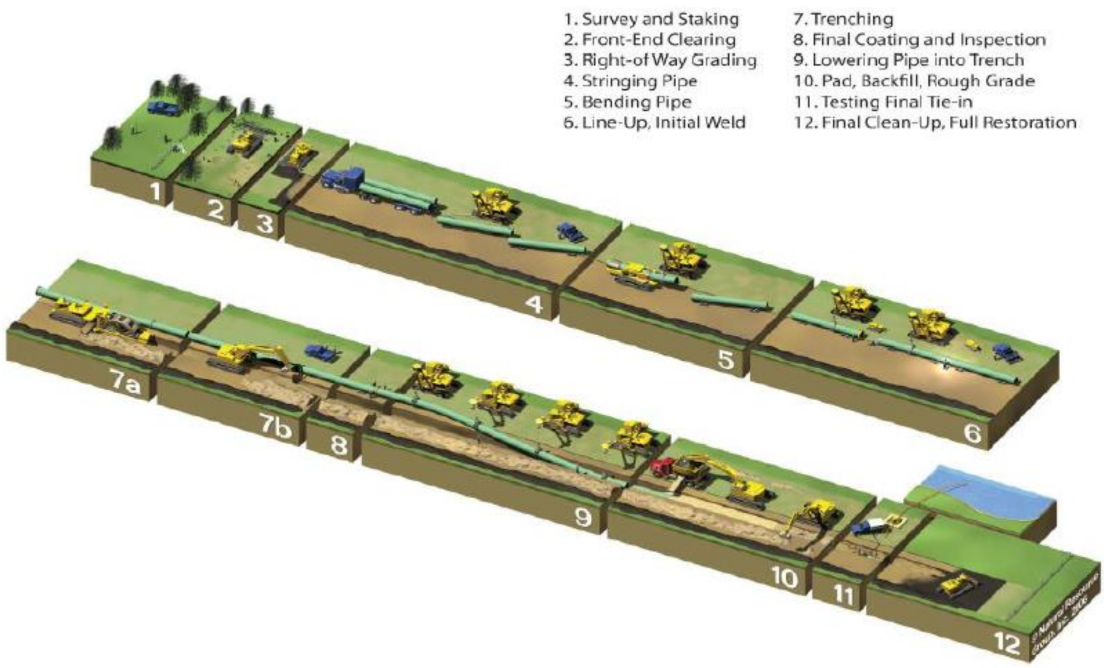


Figure 27: Typical site preparation and construction of gas pipeline infrastructure (Ephraim, 2017).

The area that is directly affected during the construction phase will typically be about 50 m wide as shown below with most of the activity being within a 40 m wide strip (20 m either side of the pipeline) (Figure 28). Where the pipeline has to traverse more rugged terrain, especially when traversing across steep slopes, the width that is affected will depend in the terrain but could be substantially greater.

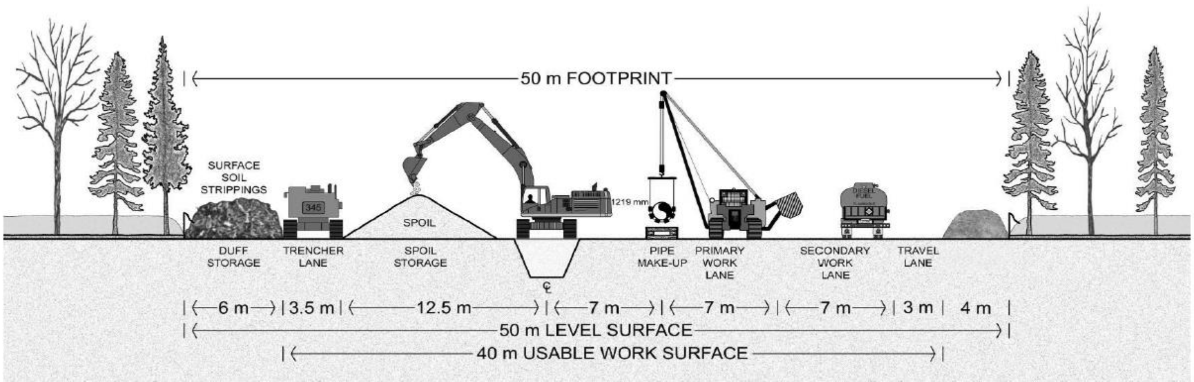


Figure 28: Typical construction footprint of gas pipeline infrastructure (Ephraim, 2017).

Access for maintenance and servicing during the operational phase will require the maintenance of access roads to at least the pigging stations. These need to be suitable for periodic use by a pickup or small truck and would need to be at least a typical two lane (wheel) track. In sandy areas and on slopes a permanent surface will be needed and will potentially involve more construction where the construction work lanes are not suitable. Access to the pigging sites will require similar road constructed to similar standards.

The key potential impacts of gas pipeline development to the Fynbos Biome may be concisely summarised as:

- Disturbance to soils, flora and fauna (incl. increased human activity, poaching, noise, dust, erosion, and oil/fuel spills);
- Introduction and establishment of alien invasive species and non-local genetic stock; and
- Habitat loss and alteration (incl. changes in ecosystem function, and local extinction or decline in populations of endemic and rare species).

The kinds of impacts on the terrestrial ecosystems can be divided up according to the stages of the pipeline construction and operation, and are unpacked in detail in Section 5.1 to 5.4 below. These impacts will be particularly important in some conservation categories (e.g. CBA1) and in protected areas. The WCBSP (Pool-Stanvliet et al., 2017) recommends some special considerations that should be applied to activities affecting threatened vegetation types or protected areas during the planning and construction stages (See Boxes 1 and 2).

