Scenarios-based risk model for shale gas scientific assessment

G. Schreiner[1], L. Snyman-Van der Walt[1], D. Fischer[2] and L. Cape[1]
[1]Council for Scientific and Industrial Research, Stellenbosch, South Africa.
[2]National Department of Environmental Affairs, Pretoria, South Africa.
Corresponding author: Lydia Cape, Tel.: +27 21 888 2429, Email: lcape@csir.co.za

Abstract

The shale gas Strategic Environmental Assessment (SEA), compiled by over 200 authors and peer reviewers from around the world, was the largest assessment of its kind undertaken in South Africa. Seventeen topics were assessed across four scenarios providing temporal and spatial scales following a rigorous risk assessment approach. The sensitivity of spatially explicit receiving environments in the Central Karoo region of South Africa were classified and mapped to enable the assessment of risks per sensitivity class, with- and without mitigation, across the four scenarios. The risk profiles were determined by taking into account the consequence and the likelihood of an impact, with topic consequence terms calibrated to ensure consistency through the risk classifications. Finally, a composite spatial overlay was generated to demonstrate the evolution of the risk profile across the four scenarios for the full life-cycle of proposed shale gas development activities.

Introduction

Exploration and production of shale gas (collectively called "development") in the Central Karoo region of South Africa remains a contested issue, due in part, to uncertainty regarding the distribution and magnitude of the gas reserves (Burns et al., 2016) coupled with the potential social, economic and ecological consequences associated with a domestic gas industry (de Wit, 2011). The Strategic Environmental Assessment (SEA) for Shale Gas Development in South Africa was commissioned by the Republic of South Africa in February 2015 under the leadership of the Department of Environmental Affairs. The purpose of the SEA is to provide an integrated assessment and decision-making framework to enable the establishment of effective policy, legislation and sustainability conditions under which shale gas development could occur. During the SEA, a 'scientific assessment' was conducted by 146 experts covering seventeen topics including: geophysics, water resources, terrestrial biodiversity, air quality, social fabric, visual and noise, heritage resources, agriculture, tourism, waste management, infrastructure planning, energy planning and economics[1] within a 171 811 km^2 study area (Figure 1). A scenario-based risk assessment combined with spatial modelling was followed during the assessment to provide an integrated 'picture' of cumulative risk over the extent of the study area and temporal range of the scenarios. The assessment was peer reviewed by 25 local and 46 international independent review experts and by a large number of stakeholders involved in the process.

