Annexure "B"

Comments on the 2025 Regulations for Hydraulic Fracturing – Impacts on Terrestrial Biodiversity of the Karoo

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"Ecological solutions for landscapes and livelihoods"

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CONTENTS

1. INTRODUCTION

On the 7 November 2025 the Department of Forestry, Fisheries and the Environment (DFFE) published four sets of Regulations for public comments. Collectively these are referred to as "**The Regulations**". Individually each Regulation is referred to as indicated in bold below.

1. Government Notice 6806: "**Exploration and Production Regulations**"
CONSULTATION ON THE PROPOSED REGULATIONS FOR THE EXPLORATION AND PRODUCTION OF ONSHORE PETROLEUM RESOURCES REQUIRING FRACTURING TECHNOLOGY
2. Government Notice 6808: "**Minimum Information Requirements Regulations**"
CONSULTATION ON THE INTENTION TO PRESCRIBE MINIMUM INFORMATION REQUIREMENTS FOR THE EXPLORATION AND PRODUCTION OF ONSHORE PETROLEUM USING FRACTURING TECHNOLOGY
3. Government Notice 6811: "**Baseline Monitoring Regulations**"
CONSULTATION ON THE INTENTION TO PRESCRIBE MINIMUM INFORMATION REQUIREMENTS FOR BASELINE MONITORING FOR ONSHORE EXPLORATION OPERATIONS
4. Government Notice 6818: "**Decommissioning Regulations**"
CONSULTATION ON THE INTENTION TO PRESCRIBE ONSHORE WELL DECOMMISSIONING GUIDELINES PREPARED BY PETROLEUM AGENCY SA

All the regulations are focused on impacts at the well-pad site scale. Individually these may have low impacts on terrestrial biodiversity, collectively however all the drill sites and their supporting infrastructure will undoubtedly have a very high impact on terrestrial biodiversity and the ecology of the region. It is the cumulative impacts of hydraulic fracturing that must be addressed as these will have both a very high likelihood, and a very high impact, of harm to the Nama Karoo and surrounding semi-arid biomes (hereafter referred to simply as the 'Karoo').

2. CUMULATIVE SURFACE IMPACTS (IMPACTS ACROSS SPACE)

2.1 SCALE-DEPENDENT ECOLOGICAL RISKS

The ecological impacts of shale gas development in the arid Karoo environment, in which many ecological processes operate over vast spatial extents, are likely to be felt at the landscape scale. The Karoo is characterized by low primary productivity and sensitivity to degradation, resulting in impacts having long-lasting effects. Unlike more resilient mesic systems, recovery from degradation in this region is very slow, frequently inhibited by resource scarcity and slow successional rates.

2.2 Habitat Fragmentation

The primary driver of biodiversity loss from fracking is habitat fragmentation. The construction of well-pads, access roads, pipelines, lay-down areas and storage facilities carves up continuous landscapes into isolated patches. The conversion of contiguous landscapes into a mosaic of isolated patches disrupts established wildlife corridors and alters the spatial configuration of habitat available to indigenous animals and plants. Plants and animals are adapted to optimise sporadic or episodic resource availability e.g., to complete their life-cycle when resources are available (annual plants and many insects), seasonal migration and opportunistic nomadism following pulsed resource abundance. The low resource availability within this arid region means that viable populations of plants cover large areas, and that animals need a large home range. Other impacts of fragmentation on plants include disruption of the pollination and dispersal systems.

Roads will often need to be fenced (largely to minimise the impact on commercial farming, viz, livestock grazing), which will have major impacts on large animal movement. However, very little is known of the impact of fragmentation on ecological processes in the Karoo , and almost nothing can be predicted for the impacts on Karoo invertebrate diversity and functioning. 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 region.

2.3 Edge Effects

For many species, shale gas development is more than the physical loss of space; each spatial impact also disrupts ecological processes and creates "edge effects" that penetrate significantly further than the development footprint.

- Cleared and disturbed areas around wellpads, along roads and pipelines will increase the vulnerability of these areas to invasion by alien plants into core habitats in the Karoo (Gelbard & Belknap, 2003).
- Dust deposition on leaf surfaces reduces photosynthetic efficiency and gas exchange of plants in the surrounding areas, while the ingestion of dust-laden forage causes premature dental attrition in indigenous ungulates (Trombulak & Frissell, 2000).