5.1 Planning Stage

- **Impact 1: Final selection and laying out of the pipeline route. Disturbance and vegetation modification due to arrival and movements of people and vehicles on site (assuming untransformed communities), disturbance of soil and creation of dust**
    - Mitigation:
        - Avoid High and Very High sensitive areas during the route planning
        - Avoid crossing key migration or movement corridors for fauna during the route planning
        - Where avoidance is not possible, in areas of Moderate to Very High sensitivity undertake specialist faunal and plant species assessments to propose mitigation or recommend alternatives prior to finalising the route; and in areas of lower sensitivity specialist surveys or inspections to establish whether threatened or endemic species are present
        - If populations of threatened or endemic species are encountered and unavoidable then specialist inputs should be obtained
        - Require specialists to inspect the proposed route prior to clearing of vegetation and breaking of ground to ensure no animal burrows (e.g. porcupine, aardvark, carnivores) are harmed
        - Avoid burrows of porcupines, aardvarks and carnivores and provide sensitivity buffers where they are in the vicinity
        - Vehicle speeds must kept slow to minimise potential collisions with animals and dust creation

5.2 Construction Stage

- **Impact 2: Disturbance due to arrival of people and heavy equipment on site. Removal and disturbance of vegetation during construction resulting in the loss of foraging habitat and shelter for fauna, disturbance of soil and creation of dust.**
    - Mitigation:
        - Minimise the development footprint
        - Control dust to minimise impacts by regulating vehicle speeds and using geotextiles, particularly on soil dumps

        - Control sediments in runoff to minimise impacts on rivers and wetlands
        - Minimise the duration of the activities on site
        - Vehicle speeds must kept slow to minimise potential collisions with animals

- **Impact 3: Risk of oil and fuel spills from equipment or vehicles and their impacts on ecosystems**
    - Mitigation
        - Prevent fuel or oil leaks and make provision to contain them (e.g. in drip trays) to minimise contamination of surrounding soil and water

- **Impact 4: Dispersal of fauna due to noise and vibrations from trenching, drilling and possible blasting. Short-term impact for more mobile and resilient species but longer term or permanent for less mobile or more sensitive species.**
    - Mitigation:
        - Control dust to minimise impacts by regulating vehicle speeds and using geotextiles, particularly on soil dumps
        - Avoid construction activities in the breeding season of conservation important taxa

- **Impact 5: Harm to animals or loss/alteration of both normal and breeding habitat, including poaching. Threatened or collectable plant species theft**
    - Mitigation:
        - See Impact 1 above on selection of route for mitigation measures
        - Ensure that all staff understand that no animals may be intentionally harmed or killed for any purpose or poached

- **Impact 6: Entrapment of animals in the open trench which then could die through drowning in water puddles, dehydrate due to exposure, or starve because they have no access to food.**
    - Mitigation:
        - Minimise the physical extent of construction activities and complete them in as short a time as possible.
        - Wherever possible, time construction activities to avoid the breeding or migration periods of the threatened or important taxa that may occur along the route
        - Equip open trenches with suitable ramps or steps every 50m 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

- **Impact 7: Invasive alien species, particularly plants**
    - As noted earlier, the **altered vegetation structure and access by vehicles may favour invasions by alien species**, especially plants, during the construction and operational phases. Machinery can also bring propagules onto site in the form, for example, 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. Many of the Fynbos invaders are woody plants which have deep roots and would have to be controlled if they occurred 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 alien plant species cover within the pipeline servitude is reduced to, and maintained at, less than 5% canopy cover.
    - Mitigation:

- 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 invasive species 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
- Carry out initial control measures prior to the construction
- 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[5] of invasive species, particularly plants and/or screening such materials to ensure they are propagule free
- Post-construction and during rehabilitation and operation ensure that appropriate follow-up operations are continued until the invading species are effectively under control
- During the operational phase carry out regular surveys to identify invading species; where they are found, carry out the necessary control operations
- If and when the pipeline is replaced then follow the same procedures as for the construction.
- 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.

Box 1: Special considerations for threatened vegetation types (Pool-Stanvliet et al., 2017).

- No linear surface impacts such as those caused by pipelines or permanent installations (i.e. buildings) are allowed in areas assessed as CBA 1 because they will compromise the biodiversity objectives.
- For CBA 2 or ESAs such impacts are only permissible under restricted conditions.
- Each portion that is traversed will have to be justified and the cumulative impacts will be considered important in proposing possible alternative routes.
- Mitigation:
  - Firstly, ensure that such crossings are avoided and minimised as far as possible.
  - Locate all such structures on transformed, disturbed or low-value agricultural land, wherever possible.
  - Avoid special habitats or populations of endemic or threatened species.

Box 2: Special considerations for Protected Areas (Pool-Stanvliet et al., 2017).

- These include national and provincial parks as well as private conservancies and stewardship sites which should be avoided if at all possible.
- A proclaimed national or provincial park should be regarded as a potential no-go area.
- Crossings may be acceptable provided the pipeline is aligned with other features (e.g. servitudes, roads).
  - Mitigation:
    - All such crossings however should be subject to environmental management best practice and stringent standards to minimise the impacts.
    - They also should be subject any measures prescribed by the management plan for that protected area.
    - Consideration should be given to burying the pipeline much deeper to minimise the need for ongoing vegetation management.

