

CHAPTER 7

Biodiversity and Ecological Impacts: Landscape Processes, Ecosystems and Species

CHAPTER 7: BIODIVERSITY AND ECOLOGICAL IMPACTS: LANDSCAPE PROCESSES, ECOSYSTEMS AND SPECIES

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Executive Summary

Nature of the study area and shale gas development (SGD) impacts

1. **The study area includes relatively high levels of biodiversity, including highly sensitive and unique ecosystems and -species.** Seven different biomes and 58 vegetation types, 119 range-restricted plant species, and 12 globally threatened animal species have been recorded from the study area. See Section 7.1.3: Special features of Karoo ecology and biodiversity.
2. **The Karoo is an arid ecosystem characterised by ecological processes that operate over extensive areas.** In addition, the Karoo is sensitive to disturbance, and disturbance has long-term impacts; recovery in disturbed areas is generally not spontaneous and rehabilitation is often met with poor success. See Section 7.1.3: Special features of Karoo ecology and biodiversity.
3. **A major concern is that the extensive linear infrastructure associated with SGD will result in fragmentation of the landscape.** Loss of connectivity, edge effects and disruption of ecological processes associated with a network of linear structures (such as roads, powerlines and pipelines) are likely to undermine the biodiversity integrity of the study area. This supports the requirement for landscape-level mitigation, discussed below. This issue is examined in Section 7.2.3: Cumulative impacts.
4. **Impacts on species, ecosystems and ecological processes extend well beyond the actual activity or physical footprint.** For many species the impacts of noise, pollution, erosion and other disturbance can extend for hundreds of metres or kilometres from the source, and fragmentation of the landscape can disrupt ecological processes over large areas. Potential impacts across the landscape are examined in Section 7.2: Key potential impacts and their mitigation.
5. **Impacts on species and ecological processes can have cascading effects.** Although the dynamics of a specific impact are difficult to predict, cascading ecological impacts are likely to occur. Again, this supports landscape-level mitigation whereby a representative sample of the biodiversity of the study area, as well as key ecological processes, are secured. Impacts are examined in Section 7.2: Key potential impacts and their mitigation.

Strategic landscape-level approach to mitigation of impacts

6. **Mitigation of ecological and biodiversity impacts must take place not only at the site scale but also at the landscape scale.** The scientific assessment has identified areas of Ecological and Biodiversity Importance and Sensitivity (EBIS), from EBIS-1 (highest) to EBIS-4 (lowest). **The primary mitigation for SGD is avoiding and securing the EBIS-1 and EBIS-2 areas, which effectively makes EBIS-3 and EBIS-4 areas available for SGD.** Strategic mitigation at the

landscape level is essential, as the impacts of SGD cannot be effectively mitigated on site or at the operational level. The explanation for this approach is given in Section 7.3: Risk Assessment.

7. **EBIS-1 and EBIS-2 areas make up 50% of the study area.** Loss or degradation of habitat in these areas must be avoided and they should be secured through legal mechanisms. This may involve formal protected area declaration (including through biodiversity stewardship agreements), but can include other types of stewardship, protection under Section 49 of the MPRDA, appropriate designation in land use schemes, or protection through other legal means. Securing these areas may lend itself to a fast-tracked, integrated protected area expansion strategy, similar to Operation Phakisa in the marine environment. This issue is examined in Section 7.3: Risk Assessment.

8. **EBIS-1 areas contain extremely sensitive features and are irreplaceable.** Activities related to SGD in these areas are assessed as very high risk. **It is not possible to minimise or offset impacts of SGD in EBIS-1 areas**, and impacts of SGD in these areas would undermine the ecological integrity of the study area (and more broadly, the Karoo). See Section 7.3: Risk assessment.

9. EBIS-2 areas contain highly sensitive features and features that are important for meeting biodiversity targets and/or maintaining ecological processes in the study area. **Where SGD activities in EBIS-2 areas are unavoidable, the impacts must be minimised and residual impacts must be offset by securing ecologically equivalent sites in EBIS-1 or EBIS-2 areas** for the representation of biodiversity and maintenance of ecological processes. In the case of such offsets, appropriate national and provincial offset guidelines and methodologies should be applied to ensure no net loss. This issue is examined in Section 7.3: Risk Assessment.

10. **Environmental compliance in EBIS-3 and EBIS-4 areas is still required.** This includes specialist-led assessment of local sensitivities and identification of appropriate mitigation. It is necessary to ground-truth desktop assessments and avoid unnecessary impacts. Specific impacts are discussed in Section 7.2.2: Activities, impacts and mitigation measures and monitoring requirements are discussed in Section 7.4: Best practice guidelines and monitoring requirements.

11. **The cumulative and unforeseen impacts of SGD, as well as effectiveness of mitigation, must be monitored.** The outcomes of the monitoring programme need to dynamically inform ongoing strategic and regional-level decisions on SGD. Monitoring requirements are discussed in Section 7.4: Best practice guidelines and monitoring requirements.

CHAPTER 7: BIODIVERSITY AND ECOLOGICAL IMPACTS

7.1 Introduction and scope

7.1.1 *What is meant by this topic?*

Biodiversity¹ is commonly considered to include three components or levels: ecosystem diversity, species diversity and genetic diversity. This topic deals with biodiversity at the ecosystem and species level, as well as with the ecological processes at the landscape scale which support this biodiversity. As discussed in several places in the scientific assessment, the ecological impacts of shale gas development (SGD) in the arid Karoo environment, in which many ecological processes operate over extensive spatial areas, are likely to be felt especially at the landscape scale. A focus on landscape processes and connectivity in the landscape is often difficult to achieve in individual Environmental Impact Assessments (EIAs), because the spatial scale at which these processes operate is generally larger than the individual projects for which EIAs will be conducted, so it is particularly important to address these aspects in the scientific assessment, with its broad spatial scope.

In addition to the strong emphasis on ecosystems and landscape-scale ecological processes, this topic also covers plant and animal species, focusing on species of special concern, which include threatened species and species endemic or near-endemic to the study area. An additional focus is on ecological infrastructure² and ecosystem services. In particular, aquatic ecosystems, such as rivers and wetlands, play a key role in underpinning ecological infrastructure, which is important for delivering a range of services and benefits to people. In the arid Karoo context, ecological infrastructure that is linked to water-related ecosystem services is especially vital.

The topic covers terrestrial and aquatic biodiversity. The topic of biodiversity and ecological impacts has links with several other topics, including:

- Water resources (Hobbs et al., 2016);
- Tourism (Toerien et al., 2016);
- Visual impacts (Oberholzer, et al., 2016);
- Noise (Wade et al., 2016);
- Sense of place (Seeliger et al., 2016); and

¹ Biodiversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. It includes diversity within species, between species and of ecosystems. (Convention on Biological Diversity, Article 2).

² Ecological infrastructure means naturally functioning ecosystems that generate or deliver valuable services to people. It is the nature-based equivalent of built or hard infrastructure, and is just as important for providing services and underpinning socio-economic development (SANBI, 2013).

- Agriculture (Oettle et al., 2016).

Impacts on these other elements are dealt with in these separate topics. A particularly important split is the one in aquatic systems: this scientific assessment deals with aquatic ecosystems and species, while issues related to water as a resource (such as water use) are dealt with in Hobbs et al. (2016).

The approach taken in this scientific assessment is based on of the following key assumptions:

- Avoiding impacts on sufficient area that represents all known aspects of biodiversity (i.e. sufficient suitable habitat of each distinct type) in a spatial configuration that allows for ecological processes to be maintained (i.e. that maintains landscape connectivity, that avoids fragmentation across the entire landscape, and that secures sufficient internal habitat that is not impacted by edge effects) will result in the long-term persistence of biodiversity.
- Biodiversity issues related to genetic diversity are sufficiently dealt with through the broader level assessments of ecosystems, species and ecological processes.
- Enough is known about biodiversity and ecological processes in the Karoo to understand the potential impact of SGD on these components, but it is clear that there are major knowledge gaps. For example, almost nothing is known of the impact of fragmentation (a key focus of this scientific assessment) on ecological processes in the Karoo. Further, the understanding of Karoo invertebrate diversity is very poor. Therefore, the assumption is that by avoiding impacts on sufficient habitat that is representative of all known biodiversity, in a spatial configuration that maintains known ecological processes, the needs of unknown and poorly known aspects of biodiversity will also be met and poorly understood ecological processes will be allowed to be maintained.

7.1.2 Overview of international experience

SGD has outpaced both research and legislation (Souther et al., 2014; Robbins, 2013), with the result that many of the negative ecological impacts of SGD are only starting to emerge now as long-term studies begin to provide results. Brittingham et al. (2014) reviewed the potential impacts of SGD on ecosystems and species, but acknowledged that actual studies on impacts are currently rare. As a result, the existing literature contains a lot of speculative conclusions and anecdotal evidence, and many presumed impacts are inferred based on similar extractive industries such as oil and conventional gas. Clearly there is no directly relevant information in South Africa as an active onshore oil and gas industry or any significant industrial activity does not exist in the Karoo. Comparisons with existing research are useful, but the limitations should be kept in mind, as these studies have been conducted in different, usually much wetter, ecosystems and the affected ecosystems and fauna do not always have direct analogues here. To date, the only published study on

the ecological impacts of SGD in South Africa is that of Todd et al. (2016) who provide a review of the international literature on SGD and interpret the findings in terms of Karoo ecosystems and risks posed by the different activities associated with SGD.

Assessing the direct impact of SGD in the form of loss of intact habitat is relatively simple, as this can easily be determined from the footprint of the development as assessed on the ground or through satellite imagery. Jones et al. (2014) found that impacts on vegetation disappeared within 25 m of the development footprint, and that the direct footprint of SGD in their study site in Uzbekistan was less than 1% of the landscape, which is likely to be similar to the extent of direct habitat loss under the SGD scenarios considered in this scientific assessment. However, SGD is also likely to generate significant indirect impacts that extend beyond the direct footprint. Much of this impact is associated with seismic exploration activities and the development of roads and pipelines that fragment the landscape (Brittingham et al., 2014). Disturbed areas around wellpads and along roads will increase the vulnerability of these areas to invasion by alien plants (Gelbard & Belknap, 2003), which may then spread to intact areas and impinge on ecosystem services, biodiversity and agricultural production (Jones et al., 2015). The introduction of invasive and non-native plants on vehicles (for example in seed mixes) is a particular problem and is difficult to avoid. Disturbance generated by road and pipeline construction and maintenance increases the ability of invasive plants to spread (Brooks & Berry, 2006; Mortensen et al., 2009). Once present, these invasive species can out-compete native species and severely reduce habitat quality and ecosystem service delivery (Brooks 2000, Pimentel et al., 2001; Jones et al., 2015). The impacts of access roads in the Karoo may be higher than most overseas situations due to the arid conditions and increased propensity for dust to be generated by vehicles, which may affect vegetation and fauna over broader areas (Trombulak & Frissell, 2000).

Impacts on fauna are more difficult to quantify as behavioural and demographic responses to disturbance by sometimes elusive species have to be monitored. A range of studies have documented faunal impact resulting from spills from waste water ponds when blowouts or failure of ponds occur. A number of instances resulting in mortality of in-stream fish or mammals that drank the water from affected streams have been documented (Robbins, 2013). Furthermore, animals tend to drown in or be poisoned by the waste water storage ponds (Wall et al., 2013) as they are often attracted to them (Hein, 2012; Ramirez, 2009). Under such circumstances storage ponds act as ecological traps for a wide range of species (Kiviat, 2013). This is likely to be problematic in the Karoo as many animals are attracted to standing water under the prevailing arid conditions. The best mitigation for this is to ensure that waste water is kept in closed containers or in suitably sealed ponds covered with shade cloth. Lights around wells can also cause avian entrapment which occurs particularly during foggy or

cloudy conditions when birds are attracted to lights and fly around them till exhausted (e.g. Gauthreaux & Belser, 2006).

Apart from the direct impacts on fauna, there are also indirect impacts on sensitive fauna, usually through disturbance and noise (see Andrews et al., 2008; Barber et al., 2010; Blickley et al., 2012). International examples of shy species include Sage Grouse, which could be compared to the various Korhaan and Bustard species that occur across the Karoo, as well as Moose and Mule deer which could be seen to have similar responses to large ungulates such as Kudu here. Impacts on fauna require long-term detailed monitoring and such studies are only just starting to emerge. Many of these studies are highlighting the cumulative impact of development on sensitive species and the interactive role that disturbance-related stress plays in breeding success and susceptibility to disease (e.g. Barber et al., 2010; Gavin & Komers, 2006).

Although habitat loss is a leading cause of ecological impact in many parts of the world, most of the vegetation types within the Karoo are still largely intact and, while they may have been impacted by livestock overgrazing and consequent degradation, they retain a significant proportion of their biodiversity and ecological integrity. However, roads, pipelines and other associated infrastructure will generate a significant amount of habitat loss and landscape fragmentation within the affected areas (Jones et al., 2015), especially under Scenario 3 (the Big Gas scenario). The impacts of fragmentation will be variable, depending on both the habitats and species affected. In addition, habitat fragmentation is usually associated with increases in other disturbance factors such as noise and human presence (Brittingham et al., 2014), and while some species are likely to become habituated to these conditions, it is likely that some species will remain sensitive (Epps et al., 2005; Sawyer et al., 2006).

As mentioned, it is important to consider the manner in which roads and associated fragmentation will impact Karoo ecosystems. Large parts of the Karoo consist of low, relatively open shrublands or shrubby grasslands with regular, relatively open or bare areas. Consequently, most fauna present are adapted or accustomed to traversing open areas and the loss of cover resulting from smaller roads may have little effect in these areas. However, in areas of high vegetation cover such as the Thicket Biome areas in the south-east of the study area and the higher elevation grasslands of the east, the fauna present are more likely to be averse to traversing open ground or more vulnerable to predation and so the potential for disruption of dispersal and other processes is higher (e.g. Andrews & Gibbons, 2005; Epps et al., 2005). A significant increase in faunal impact due to roadkill as a result of increases in traffic volumes as well as the construction of many new access roads is potentially significant across the entire study area (Collinson et al., 2015). Impacts on slow reproducing (e.g. tortoises), slow

moving species (e.g. snakes, tortoises) and species attracted to roads due to the presence of roadkill themselves (e.g. Bat-eared Foxes, polecats) is of potential concern (Andrews & Gibbons, 2005; Clarke et al., 2010).

7.1.3 Special features of Karoo ecology and biodiversity

The Karoo is an arid ecosystem characterised by low, unpredictable rainfall and episodic drought events (Hoffman & Cowling, 1990). This has important implications for the dynamics of vegetation within the region. Concepts such as succession and gradual, stepwise and predictable changes in vegetation composition do not apply well in arid ecosystems, and instead ecologists have recognised the event-driven, non-linear dynamics of arid systems such as the Karoo (Milton & Hoffman, 1994; Wiegand & Milton, 1996). Recognition is given under this concept to the unpredictable nature of such systems and their ability to switch quickly from one state to another in response to climatic or biotic events, without the need to pass gradually through intermediate stages. This has important implications for physical disturbance in the Karoo and the ability of humans to repair these impacts (Visser et al., 2004). Many of the shrub species present are long-lived (hundreds of years) and recruitment occurs infrequently in response to rare sequences of rainfall and climate conditions (Wiegand & Milton, 1996). As such, it can be very difficult to re-establish the dominant shrub species in disturbed areas as recovery does not occur spontaneously and active rehabilitation is often met with poor success (Carrick & Kruger, 2007; Visser et al., 2004). This has important implications for the manner that SGD should take place within this environment. Disturbance can persist for decades or even centuries, and many areas are also vulnerable to erosion once the vegetation has been disturbed (Boardman et al., 2003). Therefore, the primary avenue through which to minimise negative impacts in this environment is to ensure that the disturbance footprint is kept to a minimum.

Special features related to the following are discussed below:

- Terrestrial ecosystems;
- Plant species diversity and endemism;
- Terrestrial fauna (including mammals, birds, reptiles and invertebrates); and
- Aquatic ecosystems and species.

7.1.3.1 Terrestrial Ecosystems

The study area includes seven different biomes of which the Nama Karoo (Mucina et al., 2006), at 68% of the exploration application area, is by far the most important (Table 7.1). There are 58 vegetation types within the area (out of approximately 430 vegetation types nationally), of which ten have more than 75% of their extent within the study area, based on the national map of vegetation

types of South Africa (Mucina & Rutherford, 2006). Nine of the 14 Nama Karoo vegetation types are represented, five of which have more than 75% of their extent within the study area. However, it is important to recognise that the 14 vegetation types of the Nama Karoo Biome as mapped in the national map of vegetation types do not adequately reflect the diversity of this area, as the national vegetation types have not been mapped at a homogenous scale across the country. The vegetation types within the Nama Karoo have been conceived very broadly relative to those in much of the rest of the country, and include levels of variation that were considered indicative of different vegetation types within the adjacent biomes. At a broad level, areas of potential concern would be Central Mountain Shale Renosterveld, Roggeveld Shale Renosterveld, Karoo Escarpment Grassland and Eastern Lower Karoo, all of which have the majority of their area within the exploration application area and have high levels of diversity or endemism. Ecosystem types in the SGD area are largely not listed as threatened ecosystems in terms of the National Environmental Management: Biodiversity Act (NEMBA) (Act No. 10 of 2004), though Ceres Shale Renosterveld, listed as Vulnerable, extends into the study area.