[1] see http://seasgd.csir.co.za/scientific-assessment-chapters/

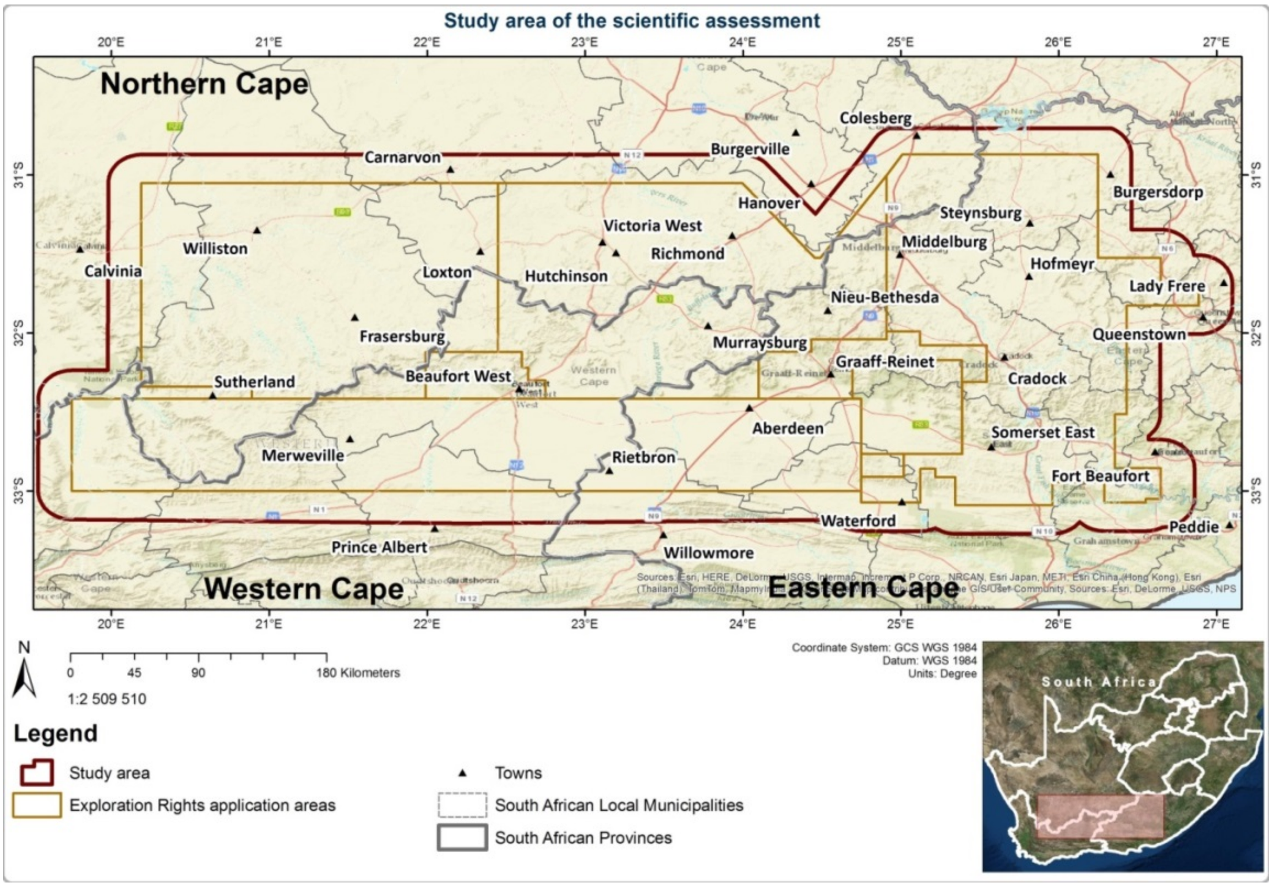


Figure 1: Scientific assessment study area delimited by current applications for shale gas exploration rights plus a 20 km buffer (Source: Scholes et al., 2016).

Methodology

1. Scenario development

Scenarios originate on the assumption that the future is fundamentally unpredictable (van der Heijen, 2000) but acknowledge that complexity and uncertainty can be reduced to within logical parameters (Ash et al., 2010). As such, scenarios provide the qualitative and quantitative information from which an assessment of future activities can be made across a range of spatial and temporal scales. The scenarios were developed in an iterative manner based on the identification of major concerns (nominal risk associated with increasing shale gas development activities in the sensitive receiving environment of the Central Karoo) and the determination of major uncertainties (volumes of economically recoverable gas reserves). Through a collaborative process of expert engagement workshops consisting of more than 60 experts from the oil- and gas industry, petroleum geologists, engineers, energy planners; and natural- and social scientists, three cumulative scenarios were generated in relation to a dynamic Reference Case[2] where no shale gas development occurs but regional trends continue on observed trajectories (Table 1).

[2] A reference scenario is usually a plausible and relatively nonthreatening scenario, featuring no surprising changes to the current environment and continued stable growth (Ash et al., 2010).

Table 1: Summary of the scenarios

Reference Case scenario (S0)	No shale gas development.
Exploration Only scenario (S1)	Results from exploration indicate that production is not economically viable. All sites are rehabilitated, drilled wells permanently plugged and monitoring of the abandoned wells implemented. National energy supply in South Africa is supported by imported natural gas either via pipeline or from Liquefied Natural Gas importation.
Small Gas scenario (S2)	Results from exploration indicate relatively small, but economically viable, shale gas resource. Approximately 5 trillion cubic feet (tcf) of gas is produced from 550 wells on about 55 wellpads in one 30 x 30 km production block. Downstream development results in a 1 000 megawatt (MW) combined cycle gas turbine power station located less than 100 km from the production block.
Big Gas scenario (S3)	A relatively large shale gas discovery of 20 tcf is made, produced from 4100 wells on about 410 wellpads distributed across four production blocks. Downstream development results in the construction of two CCGT power stations (each with a generation capacity of 2 000 MW) and a gas-to-liquid plant located at the coast with a refining capacity of 65 000 barrels per day.