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

5.3 Post-construction rehabilitation stage

This will be critical to the overall environmental performance of the project (Sahley et al., 2017). However, as pointed out in the text there is a high to very high risk that rehabilitation will fail in the arid parts of the biome due to the low and unreliable rainfall. Provision must be made to re-do the rehabilitation should it fail until at least an acceptable degree of success is achieved and a high degree of success in highly and very highly sensitive areas. Rehabilitation to the full diversity of the original communities is not possible so there will always be some loss of ecosystem function and interactions and alteration of the habitat. The primary reason for this is the factors that determine success rates of re-establishment of most of the very diverse Fynbos plant species and specialised faunal groups (e.g. many of the invertebrates) are poorly known, in other words rehabilitation success is highly unpredictable. Given these limitations, the primary aim should be to restore ecosystem function so that the ecosystem is self-maintaining with as high a diversity of species as possible. Where there were endemic and threatened species, every effort should be made to reintroduce them. The exclusion of deep-rooted plant species from the vicinity of the pipeline may result in some loss of endemic, rare or threatened species within this area but such impacts should be minimised.

- **Impact 8: Introduction of non-local genetic stock**
    - Mitigation
        - All plant stock and seed must be from local populations wherever possible to 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
        - Wherever there is an evident change in the vegetation or community, keep the rehabilitation material for each community's section separate to minimise introduction of non-local genetic stock

- **Impact 9: Partial or complete failure to achieve effective rehabilitation affecting species diversity, resulting in changes in habitat suitability, reduction in endemic species populations or local or global extinction; changes in species movements, abundance and distribution, ecosystem functions and interactions; exposure of adjacent communities to unfavourable edge effects such as susceptibility to invasions by alien species**
    - Mitigation
        - 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
        - Replacement of the top soil (seed bearing soil) should take place as soon as possible
        - Control dust to minimise impacts by regulating vehicle speeds and using geotextiles, particularly on soil dumps
        - 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)
        - Vehicle speeds must kept slow to minimise potential collisions with animals

5.4 Operations and Closure Stage

All the impacts and mitigation measures specified for construction (in Section 5.2 above), can also occur during operation and maintenance activities, during potential replacement of the pipeline, or during the eventual closure, particularly if the pipeline is removed.

The following additional mitigation actions are recommended:

- The access routes for maintenance activities must be kept as limited as possible and access should be controlled by gating access routes
- Vehicle speeds must kept slow to minimise potential collisions with animals and dust creation

      - Time environmental inspections to avoid the breeding season of conservation important taxa

- **Impact 10: Exclusion of deeper-rooted vegetation from the pipeline route and the access routes**
  - Gas pipelines are generally buried to a depth of ±1m below the surface and should not come into contact with plant roots. 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). Exclusion of the deeper-rooted species in the flora will alter the structure and habitat suitability of the pipeline strip, resulting in, for example, the loss of cover for small, slow moving species to shelter beneath. Although the strip that is kept under short vegetation may only be about 10 m in width (potentially wider in places), that, combined with its length, may still be enough to affect the movements of some fauna and dispersal of seeds.
    - Mitigation:
      - No direct measures. It is unlikely that the long-term disruption and fragmentation of the plant and animal communities will be a significant factor overall, provided the necessary processes (e.g. fires in the Fynbos and renosterveld) are maintained in the affected areas. However, there are likely to be ongoing and potentially significant impacts on ecosystem processes such as plant seed dispersal and movements of small, slow moving surface dwelling fauna.
      - Ongoing control of invading plant species (see above) as the alteration of the habitat structure and species composition may make the pipeline track more susceptible to invasion.

The generic impacts and degrees of mitigation that may be achieved have been summarised below (Table 6). There are no hard standards for defining the degree of mitigation but the following descriptions will give some background. Low mitigation implies that a basic community of plant and animal species would become established but species diversity, vegetation cover and ecosystem structure and function would be significantly altered compared to the original community. For example, only annual plant species may establish with no perennial species to provide habitat or act as foci for the recruitment of other species into the community; or the vegetation cover may be too sparse or ephemeral to prevent soil erosion. Given what is observed on old lands in these low rainfall environments, it is possible that the highly simplified vegetation community that will establish will remain little changed for decades. High mitigation implies that, over time, ecosystem structure and function will be reinstated, vegetation cover will reach levels comparable to the pre-development community, and that most species will re-establish themselves albeit with altered abundances. Some species may still not re-establish themselves, at least for some years. Moderate mitigation would result in a community somewhere between these two extremes on one or more measures.

The degree of confidence in the potential level of mitigation must be strongly tempered by the fact that this assessment deals with three broad types of ecosystems that occur over a very wide range of environmental conditions. This inherent variability will affect how these broad ecosystem types respond to the different kinds of impacts and mitigation. It is not possible to be specific about the effects on populations of every threatened species, especially animals, as one species may respond very differently from another. There are some generalisations such as the greatest impacts are likely to be on most ground dwelling and/or slow-moving, small bodied animals with narrow distributions and/or specific habitat requirements, and the lowest impacts will be on highly mobile, large species. Even for plants which, for example, can be divided into guilds based on their methods of persistence and reproduction, such as seed banks, will vary in other ways that could affect the impacts. For example, Fynbos includes species with canopy stored seeds which have no dormancy, seeds which require smoke chemicals to stimulate germination, some which require heat or more extreme soil temperatures to stimulate germination and many which have unknown cues. Each guild could respond differently to the removal and replacement of the top layer of the soil.