Table 7.1: Extent of the different biomes within the exploration application area, showing the preponderance of the Nama Karoo Biome within the study area with some Grassland and minor areas of the other biomes. All areas are in km².

Biome	Study area extent (km²)	Exploration application extent (km²)	Proportion of study area (%)	Proportion of exploration application area (%)
Albany Thicket Biome	12945	6854	7.5	5.5
Azonal Vegetation	7985	5819	4.6	4.6
Forests	85	38	0.05	0.03
Fynbos Biome	5774	3725	3.3	3.0
Grassland Biome	21917	14559	12.7	11.6
Nama-Karoo Biome	108229	85753	62.6	68.3
Savanna Biome	362	0	0.2	0.00
Succulent Karoo Biome	15517	8815	9.0	7.0
Total	172815	125565	100	100

Invasive Alien Plants in the Karoo

Invasive alien plants require management because they may impact biodiversity as well as the provision of ecosystem services which contribute to human livelihoods and well-being (Richardson & Van Wilgen, 2004; Van Wilgen et al., 2008).

In terms of legislation, the Alien and Invasive Species Regulations (2014), promulgated under the National Environmental Management: Biodiversity Act (Act No 10 of 2004) require that land users clear *Declared Weeds* from their properties and prevent the spread of *Declared Invader Plants* on their properties.

The Karoo has a long history of alien plant invasion, with the Boetebos (*Xanthium spinosum*) being the first species to be legislated as a declared invader in 1860. Prickly Pears (*Opuntia* spp.) were also once a widespread problem in the Karoo but were controlled in most areas by *Cactoblastis* and Cochineal biocontrol agents.

Disturbance is a major driver of alien plant invasion, and roads in particular have been identified as an avenue of alien plant invasion (Gelbard & Belnap, 2003; Von Der Lippe & Kowarik, 2007). This applies in the Karoo, where most common invasive species are already present at low density and are able to expand rapidly into disturbed areas, aided by the low cover of indigenous species in these areas as well as water subsidies received from adjacent roads and other disturbed or hardened surfaces. As discussed in Section 7.2, roads and other forms of disturbance are among the key potential impacts of SGD in the study area, including but not only because of risks related to invasion by alien species.

Invasive alien species of economic or ecological concern in the Karoo include the various *Prosopis* hybrids which together occupy more than 1.5 million hectares of the country and generate a significant negative hydrological impact through their use of groundwater and suppression of indigenous species (Dzikiti et al., 2013; Ndhlovu et al., 2011). There are also various *Opuntia/Cylindropuntia* species and other Cactaceae which reduce grazing capacity and may have thorns which injure animals; *Xanthium spinosum* which has burrs that affect the quality of wool and mohair; Satansbos (*Solanum elaeagnifolium*) which is a problem on cultivated lands and overgrazed veld; as well as a number of other significant invasive alien species which are a general problem in disturbed areas including *Salsola kali* and *Argemone ochroleuca*.

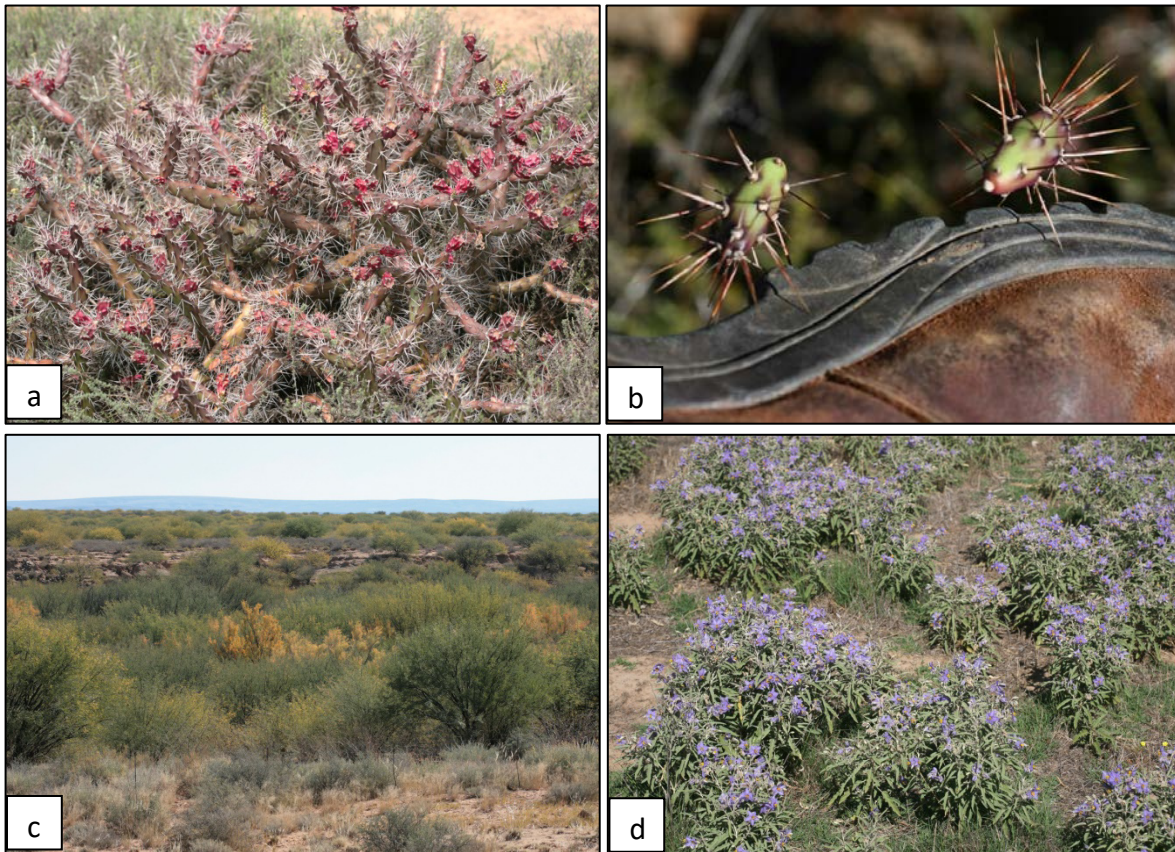


Figure 7.1: a) Jointed cactus (*Opuntia aurantica*) is an aggressive invasive plant with segmented stems that break off easily when their sharp barbed spines attach to passing animals or people. b) This species can render areas unusable for livestock grazing as the cladodes (leaves) stick to animals' hooves and mouths leaving them unable to walk or eat. c) Mesquite *Prosopis* spp. hybrids occupy large tracks of the upper Karoo especially along drainage lines and bottomlands. d) The aptly-named satansbos (*Solanum elaeagnifolium*) is notoriously difficult to eradicate as it is able to regenerate from small root fragments.

7.1.3.2 Plant species diversity and endemism

There are 193 endemic or near-endemic plant species out of a total of 2 158 indigenous species known to occur in the study area. Of the endemic or near endemic species, 119 (Digital Addendum 7A) can be considered to be of conservation concern because they have ranges and habitat requirements that are narrow and specific enough to make them vulnerable to development impacts. A large proportion of these range-restricted species (75 species, or 63%) occur in the mountains and are concentrated in the botanical centres of endemism, including the Roggeveld Escarpment around Sutherland (46 species), the Cape Midlands Escarpment that includes the Sneeuwberg Massif that surrounds Graaff-Reinet (23 species) and the Nuweveldberge (12 species) just west of Beaufort West. This limits their vulnerability to impacts of SGD, as mountainous areas tend to be less suitable for SGD. However, there are 44 range-restricted species that are associated with the open plains of the Karoo. These are mainly succulent plants from the families Aizoaceae (*Vygies* especially small succulents within the genera *Aloinopsis*, *Cylindrophyllum*, *Peersia*, *Deilanthe*, *Stomatium* and *Pleiospilos*); Euphorbiaceae

(Euphorbias) and Apocynaceae (Stapeliads especially in the genera *Orbea*, *Piarranthus*, *Duvalia* and *Hoodia*). Although some of these occur on dolerite outcrops, where they are less likely to be impacted, 25 species are reportedly restricted to clay and gravel flats where they would be highly vulnerable to the impacts of SGD (see text box below). It is worth pointing out that information on many plant species is lacking due to the poor historical sampling of the area.

Where in the Karoo Landscape is Plant Diversity?

In order to understand the potential impact of SGD on the Karoo, it is useful to know the distribution of plant diversity among the different landforms of the Karoo as these will not be equally impacted by SGD. It can be anticipated that SGD will have a disproportionate impact on the plains and relatively low-slope hills and less impact on rocky outcrops and mountains, especially where these are dolerite in origin. A number of studies provide some insight in this regard. Burke et al. (2003) found that species richness of mesas was not significantly higher than the plains near Middelburg, but that the proportion of species shared between plains and mesas declined with increasing size of the mesas. Cowling et al. (1994) compared species richness at paired sites on plains and rocky hills across the Karoo and found that the rocky hills had significantly higher species richness than the adjacent plains. Todd (2003) conducted a detailed vegetation study near Beaufort West and compared species richness within five different habitats and found that calcrete and sandy plains had significantly lower species richness than dolerite hills, shale gravel hills and drainage lines (Figure 7.2). In terms of the proportion of species shared between the different habitats, approximately 25% of the species found on the rocky hills are unique and not found elsewhere, while less than 2% of the species on the calcrete plains are unique to this habitat. The overall implication of these different studies is that development on the open plains would have less impact on plant diversity than development within other habitats. Although there is little supporting data, it is also likely that turnover (β -diversity) across the rocky hills is greater than on the plains (Figure 7.3).

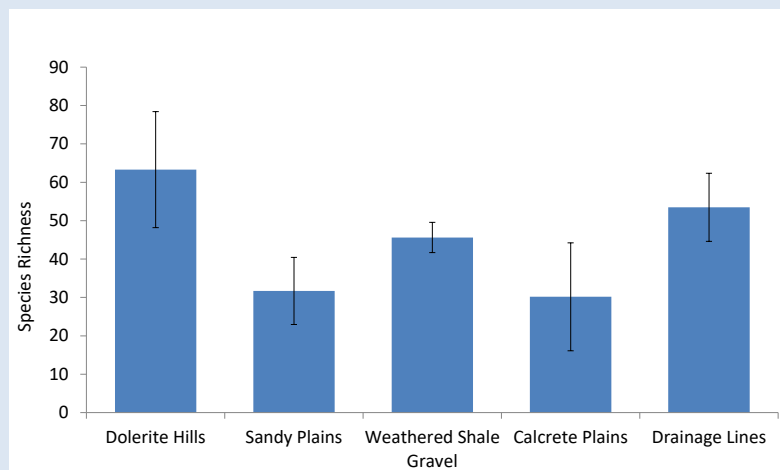


Figure 7.2: Mean species richness with standard deviation bars within five habitats within the Karoo near to Beaufort West (from Todd, 2003).



Figure 7.3: Although there are some plant species of conservation concern that are restricted to the plains, the majority of range-restricted endemic plant species are associated with mountains and rocky hills of the Karoo. This may limit the potential impact of SGD on plant species of conservation concern.

7.1.3.3 Terrestrial fauna

The vertebrates of the Karoo are well adapted to the unpredictability of the system through a range of physiological and behavioural traits. Many larger mammal species have extensive home ranges and occur at a low density across broad areas. For such species, mobility and the ability to move about the landscape is a key adaptation allowing them to persist in an arid landscape.

The majority of mammals in the Karoo are species with a widespread distribution that originate in the Savanna and Grassland biomes. The MammalMap database³ lists approximately 177 indigenous species for the study area of which at least 11 are confined to protected areas where they are conservation dependent and cannot be considered free-ranging. Widespread species which occur in the study area and which are of conservation concern include three species categorised as Vulnerable on the International Union for Conservation of Nature (IUCN) Red List; Leopard, *Panthera pardus*, Black-footed Cat, *Felis nigripes*, and White-tailed Mouse, *Mystromys albicaudatus*, and the Critically Endangered Riverine Rabbit, *Bunolagus monticularis*. Impacts are likely to be most serious for

³ MammalMap database available at: <http://vmus.adu.org.za/>

species that are endemic or near endemic to the study area, which include Grant's Rock Mouse, *Micaelamys granti*, the Riverine Rabbit, a subspecies of Sclater's Golden Mole, *Chlorotalpa sclateri shortridgei*, and the recently described Karoo Rock Sengi, *Elephantulus pilicaudus*. Of these the most critical species is the Riverine Rabbit which is recognised as one of the most threatened terrestrial mammals in southern Africa and is strongly associated with riparian habitat adjacent to seasonally dry river systems. Two-thirds of its habitat has been fragmented or destroyed in the past 50 years by human activity. The alluvial soil terraces along seasonal rivers typically support halophytic shrublands that are essential for Riverine Rabbit forage and cover. The Riverine Rabbit functions as an indicator species of the condition of river ecosystems, specifically riparian habitat, in the Karoo and its local extinction in many areas is indicative of degradation, fragmentation and loss of the valuable riparian vegetation cover caused by over-utilisation and cultivation. Populations become isolated where riverbanks and floodplains have been transformed for cultivation of crops or other development. Such isolated populations are less able to persist over the long-term and more vulnerable to local extinction.

Some mammals such as aardvark and porcupine are considered especially important due to the ecological impact that they have, especially with regard to the diggings they create when foraging, which creates soil disturbances that are important for plant establishment and the maintenance of diversity (Bragg et al., 2005). In addition, the burrows they dig are important for other fauna as they are used by many other animals which do not usually dig their own burrows but use or modify aardvark or porcupine burrows. Both porcupine and aardvark are considered vulnerable to impact from SGD, due to poaching, traffic collisions and in the case of aardvark disturbance and noise as well. These are useful species for monitoring as they are widespread, have broad habitat requirements, are good indicators of ecological condition, and are vulnerable to impact.

In terms of reptiles, the Karoo is relatively diverse and 35 snake, 49 lizard (including 15 gecko and two chameleon) and five tortoise and terrapin species have been recorded from the study area. One tortoise species, the Karoo Padloper, *Homopus boulengeri*, and two subspecies of the Tent Tortoise, *Psammobates tentorius*, are largely restricted to the Karoo and the Karoo Padloper is listed as Near Threatened. The Plain Mountain Adder, *Bitis inornata*, which is restricted to the Nuweveldberge, is the only snake species that is endemic to the study area and it is categorised as Endangered. The degree of endemism is low for the lizards and most species derive from the Succulent Karoo or Savanna. Three lizard species, however, are largely restricted to the Nuweveldberg area of the Karoo; Braack's Pygmy Gecko, *Goggia braacki*, Cloete's Girdled Lizard, *Cordylus cloetei*, and the Crag Lizard, *Pseudocordylus microlepidotus namaquensis*. Three other lizard species, the Dwarf Karoo Girdled Lizard, *Cordylus aridus*, the Karoo Flat Gecko, *Afroedura karroica*, and Thin-skinned Gecko *Pachydactylus kladaroderma* have much of their distribution in the Karoo.

Several terrestrial invertebrate groups include species with narrow ranges, but there is insufficient data to be able to identify endemics with any certainty, and the threat status of most invertebrate groups has not been assessed according to the IUCN criteria. Butterflies are an exception, with good data and a recent conservation assessment (Mecenero et al., 2013). Nineteen species or subspecies recorded from the area have more than 60% of their distribution in the study area, and four of these are wholly endemic to the area (*Aloeides pringlei*, *Lepidochrysops victori*, *Thestor compassbergae*, *T. camdeboo* and *Cassionympha camdeboo*). *Lepidochrysops victori* is categorised as Vulnerable, and is only known from montane grassland in the foothills of the Great Winterberg. Eight terrestrial mollusc species are endemic to the study area and several of these species are restricted crevices in rocky areas where there is some moisture (Digital Addendum 7A). Three Orthoptera (grasshopper/katydid) species are only known from the study area (Digital Addendum 7A), and it is likely that there are many other endemic invertebrates as well.



Figure 7.4: Although the national vegetation map identifies relatively few vegetation types within the Nama Karoo, this belies the large amount of landscape variation that is present and that is important for the fauna. Many species use different parts of the landscape at different times of the year or even each day. As much of the landscape is very open, drainage lines and other areas of dense vegetation can be especially important for animals.