- The Karoo maintains a low ambient noise floor. Industrial operations, specifically heavy vehicle transit, generate noise levels (up to 40 dB at 1 km) that represent a 100% increase over natural background levels. A 3 dB increase in ambient noise results in a 50% reduction in the "listening area," a phenomenon that inhibits intraspecific communication, predator detection, and mate localization in shy or acoustic-dependent species (Holness et al. 2016).
- Vibrational impact on subterranean taxa may extend over considerable distances. Specialized subterranean mammals, including the golden moles, utilize vibrational and physically conducted cues for foraging. The high-amplitude vibrations associated with seismic exploration and drilling operations will disrupt these sensory mechanisms. Even heavy vehicle traffic and machinery will have an impact over shorter distances, and impact surface dwelling animals that are use soil vibrations to find prey, e.g. snakes and other reptiles.
- Artificial light can affect the population and behavioural ecology of organisms and can lead to changes in behaviour associated with foraging, reproduction, migration and communication. Light pollution affects predator-prey interactions and foraging behaviour. Ditmer et al. (2021) found large-scale, positive and negative behavioural shifts in both herbivores and predators where human lighting influenced their environment. Artificial Light clearly modifies the population and behavioural ecology of nocturnal organisms. Light avoidance is evident in certain rodents, lagomorphs (rabbits), snakes and other reptiles. Conversely, lights can also have a concentrating effect on animals, especially insects, creating patches of prey superabundance, attracting opportunistic insectivores (e.g., bats, geckos etc.).
- Increased runoff and erosion from cleared areas and hardpacked surfaces. Removing plants, organic matter, surface heterogeneity, levelling and compaction, are associated with virtually every aspect of shale gas development (well-pads, lay-down areas, pipelines, parking areas, access roads, accommodation etc.). This changes the infiltration and runoff properties on-site, and exports the water and erosive capacity off-site. Bearing in mind that the low natural vegetation cover, high clay and low organic matter content of these soils makes Karoo landscapes highly susceptible to erosion.

2.4 Direct Effects

A further impact on bird and other animal populations 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 . This creates a localized abundance of carrion, which may artificially inflate populations of generalist scavengers including raptors and crows and even small species such as the Fiscal Shrike. Animals eating road kill, and foraging on roads, are vulnerable to themselves becoming roadkill. Crows attracted to roads by the availability of road kills subsequently increase predation pressure on small vertebrates and reptiles in the surrounding habitats Joseph et al. (2017).

Species such as spotted thick-knees (dikkops) and nightjars are attracted to open spaces created by well pads, roads etc., and are active in the evenings and sometimes into the night, frequently being killed by vehicles. Certain reptiles are attracted to cleared compacted areas to take advantage of the warm surface (thigmothermy), and are similarly vulnerable.

Flares to burn off excess gas may be another hazard for birds that has not been quantified. Migrant birds flying at night are attracted to lights and may inadvertently stray into the flares.

Impacts on slow reproducing (e.g. tortoises, honey badgers), slow moving vertebrates (e.g. snakes, tortoises) and species attracted to roads due to the presence of roadkill themselves (e.g. bat-eared foxes, polecats) is potentially the greatest concern.

3. Cumulative Underground Impacts (impacts across time)

3.1 Unquantified Underground Risks

Impacts on underground water resources constitute one of the most significant and least well understood risks of shale gas development in the Karoo . Groundwater systems in the Karoo underpin not only human water security but also a wide range of surface ecosystems. The likelihood of adverse impacts on groundwater arising from shale gas extraction remains uncertain. However, should such impacts occur, their consequences for biodiversity and ecosystem functioning would be severe and potentially irreversible.

Unlike many surface disturbances, impacts on groundwater operate over long temporal and large spatial scales. Contamination or depletion of aquifers may manifest only decades after the initiating activity, and may extend far beyond the immediate footprint of drilling and hydraulic fracturing operations. Given the Karoo 's reliance on groundwater-fed ecosystems, including ephemeral rivers, springs, pans, and wetlands, any alteration to groundwater quality or quantity has the potential to cascade through ecological systems, affecting species assemblages, ecological processes, and ecosystem services.

3.2 Toxicity from Mixing of Underground Reservoirs

The hydrogeology of the Karoo is strongly influenced by the widespread occurrence of dolerite dykes, sills, and ring structures. These intrusive features play a critical role in controlling surface and subsurface drainage patterns, groundwater storage, and the spatial distribution of watercourses, springs, and wetlands. Fractures associated with dolerite intrusions often act as preferential pathways for groundwater movement, feeding wetlands and ephemeral streams through seepage from deep fractured aquifers or, in some cases, unconfined alluvial aquifers.