2. Risk assessment

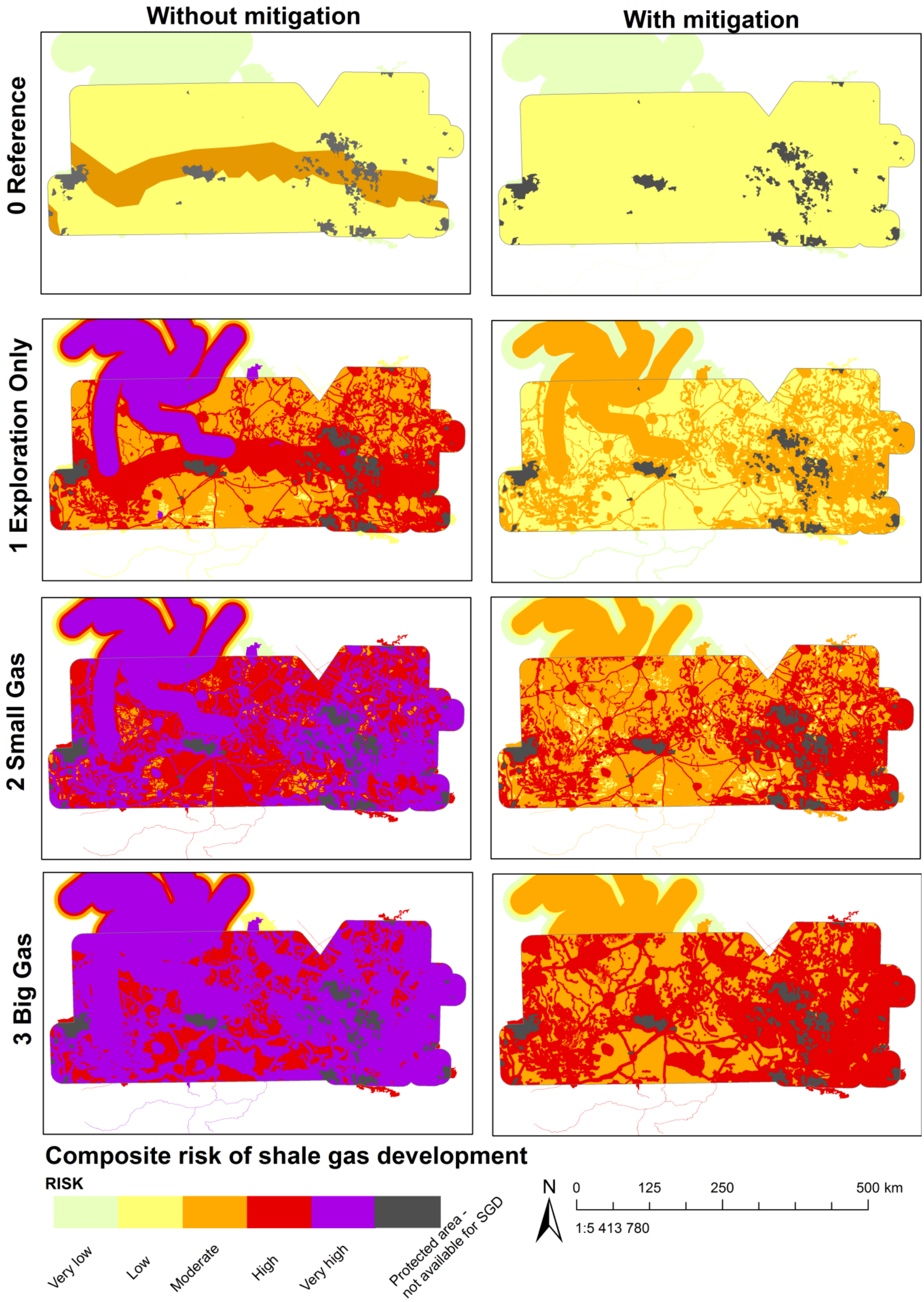
The risk assessment approach was developed based on the Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC) which defines risk as "the probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur" (IPCC, 2014). Risk was determined by estimating the likelihood of events or trends occurring, in relation to their consequences (Risk= likelihood x consequence, ranging from very low to very high risk). Consequences were calibrated for each topic based on quantitative and qualitative descriptions of the consequence terms ranging from slight to extreme, which ensured consistency in the manner risks were measured, enabling integration across different topics, and providing a common conceptual and spatial understanding of risks (Table 2). Risks were assessed with- and without mitigation, across the four scenarios (S0, S1, S2 and S3). 'Without mitigation' assumed inadequate governance capacity, weak decision-making and non-compliance with regulatory requirements. 'With mitigation' assumed effective implementation of best practice principles, adequate governance and responsible decision-making. The assessment of the four scenarios, both with- and without mitigation led to increased scenario variance and provides decision-makers with practical estimation of the importance of strong governance and institutional functionality.