The Karoo lacks a distinctive avifauna (Winterbottom, 1968) but is rich in bird species around the edges, with a steady decrease in species richness towards the arid centre. This is, however, accompanied by a shift in the way that birds use the environment and a concomitant increase in the

number of nomadic species, with a trend towards high temporal variability in the density of individuals of resident species (Dean, 1995). There are no families of birds endemic to the Karoo, but members of the Alaudidae, Cisticolidae, Sylviidae, Muscicapidae and Fringillidae are well represented. Very few species of birds in the Karoo are considered to be rare throughout most of their geographic ranges. Most species that are rare in the Succulent and Nama Karoo are common in substantial parts of their geographic ranges elsewhere. At least ten species that have been recorded in the study area were categorised as Threatened in the latest national assessment (Taylor et al., 2015) (Digital Addendum 7A).

There is very little hard data on the impacts of SGD on birds from anywhere in the world, apart from a recent study in the Appalachian forest (Farwell et al., 2016). Almost all written information on the impacts on birds lack publication in peer reviewed journals, and whatever has been posted on various internet sites refers almost entirely to the situation in relatively well-watered sites. However, based on responses of avifauna to disturbance in general, a number of conclusions regarding the likely impacts of SGD on avifauna can be reached.

The density of birds in the Karoo is unusually low compared with other biomes. There are no data available for most of the Nama Karoo, but an estimated density, calculated from counts along transects, suggests that there are 32 individual birds /km² in plains shrubland on the southern edge of the Nama Karoo (Dean & Milton, 2001). The following density data are available for 3 common and widespread Karoo species that make up most of the local community at Tierberg near Prince Albert: Karoo Long-billed Lark, *Certhilauda subcoronata* (ca 6 birds/km²), Karoo Chat, *Cercomela schlegelii* (ca 10 birds/km²) and Rufous-eared Warbler, *Malcorus pectoralis*, (ca 10 birds/km). All three of these species are territorial to some extent; all avoid settlements, even small settlements such as would be represented by shale gas wellpads. In addition, habitat loss for such species is not equivalent to the wellpad footprint, as birds may avoid areas as much as 200 m from settlements. Under the Big Gas scenario, this would result in habitat loss at the landscape scale of as much as 15%, from wellpads alone. Taking additional habitat loss and disturbance along roads into account, it is not unreasonable to expect declines of as much as 20% in the abundance of the above species.

A major impact on bird populations and local communities is likely to be through increased vehicular traffic. A large number of species of mammals, birds and reptiles are killed, both diurnally and nocturnally, on the roads in the Karoo (Siegfried, 1965), providing food for a number of scavenging birds, including raptors and crows (Collinson et al., 2015; Dean & Milton, 2003; Dean et al., 2006; Macdonald & Macdonald, 1985; Malan, 1992; Schmitt et al., 1987; Steyn, 1982; Winterbottom, 1975) and even small species such as the Fiscal Shrike, *Lanius collaris*, (pers. obs.). Birds (and other

animals) eating road kills, and foraging on roads, are vulnerable to themselves becoming roadkill (Collinson et al., 2015); both raptors and crows have been recorded killed on roads (Dean & Milton, 2003).

Adaptable bird species such as crows may increase in response to human activity, which can have negative effects on other biota. Crows attracted to roads by the availability of road kills are likely to also forage in the surrounding shrublands, impacting smaller birds and reptiles. The lights at the wellpads that are on all night will attract insects, and therefore will attract nightjars, some of which may settle on roads near the wellpads and get killed on the road. Spotted Thick-knees (Dikkops), *Burhinus capensis*, are active in the evenings and sometimes into the night; this species is frequently killed on roads.

Another hazard to birds is likely to be posed by the water produced from shale gas drilling operations. In fact, for many birds, this may be the major hazard connected with well sites, and is the most documented aspect of the problems associated with gas and oil wells. Pits or sludge dams constructed near well sites to hold produced water may be lethal to birds. Open water is a limited resource in the Karoo, but a number of nomadic bird species utilise ephemeral ponds for foraging and breeding. While it is not likely that birds would use ponds immediately adjacent to active drilling activities on wellpads, there may be negative impacts from spills and there is also the possibility that ponds are left in place during the production phase when disturbance would be lower and at such time there would be a strong possibility that birds will land on the water, and species such as swifts and swallows (and bats), that drink on the wing by flying across ponds, will attempt to land or to drink. The use of mechanical birds (that look like raptors) perched on the fence surrounding the ponds may be effective deterrents. Recommendations for “reserve pits” to hold produced water include fencing to keep out walking animals and netting over the pits to keep out flying animals (Ramirez, 2009).

Flares to burn off excess gas may be another hazard for birds that has not been quantified. Many bird species migrate and fly through the night to reach their wintering or summering grounds. It is known that migrant birds flying at night are attracted to lights and may inadvertently stray into the flares. This hazard cannot be easily mitigated, but its prevalence would depend on the extent of flaring.

Of interest and potential conservation concern in the Karoo are relic species and habitats that are indicative of a wetter past. These are concentrated along the Great Escarpment and are best exemplified by the various freshwater molluscs that occur in these areas as well as the presence of Ice Rats, *Myotomys sloggetti*, on the highest peaks of the Nuweveldberge, and the presence of an isolated,

potentially new species of ancient Velvet Worm (Onychophora) in the Graaff-Reinet area (Daniels et al., 2016).

7.1.3.4 Aquatic ecosystems and species

The Karoo landscape is heavily influenced by the occurrence of dolerite dykes, sills and rings (see Burns et al. (2016) for a description of these geological features), which control surface and subsurface drainage patterns and the occurrence of watercourses and wetlands (Woodford & Chevalier, 2001; Gibson, 2003) (see Hobbs et al. (2016) for definitions of aquatic ecosystems). The low rainfall across the study area means that evaporation is the dominant component of the water balance (Allan et al., 1995), and while rainfall drives the inundation periodicity of the aquatic ecosystems in the area, surface–groundwater interactions are thought to be important for sustaining them. Most of the surface water ecosystems in the study area are thus intermittent or ephemeral, being inundated only for brief periods each year, with periods of drought that are predictable in frequency but unpredictable in duration.

The less common but more perennial springs and seeps associated with Karoo dolerite dykes and sills occur on peaty soils typically at the base of dolerite cliffs or on dolerite slopes, in depressions along fractures or topographical breaks, and are fed by groundwater seeping from deep, fractured aquifers, or even from unconfined alluvial aquifers (Nhleko, 2003). These aquatic ecosystems are one of five types of aquifer-dependent ecosystems (ADEs) recognised in South Africa (Chevalier et al., 2004; Colvin et al., 2007).

The ephemeral rivers of the Karoo are highly dependent on groundwater discharge, which occurs at springs and when groundwater recharge (through precipitation at higher elevations) allows the water table to intersect with the river channel. The upper reaches of the Salt River (Beaufort West), the Kamdeboo, Sundays and Brak Rivers (De Aar) are all good examples of these groundwater-fed watercourses.

Ephemeral rivers are particularly vulnerable to changes in hydrology, as they are specifically adapted to brief periods of inundation and flow (Figure 7.5). Consequently, pollutants and sediments entering these watercourses are not regularly diluted or flushed out of the catchment, leading to a lack of resilience to pollution, erosion and sedimentation (Figure 7.6). The same can be said of ephemeral or seasonal wetlands, which make up the majority of the lentic systems located in the study area. Many of these wetlands – predominantly depressions or pans – are endorheic, i.e. isolated from other surface water ecosystems, usually with inflowing surface water but no outflow.



Figure 7.5: The same stream a few hours after a large rainfall event (left) and some days thereafter (right), showing how such aquatic ecosystems can come down in spate but dry up very quickly afterwards.



Figure 7.6: Although the Karoo is arid, it can experience occasional intense showers (left), and due to the low vegetation cover and susceptible soils, erosion can be high (right).

A dominant feature of the Karoo landscape is the alluvial floodplains, washes and fans. These systems are difficult to classify, as their hydrological characteristics (the way water flows into, through and out of these features) are difficult to determine. They are characterised by multiple channels that traverse a floodplain, valley floor or alluvial fan. Surface water may flow along a particular channel in one year, but owing to little topographic definition or gradient across the landscape, a parallel channel may be eroded the following year, leading to a network of channels. The ecological functioning and importance of these alluvial features are not known.

There are several Threatened faunal species that are associated with permanent rivers and wetlands in the Eastern Cape portion of the study area. This includes five Threatened freshwater fish species that occur in rivers in this area - the Eastern Cape Redfin, *Pseudobarbus afer*; the Cape Rocky, *Sandelia*

bainsii; *Barbus trevelyani*; *Pseudobarbus asper*; and the Amatola Barb, *Barbus amatolicus*. Two Threatened damselfly species, the Kubusi stream-damsel, *Metacnemis valida*, and the Basking Malachite, *Chlorolestes apricans*, are restricted to rocky, fast-flowing streams in the more mountainous part of the Eastern Cape. Twenty-six frog species have been recorded from the study area out of a total of 123 species in South Africa. This is a relatively high diversity given the aridity of much of the area and paucity of perennial water. The only frog species which can be considered endemic to the Karoo is the Karoo Dainty Frog, *Cacosternum karooicum*.

The fauna of the more seasonal to ephemeral ecosystems is not well known, but they have been found to provide aquatic habitat to a diverse array of faunal species that depend on brief periods of inundation for hatching, mating, feeding and refuge (Anderson, 2000; Hamer & Rayner, 1996; Minter et al., 2004). For instance, many frogs of the Karoo region breed in temporary pools associated with watercourses and wetlands, this includes the Karoo Toad, *Vandijkophrynus gariepensis*, and Karoo Dainty Frog, *Cacosternum karooicum*. A great number of other organisms are not confined to these temporary systems, but derive crucial benefits from them, like migratory birds and many invertebrates that migrate from permanent to temporary habitats on a regular basis. Connectivity between aquatic ecosystems, and between aquatic ecosystems and the surrounding terrestrial landscape, is essential for supporting the fauna of the region, including their need to feed, breed and migrate.

Very little is known of the invertebrate fauna of the watercourses and wetlands of the Karoo region. Given the constant shift from aquatic to dry phases, ephemeral ecosystems support unique, well-adapted biotic communities with species that show rapid hatching, fast development, high fecundity, and short life spans. Organisms that inhabit these ecosystems rely on the production of desiccation-resistant or dormant propagules (such as eggs, cysts, seeds, spores) to survive the dry period, and then become active again when the wetland is inundated. The eggs of these organisms can survive in the sediments for many years, and rapidly hatch when sufficient rain falls. Many taxa will reproduce asexually several times during the wet season.

The ephemeral pans and rock pools in the Karoo are inhabited by branchiopod crustaceans, commonly known as fairy shrimps (Anostraca), tadpole shrimps (Notostraca), clam shrimps (Spinicaudata and Laevicaudata), and water fleas (Cladocera), and also the ostracods or seed shrimps (Lloyd & Le Roux, 1985; and Musa Mlambo, Albany Museum, pers. comm., January 2016). There are several taxa that are completely dependent on ephemeral wetlands to complete their life cycle. For example, the tadpole shrimp, *Triops granarius*, is reportedly common where mean inundation is less than one month; this invertebrate reaches sexual maturity within days (Figure 7.7). Two fairy shrimp species have only been recorded from the study area – *Branchipodopsis browni* and *B. hutchinsoni*; both have

been recorded in temporarily inundated ditches along the road. There are also specially adapted copepod, ostracod and cladoceran crustaceans that inhabit these pools.



Figure 7.7: Tadpole shrimps (*Triops granarius*) are common in pans in the Karoo but spend most of their time as dormant eggs in the soil, sometimes with years between life cycles.

7.1.4 Relevant legislation and policy

National legislation central to the management and conservation of biodiversity in South Africa includes:

- The National Environmental Management Act (NEMA) (Act 107 of 1998, as amended) 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.” Its associated EIA Regulations and Listing Notices identify activities deemed to have a potentially detrimental effect on natural ecosystems and outline the requirements and timeframe for approval of development applications.
- The National Environmental Management: Biodiversity Act (NEMBA) (Act 10 of 2004, as amended), provides for, *inter alia*, the management and conservation of South Africa’s biodiversity, the protection of species and ecosystems that warrant national protection, and the sustainable use of indigenous biological resources.
- The National Environmental Management: Protected Areas Act (Act 57 of 2003, as amended) provides for; *inter alia*, the protection and conservation of ecologically viable areas representative of South Africa's biodiversity and its natural landscapes and seascapes. The Protected Areas Act provides for protected areas to be declared on private or communal land, with the landowner retaining title to the land. This has led to the development of biodiversity stewardship programmes, in which conservation authorities (such as provincial conservation agencies) enter into contractual agreements with landowners. Nature Reserves and Protected Environments declared through biodiversity stewardship programmes are considered formal

protected areas, and are collectively referred to as contract protected areas (distinguished from state-owned protected areas).

- The National Water Act (NWA) (Act 36 of 1998) addresses, *inter alia*, the “protection of the aquatic and associated ecosystems and their biological diversity”. The Act regulates all water uses, some of which are non-consumptive but which may impact on the integrity, functioning and biodiversity of wetlands and watercourses. The process to be followed to obtain authorisation for these categories of water use relate to the risk associated with the water use, where authorisation of low risk activities is a simpler, faster process than for full Water Use Licence Application (WULA). Generally, non-consumptive water uses that impact directly on a wetland, or which occur within 500 m of a wetland or within the outer edge of the 1 in 100 year floodline or delineated riparian area of a watercourse are of medium to high risk, requiring a full WULA.
- The Mineral and Petroleum Resources Development Act (MPRDA) (Act 28 of 2002) and its associated regulations provide for the protection of water resources, and stipulate required setbacks from wells, in order to protect the integrity of watercourses and wetlands. Section 49 of the MPRDA provides a mechanism for excluding mining from certain areas.

In addition to legislation, several national strategies and plans are central to the management and conservation of biodiversity in South Africa:

- As a contracting party to the Convention on Biological Diversity (CBD), South Africa is obliged to develop a National Biodiversity Strategy and Action Plan (NBSAP). Strategic objectives of the recently revised NBSAP for 2015 to 2025 (Department of Environmental Affairs (DEA), 2015a) include that the management of biodiversity assets and their contribution to the economy, rural development, job creation and social wellbeing is enhanced, and that investments in ecological infrastructure enhance resilience and ensure benefits to society.
- Spatial assessment and prioritisation of biodiversity based on the principles of systematic biodiversity planning is strongly embedded in the policy and practice of the biodiversity sector in South Africa, for example through the National Biodiversity Assessment (NBA) (Driver et al., 2012), the National Protected Area Expansion Strategy (NPAES) (Government of South Africa, 2010), the Atlas of Freshwater Ecosystem Priority Areas of South Africa (FEPA) (Nel et al., 2011), and provincial spatial biodiversity plans. These principles include the need to conserve a viable representative sample of all ecosystems and species, as well as the ecological and evolutionary processes that allow biodiversity to persist over time.

At the provincial level, provincial environmental affairs departments are often the authority for permitting or authorising for a range of activities, and they provide comments on mining-related authorisations. Provincial spatial biodiversity plans identify Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) which guide such authorisations and comments.

7.2 Key potential impacts and their mitigation

This section identifies and describes potential impacts of SGD on the study area, and recommends mitigation measures based on the ecology and biodiversity of the area. The mitigation measures are structured according to the mitigation hierarchy that is widely applied in EIAs – avoid, minimise, rehabilitate, offset.

Because of the potential cumulative landscape-scale impacts of SGD, the mitigation hierarchy should be applied not only at the site level in EIAs, but also at a strategic landscape level. A framework for application of the mitigation hierarchy at the landscape level is set out in Section 7.2.1 (Table 7.2), followed by more detailed discussion of mitigation measures for specific activities related to SGD in Section 7.2.2 (Table 7.3). Cumulative impacts are discussed further in Section 7.2.3, and gaps in capacity for implementing mitigation measures at both the landscape level and site level are outlined briefly in Section 7.2.4.

As discussed in Section 7.1.3, rehabilitation efforts in the Karoo environment are often met with poor success, and disturbance can persist for decades or even centuries. This means that the preferred mitigation measures in this environment are to *avoid* or *minimise* impacts, whether at the landscape level or the site level. In cases where rehabilitation measures are recommended, they are generally aimed at restoring basic ecological functioning rather than at restoring species composition. In cases where residual impacts (after avoiding and minimising) need to be *offset*, ecologically equivalent sites must be identified and secured. An ecologically equivalent site means a site that contains equivalent ecological processes, ecosystems and species, and that compensates for the full ecological impact of the activity as identified through a detailed study.