Shale gas development introduces several pathways through which toxic substances could contaminate groundwater systems. Under natural conditions, permeable rock layers containing water, gas and other hydrocarbons are separated by impermeable strata that have maintained hydraulic isolation for millions of years. Shale gas operations rely on engineering and regulatory controls to preserve this separation. For instance, the "**Decommissioning Regulations**" frequently require two competent isolation barriers be placed across the wellbore at the position of the impermeable rock layers or cap rock. To be effective these permanent isolation barriers will need to remain in place and intact for centuries, at a minimum. If geological or engineered barriers fail, specific risks include:

- loss of hydrocarbon containment from hydrocarbon bearing formations previously not in communication with the surface environment
- transfer of fluids between formations (crossflow) resulting in unnatural pressurisation or contamination of formations, including freshwater aquifers.

Such failures may arise from degradation of well casings and plugs over time or from fracturing-induced damage to impermeable strata.

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. Many of these, predominantly depressions or pans, are endorheic, i.e. isolated from other surface water ecosystems, usually with inflowing surface water but no outflow, making them especially vulnerable to pollutant, toxin and saline accumulation.

Ephemeral pans and rock pools in the Karoo are easily overlooked (and considered barren), however, these support specialised invertebrate communities, including crustaceans such as fairy shrimps (Anostraca), tadpole shrimps (Notostraca), clam shrimps (Spinicaudata and Laevicaudata), as well as cladocerans and ostracods (Lloyd & Le Roux, 1985). Several taxa are entirely dependent on ephemeral wetlands to complete their life cycles. Although the invertebrate fauna of Karoo wetlands and watercourses remains poorly studied, these ecosystems are known to harbour unique, highly adapted species characterised by rapid hatching, accelerated development, high fecundity, and short life spans. Contamination of groundwater feeding these systems could therefore lead to localised extinctions and loss of biodiversity with limited capacity for recovery. These ephemeral wetlands and their booming invertebrates populations create a pulse of resources available to higher trophic levels. Migrant birds, e.g. flamingos, concentrate in large numbers when these resources are available.

3.3 Exhaustion of Water Resources

In addition to risks of contamination, shale gas development poses a substantial threat through the depletion of limited water resources. Significant volumes of water are required not only for hydraulic fracturing itself but also for associated activities such as drilling, dust suppression, cleaning of well pads, machinery and infrastructure, as well as meeting the domestic needs of an influx of workers into the region. In an arid environment such as the Karoo , where surface water is scarce and highly variable, these demands are likely to be met primarily through abstraction of groundwater.

Reduced groundwater availability may diminish or eliminate baseflow to springs, wetlands, and ephemeral rivers, leading to the degradation or complete loss of aquatic and riparian habitats. Water-dependent terrestrial ecosystems, including those supporting endemic plant species and grazing systems relied upon by wildlife and livestock, may also be adversely affected.

Declining water tables can alter water chemistry, increase salinity, and concentrate pollutants, further stressing biotic communities. Given the slow recharge rates characteristic of Karoo aquifers, such impacts may persist for generations.

3.4 Toxicity of waste water to biodiversity

The management and disposal of waste water generated during shale gas operations represents another risk to terrestrial biodiversity. Flowback and drill-produced water typically contain a complex mixture of hydraulic fracturing additives, dissolved salts, heavy metals, naturally occurring radioactive materials, and hydrocarbons.

Documented incidents, from other shale gas regions, include acute mortality of in-stream fish following contamination of watercourses, as well as deaths of terrestrial mammals that consumed polluted water from affected streams. Waste water ponds themselves pose direct hazards to wildlife. Animals may drown after becoming trapped or suffer poisoning following ingestion or dermal exposure.

In the Karoo context, these risks are amplified by prevailing arid conditions that concentrate animal activity around limited water sources. Birds, mammals, and reptiles are likely to be drawn to any standing water, including artificial waste water ponds. Chronic exposure to low levels of contaminants may also result in sub-lethal effects, such as impaired reproduction, altered behaviour, and bioaccumulation of toxic substances through food webs, with long-term consequences for population viability.

The most effective mitigation measure for reducing biodiversity impacts from wastewater is to avoid the use of open storage ponds altogether. Instead, wastewater should be stored and transported in closed, leak-proof containers and treated or disposed of in accordance with stringent environmental standards. Continuous monitoring, robust regulatory oversight, and the application of the precautionary principle are essential to safeguard the Karoo 's vulnerable ecosystems.