Table 2: Risk assessment classes (Source: Scholes et al., 2016).

Risk category	Definition
Very low risk	Extremely unlikely (<1 chance in 10 000 of having a consequence of any discernible magnitude); or if more likely than this, then the negative impact is noticeable but slight, i.e. although discernibly beyond the mean experienced in the absence of the impact, it is well within the tolerance or adaptive capacity of the receiving environment (for instance, within the range experienced naturally, or less than 10%); or is transient (< 1 year for near-full recovery).
Low risk	Very unlikely (<1 chance in 100 of having a more than moderate consequence); or if more likely than this, then the impact is of moderate consequence because of one or more of the following considerations: it is highly limited in extent (<1% of the area exposed to the hazard is affected); or short in duration (<3 years), or with low effect on resources or attributes (<25% reduction in species population, resource or attribute utility).
Moderate risk	Not unlikely (1:100 to 1:20 of having a moderate or greater consequence); or if more likely than this, then the consequences are substantial but less than severe, because although an important resource or attribute is impacted, the effect is well below the limit of acceptable change, or lasts for a duration of less than 3 years, or the affected resource or attribute has an equally acceptable and un-impacted substitute.
High risk	Greater than 1 in 20 chance of having a severe consequence (approaching the limit of acceptable change) that persists for >3 years, for a resource or attribute where there may be an affordable and accessible substitute, but which is less acceptable.
Very high risk	Greater than even (1:1) chance of having an extremely negative and very persistent consequence (lasting more than 30 years); greater than the limit of acceptable change, for an important resource or attribute for which there is no acceptable alternative.

3. Risk modelling

An integrated risk model was developed, per scenario with- and without mitigation, based on the allocation of sensitivity ratings to geographically distinguishable receiving environments and the determination of risk profiles for these sensitive areas of the receiving environment. Spatially explicit risk profiles were then overlayed and depicted using the 'maximum rule' to prioritise the highest risk areas over those of lower risk (Figure 2). The risk model aims to demonstrate the evolution of the risk profile across the four scenarios for the full life-cycle of shale gas development activities and to test the efficacy of proposed mitigation actions in reducing risks.



<u>Figure 2:</u> Composite map of spatially explicit risk profiles within the study area, depicting the risk of shale gas development across four scenarios without-and with mitigation (Scholes et al.,).

Results and Discussion

The risk model presents a mosaic of cumulative risk, evolving across the scenarios. Risks range from low to very high in the study area, with higher risk areas prevalent towards the eastern portion of the study area. This may be attributed to more variable landscape features which are characterised by a denser distribution of towns, more diverse habitats and a greater concentration of protected and sensitive areas, higher agricultural production potential and an increased concentration of scenic resources and landscapes. Through effective project planning, many of sensitive features of the Central Karoo can be avoided. This includes high sensitivity water resources, biodiversity resources, high sensitivity agricultural land, heritage features, important tourism areas or routes, vulnerable people living in towns or rural communities, high sensitivity visual resources and the footprint of the South African mid-frequency array of the Square Kilometre Array Phase 1 project[3]. Without mitigation, the risks associated with shale gas development from S1 to S3 increase incrementally from moderate-very high to high-very high. Effective implementation of mitigation and best practice principles may reduce the risk profile to low-moderate for S1, and overall moderate-high for S2 and S3 scenarios. At the strategic-level of assessment, the risks associated with S1 could be mitigated to low-moderate. Best practice mitigation is reliant on the veracity of the future decision-making processes which should be guided by evidence-based policies, robust regulatory frameworks and capacitated institutions in a manner that is ethical, responsible and transparent. Most of the features mapped at the scale of this assessment would require additional project-level assessment processes for specific development applications, where the exact nature, location and extent of shale gas development activities are clearly defined, in order to ground-truth features on-site. South Africa is in the advantageous position of being able to accumulate a broad baseline dataset and start building or supporting the institutions capable of collecting, managing and analysing that data in a responsible manner. Decisions regarding shale gas development should be considered in a 'step-wise' manner with baseline and on-going monitoring data repeatedly collected and fed back into the evidentiary base to critically test decisions, the efficacy of management actions and scientific assumptions.

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[3] The final phase of the SKA project is currently a high level concept and a detailed description is not available in the public domain. Conservative buffers were provided in order to map potential sensitivities resulting of the future phase of the SKA development in the Karoo region of South Africa.

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