7.2.1 Strategic approach to mitigation at the landscape level

The table below sets out a framework for mitigation at the landscape level. It is underpinned by the spatial analysis that identified areas of EBIS in the study area, from EBIS-1 (highest) to EBIS-4 (lowest), as described in Section 7.3.1. Protected areas, EBIS-1 areas and EBIS-2 areas collectively meet targets for representation of biodiversity and maintenance of ecological processes in the study area, in a spatial configuration designed to ensure connectivity in the landscape.

The primary mitigation for SGD in the Karoo as a whole is securing the EBIS-1 and EBIS-2 areas; which effectively make EBIS-3 and EBIS-4 areas available for SGD. EBIS-1 and EBIS-2 areas should be secured through legal mechanisms that limit loss and degradation of habitat, such as:

- Establishing or expanding a state-owned protected area;
- Establishing a contract protected area, for example through legally binding biodiversity stewardship agreements (this could be either a contract Nature Reserve or a contract Protected Environment, in which landowners enter into a long-term contractual agreement with a conservation authority);
- Establishing a lower tier biodiversity stewardship agreement (for example, a Biodiversity Management Agreement or Biodiversity Partnership Area);
- Zoning the land as an appropriate zone (e.g. conservation) in a municipal Land Use Scheme;
- Protection under Section 49 of the MPRDA.

Securing EBIS-1 and EBIS-2 areas may lend itself to a fast-tracked, integrated programme to expand the protected area network, which takes a strategic approach rather than an *ad hoc* piecemeal approach, similar to Operation Phakisa in the marine environment. Biodiversity offsets can also play an important role in securing EBIS-1 and EBIS-2 areas as protected areas; EBIS-1 and EBIS-2 areas are first-tier and second-tier receiving areas respectively for biodiversity offsets.

In addition to securing EBIS-1 and EBIS-2 areas, it is critical that an effective set of operating rules is established for all areas to ensure that overall impacts on the landscape in general, and impacts on EBIS-1 and EBIS-2 areas in particular, are kept within acceptable limits. Subject to reasonable on-site operating rules to reduce unnecessary impacts, and careful minimisation of any broader impacts on adjacent EBIS-1 and EBIS-2 areas, biodiversity loss within EBIS-3 areas could be absorbed without compromising the overall function and integrity of the Karoo ecosystem as a whole. Impacts restricted to EBIS-4 areas are unlikely to be of ecological significance.

Table 7.2: Strategic application of the mitigation hierarchy at the landscape level, based on the map of EBIS.

Ecological and Biodiversity Importance and Sensitivity (EBIS)	Primary focus of mitigation, based on the mitigation hierarchy
Protected areas	<p>AVOID</p> <ul style="list-style-type: none"> • These areas are legally protected in terms of the Protected Areas Act.
EBIS-1 (highest)	<p>AVOID</p> <ul style="list-style-type: none"> • EBIS-1 areas contain extremely sensitive features and are irreplaceable. Because they are irreplaceable, it is <u>not possible to minimise or offset</u> impacts of SGD activities in these areas. • SDG activities <u>must always be avoided</u> in these areas. • Ideally these areas should be <u>secured</u> through legal mechanisms that limit habitat loss and degradation. • These are <i>first-tier receiving areas for biodiversity offsets</i>.
EBIS-2	<p>Best option: AVOID Otherwise: MINIMISE AND OFFSET RESIDUAL IMPACTS</p> <ul style="list-style-type: none"> • EBIS-2 areas contain highly sensitive features and features that are important for representation of biodiversity and/or maintaining ecological processes. • Ideally they should be <u>secured</u> through legal mechanisms that limit habitat loss and degradation. • If they cannot be avoided, then ecologically equivalent sites must be secured through biodiversity offsets. • These are <i>second-tier receiving areas for biodiversity offsets</i>. <p>For shale gas <u>exploration</u> in EBIS-2 areas, it may be possible to minimise impacts sufficiently at the site level to achieve no loss or degradation of habitat i.e. no residual impacts. In such cases, an offset will not be required.</p> <p>For shale gas <u>production</u> in EBIS-2 areas, impacts of production cannot be effectively mitigated on-site or at the operational level: There will <u>always be residual impacts</u> that must be offset.</p>
EBIS-3	<p>MINIMISE</p> <ul style="list-style-type: none"> • EBIS-3 areas are natural areas that do not contain currently known sensitive or important features. • Environmental compliance is required. This includes specialist-led assessment of local sensitivities and identification of appropriate mitigation. • From a biodiversity and ecological perspective, SGD activities need not be avoided in these areas IF there is no loss or degradation of EBIS-1 and EBIS-2 areas. • These are <i>third-tier receiving areas for biodiversity offsets</i>.
EBIS-4 (lowest)	<p>MINIMISE</p> <ul style="list-style-type: none"> • EBIS-4 areas have no remaining natural habitat. • Environmental compliance is required. • From a biodiversity and ecological perspective, there is no need to avoid SGD in these areas; however, there may well be other reasons to avoid SGD in these areas.

7.2.2 Activities, impacts and mitigation measures

This section focuses in more detail on mitigation measures for those activities associated with SGD that are most relevant from a biodiversity and ecological point of view. In the Karoo environment, where transformation for cropping and other intensive agricultural activities is limited, habitat loss at a local scale is not usually of high significance (with EBIS-1 areas being a clear exception). As discussed, a major concern is the cumulative and interactive effect of the activities at the landscape scale, particularly through activities on the land surface that fragment the landscape, and the resulting impact on spatially extensive ecological processes. The actual drilling footprint is in general less significant than the ancillary infrastructure and activity, including roads and vehicular activity.

From a terrestrial ecology perspective, the activities of most concern or relevance are removal of indigenous vegetation and destruction of natural habitat; construction and maintenance of roads, wellpads and other physical infrastructure; off-road driving; vehicular traffic on roads; and activities linked to ongoing operation, including human activities such as collection of species of special interest, disturbance such as light and noise, and industrial accidents. From an aquatic ecological perspective, the activities of most concern or relevance are waste water management; water extraction and use; destruction of natural habitat in riparian areas and wetlands; construction and maintenance of roads that traverse watercourses or wetlands; and off-road driving through watercourses and wetlands.

Table 7.3 sets out activities and their associated impacts, as well as potential mitigation measures structured according to the mitigation hierarchy (avoid, minimise, rehabilitate, offset). Some impacts are closely tied to the location and layout of activities. In many cases, careful planning of the siting and layout of activities away from EBIS-1 and EBIS-2 areas can substantially avoid impacts. The map of EBIS (see Section 7.3.1) should be used to inform the siting of activities. Others impacts are linked to the carrying out of ongoing activities as part of operations.

Table 7.3: Activities, impacts and mitigation measures.

Activity	Description	Mitigation measures
Exploration	<p>Exploration will generate physical disturbance as well as above and below ground noise. Although the noise will be short-lived and probably not of long-term consequence, off-road driving in unsuitable conditions can cause long-term impacts.</p> <ul style="list-style-type: none"> • Driving of heavy vehicles even once over wet clay floodplain areas can have major impact as these areas are highly sensitive to change. The whole ecology of the system is dependent on water spreading out over vast flat areas during rainfall events. Tracks left by vehicles after driving over the soil surface when it is wet can cause significant changes in water run-off patterns and will remain in the landscape for decades. • Many different subterranean animals, including golden moles, use soil vibrations to find prey and the loud noises generated by seismic exploration may have a significant impact on such species, but this is not well known and the severity or extent of this problem should be investigated. • Although the footprint of exploration is likely to be relatively limited, it may cover a large area. 	<p><u>Avoid</u></p> <ul style="list-style-type: none"> - No driving off-road for prospecting when there are wet soil conditions. - No exploration within sensitive habitats such as wetlands, quartz patches, and rack pavements. <p><u>Minimise</u></p> <ul style="list-style-type: none"> - Minimise disturbance footprints. <p><u>Rehabilitate</u></p> <ul style="list-style-type: none"> - Rehabilitation of disturbed areas on steep slopes and other sensitive areas required.
Vegetation clearing, destruction or other loss of intact vegetation	<p>Vegetation clearing for roads, wellpads, pipeline routes and other infrastructure. This can lead, <i>inter alia</i>, to the following impacts:</p> <ul style="list-style-type: none"> • Fragmentation of natural habitat, resulting in loss of connectivity in the landscape. This impact extends far beyond the footprint of the cleared areas themselves, and may impact on all ecological processes in the Karoo. It includes fragmentation of aquatic habitat within wetlands and watercourses. • Altered surface water flow patterns, e.g. changing sheet flow to concentrated flows, which leads to erosion, altered flow regimes and changes in water availability. Driving on wet clay forms ruts that later develop into dongas or holes too deep for vegetation establishment. 	<p><u>Avoid</u></p> <ul style="list-style-type: none"> - Design and layout of infrastructure to avoid restricted habitats and high sensitivity areas. - No wellpads within EBIS-1 and EBIS-2 areas, unless an offset has been implemented. - No land application of waste fluids. - No injection/disposal wells. - No direct discharge of waste water to wetlands and watercourses. <p><u>Minimise</u></p> <ul style="list-style-type: none"> - All traffic off of public roads should adhere to 40 km/h speed limits or lower. - No off-road driving in wet conditions. In particular, no driving in veld should take place on clay or fine-textured soils following rain. - Preferably roads should not be fenced off as this increases fragmentation for

Activity	Description	Mitigation measures
	<ul style="list-style-type: none"> • Erosion and sedimentation are important ecological processes in the Karoo. Loss and fragmentation of habitat disrupt these processes. Erosion is a particularly high risk on steep slopes, and in drainage lines that lack channel features and are naturally adapted to lower energy runoff with dispersed surface flows (such as unchannelled valley-bottom wetlands), and naturally less turbid freshwater systems. • Spread of invasive alien species. Altered soil structure, moisture availability and light availability can lead to invasion by weeds and invasive alien plants and animals. 	<p>many fauna.</p> <ul style="list-style-type: none"> - If roads or structures are fenced, use plain strands and not jackal proof fencing to ensure animals can still move through fences. - Design to use as much common/shared infrastructure as possible with development in nodes, rather than spread out. - Access routes should use existing roads and tracks before making new roads. - If unavoidable, surface discharge of waste water to the environment must be monitored to the highest possible water quality standards. - Waste water storage or treatment ponds must be fenced and covered with shade cloth. <p><u>Rehabilitate</u></p> <ul style="list-style-type: none"> - All cleared areas that are not being used must be rehabilitated with perennial shrubs from the local environment.
<p>Construction activity and maintenance of roads, wellpads and other physical infrastructure</p>	<p>Construction phase earth moving, construction and the maintenance of roads and other infrastructure will affect runoff amount and quality as well as generate significant amounts of dust.</p> <ul style="list-style-type: none"> • Dust can have a direct negative impact by covering the leaves of plants, which affects their growth and reproduction (and wears away the teeth of herbivores such as indigenous antelope and livestock); by degrading the habitat of animals and causing them to move away; and by causing accumulation of sedimentation in adjacent drainage lines which clogs the gills of fish and aquatic invertebrates. This impact can extend quite substantial distances from the construction activity and can last for a long time after the activity is completed. • Stormwater runoff from roads, buildings, borrow pits and excavation sites may cause erosion and channelling of flow, changes in flow patterns, head-cut and gully erosion, and sedimentation in wetlands and watercourses. • The disruption of surface drainage patterns where roads are raised above the base level of natural drainage channels or wetlands can cause fragmentation of aquatic ecosystems, and loss of connectivity, and can hamper the movement of aquatic 	<p><u>Avoid</u></p> <ul style="list-style-type: none"> - No vehicles, machinery, personnel, construction material, cement, fuel, oil or waste outside of the demarcated working areas. - No fuel storage, refuelling, vehicle maintenance/washing or vehicle depots within 50 m of the edge of any wetlands or watercourses. <p><u>Minimise</u></p> <ul style="list-style-type: none"> - Refuelling and fuel storage areas, and areas used for the servicing, washing or parking of vehicles and machinery located on impervious bases and with bunds around them. Bunds sufficiently high to ensure that all the fuel kept in the area will be captured in the event of a major spillage. - Use existing bridges for watercourse or wetland crossings wherever possible. - Minimise new crossings over wetlands and watercourses. If wetlands or watercourses cannot be avoided, ensure that road crossings are constructed using riprap, gabion mattresses, and/or other permeable material to minimise the alteration of surface and sub-surface flow. Drift crossings are preferable to bridge crossings, where feasible. - Flow of water under roads must be allowed to occur without leading to concentration of surface flow. This can be achieved through designing bridges that span the entire width of aquatic ecosystems where possible, or laying down pipes or culverts to ensure connectivity and avoid fragmentation of surface aquatic ecosystems. Bank stabilisation measures (gabions, eco logs, geofabric,

Activity	Description	Mitigation measures
	<p>or semi-aquatic fauna along riverine corridors or within and between wetlands.</p> <ul style="list-style-type: none"> • Construction results in substantial noise pollution. This has general disruptive influences on mammals and birds causing shy and sensitive animals to avoid areas where noise pollution occurs. Mating systems for various animals including some insects are disrupted by noise which is likely to result in reduction in populations. • Construction will result in disturbance of vertebrate species. This is especially detrimental to ecological processes when species that are ecosystem engineers (Bat-eared Foxes, Porcupines) are affected. This can include the death of animals, especially of slow-moving and burrow-dwelling animals that are not able to move away. • Construction can introduce invasive alien species, and lead to the spread of those that are already present. Invasive species will negatively compete with indigenous species and disrupt ecological processes. • Construction and maintenance of roads and other infrastructure can be associated with spills of fuel and other chemicals. 	<p>sediment fences) required when wetland or watercourse banks steeper than 1:5 are denuded during construction.</p> <ul style="list-style-type: none"> - Ensure erosion control along roads. Put in culverts at drainage lines. Build water diversion structures at 20 to 50 m intervals (depending on the steepness of the slope) along veld tracks. Soil should be dug out across veld tracks and used to create berms downslope of the ditch. Berms must be at least three times the width of the road, to prevent water running around the berm and back onto the tracks. Berm ends should be extended on the downslope side of the road with rocks to prevent diverted water eroding the soil. These will prevent veld roads acting as water channels, causing donga erosion. It will also facilitate vegetation recovery on closed roads. - If construction areas are to be pumped of water (e.g. after rains), this water must be pumped into an appropriate settlement area, and not allowed to flow straight into any watercourses or wetland areas. - Stormwater runoff from all roads must be spread as much as possible, to avoid concentration of flows off compacted or hardened surfaces. - Roads should not be raised above the natural base level, allowing surface runoff to flow uninterrupted. Crossings over watercourses and wetlands should be built as stabilised drifts rather than using culverts or pipes. - Any materials brought in to construction sites should be from sources free of invasive alien species. - There must be regular dust suppression during construction. <p><u>Rehabilitate</u></p> <ul style="list-style-type: none"> - Clearing of invasive alien species must take place during and after extraction work. - Impact of clearing and rate of recovery of vegetation must be monitored. - Clearing of invasive alien plants must take place coupled with the sowing of seeds of indigenous grass species to stabilise disturbed habitats. - Roads must be closed properly after use with the construction of multiple berms. Temporary roads must be closed on termination of the exploration or other activity for which they were used. - Compacted bare ground should be loosened and pitted, and covered with branches or stones. This will improve the ability of the surfaces to trap seeds and to absorb rainwater, thereby hastening vegetation recovery.

Activity	Description	Mitigation measures
		<ul style="list-style-type: none"> - Domestic livestock should be excluded from areas under rehabilitation until the vegetation has recovered sufficiently.
Vehicular traffic on roads	<p>Construction and to a lesser extent operation will significantly increase traffic volumes within the affected areas and this may lead to significant increases in mortality of susceptible species.</p> <ul style="list-style-type: none"> • Increased vertebrate roadkill is expected to occur. Some species such as Bat-eared Foxes appear particularly vulnerable to roadkill and may be disproportionately affected. • Shy animal species may avoid the proximity of busy roads and thus experience habitat loss. 	<p><u>Avoid</u></p> <ul style="list-style-type: none"> - No driving off roads. - No driving at night. <p><u>Minimise</u></p> <ul style="list-style-type: none"> - Establish culverts for fauna crossings. - Establish and enforce strict speed limits.
Waste water management including treatment, storage and disposal of waste water (flowback and produced water and sewage)	<ul style="list-style-type: none"> • Waste water ponds that are accessible to animals are likely to cause mortalities from consumption and drowning. Leaks, spills, and spread of contaminants are the most significant concern for freshwater species and also others that depend on access to water. • Water pollution/contamination from waste water treatment, flowback and produced water, e.g. releases from waste water ponds, or from accidental releases associated with natural flood events; leaking infrastructure (e.g. ponds, closed water treatment units); and spills of waste water. Flowback and produced water is likely to contain drilling fluids, drilling mud, contaminated fossil water, radioactive nucleotides, biocides and other toxins (e.g. heavy metals), and is likely to have a high salinity. 	<p><u>Avoid</u></p> <ul style="list-style-type: none"> - No land application of waste fluids. - No injection/disposal wells. - No direct discharge of waste water to wetlands and watercourses. <p><u>Minimise</u></p> <ul style="list-style-type: none"> - If unavoidable, surface discharge of waste water to the environment must be monitored, in order to ensure that the water quality guidelines for maintenance of aquatic ecosystems, as provided by Department of Water & Sanitation (DWS), are adhered to. In addition, the regulations regarding the use of water for mining and related activities in order to protect water resources (GN 704/1999 in Government Gazette of 4 June 1999) must be applied (see Hobbs et al., 2016). - Waste water storage or treatment ponds must be fenced and covered with shade cloth. - The mining companies must be responsible for dealing with the waste water generated by SGD activities on site.
Water abstraction and use including water used for fracking	<p>Extensive abstraction of water (surface or groundwater) in the arid Karoo environment will result in impacts on inundation/saturation regimes in wetlands, and flow regimes in watercourses. Abstraction of groundwater will also result in localised drawdown of the water table.</p> <ul style="list-style-type: none"> • Large-scale abstraction of water (surface or groundwater) 	<p><u>Avoid</u></p> <ul style="list-style-type: none"> - No groundwater abstraction or drilling of boreholes within 500 m of existing springs, wellpads or boreholes. - No water abstraction from perched water tables.