4. MONITORING (PRE- AND POST-DRILLING) AND REHABILITATION

Baseline monitoring, rehabilitation after fracking, and monitoring after fracking or well decommissioning are insufficiently, in fact naively, dealt with in **"The Regulations'**. Where any periods for baseline monitoring are set, they concern surface water monitoring for a period of 24 months (s.3.1.2 "**Baseline Monitoring Regulations**" and s.8.5 "**Exploration and Production Regulations**"). Specific ecological rehabilitation stipulations are lacking, and those for monitoring after hydraulic fracturing has ceased, concern seismic activity (Appendix 1, s.10.2 "**Exploration and Production Regulations**").

Alternating wet and dry cycles are now well established for the Karoo region (du Toit & O'Connor 2014). Long and shorter cyclicity is driven by a variety of global (and solar) climatic dynamics, e.g. El Niño Southern Oscillation (ENSO). Recent droughts of 3-8 years in the Karoo (depending on location) are fairly typical. Therefore, monitoring of surface water flow, aquifer resources, discharge and recharge etc. for periods of less than a decade is potentially meaningless. This applies equally to monitoring post-drilling and post-fracking, especially as monitoring is likely to be largely restricted to surface water flow and near-surface aquifers as indicators of all sub-surface impacts (mostly occurring at deeper levels).

Recovery of biodiversity in the Karoo , after degradation, is generally not spontaneous, and even where a number of active rehabilitation measures have been implemented, it is often met with poor success (Carrick 2023). All cleared areas (roads, well-pads, staging areas etc.), whether compacted or not, will have had the topsoil and seedbank removed, and will require at least soil amelioration and seeding interventions. Even where ecologically sound restoration methods have been used, recovery is very slow in these arid systems, and little re-growth or natural succession will take place in degraded or surrounding (edge-affected) areas in drought years (Carrick 2023). Therefore, rehabilitation monitoring periods of at least a decade are required to evaluate site level rehabilitation.

The lack of concrete monitoring and rehabilitation regulations is particularly worrying given that where these have been more adequately developed and govern surface mining, where the risks are well understood, they are infrequently followed and infrequently enforced after a mine has been decommissioned (Carrick & Kruger 2007).

5. Strategic Environmental Assessment

In 2016 the leading scientific institutions of South Africa, with participation from a vast number of the leading scientists, completed a 1 400-page scientific assessment of the opportunities and risks of shale gas development in the central Karoo (Scholes et al. 2016). This constitutes a Strategic Environmental Assessment (SEA) of the risks of hydraulic fracturing in the central Karoo . For the biodiversity and ecological impacts chapter (Holness et al. 2016), the unequivocal outcome is that environmental impacts need to be assessed cumulatively, not individually. The importance of cumulative environmental assessments is also highlighted in the chapter on water resources, both on the surface and underground (Hobbs et al. 2016). Around the same time, several other studies and papers were published on the overarching impacts of shale gas development for South Africa (e.g., Todd et al. 2016).

Across all four of **"The Regulations"** published in 2025 there is little or no reference to cumulative effects or a Strategic Environmental Assessment. An exception is found in the "**Baseline Monitoring Regulations**" s.3.4 in which an SEA is mentioned in relation to monitoring seismic activity.

The biodiversity and ecological impacts chapter (Holness et al. 2016) develop detailed models of the biodiversity impacts for both a large and a small gas development scenario; scenarios which are outlined in the SEA for shale gas development in the central Karoo (Scholes et al. 2016). Leaving aside the impacts of reconnaissance and exploration, the minimal infrastructure required directly for just a small shale gas development scenario is (this represents the smallest possible economically viable development):

- 550 wells on about 55 well-pads in one 30 x 30 km production block
- downstream development results in a 1 000 MW combined cycle gas turbine power station located less than 100 km from the production block.

In this small gas scenario, the total estimated footprint of development within a 30x30 km block would be:

- approximately 110 ha of well-pads
- 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, the cumulative impact is that 25% of the area is within 500 m of a well-pad or access road and 48% is within 1 km.

Hollness et al. (2016) present a spatial SEA for the 171 811 km2 region of the central Karoo for which an exploration right had been lodged by Shell (the primary shale gas development area).