What can be said as a general rule is that where areas have been identified as conservation priorities based on the occurrence of threatened species, or the status of the vegetation type, they should be avoided completely (see also Boxes 1 and 2). If there is absolutely no alternative, then the routing should be such that: (a) in the case of threatened vegetation types, it should follow the edge rather than passing through the centre of a patch or cross it at a narrow point to minimise fragmentation of that remnant; and (b) in the case of threatened species, it avoids going through or near to such populations to prevent or minimise disturbance of themselves and their habitat. This level of route planning is best addressed when, and if, the actual pipeline routes are being selected and planned in detail.

Table 6: Summary of activities and impacts, including the timing (stage) and mitigation potential of impacts. These have been aligned with the stage in the development and grouped into categories. The number of the impact used above has been included as a guide but is not compete as some impacts are only described under one but are applicable to other stages as well as emphasised in the text.

Activity	Impact (number)	Timing	Mitigation potential
Impacts generic to all activities	**1, 2, 4, 5**: Human activities, movements and noise (including engine noise), creating disturbances for fauna and flora (including poaching and theft), and soil disturbance	Throughout	L
Pre-construction route surveys	**1**: Dust from vehicle movements affecting flora and fauna	Planning	M
Creation of access routes for machinery	**7**: Importation of alien species imported in road surfacing material	Construction	M-H
Movement of machinery onto site	**7**: Introduction of alien species via machinery and construction materials	Construction	M
	2: Dust from vehicle and machine movement and activities affecting flora and fauna	Construction	M
Machinery and vehicles working on site	**3**: Oil and fuel spills and their impacts on soils, fauna and flora	Construction	H
Removal of vegetation cover and top soil layer within pipeline footprint	**2**: Habitat loss and alteration, loss of shelter for fauna	Construction	M
	5: Endemic/rare species loss	Construction	M
	5: Endemic/rare species displacement	Construction	M
	2: Dust from removal and stockpiling of top soil layer affecting flora and fauna	Construction	M
Transport of pipes and other materials to site	**2**: Dust from vehicle and machine movement and activities on flora and fauna	Construction	M
	7: Impacts from introduction of alien species via vehicles and construction materials	Construction	H
Construction of pipe	**4**: Impacts of pipeline welding, assuming gas rather than arc welding	Construction	H
Excavation of pipe line trench	**2**: Dust from machine movements, excavation and stockpiling of material affecting flora and fauna	Construction	M
	6: Entrapment of fauna in the open trench	Construction	H
Refilling of trench	**2**: Dust from machine movements, replacement of material affecting flora and fauna	Construction	M
Levelling of site for top soil	**2**: Dust from machine movements, replacement of material affecting flora and fauna	Construction	M
Replacement of top soil layer	**2**: Dust from machine movements, replacement of material affecting flora and fauna	Construction	M
Introduction of plant material for active rehabilitation	**8**: Introduction of non-local genetic stock	Construction	H
	7: Introduction of alien species in plant material	Construction	H
	7: Establishment of alien invasive species	Construction	H
Recovery of rehabilitated	**9**: Recovery of only a few species (depends on	Rehabilitation and	L-M

Activity	Impact (number)	Timing	Mitigation potential
ecosystem (some impacts will persist e.g. when rehabilitation is not successful this could have medium to long-term effects and affect the operation phase as well)	many factors)	operation	
	9: Complete failure of recovery (depends largely on the amount and reliability of the rainfall)	Rehabilitation	L-M
	9: Changes in habitat suitability within the footprint	Rehabilitation and operation	M
	9: Endemic/rare species loss	Rehabilitation and operation	M
	9: Endemic/rare species population declines	Rehabilitation and operations	M
	9: Changes in species movements, abundance and distribution	Rehabilitation and operation	M
	9: Changes in ecosystem functions and interactions	Rehabilitation	M
	9: Exposure of adjacent vegetation to unfavourable edge effects such as susceptibility to invasions by alien species	Rehabilitation	M
Maintenance of access roads and infrastructure	**1**: Vegetation disturbance in pipeline route	Operation	L
	7: Introduction of alien species on vehicles	Operation	H
	7: Establishment of alien species	Operation	H
	5: Increased access to sensitive areas (poaching and collection of rare species)	Operation	H
Establishment of a linear feature (resulting in fragmentation of habitats and creation of edge effects and leading to impacts):	**10**: Changed in habitat suitability within the footprint	Operation	M
	10: Endemic/ rare species loss	Operation	M
	10: Endemic/rare species population declines	Operation	M
	10: Changed species movements, abundance and distribution	Operation	M
	10: Changed ecosystem functions and interactions	Operation	M
	10: Exposure of adjacent vegetation to unfavourable edge effects such as susceptibility to invasions by alien species	Operation	L-M

6 RISK ASSESSMENT

6.1 Consequence levels

Five consequence levels are proposed i.e. slight, moderate, substantive, severe, and extreme.

As a broad guideline, the following is proposed as definitions for the consequence categories:

- Extreme – Over 50% of a threatened habitat or Critically Endangered, Endangered or Vulnerable species populations are destroyed, severely disturbed or displaced even with mitigation.
- Severe – Any areas of a very highly sensitive environment or any individuals of Critically Endangered or Endangered species are destroyed, severely disturbed or displaced without appropriate mitigation.
- Substantial - Any areas of a highly sensitive environment are destroyed, and/or Vulnerable species are destroyed, severely disturbed or displaced without appropriate mitigation.
- Moderate - Any area of a moderately sensitive environment is destroyed or severely disturbed without appropriate mitigation.
- Slight - Areas of habitats or species not mentioned above are destroyed.