Activity	Description	Mitigation measures
	<p>in the Karoo environment is likely to have a catastrophic effect on the condition of aquatic ecosystems, other water-dependent ecosystems, and associated species. In extreme cases it may cause subsidence.</p> <ul style="list-style-type: none"> • Ephemeral and seasonal pools lower down in catchments are more vulnerable as they are more dependent on groundwater. • Abstraction of water will cause a decline of species dependent on water availability, including amphibians and fish, and may impact availability of breeding habitats for aquatic species. • Riparian plant species and communities dependant on perched water tables (such as <i>Valchelia karroo</i>, <i>Searsia lancea</i>, <i>Phragmites australis</i>) will be impacted. • Deeper fossil water (if used for fracking) can contaminate shallower aquifers during fluid migration, and ecosystems dependent on these. 	<p><u>Minimise</u></p> <ul style="list-style-type: none"> - Water use must be subject to the determination of a comprehensive Ecological Reserve, both for surface and groundwater resources. - Sound assessments of water quantity available must be conducted. - Water levels in source water holes must be monitored.
<p>Activities linked to ongoing on-site operations and maintenance</p>	<p>Human presence/activity has impacts such as: increased firewood collection; increased poaching of species for human consumption (e.g. Kudu, Porcupine); killing of animals seen as dangerous (e.g. snakes and spiders); increased collection of species of special interest (e.g. medicinal plants and species popular for the pet trade such as scorpions, baboon spiders and reptiles; trampling of habitats; increased domestic and feral animals which kill indigenous animals, especially birds; and increased fishing in larger river systems (e.g. Sundays River, Fish River).</p> <ul style="list-style-type: none"> • Disturbance, such as light and noise. This changes behaviour of species. Impacts can occur over long distances. Noise pollution frightens animals away. Persistent noise results in habitat degradation and impacts on predation and reproduction. Numerous invertebrates groups are negatively impacted by light pollution due to disorientation, and disruption to mating systems. Lights cause prey community change, which affects some bat species; it affects predation on rats by owls and small carnivores; and can disturb behaviour of invertebrates at night. • Industrial accidents e.g. chemical or fuel spills, lead to contamination of soils and water, and result in habitat 	<p><u>Avoid</u></p> <ul style="list-style-type: none"> - Staff should not be permitted to walk into the veld but should remain only on the wellpads. - No collection of fire wood, medicinal plants, or animals with potential for the pet trade permitted. - Wells must be sited to avoid ecological buffers determined for the protection of biodiversity, and adhere to the buffers set by Hobbs et al. (2016) for protection of the water resource. - No fuel storage, refuelling, vehicle maintenance or vehicle depots within 50 m of the edge of any wetlands or watercourses. <p><u>Minimise</u></p> <ul style="list-style-type: none"> - Minimise the amount of lighting at all facilities and use downward-directed low-UV emitting LED lights at wellpads and direct these exclusively to the areas where night-time lighting is required. - Minimise noise from facilities and infrastructure. - An emergency protocol must be developed that deals with accidents and spills. This must include methods for absorbing chemicals/oils/fuel, and the transport and disposal of all contaminated material in a suitable hazardous waste site.

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Activity	Description	Mitigation measures
	degradation and mortalities.	<ul style="list-style-type: none">- Refuelling and fuel storage areas, and areas used for the servicing or parking of vehicles and machinery, should be located on impervious bases and should have bunds around them. Bunds should be sufficiently high to ensure that all the fuel kept in the area will be captured in the event of a major spillage. Water permits must be issued both for use or water as well as discharge.- Toilets must not be allowed to leak or drain into natural areas.- Ensure sufficient capacity for management of water contamination. <p><u>Rehabilitate</u></p> <ul style="list-style-type: none">- Areas contaminated by accidents and spills must be rehabilitated.

7.2.3 Cumulative impacts

It is often cumulative impacts and related fragmentation of the landscape that are of major concern from an ecological point of view, rather than the impact of any particular activity at the level of an individual site. Given the extensive nature of the Karoo, the development of a few widely scattered wellpads is not likely to generate any impacts of broader significance. However, the cumulative impact of numerous wellpads and associated infrastructure across an extraction area is likely to generate significant impacts on ecological patterns and processes.

The different scenarios have the potential to generate different levels of cumulative impact. Under the Small Gas scenario, the total estimated footprint of development within a 30x30 km block would be approximately 110 ha of wellpads and up to 61 km of new access road equivalent to approximately 61 ha of transformation assuming that roads are 10 m wide. This represents less than 1% of the 30x30 km development block. However, this does not adequately indicate the potential for cumulative impact. Under the Small Gas scenario there is no point more than 5 km from a wellpad or access road and 25% of the area is within 500 m of a wellpad or access road and 48% is within 1 km. By comparison, under the Big Gas scenario, 54% of the block would be within 500 m of a well or access road and 86% is within 1 km. Clearly, within the Big Gas scenario it is impossible for fauna to avoid the SGD. The landscape fragmentation impacts of the Small and Big Gas scenarios are illustrated schematically in Figure 7.8. It is not the extent of direct habitat loss that is of concern, but rather impacts that extend beyond the footprint such as noise or increased impediments to faunal movement such as fences, as well as a combination of such factors.

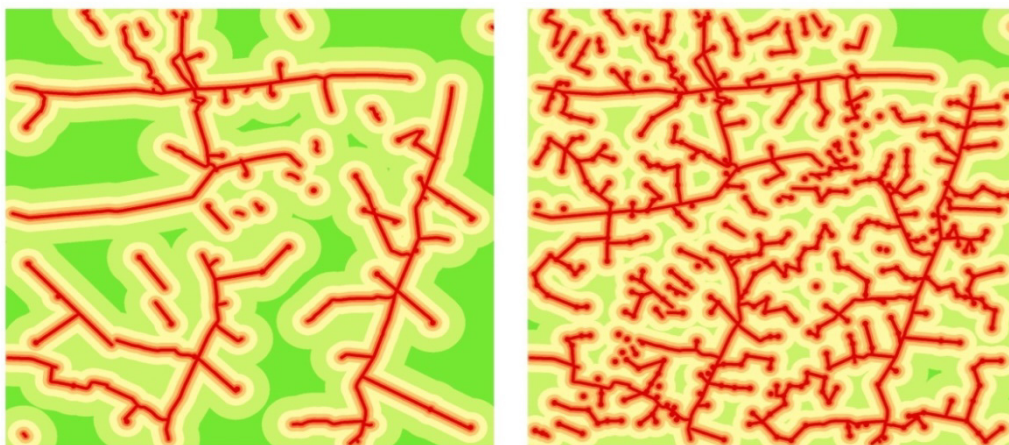


Figure 7.8: Distance surfaces from shale gas infrastructure, under the Small Gas scenario (left) and the Big Gas scenario (right), illustrating the fragmentation of the landscape by SGD, even where it occupies a small proportion of the landscape.

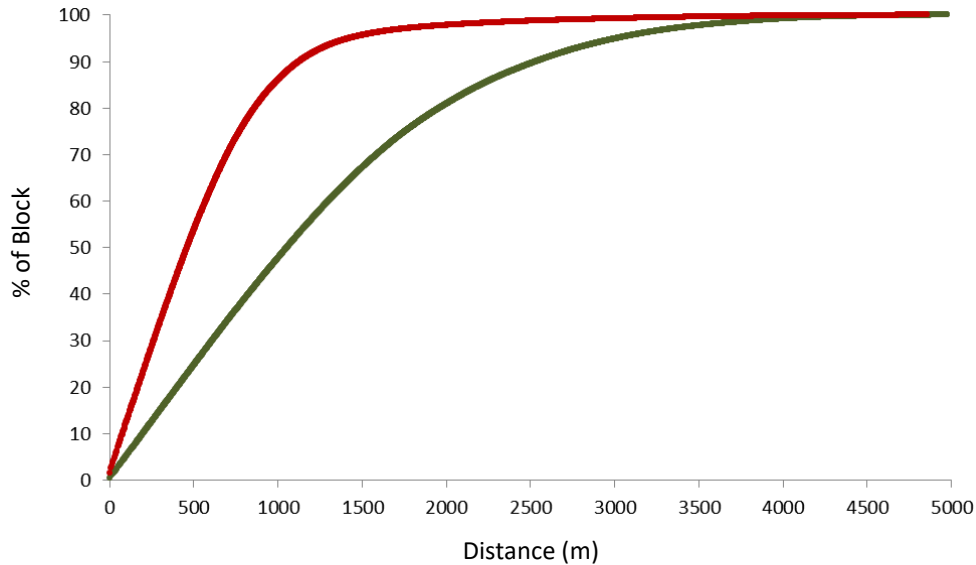


Figure 7.9: Cumulative distance curves illustrating the proportion of a 30x30 km block that would be within the x-axis distance from an access road or wellpad under the Small Gas scenario (green) and the Big Gas scenario (red).

For many small fauna which can complete their life cycle within a few hectares, the main impact of SGD would be habitat loss roughly equivalent to the development footprint. However, as the mobility or home range of fauna increases, they are increasingly likely to encounter shale gas infrastructure and hence potential negative impact. For larger mobile species, typical reported home ranges are in the order of 2 – 5 km² for Aardvark, *Orycteropus afer*; 1 – 6 km² for Aardwolf, *Proteles cristatus*; 6 – 48 km² for Caracal, *Caracal caracal*; 5 – 15 km² for Black-footed Cat, *Felis nigripes*; up to 500 km² for Honey Badger, *Mellivora capensis*; and up to 21.9 km² for Kudu, *Tragelaphus strepsiceros* (Skinner & Chimimba, 2005). With a projected average well density of one wellpad every 2.25 km² under the Big Gas scenario; it is clear that resident individuals of these species would need to negotiate shale gas infrastructure or disturbance on a daily basis. Although many fauna become habituated to human activity, certain impacts such as roadkill are not conducive to habituation and cumulative long-term impact may compromise local populations of vulnerable species.

Cumulative impacts result both from the repeated nature of each impact across the landscape as well as the combined impact of each different impact source. For some species there may be a dominant source of impact, while for others there is likely to be a combination of contributing factors. In addition, many impacts are likely to be context specific and would not operate equally across different habitats or environments. For example, within the Gamka Karoo, there are extensive tracts of stony ground where vegetation cover rarely exceeds 10%. A 10 m wide gravel road in this area would hardly be noticed by most resident fauna as they are accustomed or adapted to conditions of low vegetation cover. In contrast, vegetation cover in the Sundays Noorsveld or adjacent Thicket

communities may be in the order of 80-90%, and in these areas many species would avoid crossing such roads or would be vulnerable to predation when doing so (Figure 7.10). The impacts of noise on the other hand may operate in the other direction as vegetation would dampen noise in the thicket much more quickly than on the open plains and fauna may also be more tolerant of noise in the thicket due to the cover it provides.



Figure 7.10: The impacts of SGD are likely to be very different in vegetation types with low vegetation cover such as this Gamka Karoo near Laingsburg (left), compared to Thicket vegetation types with a high standing biomass such as this Great Fish Thicket near Riebeeck East (right).

Although it is difficult to predict which species would be impacted and to what extent, where these are ecologically important species, ecosystem-level changes and cascade effects are likely to occur as a result. Although cumulative impacts are identified here as a likely key impact associated with SGD, these impacts are hard to quantify due to the large spatial scales over which they are likely to occur and the difficulty of identifying appropriate indicators for monitoring, compounded by the paucity of knowledge of the potential impacts of such large-scale disturbance in an environment which has not experienced anything like it before.

7.2.4 Capacity gaps for implementation of mitigation measures

The implementation of the strategic approach to mitigation set out in Table 7.2, as well as the specific mitigation measures set out in Table 7.3, assumes the existence of appropriate capacity in a range of organs of state including regulatory authorities. Capacity is currently weak with regard to some of the mitigation measures, and would need to be strengthened in order to support their successful implementation.

A major gap exists in capacity to expand the protected area network to secure EBIS-1 and EBIS-2 areas, either through state-owned and managed protected areas or through contract protected areas in partnership with landowners. This is essential for achieving the strategic landscape-level approach to

mitigation set out in Table 7.2. Biodiversity stewardship programmes have a key role to play, as do mechanisms for private entities to purchase land and transfer it to the state along with an annuitised lump sum for management for an agreed period. Both of these provide avenues for the implementation of biodiversity offsets, for which EBIS-1 and EBIS-2 areas are the first-tier and second-tier receiving areas, respectively.

Biodiversity stewardship is an approach to securing land in biodiversity priority areas through entering into agreements with private or communal landowners, led by conservation authorities (SANBI, 2015). Biodiversity stewardship programmes in provincial conservation authorities in the Northern, Eastern and Western Cape currently lack capacity to enter into new agreements with landowners, and to support existing agreements with landowners. The Northern Cape Department of Environment and Nature Conservation (DENC) have recently initiated a biodiversity stewardship programme but this is largely restricted to the Succulent Karoo, and implementation of biodiversity stewardship in the province currently relies heavily on Non-Government Organisation (NGO) support. In CapeNature, the biodiversity stewardship programme is small and its capacity is already fully allocated to supporting existing agreements with landowners. CapeNature also depends on resources from the NGO sector to supplement the implementation of biodiversity stewardship. The Eastern Cape Parks and Tourism Agency (ECPTA) has a small biodiversity stewardship programme, which, despite limited staffing, has recently secured the declaration of a Protected Environment in the Compassberg area of the SGD study area. South African National Parks (SANParks) has active stewardship programmes in the buffer regions around the 5 National Parks in the study area, although the current focus is on the Mountain Zebra to Camdeboo corridor and contractual National Park declarations in the north portions of Addo Elephant National Park.

Recommendations in the recently approved Business Case for Biodiversity Stewardship (SANBI, 2015) provide an excellent starting point for addressing these capacity constraints. Implementation of these recommendations requires proactive support from the DEA and National Treasury to unlock resources for strengthening biodiversity stewardship programmes.

In addition to lack of capacity for expanding the protected area network in EBIS-1 and EBIS-2 areas in support of strategic landscape-level mitigation (Table 7.2), the following gaps exist for implementing the activity-specific mitigation measures proposed in Table 7.3:

At the national level:

- In the DWS:
 - Capacity to issue water use licences, and to monitor and enforce conditions of these licences;

- Capacity to determine and monitor the implementation of the ecological reserve for rivers and wetlands in the study area;
- Capacity to determine and implement Resource Quality Objectives for rivers and wetlands in the study area; and
- Capacity to monitor water quality and aquatic ecosystem condition.
- In DEA:
 - Capacity to evaluate and deal with cumulative impacts across the landscape;
 - Capacity to process EIAs; and
 - Capacity of Environmental Programmes to deal with invasive alien plants.
- In SANParks:
 - Capacity to fully implement biodiversity stewardship in buffer regions around National Parks;
 - Capacity to incorporate biodiversity offset receiving areas into the National Park network.
- In the Department of Mineral Resources (DMR); and
 - Capacity to declare sensitive areas (e.g. EBIS 1 areas) as off-limits for mining and prospecting, using Section 49 regulations of the MPRDA.

At the provincial level:

- In provincial conservation authorities (DENC, CapeNature, ECPTA):
 - Capacity to implement biodiversity stewardship, as discussed above;
 - Capacity to comment on development applications; and
 - Capacity to enforce restrictions on collection of firewood, medicinal plants, or animals with potential for the pet trade.
- In provincial environmental affairs departments (DENC, DEADP, DEDEAT):
 - Capacity to process development applications; and
 - Capacity to monitor and enforce requirements set out in Records of Decision – this is a critical concern, and mitigation should include increasing capacity of provinces in this regard.