Four levels of "Ecological and Biodiversity Importance and Sensitivity (EBIS)" are mapped across this area and incorporating, among others, the impact on:

- Provincial spatial biodiversity plans, "Critical Biodiversity Areas (CBAs)" and "Ecological Support Areas (ESAs)"
- terrestrial ecosystems
- plant species diversity and endemism
- terrestrial fauna (including mammals, birds, reptiles and invertebrates)
- aquatic ecosystems and species
- extent of impact on South African biomes, vegetation types and edaphic habitats
- mitigation measures

Todd et al. (2016), similarly, deals with the impacts of shale gas development at the landscape scale, across four regions of South Africa that had been identified with potential reserves. Impacts are described for vascular plants, mammals, birds, amphibians, reptiles and lepidoptera (butterflies and moths), as well as those of each major development activity (Tables 14.2, 14.3 and 14.5). Since the publication of these reports, two more recent National Biodiversity Assessments have been completed (Skowno et al. 2019; Skowno et al. 2025). DFFE should envisage and updated for SEA for any future area identified shale gas development, and potentially that this integrates with, and leads to a Biodiversity Management Plan for Ecosystems (BMP-E), by which the region is managed to minimise and mitigate impacts to biodiversity. Recent SEA processes conducted for solar and wind development could provide insight and experience developing **"The Regulations"** to address the cumulative impacts

6. Oversights in Specific Regulations

Throughout the "**Exploration and Production Regulations**", the Minister responsible for water affairs (Department of Water and Sanitation) is required to give concurrent approval for applications/activities/monitoring with the competent authority or designated agency (Petroleum Agency South Africa). In certain sections the Minister responsible for water affairs does not appear to approval rights, but is rather delegated simply to "review and archive" reports (s.17.1 of the "**Exploration and Production Regulations**") or is given incredibly short time frames for approval (e.g. five days; s.19.1 of the "**Exploration and Production Regulations**"), and where this time frame is exceeded, approval is deemed to have been given.

Leaving aside the inherent conflict of interest in the regulatory agency, and the possible additional roles for the Department of Forestry, Fisheries and the Environment, and the

Department of Mineral Resources and Energy, **“The Regulations”** create a duplication of tasks, and place an incredible burden on Department of Water and Sanitation and the Petroleum Agency South Africa for an array of procedures for which they will need to provide processing, verification, assessment and authorisation. Will increased financial resources be available to these departments in order to develop the greater capacity that these responsibilities entail? The institutional and human resource capacity of the Department was deemed insufficient in the 2016 SEA report (Hobbs et al. 2016) to implement a robust and effective water resource monitoring and management programme for shale gas development, let alone take on additional roles.

The **“Decommissioning Regulations”** are principally technical engineering regulations. Scientific evidence for the calculation of the risk of geological or engineered barriers failing does not appear to have been developed (see Section 3.1). Moreover the **“Decommissioning Regulations”** have been put out by DFFE under the National Environmental Management Act, 1998 (Act No. 107 of 1998) “NEMA”, but reference predominantly the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) “MPRDA”, and as stated above the monitoring authority for most of the hydraulic fracturing regulations is the Department of Water Affairs. Certainly, the impact geological or engineering failures would massively impact water resources. It is thus entirely unclear which agency would exercise oversight over this critical aspect; the regulations themselves frequently refer to the “Designated Agency”.

The “**Baseline Monitoring Regulations**” have not been comprehensively developed. Section 3.6 of the regulations, covering terrestrial Biodiversity and species, is an extremely basic list of biodiversity information and envisages species as static or fixed entities and does not conceptualise e.g. interactions or cumulative impacts (see Section 2 of this report).

s.7 of the “**Exploration and Production Regulations**” provides another example of a lack of specificity or development. These regulations instruct applicants to identify, assess, avoid and if avoidance is not possible, to mitigate, manage and monitor all potential environmental impacts. They speak to “environmental attributes”, however, no indication is given as to what these are, what should be measured, what standards should be applied, etc.

The **“Minimum Information Requirements Regulations”** have been adequately developed, and are often comprehensive for the development of a single site (conceptualising interactions and knock-on effects e.g., s.2.8.1 “the impact on terrestrial biodiversity through the loss of indigenous vegetation due to clearing, changes to the ecological functioning and processes, the establishment and spread of declared weeds and invader plants due to clearing and disturbance of vegetation… the interference with ecological corridors, and the general disturbance of habitats”). The omission is the conceptualisation of cumulative impacts and their interactions across the all the shale gas development sites.

Finally, several new methods of non-aqueous fracturing have been engineered that do not require the use of water (Wang et al. 2016). These methods are already being tested and implemented globally. **“The Regulations”** do not mention any of these and have seemingly been produced with conceptualising innovation and alternatives that may be available and make limited use of water.

7. Sources of Information

7.1 Referenced Papers

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Tolley, K., 2026 – Effects of cleared areas roads and edge effects on vertebrates, particularly small mammals and reptiles.