6.2 Risk assessment results

The risk assessment involves the consideration, at a high, strategic level, the three key impacts describes in section 5, with and without mitigation actions (i.e. actions to mitigate negative impacts or enhance benefits). The primary risk identified by this assessment is that of a failure to achieve an acceptable level of recovery of the disturbed ecosystems in terms of cover and function in the sense of being a self-sustaining ecosystem. As discussed elsewhere, because deep-rooted plants have to be excluded from the vicinity of the pipeline, most if not all of the shrub components of the ecosystems will have to be excluded from this areas. Therefore, it will be impossible to return these ecosystems to something closely resembling their original botanical and faunal composition and structure.

The growing body of research into Fynbos restoration and ongoing practical experience shows that ecosystem rehabilitation to an acceptable level of cover and composition can be achieved in the higher and more reliable rainfall areas of the Fynbos Biome (although the restoration of ecosystem function is less certain) (Esler et al., 2014; Fill et al., 2017; Gaertner et al., 2012b; Holmes, 2005; Holmes and Foden, 2001; Holmes and Richardson, 1999; Pretorius et al., 2008; Ruwanza, 2017). The affected areas include the Grassy Fynbos of the eastern parts of the biome (e.g. Phase 7), which should be easier to rehabilitate, at least to a reasonable grass cover. There are a number of examples of successful rehabilitation in the higher rainfall areas where roads have been upgraded during the past 10-15 years, although there are also examples of failures. Many climatic characteristics can play a role in determining the likelihood of successful rehabilitation of a given ecosystem but rainfall is a relatively easy example to use because rainfall amounts and temporal distribution are critical for soil moisture regimes and those regimes, in turn play a significant role in the likelihood of successful seed germination and plant establishment. This argument has focused on plants because they create the habitat and provide the food and shelter for the fauna but, obviously, species composition and structure (both vertical and horizontal) are key determinants of habitat suitability for fauna.

A feature of the rainfall in South Africa is the increasing variability in the rainfall as the amount of the rainfall decreases (Schulze et al., 2008; Zucchini et al., 1992). Although the winter rainfall experienced in the Fynbos Biome is particularly reliable (Cowling et al., 2005), the reliability of that rainfall decreases as the amount decreases. There is no clear threshold, but the risk of rehabilitation failure becomes high once the annual rainfall is less than 400 mm and very high when it is less than 200 mm (Figure 29). Areas with less than 400 mm per year occupy extensive areas in all the corridors, especially on the West Coast and in the interior and the Inland corridor. The Strandveld and Sand Plain Fynbos (e.g. the Sandveld) are expected to be particularly vulnerable to low and variable rainfall because of their generally well-drained soils. Alien species introductions are more likely to lead to their establishment and invasion in higher rainfall environments so alien species control measures will have to be more intensive and effective in these environments.

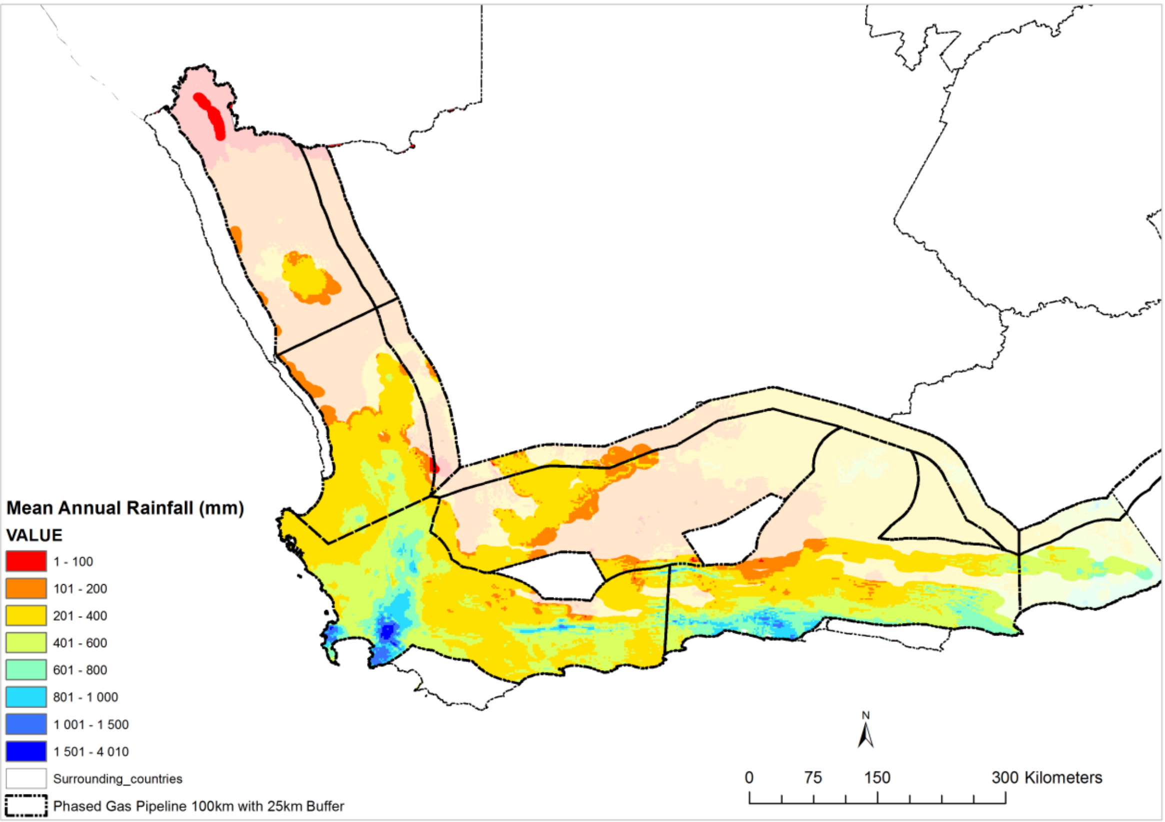


Figure 29: Mean annual rainfall in the Fynbos Biome (Schulze et al., 2008) with the biome boundary buffered by 5 km.