At the municipal level:

- Capacity to treat waste water to acceptable limits – this is a critical concern, and mitigation should include increasing capacity of municipalities in this regard;
- Capacity to manage stormwater, including runoff from roads and new infrastructure;
- Capacity to enforce restrictions on off-road driving, including driving in wet conditions and driving at night;
- Capacity to enforce speed limits for vehicles on roads;

- Capacity to develop and implement emergency protocols for dealing with accidents and spills of hazardous materials;
- Capacity to enforce restrictions on movement of shale gas staff into natural areas beyond SGD sites;
- Capacity to accommodate shale gas staff in towns – important for limiting impacts at SGD sites; and
- Capacity to develop Land Use Schemes in terms of the Spatial Planning and Land Use Management Act (SPLUMA) (Act 16 of 2013) – a key mechanism for protection of EBIS-1 and EBIS-2 areas is to zone them appropriately (e.g. conservation) in Land Use Schemes.

Among consultants and specialists:

- Small number of biodiversity specialists (e.g. freshwater ecologists, botanists, zoologists, taxon experts) able to do site assessments and specialist reports for EIAs; and
- Limited capacity at museums, in science councils and universities to assist with identification of material collected in EIAs, especially for animals.

7.3 Risk assessment

This section begins with a brief explanation of how ecologically important and sensitive areas, which form the basis of the risk assessment, were identified. More detail is available in Digital Addendum 7B. It goes on to discuss the approach used for measuring risk, and the limits of acceptable change. It concludes with a risk assessment table which links the areas of EBIS to degrees of risk, with and without mitigation.

7.3.1 Identification of areas of EBIS

A hybrid approach to identifying areas of EBIS was taken, combining multi-criteria analysis with systematic biodiversity planning (also known as systematic conservation planning). The multi-criteria part of the analysis allows for identification of the ecologically important and sensitive areas features in the landscape where the whole feature falls within a specific level of sensitivity or importance (e.g. a riparian area or a buffer around a protected area). However, in landscapes such as the Karoo, where there is a great deal of choice of location for meeting targets for biodiversity features, it is usually not necessary to secure the whole ecosystem or habitat to ensure the ongoing integrity of the area, but nevertheless necessary to ensure that enough area of each feature remains intact. A multi-criteria approach does not allow for the identification of a set of areas which, if secured, would allow Karoo ecosystems, key ecological processes and important species to persist. Hence, a systematic biodiversity planning approach was also applied. This approach, which is widely accepted in South

Africa as best practice for the identification of spatial biodiversity priorities (see Section 7.1.4), aims to identify a set of areas which meets targets for all biodiversity features in a way that is ecologically sustainable, efficient and least conflicting with other activities and land uses. See Cadman et al. (2010) for an explanation of South Africa's systematic approach to prioritising within multi-use landscapes to conserve biodiversity and promote ecosystem resilience.

The biodiversity features on which the analysis was based included the full set of biodiversity pattern features (e.g. the individual habitat types and areas for key species) and ecological process features (e.g. portions of the landscape supporting key ecological process features such as hydrological processes or adaptation to climate change impacts).

Targets were set for the significant biodiversity pattern and ecological process features found within the landscape. These targets refer to the portion of the historical extent of a particular feature which needs to be kept intact in order for that feature to persist into the future. Targets were carefully determined in order to ensure that sufficient of each type of feature was included in the set of areas of EBIS. Targets for ecosystems, species and ecological process areas were set.

The approach aims to identify a *configuration of sites* which is ecologically sustainable. Although the total quantity of each feature is important to ensure that sufficient area is kept intact, in many ways a more important issue is making sure that the prioritised areas are *linked together in an ecologically connected way across the landscape*. It is critical that the individual areas that are identified are connected in a way that allows ecological process to take place at a variety of spatial scales. These scales can range from broad landscape-level linkages which are important for climate change adaptation, through to hydrological processes occurring in catchments and linked groundwater systems, to local-level processes such as pollination or the movement of small mammals. The analysis aims to identify a set of areas which fully secures all these key ecological processes across the landscape.

The set of areas is designed to be *efficient and least conflicting with other land uses*. Where possible, sites are selected which meet targets for a range of biodiversity features rather than just for a single feature. This ensures that the most important areas are selected, and also allows the targets to be met in the smallest possible area. Wherever possible, the analysis also aims to select areas which are in the best possible ecological condition, as these sites are likely to retain the fullest suite of biodiversity features and are more likely to persist into the future than sites in poorer ecological condition.

Importantly, the approach identifies a coherent set of areas which together meet targets for representation of biodiversity and maintenance of ecological processes in an efficient way. A key issue is that this whole identified set of priority areas needs to be kept ecologically intact (via means such as development controls, appropriate zoning in land use scheme, biodiversity offsets, or biodiversity stewardship and other forms of protected area expansion) in order to secure the Karoo's biodiversity against landscape-scale impacts in the remaining areas. Should any of the prioritised areas be lost, ecologically equivalent sites would need to be identified to sufficiently secure biodiversity and ecological integrity. Because the current set of areas of EBIS is as efficient as possible, any loss of these areas would require larger alternate areas to be selected to offset any loss.

The approach is built on the concept of spatial optimisation. Instead of identifying a large number of areas across the landscape with moderate levels of biodiversity importance, which could result in impacts being spread throughout the landscape and could compromise the ecological integrity and functioning of the entire area, an optimal set of areas has been identified. If kept intact, these areas would ensure that the ecological integrity of the Karoo is retained. This set of priority areas contains both irreplaceable sites (i.e. sites for which there is no choice of an equivalent site for meeting the targets for the biodiversity features concerned) and optimal sites (i.e. sites identified through the systematic biodiversity planning process as being the best option for meeting targets). In some cases there is little choice, and although a site is flagged as optimal rather than being truly irreplaceable, few viable alternatives may exist and it may not in practice be possible to find other sites to meet targets. In other cases, viable alternatives may be available and some exchange of sites (e.g. as part of a biodiversity offset process) could be possible.

The analysis builds in the concepts of both ecological *importance* and *sensitivity*. Importance refers to the sites which are most needed for meeting biodiversity targets (in other words are most irreplaceable) while sensitivity refers to sites containing features which are highly vulnerable to disturbance or where recovery is slow.

Four levels of EBIS were identified:

- **EBIS-1** – areas that contain extremely sensitive features, such as key habitat for rare, endemic or threatened species, or features that perform critical ecological functions. These sites are irreplaceable (i.e. no ecologically equivalent sites exist and there is no exchangeability between sites). SGD activities must be avoided in these areas, as impacts of SGD in these areas would undermine the ecological integrity of the Karoo. Ideally these areas should be secured through appropriate zoning, development controls, or protected area expansion through stewardship and other mechanisms.

- **EBIS-2** – areas that contain highly sensitive features and/or features that are important for achieving targets for representing biodiversity and/or maintaining ecological processes. These areas represent the optimal configuration for securing the species, ecosystems and ecological processes of the Karoo. Impacts of SGD in these areas are undesirable, and any impact would need to be offset and ecologically equivalent sites identified to represent the same suite of biodiversity features that were impacted.
- **EBIS-3** – other natural or semi-natural areas that do not contain currently known sensitive or important features, and are not required for meeting targets for representing biodiversity or maintaining ecological processes. Provided that EBIS-1 and EBIS-2 areas are secured, loss of habitat in EBIS-3 areas should not compromise the ability to achieve biodiversity targets in the Karoo, as long as the impacts in EBIS-3 areas do not extend into adjacent areas of higher importance or sensitivity. However, if any impacts occur in EBIS-2 areas, additional sites from EBIS-3 areas may be required as alternatives for representing biodiversity and maintaining ecological processes.
- **EBIS-4** – areas in which there is no remaining natural habitat, e.g. urban areas, larger scale highly degraded areas, large arable intensively farmed lands. SGD activities in these sites should result in minimal biodiversity loss, as long as the impacts do not extend to adjacent EBIS-1 or EBIS-2 areas.

The extent of the study area falling within each of these categories of importance and sensitivity is provided in Table 7.4, a map of the categories is shown in Figure 7.12, and a summary of features included in each category is provided in Table 7.5. See Digital Addendum 7B for more detail on the methodology.



Figure 7.11: Mountainous and topographically heterogeneous areas are generally more diverse for both fauna and flora than the intervening open plains. A significant proportion of the areas identified as being of high importance for biodiversity are mountainous and therefore would tend not to be suitable for SGD.

Table 7.4: Extent of areas of EBIS within the study area (hectares and percentage)

	Extent (Hectares)	Extent (%)
Protected areas	828 191	5
EBIS-1	2 253 544	13
EBIS-2	6 348 763	37
EBIS-3	7 593 740	44
EBIS-4	156 900	1
Total	17 181 138	100

Table 7.5: Summary of features included in each category of EBIS.

Features included	Ecological and Biodiversity Importance and Sensitivity (EBIS)				
	Protected areas	EBIS-1 Irreplaceable sites (no choice exists)	EBIS-2 Optimal sites (some choice exists)	EBIS-3 Sites not required to meet targets	EBIS-4 No site-specific ecological or biodiversity importance
Biodiversity features	--	<ul style="list-style-type: none"> Wetlands, springs (including intact buffers) Specific sites important for Threatened species and for range-restricted endemic or near-endemic species (fauna and flora) High priority habitat for Threatened species or for range-restricted endemic or near-endemic species 	<ul style="list-style-type: none"> Rivers and associated habitats (including intact buffers) Special habitats e.g. rocky outcrops, escarpment areas, riparian vegetation Sites selected through a systematic biodiversity planning process to meet targets for terrestrial or aquatic ecosystems in an efficient configuration that aligns with other biodiversity features and priority areas 	<ul style="list-style-type: none"> Severely modified areas that retain some importance for supporting ecological processes (e.g. agricultural fields within buffers around rivers and wetlands) Natural habitat which is not irreplaceable and has not been selected as part of the optimal sites 	<ul style="list-style-type: none"> Areas that have been severely or irreversibly modified and that are not important for supporting provision of ecological processes
Other biodiversity priority areas	<ul style="list-style-type: none"> Areas declared or recognised in terms of the Protected Areas Act 	--	<ul style="list-style-type: none"> Incorporates all Freshwater Ecosystem Priority Areas (FEPAs), both rivers and wetlands Includes Critical Biodiversity Area One (CBA 1) from relevant provincial biodiversity plans Buffers around protected areas (intact areas) UNESCO Biosphere Reserve 	--	--

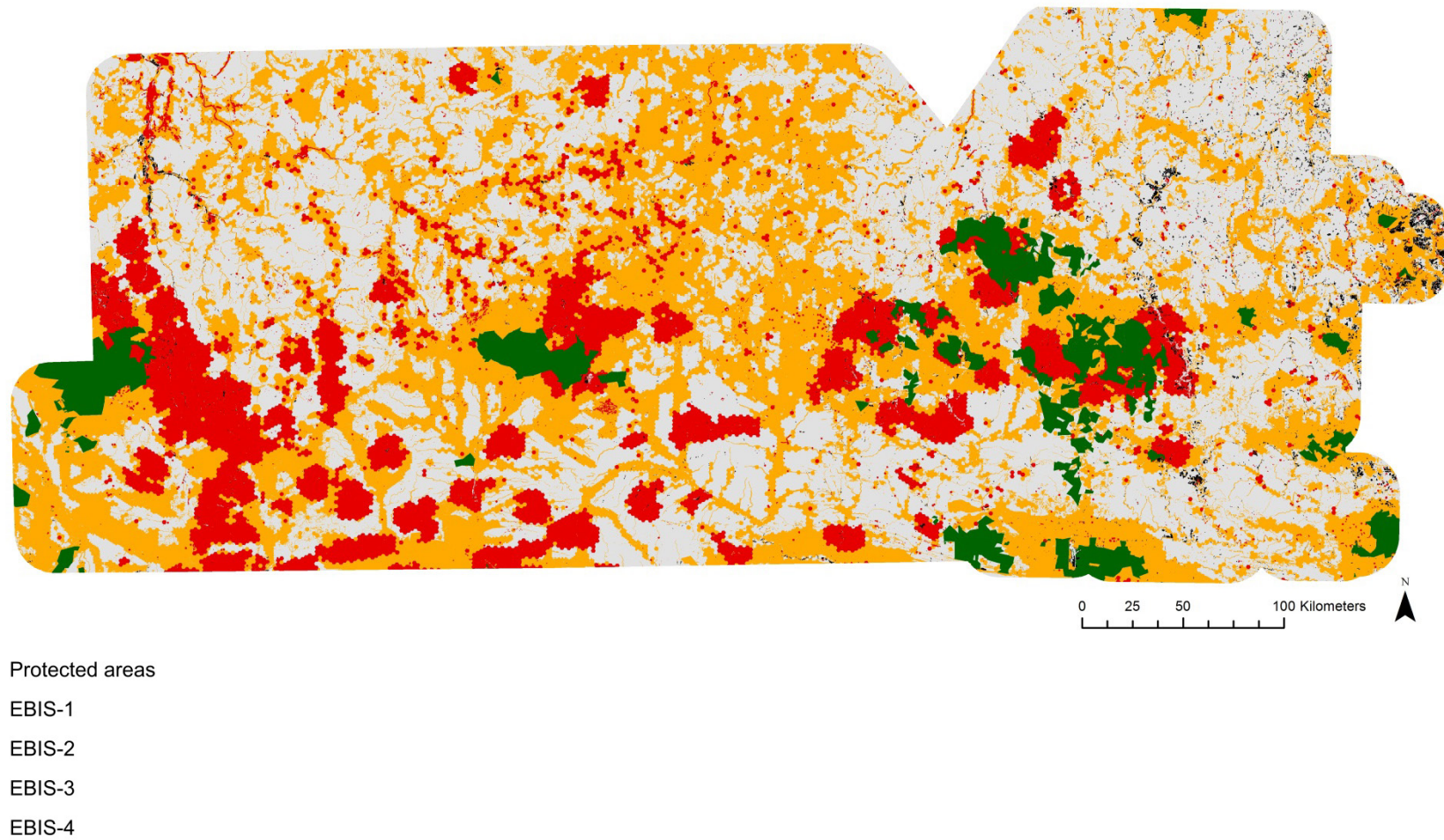


Figure 7.12: Map of Ecological and Biodiversity Importance and Sensitivity (EBIS) in the study area. Protected areas (5% of study area) are legally protected. EBIS-1 areas (13% of study area) contain extremely sensitive features and are irreplaceable. EBIS-2 areas (37% of study area) contain highly sensitive features and/or features that are important for achieving targets for representing biodiversity and/or maintaining ecological processes. Protected areas, EBIS-1 areas and EBIS-2 areas collectively meet targets for representation of biodiversity and maintenance of ecological processes in the study area. EBIS-3 areas (44% of the study area) are natural areas that do not contain currently known sensitive or important features. In EBIS-4 areas (1% of study area) there is no remaining natural habitat.

7.3.2 How the risks are measured

For biodiversity and ecological impacts, risk is measured in terms of disruption of ecological processes, loss or degradation of ecosystems, and/or loss of species. The degree of risk is assessed against targets for maintaining the functioning of all key ecological processes, maintaining a proportion of each ecosystem in good ecological condition, retaining all threatened species, and retaining a representative sample of all endemic or near-endemic species. In measuring and assessing risk, a key focus is on the need to maintain the ecological integrity of the landscape as a whole, rather than simply on retaining individual biodiversity features in and of themselves. Protected areas, EBIS-1 areas and EBIS-2 areas collectively meet targets for representation of biodiversity and maintenance of ecological processes in the study area, in a spatial configuration that ensures connectivity in the landscape. The assessment of risks can therefore be expressed in terms of loss or degradation of these areas.

Opportunity is measured in terms of strengthening protection of ecological processes, ecosystems and species, for example through protected area expansion (including through biodiversity stewardship contracts) and/or biodiversity offsets, especially in EBIS-1 and EBIS-2 areas. It is possible to mitigate almost all impacts in EBIS-2 areas by securing ecologically equivalent sites. This opportunity to mitigate risk through securing sufficient intact areas is a viable and practical approach to dealing with impacts associated with SGD, so long as sufficient areas are properly secured before any large-scale impacts occur, and broad regional impacts of development are carefully managed through the application of robust site-level management procedures even in EBIS-3 and EBIS-4 areas.

7.3.3 Limits of acceptable change

The limits of acceptable change relate to the ability to meet biodiversity targets for ecological processes, ecosystems and species, which underpin the identification of areas of EBIS. As discussed in Section 7.3.1, the identification of these areas is based on targets for biodiversity features relating to biodiversity pattern and ecological processes.

No loss or degradation of EBIS-1 areas is acceptable. These areas are irreplaceable and no ecologically equivalent areas exist for securing the features they contain.

In EBIS-2 areas, loss or degradation is acceptable only if ecologically equivalent sites are identified and secured through biodiversity offsets or equivalent mechanisms. An ecologically equivalent site means a site that contains equivalent ecological processes, ecosystems and species, and that compensates for the full ecological impact of the activity as identified through a detailed study. In

addition, loss or degradation of EBIS-2 areas will result in the need to identify additional sites from within EBIS-3 for inclusion in EBIS-2, in order to meet targets for ecological processes, ecosystem and/or species. The limits of acceptable change in EBIS-2 areas are determined by the ability to find ecologically equivalent sites in the remaining intact EBIS-3 areas.

Loss or degradation of In EBIS-3 areas is acceptable, as long as there is no impact on EBIS-1 or EBIS-2 areas. Activities that are authorised in EBIS-3 areas need to be assessed for potential impacts on EBIS-1 or EBIS-2 areas.

In EBIS-4 areas, site-level impacts are not significant from a biodiversity or ecological point of view. Change is acceptable as long as it does not impact on EBIS-1 or EBIS-2 areas.

7.3.4 Risk assessment table

Table 7.7 sets out the assessment of risk for each of the scenarios, based on the consequences and likelihood of occurrence of impacts of SGD, with and without mitigation. The consequence levels used in Table 7.7 have been calibrated based on a series of thresholds, set out in Table 7.6. The thresholds for species are linked to thresholds used in IUCN Red List assessments, and those for ecosystems and ecological processes are linked to thresholds used in national assessments of ecosystem threat status and in biodiversity planning in South Africa.

The assessment of *risk with mitigation* is based strongly on the application of the mitigation hierarchy at the landscape scale, as set out in Section 7.2.3, based on the map of EBIS shown in Figure 7.12. As discussed in Section 7.2.1, the primary mitigation for SGD in the Karoo as a whole is securing the EBIS-1 and EBIS-2 areas, which effectively makes EBIS-3 and EBIS-4 areas available for SGD. This sort of strategic mitigation at the landscape level, in addition to mitigation at the site or operational level is essential in order to reduce risk levels.

EBIS-1 and EBIS-2 areas need to be retained in a natural state and secured through appropriate zoning or legal mechanisms that limit habitat loss or degradation in these areas. As long as EBIS-1 and EBIS-2 areas have been secured, overall ecological integrity and retention of the biodiversity value of Karoo ecosystems would be ensured. Subject to reasonable on-site operating rules to reduce unnecessary impacts, and careful minimisation of any broader impacts on adjacent EBIS-1 and EBIS-2 areas, biodiversity loss within EBIS-3 areas could be absorbed without compromising the overall function and integrity of the Karoo ecosystem as a whole. Impacts restricted to EBIS-4 areas are unlikely to be of ecological significance.

Table 7.7 shows that under the Big Gas scenario *without mitigation*, the risk is very high for EBIS-1 areas and high for EBIS-2 areas – it is very likely that there would be impacts with extreme consequences for the biodiversity and ecological features in EBIS-1 areas and severe consequences for those in EBIS-2 areas. *With mitigation*, the risk is reduced to moderate. Although there is no change in the consequence level of impacts in EBIS-1 and EBIS-2 areas, the likelihood of occurrence of these impacts is substantially reduced, as mitigation requires avoiding SGD activities altogether in EBIS-1 areas and avoiding or offsetting impacts in EBIS-2 areas. *This strategic form of mitigation at the landscape level allows for the risks of SGD to be reduced to moderate levels even under a Big Gas scenario.*

Figure 7.13 presents a risk map of impacts on ecology and biodiversity across four SGD scenarios, with and without mitigation.

The same logic applies under the Small Gas scenario where risk levels *with mitigation* are moderate for EBIS-1 areas and low for EBIS-2 areas. Under the Exploration Only scenario *with mitigation*, EBIS-1 areas must be avoided altogether, and impacts in EBIS-2 areas must be minimised with thorough application of the strategic mitigation measures set out in Table 7.2, resulting in very low risk levels.

Risk levels drop off rapidly as one moves away from EBIS-1 and EBIS-2 areas, emphasising the importance of locating infrastructure and activities associated with SGD outside of these areas.

Table 7.6: Consequence levels used in the risk assessment, with thresholds for species, ecosystems and ecological processes. Thresholds for species are linked to thresholds used in IUCN Red List assessments, and those for ecosystems and ecological processes are linked to thresholds used in national assessments of ecosystem threat status and in biodiversity planning in South Africa.

	Consequence level →	Slight	Moderate	Substantial	Severe	Extreme
	Impact ↓					
Species of special concern	Reduction in population or occupied area*	<20% (Least Concern, LC)	20-30% (Near Threatened, NT)	30-50% (Vulnerable, VU)	50-80% (Endangered, EN)	80-100% (Critically Endangered, CR)
Ecosystems (habitat types)	Reduction in intact area**	<20% (Least Threatened, LT)	20-40% (Least Threatened, LT)	40-60% (Vulnerable, VU)	60-80% (Endangered, EN)	80-100% (Critically Endangered, CR)
Ecological processes	Disruption of ecological functioning***	<20%	20-40%	40-60%	60-80%	80-100%

* In relation to national distribution (except for keystone species – in relation to study area).

** In relation to national distribution.

*** In relation to their functioning within the study area.

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Table 7.7: Risk assessment table which sets out the assessment of risk for each of the scenarios, with and without mitigation. No SGD takes place in the Reference Case scenario, while limited shale gas production takes place in the Small Gas scenario, and extensive SGD takes place in the Big Gas scenario.

Impact	Scenario	Location	Without mitigation			With mitigation		
			Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Ecological and biodiversity impacts	Reference Case	In EBIS-1 areas	Slight	Likely	Very low	Slight	Likely	Very low
	Exploration Only		Moderate	Likely	Low	Slight	Not likely (mitigation = avoid)	Very low
	Small Gas		Severe	Likely	High	Severe	Not likely (mitigation = avoid)	Moderate
	Big Gas		Extreme	Very Likely	Very high	Extreme	Not likely (mitigation = avoid)	Moderate
	Reference Case	In EBIS-2 areas	Slight	Likely	Very low	Slight	Likely	Very low
	Exploration Only		Moderate	Likely	Low	Slight	Likely	Very low
	Small Gas		Substantial	Likely	Moderate	Substantial	Not likely (mitigation = avoid or offset)	Low
	Big Gas		Severe	Very likely	High	Severe	Not likely (mitigation = avoid or offset)	Moderate
	Reference Case	In EBIS-3 areas	Slight	Likely	Very low	Slight	Likely	Very low
	Exploration Only		Slight	Likely	Very low	Slight	Likely	Very low
	Small Gas		Slight	Likely	Very low	Slight	Likely	Very low
	Big Gas		Moderate	Very likely	Low	Moderate	Likely	Low risk
	Reference Case	In EBIS-4 areas	Slight	Likely	Very low	Slight	Likely	Very low
	Exploration Only		Slight	Likely	Very low	Slight	Likely	Very low
	Small Gas		Slight	Likely	Very low	Slight	Likely	Very low
	Big Gas		Slight	Likely	Very low	Slight	Likely	Very low

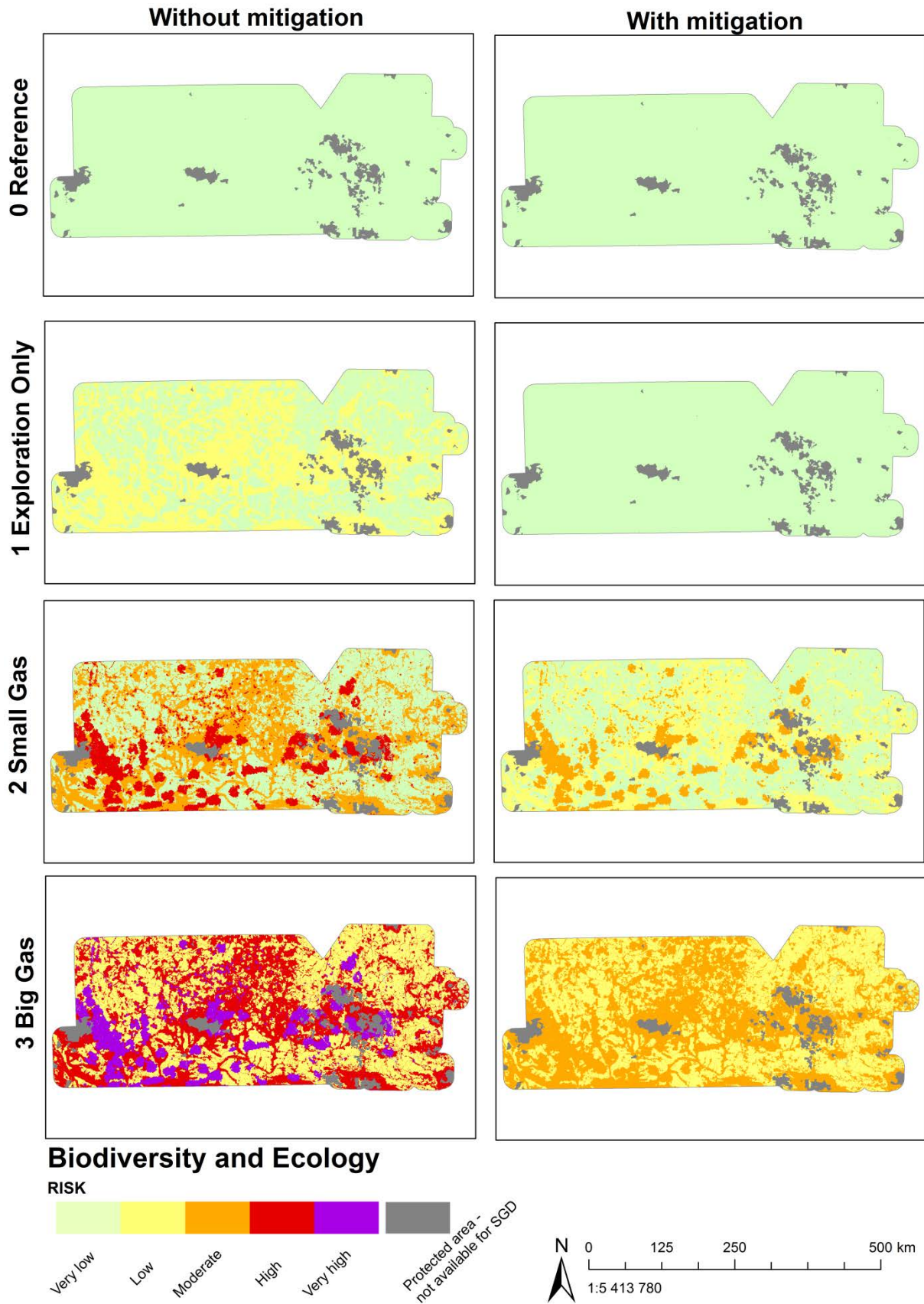


Figure 7.13: Map indicating the risk to ecology and biodiversity across four SGD scenarios, with- and without mitigation.

In summary:

EBIS-1 areas are irreplaceable. Any SGD-related activities in these areas are assessed as very high risk. Impacts in these areas would undermine the ecological integrity of the study area (and more broadly the Karoo).

The primary mitigation for SGD is securing EBIS-1 and EBIS-2 areas, which effectively makes EBIS-3 and EBIS-4 areas available for development. Strategic mitigation at the landscape level, involving avoidance and securing of EBIS-1 and EBIS-2 areas, is essential as the impacts of SGD cannot be effectively mitigated on-site or at the operational level.

EBIS-1 and EBIS-2 areas make up an estimated 50% of the study area. Loss or degradation of habitat in these areas must be avoided, and they should be secured through appropriate legal mechanisms. This may involve formal protected area declaration (including through biodiversity stewardship agreements), but can include other types of stewardship, protection under Section 49 of the MPRDA, appropriate designation in a land use scheme, or protection through other legal means. Securing EBIS-1 and EBIS-2 areas may lend itself to a fast-tracked, integrated protected area expansion strategy, similar to Operation Phakisa in the marine environment.

Where impacts in EBIS-2 areas are unavoidable, these should be offset by securing ecologically equivalent sites. Appropriate national and provincial biodiversity offset guidelines and methodologies should be applied to ensure no net loss.

Environmental compliance in EBIS-3 and EBIS-4 areas is still required. This includes specialist-led assessment of local sensitivities and identification of appropriate mitigation and it is necessary in order to ground-truth desktop assessments and avoid unnecessary impacts. Specific impacts are discussed in Section 7.2.1 and monitoring requirements are discussed in Section 7.4.

7.4 Best practice guidelines and monitoring requirements

7.4.1 Best practice guidelines

Best practice guidelines for SGD are captured broadly in the strategic mitigation measures set out in Table 7.2 as well as in the activity-specific mitigation measures set out in Table 7.3. In many cases, more detail on the application of activity-specific mitigation measures, especially those dealing with minimising or rehabilitating impacts, must be specified at the EIA stage. Detailed requirements for site-level monitoring should also be specified at the EIA stage, related to the specific characteristics of the receiving environment.

EIAs for SGD projects should include Biodiversity Specialist Studies, with more comprehensive studies required at higher levels of EBIS. Best practice guidelines for Biodiversity Specialist Studies within EIAs are outlined in Brownlie (2005) and De Villiers et al. (2005). EBIS-1 areas should be avoided altogether for SGD. This recommendation notwithstanding, should an SGD application go ahead in an EBIS-1 area, the highest level (i.e. most comprehensive) Biodiversity Specialist Study would be required. In EBIS-2 areas, the highest level of Biodiversity Specialist Study is required. In EBIS-3 areas, a less comprehensive Biodiversity Specialist Study is required. In EBIS-4 areas, the lowest level of Biodiversity Specialist Study is required. *If SGD takes place in the study area, specific guidelines for different levels of Biodiversity Specialist Study for EIAs for SGD should be developed, equivalent to those developed as part of the recent SEA for Wind and Solar Energy (DEA, 2015b).*

In addition, the Mining & Biodiversity Guideline (DEA et al., 2013) provides guidance on best practices for integrating biodiversity considerations in mining EIAs, and for managing impacts on biodiversity at different stages of the mining life cycle, from exploration through to closure.

7.4.2 Monitoring requirements

7.4.2.1 Summary of monitoring requirements and institutional arrangements

Monitoring is essential for assessing the impacts associated with SGD at the landscape, ecosystem and species level, and for informing appropriate responses. Monitoring should be linked to the biodiversity targets and limits of acceptable change which are discussed in Section 7.3, and should thus focus on species of special concern, ecosystems or habitat types, and ecological processes. In addition, because of the importance of cumulative impacts at the landscape scale in the context of the Karoo (see Section 7.2.2), monitoring should also take place at the landscape level.

Monitoring requirements from the species level through to the landscape level, including indicators and responsibilities, are summarised in Table 7.8, followed by more detailed recommendations on indicator species. Monitoring requirements do not change dramatically across the phases of SGD. This is because SGD is not distinctly partitioned and, apart from exploration, multiple phases of activity from well establishment to production happen concurrently in an SGD block.

In addition to monitoring once activities associated with SGD are underway, there is a need for baseline monitoring to establish reliable baselines for the study area. This is especially important given the large information gaps on many aspects of the biodiversity and ecology of the area (as discussed in Section 7.5). Depending on the natural variability of the variable of concern, as much as

five years' worth of data could be required to establish a reliable baseline, against which trends during and after SGD can be evaluated. This is particularly important in the ephemeral aquatic ecosystems which characterise the Karoo, as they have a high intrinsic variability in terms of aquatic community responses to inundation patterns.

Institutional arrangements and responsibilities are fundamental to the success of monitoring efforts. There is a need for independent monitoring by third parties, not just monitoring by the SGD companies themselves. This will generally be led by government. SGD companies could be required to contribute to the cost of such government-led monitoring in proportion to the scale of their activities.

As highlighted in Table 7.8, the responsibility for SGD-related monitoring is shared across several organisations. These include the South African Environmental Observation Network (SAEON), which has an important role in landscape-level monitoring and maintaining benchmark sites for the evaluation of SGD impacts, as well as SANBI, provincial conservation authorities and DWS. Some of the capacity gaps discussed in Section 7.2.4 relate to monitoring requirements, and these would need to be addressed. In some cases there is potential for NGOs to play a vital supporting role.

It is important for SGD-related monitoring efforts to be co-ordinated. This requires an organ of state to convene the different organisations, researchers and other partners involved in monitoring, and SAEON may have a role to play in this regard. In addition, a system or process should be in place for integrating monitoring data from the site level, the ecosystem level and the landscape level into a coherent set of information for the study area as a whole, which can be used to inform planning and decision-making. Information from monitoring should feed into SANBI's programme of monitoring and reporting on the state of biodiversity nationally.

Table 7.8: Monitoring requirements at the landscape, ecosystem, species and site level, including indicators and responsibilities.