Experience at the Namakwa Sands mine (Pauw, 2011) and the findings of research on Karoo shrublands (Wiegand et al., 1995) emphasise the risks posed by low and variable rainfall. The research, thus far, has found that the herbaceous annual species could be restored fairly effectively but re-establishing the perennial components that are important for cover (which reduces the risk of wind erosion) community function and ecosystem services (e.g. grazing (Richardson et al., 2005)) were difficult to restore and success rates were low. The evidence suggests that successful recruitment of these perennial species may only occur in high rainfall years which are very difficult to predict. The findings at the Namakwa Sands mine were in Strandveld vegetation, but at low rainfall the rehabilitation of Renosterveld and Fynbos communities may be similarly problematic.

The three key impacts assessed for the corridors have been grouped and summarised in the Risk Assessment Table below (Table 7). More intensive and thorough the mitigation efforts must be applied in the higher the sensitivity areas. More arid environments are conducive to more dust generation and, therefore, greater dust impacts, but this can be controlled by more intensive dust management (e.g. limiting vehicles speed, using geotextiles). For some impacts the corridors have been grouped according to the likelihood that rehabilitation could fail based on the extent of arid Fynbos and Renosterveld vegetation types. The impacts of habitat loss and alteration through disturbance and changes in habitat suitability, species movements, abundance and distribution are also likely to be more severe and more persistent. The same rationale would apply to adverse changes in ecosystem functions and interactions and endemic, threatened or rare species population declines, displacement or loss. Ground dwelling and/or slow-moving, small bodied animals with narrow distributions and/or specific habitat requirements are also more likely to be severely affected.

Table 7: Assessment of the potential risks that the key impacts from constructing and maintaining gas pipeline infrastructure pose to the Fynbos biome, before- and after mitigation.

Impact	Study area	Location	Without mitigation			With mitigation		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Increased human activity (e.g. poaching, noise, movements) trampling and destroying vegetation, exposing and loosening soils, resulting in the generation of dust and leading to erosion, damaging and destroying flora and displacing or harming fauna	All Phases	Very high sensitivity area	Extreme	Very likely	Very high negative	Severe	Very likely	High negative
		High sensitivity area	Severe	Very likely	High negative	Severe	Very likely	High negative
		Moderate sensitivity	Substantial	Very likely	Moderate negative	Substantial	Very likely	Moderate negative
		Low sensitivity area	Moderate	Very likely	Low negative	Slight	Not likely	Very low negative
Introduction and establishment of alien invasive species and non-local genetic stock	All Phases	Very high sensitivity area	Extreme	Very likely	Very high negative	Severe	Not likely	Moderate negative
		High sensitivity area	Severe	Very likely	High negative	Substantial	Not likely	Moderate negative
		Moderate sensitivity	Substantial	Very likely	Moderate negative	Moderate	Not likely	Low negative
		Low sensitivity area	Moderate	Very likely	Low negative	Slight	Not likely	Very low negative
Habitat loss and alteration (incl. changes in ecosystem function, and local extinction or decline in the populations of endemic and rare species).	Phases 1,2,7	Very high sensitivity area	Extreme	Very likely	Very high negative	Severe	Very likely	High negative
		High sensitivity area	Extreme	Very likely	Very high negative	Severe	Very likely	High negative
		Moderate sensitivity	Severe	Very likely	High negative	Substantial	Likely	Moderate negative
		Low sensitivity area	Substantial	Likely	Moderate negative	Moderate	Likely	Low negative
Habitat loss and alteration (incl. changes in ecosystem function, and local extinction or decline in the populations of endemic and rare species).	Phases 5,6,Inland	Very high sensitivity area	Extreme	Very likely	Very high negative	Extreme	Very likely	Very high negative
		High sensitivity area	Extreme	Very likely	Very high negative	Extreme	Very likely	Very high negative
		Moderate sensitivity	Severe	Very likely	High negative	Severe	Very likely	High negative
		Low sensitivity area	Severe	Very likely	High negative	Severe	Very likely	High negative

6.3 Limits of Acceptable Change

The limits of acceptable change are highly subjective and 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 Critically Endangered, Endangered, Vulnerable 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 critically endangered 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. No further adverse changes should be allowed in threatened ecosystems assessed as Critically Endangered or Endangered, and should be avoided if at all possible in those assessed as Vulnerable 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 then full Biodiversity Impact Assessments should be undertaken and mitigation management guidelines followed. No destructive activities are allowed in CBA1 areas according to their guidelines. The Western Cape conservation planners have provided some specific constraints for certain activities or developments. For example, 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 the Northern and Eastern Cape provinces as well.