Feature of concern	Impact of concern	Indicator(s) (WHAT)	Selection of monitoring sites (WHERE)	Approach (HOW)	Responsibility (WHO)	Phase
Landscape-level	Loss of overall ecological integrity	<ul style="list-style-type: none"> - Progress in securing EBIS-1 and EBIS-2 areas through formal protection - Landscape-scale fragmentation relative to baseline prior to SGD (metric to be determined) 	<ul style="list-style-type: none"> - Across whole study area - Across whole study area 	<ul style="list-style-type: none"> - Based on protected area data, annually - Using aerial or satellite imagery or other appropriate data, annually 	<ul style="list-style-type: none"> - DEA, SANBI - SAEON 	Baseline Planning Construction Operations Decommissioning Monitoring and Evaluation (M&E) (post-closure)
Aquatic ecosystems and ecological processes	Loss of wetland extent and disruption of ecological functioning	<ul style="list-style-type: none"> - Assessment of changes in baseline extent of wetlands, watercourses and riparian areas 	<ul style="list-style-type: none"> - Key wetlands, watercourses and riparian areas to be identified from EBIS map, representative of all aquatic ecosystem types in study area 	<ul style="list-style-type: none"> - Desktop assessment to be done annually, using National Wetland/ Rivers Map as baseline, and aerial or satellite imagery for comparison. 	<ul style="list-style-type: none"> - DWS, in collaboration with provincial conservation authorities 	Baseline Planning Construction Operations Decommissioning M&E (post-closure)
Terrestrial ecosystems/ habitat types	Reduction in intact area	<ul style="list-style-type: none"> - Extent of each ecosystem/ habitat type still intact relative to baseline prior to SGD 	<ul style="list-style-type: none"> - All habitat types in study area, including special habitats (e.g. quartz patches) 	<ul style="list-style-type: none"> - Based on land cover data and other data on ecological condition, annually 	<ul style="list-style-type: none"> - SANBI, SAEON 	Baseline Planning Construction Operations Decommissioning M&E (post-closure)

Feature of concern	Impact of concern	Indicator(s) (WHAT)	Selection of monitoring sites (WHERE)	Approach (HOW)	Responsibility (WHO)	Phase
Species of special concern	Reduction in numbers or distribution	<ul style="list-style-type: none"> - Densities and distribution of indicator species – see recommended species below 	<ul style="list-style-type: none"> - Species-dependent 	<ul style="list-style-type: none"> - Various e.g. mark-recapture studies, camera trapping, fixed effort counts - Timing depends on species 	<ul style="list-style-type: none"> - Conservation authorities - NGOs - Citizen science programmes 	<ul style="list-style-type: none"> Baseline Planning Construction Operations Decommissioning M&E (post-closure)
Site-level monitoring	Compliance with mitigation measures	<ul style="list-style-type: none"> - Various, depending on the mitigation measure concerned - More detail to be specified in EIA 	<ul style="list-style-type: none"> - All areas with SGD activities - In many cases important to include control sites as well as impact sites - More detail to be specified in EIA 	<ul style="list-style-type: none"> - Various, depending on the mitigation measure concerned - Depends on measure being monitored - More detail to be specified in EIA 	<ul style="list-style-type: none"> - Shale gas companies (Environmental Compliance Officers) - Provincial environmental affairs departments 	<ul style="list-style-type: none"> Construction Operations Decommissioning

7.4.2.2 Recommended indicator species for monitoring

Although within any particular area or region of the Karoo, there are specific species of conservation concern that should be monitored to ensure that they are not impacted by SGD, there are also some more widespread species prevalent across large parts of the Karoo, which by dint of their ecological role or specific characteristics lend themselves to monitoring. These are briefly described below with reference to the type of issues or processes that these species represent. The advantage of using these more common and widespread species for monitoring is firstly, that impacts of SGD can be compared across regions or areas of different SGD intensity and secondly, these species are common and as such it should be more practical or feasible to monitor their abundance and response to SGD and thirdly, these species have been identified as being important or indicative of certain impacts due to their specific characteristics or vulnerabilities.

- **Tortoises** are widespread across the Karoo and are vulnerable to roadkill as well as illegal collection for food or trade. Tortoises are not highly mobile and as such, are representative of the local area equivalent to their home range, up to around 100 ha for the Leopard Tortoise, *Stigmochelys pardalis* (McMaster & Downs 2009). Tortoise movement and abundance is relatively easily assessed through radio tracking as well as mark-recapture studies and due to their longevity, lend themselves to long-term monitoring. As tortoises are present across the whole SGD area, they are identified as potentially good indicators of SGD impact across the whole study area.
- **Aardvark** are relatively wide ranging with average home ranges of 3.5 km² (van Aarde et al. 1992) and occur across the entire SGD area. This species is considered especially important as it creates fine-scale disturbance which is important for vegetation dynamics in arid ecosystems and its disused burrows are also used by a wide variety of other organisms including Ant-eating Chat, Porcupine, Aardwolf, tortoises, foxes, and various other small mammals and birds. As it has a moderately-sized home range, it is indicative of processes operating at the farm level and probably occurs at a relatively low but consistent density across the Karoo. This species is likely to be vulnerable to disturbance, poaching and roadkill and as it is generally not persecuted by farmers.
- Other animals of potential importance for monitoring include **Bat-eared Foxes**, which are particularly vulnerable to roadkill; Steenbok, which are common, widely distributed small antelope vulnerable to poaching; Riverine Rabbits which are Critically Endangered and indicative of riparian vegetation condition within the Central Karoo. **Kudu** are not present across the whole study area, but occupy the majority of the east and central part of the study area. Kudu are wide-

ranging and not restricted by standard livestock fencing and tend to avoid noise and disturbance. As such they are likely to be good indicators of disturbance impacts on sensitive species.

The above examples focus largely on fauna, but there are likely a range of **plant species** that are also useful indicators, but these vary more across the study area and as such, there are likely to be a number of such species that would be useful depending on the exact location of SGD activity. Species that are likely to be useful indicators are species that are habitat specialists or are used for medicinal purposes or sought after by collectors. Potential target species include *Boophone disticha*, *Pelagonium sidoides*, the various cycads that occur within the study area, *Dioscorea elephantipes*, *Gasteria* spp. *Euphorbia* spp. and *Pleiospilos* spp. and other dwarf succulents.

Our limited knowledge of the **species that inhabit the aquatic ecosystems** of the more arid parts of the SGD study area, their ranges, population sizes, and habitat requirements, is a constraint on the determination of the best aquatic indicator species. In the absence of spatially comprehensive records of aquatic faunal species, assessments of the condition of aquatic ecosystems in South Africa tend to focus more on community composition at a taxonomic level higher than species. Knowledge of the distribution, densities and sensitivity of key indicator species is limited. This is particularly so for lentic (non-flowing water) species, and those that occur in the ephemeral aquatic ecosystems characteristic of the more arid parts of the study area. The collection of baseline data from these ecosystems is essential for the determination of indicator species. For instance, diatoms, which occur in wetlands and in rivers and are biotic indicators in comprehensive Ecological Reserve studies, can be collected and identified during the dry or wet phases, and are possibly good indicators of disturbance (Taylor et al., 2007). Zooplanktonic groups hatch and breed rapidly after the inundation of wetlands and rivers, and the succession of species throughout the wet phase are likely to respond to changes in water quality and quantity.

In the more mesic parts of the study area, sensitive **fish species** such as the Eastern Cape Redfin, *Pseudobarbus afer*; the Cape Rocky, *Sandelia bainsii*; *Barbus trevelyani*; *Pseudobarbus asper* and the Amatola Barb, *Barbus amatolicus*, are likely to be good indicators of changes in water quality and quantity in watercourses. The sensitive damselfly species, the Kubusi stream-damsel, *Metacnemis valida*, and the Basking malachite, *Chlorolestes apricans* are also restricted species that should be monitored. Several other riverine macro-invertebrate families, such as the Heptageniid mayflies and Notonemourid stoneflies, are known to be sensitive to deterioration in water quality and are thus suitable indicator species in perennial rivers, where their distribution is well documented.

7.4.2.3 Monitoring standards & approaches

The overall aim and purpose of monitoring shale gas activities in the Karoo should be to minimise, control and mitigate the impacts associated with SGD (Esterhuysen et al., 2014). As such, it is critical that monitoring is based on reliable baseline data as well as explicit statements on limits of acceptable change and the actions that should be taken when these limits are breached (Lindenmayer et al., 2013). However, there is a high risk that monitoring programs will fail to detect when a threshold has been breached and a consequent failure to implement interventions timeously. Consequently, monitoring programs must explicitly evaluate their ability to actually detect directional change against the backdrop of the high natural variability of arid systems (Fairweather, 1991). This ability needs to conform to a predefined standard and inform the intensity of monitoring required. As the natural variability of a system will influence how many samples are required to achieve the desired level of statistical power, the specific details of the required sample sizes will only become apparent with baseline monitoring. Using the initial results of baseline studies to define the final sampling protocol to be used in the long-term, is one of the most important aspects of adaptive management that should be implemented for monitoring SGD. Exactly what the desired thresholds for the statistical power of a monitoring program should be, cannot be defined here, but must represent a compromise between sampling effort and the consequences of failing to detect a decline beyond a certain specified threshold. For species of high conservation concern or significant ecological role, the bar should be set higher than for less important species or processes. By way of example, for a species of significant concern, a monitoring program could implement a level of sampling intensity that would provide a 75% chance of detecting a 30% drop in the population and a 90% chance of detecting a 50% drop, whichever yields the greatest sample effort. The thresholds used would correspond to those limits of acceptable change defined in Table 7.6.

Ultimately for monitoring to inform management and policy, it must be question driven, and if one is to identify potential interventions triggered when limits of acceptable change are breached, then these have to be underpinned by conceptual models of how the system works (Lindenmayer & Likens, 2010). In the context of the Karoo there are many unknown variables, and a coordinated approach is required to address the fundamental knowledge gaps in the face of SGD. Furthermore, in order to ensure that cumulative and emergent impacts are not overlooked through single SGD applications, an over-arching research and monitoring agenda should be developed. Salient variables, indicators and approaches are listed below in Table 7.9. Through the monitoring and study of these variables, the impacts of SGD can be better understood and more effective mitigation and avoidance measures developed and implemented.

Table 7.9: Additional information on species and features that could be monitored, with indicators and possible study approaches. Ideally a basket of indicators selected from each level of the hierarchy should be used in an integrated way, based on the characteristics of the receiving environment and assessed risks and impacts for that area.

Target	Examples of target taxa/features	Indicators	Sample approaches
Species	<ul style="list-style-type: none"> Local endemics Threatened species Ecologically important species 	<ul style="list-style-type: none"> Density Sub-population numbers Age-structure Reproductive success 	<ul style="list-style-type: none"> Mark-recapture studies Camera trapping Fixed-effort counts Repeat photography Roadkill/mortality counts
Habitats	<ul style="list-style-type: none"> Quartz patches Pans Drainage lines Localised habitats and landscape features 	<ul style="list-style-type: none"> Extent Counts Composition Diversity 	<ul style="list-style-type: none"> Fine-scale mapping Repeat photography Fixed plots
Terrestrial ecosystems	<ul style="list-style-type: none"> Vegetation types Broad plant communities Medium- to large faunal community 	<ul style="list-style-type: none"> Extent Fragmentation Diversity Predator-prey ratios Grazing pressure 	<ul style="list-style-type: none"> Remote sensing/satellite imagery Camera trapping Collars/satellite tracking Fixed plots
Aquatic ecosystems	<ul style="list-style-type: none"> Water-dependent ecosystems Riparian vegetation Pans Aquatic fauna 	<ul style="list-style-type: none"> Discharge (rivers) Water depth (wetlands) Silt loads in rivers Water quality Stream flow Topsoil loss rates & distribution Species presence/absence/abundance South African Scoring System 	<ul style="list-style-type: none"> Vadose zone monitoring Fixed riparian plots Flow rates of springs Rapid Habitat Assessment Method or Index of Habitat Integrity (rivers) EcoStatus indicators (rivers: riparian vegetation, invertebrates, fish), WET-Health (wetlands: geomorphology, hydrology, vegetation)
Broad-scale processes	<ul style="list-style-type: none"> Wide-ranging mammals Large birds Predators 	<ul style="list-style-type: none"> Dispersal Connectivity Gene flow 	<ul style="list-style-type: none"> Mark-recapture DNA studies Collars/satellite tracking

7.5 Gaps in knowledge

The map of EBIS and the overall assessment presented in this assessment are based on the best available data. However, data gaps and limitations remain, especially in relation to species information, impacts on ecological infrastructure, understanding of complex ecological interactions and feedback including trophic cascades, and knowledge of distributions of key features such as wetlands and groundwater dependent ecosystems. Given these uncertainties; use of the precautionary principle when making decisions about SGD is recommended.

In general, species occurrence data are fragmented across several different collection institutions (e.g. museums, South African Institute for Aquatic Biodiversity (SAIAB), Agricultural Research Council (ARC)), different formats are used for the data, and for locality data the levels of accuracy for coordinates vary. The exceptions to this are where SANBI or other Threatened Species projects have compiled integrated datasets across institutions, and cleaned and geo-referenced these. This is the case for reptiles and butterflies, and threatened and restricted range plants. There is only a limited amount of data for the area in general and it is under sampled for all taxa. This limits data availability and usefulness for the SGD scientific assessment. There is also incomplete knowledge of ecological requirements of many species of special concern, as well as interactions, cascading effects and impacts on processes. Should SGD proceed, it will be critical to improve the comprehensiveness and coverage of data on threatened- and keystone species.

The map of wetlands used in this assessment is based on the National Wetland Map (2011 version), which was edited and supplemented by limited newly digitised wetland data from SPOT imagery, as well as newly available data on dry river beds. However, there are still gaps in the map of wetlands. Data on hydrological areas are inconsistent across the study area, and ideally data quality should be improved. At such time as the National Wetland Map is updated, the new map should be used to revise the identification of areas of EBIS.

These data limitations mean that the current map of EBIS is appropriate for broad-scale planning, but not for fine-scale identification of sensitive features that may be present at a particular site. As such, the map provided here does not negate the need for specialist input when development is proposed or is taking place at a site level. Within any particular area, there are likely to be sensitive habitats and species present and specialist input should be obtained for any shale gas-related development, and mitigation and avoidance measures should be implemented as appropriate. This may require additional mapping of sensitive features at a fine scale (e.g. 1:10 000) to support EIA and local-level decision-making processes.

In addition to these data limitations in relation to the map of EBIS, there are limitations with regard to knowledge of the potential impacts of SGD on biodiversity and ecology. Impacts related to SGD are not well known anywhere in the world and completely unknown in South Africa. As a result, many of the presumed impacts are based on theoretical considerations and impacts associated with other similar industries. However, factors that make SGD unique and different from most other typical forms of development include the following:

- The very high traffic volumes that are required to bring the large amount of material that is required for SGD to site on a continuous basis. This may result in long-term impacts on and declines in sensitive species. As there are various different avenues by which traffic can generate impact, such as through noise, vibration, direct disturbance, and collision, it is difficult to predict the identity and severity of impact on all affected species.
- The potential extent and dispersed nature of SGD is comparatively large relative to other types of development that could take place in the Karoo. As a result, many impacts that would otherwise be confined to a small area may occur over a broad area and the cumulative impact of this may be large. Furthermore, some impacts such as disturbance or noise may extend well beyond the footprint of the development itself, and when the development occurs in a dispersed manner across the landscape as in SGD there may be few refuges remaining for sensitive species. There is also poor knowledge about specific species' responses to impacts (e.g. light impacts on nocturnal species and communities, and soil vibrations impact on ground-living species).

Another key knowledge gap is the lack of a conceptual model of the relationships between groundwater, aquatic ecosystems and climate in the study area. Monitoring is needed to collect information for baselines and trends in this regard. This means that there is not yet sufficient knowledge to set critical thresholds for abstraction and pollution of groundwater in relation to impacts on surface water ecosystems. This is also highlighted in Hobbs et al. (2016).

The above limitations notwithstanding the map of EBIS and accompanying risk assessment table (Table 7.7), together with the recommended mitigation measures, constitute a sound resource for limiting the impacts of SGD on the biodiversity and ecology of the Karoo. In addition, use of the precautionary principle when making decisions on SGD is recommended. The knowledge gaps discussed above reinforce the importance of securing EBIS-1 and EBIS-2 areas to ensure that, even if there are significant unforeseen impacts in the areas which are developed, the overall functioning and ecological integrity of the Karoo is maintained.

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7.8 Digital Addenda 7A – 7B

SEPARATE DIGITAL DOCUMENT

Digital Addendum 7A: Species of special concern in the study area

Digital Addendum 7B: Methodology used to identify areas of Ecological and Biodiversity Importance and Sensitivity (EBIS)