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 BEST PRACTICE GUIDELINES AND MONITORING REQUIREMENTS

This section puts forward best practice guidelines and management actions that cover the different stages or phases of the development: route selection, detailed planning, pre-construction alignment in the field, construction, post-construction, operations and closure. Many of the best practices have been included in the impact mitigation section of this assessment. Final- route-selection level assessments of the impacts will have to be based on detailed field surveys along the proposed gas pipeline and where any additional facilities need to be constructed. It is essential that these surveys are commissioned so that there is time to include surveys during the winter and spring when most species are active and plants are flowering, especially seasonal geophytes which are not visible in the summer. Otherwise the assessment will miss many of the threatened and rare species. This is particularly important in the arid Fynbos found in Phases 5 and 6 where good rains may not occur every year, and also in arid Renosterveld bordering on the Succulent Karoo. This recommendation applies to all the untransformed (i.e. not urban, mined or cultivated) communities along the entire route and not only to the sections identified as high or very high sensitivity. The reason for this is that species distribution records are invariably incomplete, so populations of threatened and other important species may well occur along the route and need to be avoided or the impacts mitigated.

7.1 Planning and pre-construction phase

Plan the route to minimise crossing of conservation features, especially CBA 1 and 2 and where these areas include threatened ecosystems or populations of threatened taxa. Wherever possible, align the pipeline along existing servitudes and linear disturbance such as a road and through degraded or transformed (e.g. cultivated) areas. Avoid, as far as possible and in ascending order of importance: (a) remnants of natural vegetation in good condition, (b) ESAs (especially ESA 1), (c) terrestrial CBA 2s, and (d) CBA 1s, especially those that are Irreplaceable, or have Endangered (EN) or Critically Endangered (CR) ecosystems and threatened species populations. Where such areas are unavoidable the pipeline should be routed to minimise fragmentation of the feature.

Where areas have been identified as conservation priorities based on the occurrence of threatened species, they should be avoided completely and not considered for the route. If there is absolutely no alternative, then the impact must be mitigated by routing the pipeline so that it avoids going near to or through such populations to avoid or minimise disturbance of them and their habitat and minimise fragmentation of that remnant. If there is still no other option, then offsets could be considered.

Wherever such features are encountered on the route, field surveys of those features must be undertaken at a suitable time of the year (e.g. when plants are active and flowering) to identify the location of populations of species, rare or threatened species that are to be avoided.

7.2 Construction phase

Tightly limit and enforce the restrictions on the construction footprint and follow sound best practice for site management.

The best way to facilitate successful rehabilitation of the vegetation is to ensure that the valuable top layer of the soil containing the seed banks is carefully removed and stored. The top layer of the soil (100 to 150 mm deep) should be stripped and replaced in a way that minimises disturbance (e.g. no tillage). The deeper layers of the soil can then be removed and stockpiled as well. Soils generally have a clearly defined layering with a topsoil that can be distinguished from the sub-soil and sometimes a third layer or horizon (Fey et al., 2010). It is best to keep these layers separate and the replace the layers in the same sequence in which they were removed.

The time that it is stored for should be kept to the absolute minimum. No indication was given of how long it will take from site clearing to final clean-up but it should be a matter of days to weeks. If that is the case the soil can be stored next to where it was stripped (as indicated in the diagram) and then replaced.

If more soil needs to be removed for any reason then that soil should be stored separately and replaced first. The initial top layer stripping and replacement is essentially a form of top-dressing which contains most if not all of the seedbank and is critical for successful rehabilitation.

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.

Much of the area is subject to strong winds during the summer months, especially the West and Southern coastal lowlands. If the soils are prone to wind erosion then the option of erecting shade cloth fences or other wind-moderating barriers to minimise the risk of wind erosion. Brush packing using material removed during the site clearing is an option but could hinder follow-up work on alien plant species.

If alien plant species were present in the pipeline route prior to construction then they need to be treated appropriately during the site clearing and follow-up measures after rehabilitation of the disturbed areas. Fynbos is subject to invasions by a variety of plant species and it is not possible to list them all here. Information on the species that invade can be found in the following publications in the reference list (Bromilow, 2010; Esler et al., 2014; Esler and Milton, 2006; Henderson, 2001; Wilson et al., 2014) and on many websites including:

- Invasive species South Africa: http://www.invasives.org.za/
- Invasive Species Compendium: https://www.cabi.org/isc/

Experts should be consulted to advise on the treatments that are needed for the different species.

It is not clear whether the pipeline trench will be refilled and settled (not compacted) to the original level with material from the trench or if imported materials (e.g. sand) will be needed to bed the pipe in, at least in some locations. Assuming that no extra material is needed the soil from lower soil horizons should be used for the refilling first, then the next horizon, the replaced soil lightly compacted and the trench levelled area reshaped so that when the top layer is returned, the original surface level and slopes are restored.

7.3 Operations phase

Access roads and tracks to pigging stations and any other locations must be properly constructed and regularly maintained, especially their drainage, to ensure that ongoing disturbances of the ecosystems are minimised. This is particularly important in areas with deep, sandy soils where there is a natural tendency for them to widen, and the tracks to deepen over time. People then create new tracks which simply worsens the problem and this must be prevented.

There should be regular inspections by people trained to understand the local vegetation and to be able to monitor its recovery using recognised procedures (e.g. permanent survey and photo-plots). These surveys should be done once a year in the early stages (1-3 years) and bi-annually after that. The surveys should be in the same season so that trends can be assessed and any adverse trends in the species diversity, ecosystem structure or ecosystem function identified and addressed. Expert advice should be sought if deemed necessary. Methods for ecological surveys are too diverse to go into in detail here but should include at least the following: (a) vegetation canopy cover grouped by broad growth forms (e.g. annuals, succulent and non-succulent shrubs) to give a measure of structure; b) an estimate of soil stability or loss; and (c) record the occurrence and extent of fires in the corridor so that the fire recurrence intervals and season can be assessed against suitable standards (Kraaij and Wilgen, 2014; Richardson et al., 1994; Van Wilgen et al., 2011). The specialists involved in the route planning stage should be asked to recommend methods as part of their specialist study. Alien species invasions should be managed as part of ongoing pipeline corridor management.

7.4 Final rehabilitation and post closure

According to iGas, the current plan is that the pipeline will be formally decommissioned and hydrocarbons removed and replaced with air once the gas supply has been exhausted. The pipeline may be left *in situ* and only major valve installations and pigging stations will be removed (i.e., all above ground installations and installations that can be accessed from above ground e.g. valve pits etc.). Where the land owners require iGas to pay for the servitude, a business decision will be made at the time as to the future of the pipeline. If the pipeline becomes unsafe to operate then it could be replaced by a new pipeline, either alongside the planned pipeline or by replacing the planned pipeline with a new one in the same track. If the gas supply cannot be interrupted, then it is likely that the new pipeline will be constructed alongside the existing one and that the old one will be decommissioned as soon as the new is commissioned. Removing the old pipeline or construction of a second pipeline in sensitive areas is likely to entail even more disturbance than the construction and should be avoided if possible.

Vegetation rehabilitation to pre-construction state: This should be undertaken, whenever possible, before the onset of the winter rains to take maximum advantage of the growing season. Irrigation is not generally used in Fynbos restoration and is unlikely to be a viable option, except in special cases involving areas of a limited spatial extent.

Invasive alien plant control: management actions should not only focus on the woody shrub/tree invaders since Sand Plain Fynbos, Limestone Fynbos and Renosterveld are also very prone to invasion by introduced grasses which have a significant impact on herbaceous species and especially geophytes. Consequently management of such invasive grass species need needs special consideration. There are no set guidelines for management of herbaceous species; therefore expert input will be required when drawing up recommendations for the EMPs.

7.5 Monitoring requirements

There are far too many taxonomic groups, and species within those groups, to develop a detailed monitoring protocol here. Nevertheless there are some basic principles and basic community measures which are essential and can give important insights:

- Design the monitoring properly with appropriate sampling designs and frequencies to produce reliable data which can detect, for example, trends and undesirable outcomes in time for remedial action to be taken.
- The ideal is to sample both before and after construction with the baseline then being the pre-construction state. Given there will be changes in community structure and function, and that there is inherent variation, the best strategy is to combine before and after sampling with sampling of match sites that will not be affected by the construction.
- The sampling sites should be selected so that they include a representative sample of at least each of the different vegetation types which will be substantially affected by the pipeline development; even better would be to choose communities within those vegetation types.
- Monitoring of ecosystem function and processes is also important. This could be intensive and expensive but there are less intensive measures. A key process in all vegetation communities is regeneration or reproduction.
    - For Fynbos and Renosterveld the most basic monitoring would be to track fire incidence, i.e. how frequently a given area burns in a fire. Fire occurrence data are available from 2000 onwards and can be used to determine the historical fire frequency (and season). This information can be used to determine whether fire occurrences are changing as a result of the pipeline development. Monitoring protocols for Strandveld would need to be developed with input from specialists in these communities and could be based on existing approaches and experience (Carrick et al., 2015; Carrick and Krüger, 2007; Pauw, 2011).
    - More detailed assessments would record post-fire recruitment and determine whether selected species are regenerating as successfully within the pipeline route as they are outside it.
    - There is an important limitation which is, that although there are ways of determining, for example, whether the fire-regime is being maintained within acceptable limits for some Fynbos ecosystems and species groups (guilds) (Kraaij and Wilgen, 2014), such information is not available for most ecosystems, especially those on the margins of the Fynbos and in the ecotones with Succulent Karoo or Albany Thicket.
- Community level monitoring should focus on surveys at the growth, or life-form level with measures of the abundance of the different groups of species and community structure.
- Individual species-level monitoring can only be discussed here at a very general level as, for example, each of the taxonomic groups of threatened terrestrial species would need its own

monitoring protocol with, for example, plants, butterflies, frogs, tortoises, lizards all differing in the timing, frequency and the ways in which they are monitored. For plants the best time to monitor is in the spring as that is when most species are actively growing and flowering.

- Post-construction rehabilitation monitoring should be conducted twice yearly for the first 2 years and then annually thereafter. During the first two years, a second survey should be carried out in the autumn to assess the degree of summer-time mortality in the winter rainfall region. The timing of these surveys in the far eastern part of the biome (Phase 7) should be based on expert advice.
- If the rate of vegetation regeneration is sufficient to achieve levels of canopy cover and structure that are comparable to the un-altered communities adjacent to the pipeline with a couple of years, then there is unlikely to be significant wind or water erosion that needs to be monitored and corrected. If this is not the case, then assessments of erosion should be included and measures taken to control that erosion.
- Monitoring for alien species invasions is absolutely essential as has been noted as several points in this assessment. The process begins with ensuring that the term of reference for the surveys of the final route specify that invasive alien species occurrences and populations are mapped and the preparation of a plan for their control and management as part of the construction and operations EMPs. These plans should include monitoring of the effectiveness of the control treatments (initial control and follow-ups) as well as the recording of any new invasive species. If new species are observed, their control needs to be integrated into the control programme.

8 GAPS IN KNOWLEDGE

The gaps in current knowledge and practice have been repeatedly noted throughout this assessment, particularly in the section on assumptions and limitations (see Section 3.2), and will not be repeated here.

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