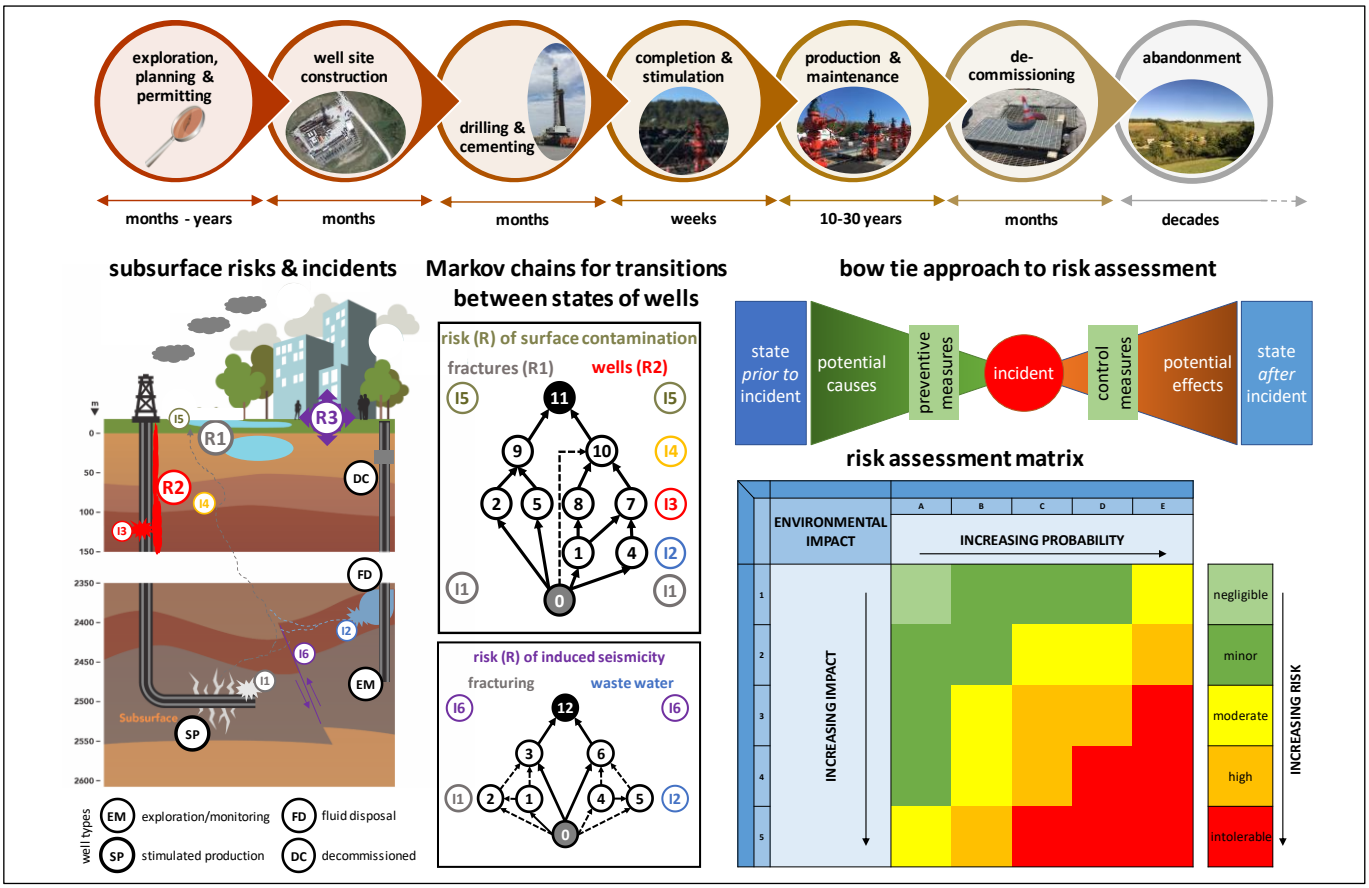
RECOMMENDATIONS FOR MINIMISING THE ENVIRONMENTAL FOOTPRINT OF SUBSURFACE SHALE GAS OPERATIONS

J. TER HEEGE



Background

The extraction of shale gas requires drilling of horizontal wells and hydraulic fracturing of the shale at multiple locations along the horizontal well section. Wells are artificial pathways that connect shale formations to surface facilities. Proper drilling, construction, operation and decommissioning is needed to prevent uncontrolled upward migration of potentially hazardous substances to the surface. Hydraulic fracturing is required to enhance permeability of the shale and obtain gas flow from the shales at economic rates. Injection of fracturing fluids leads to a fracture disturbed zone that may extend out of the shale formation and lead to upward migration of potentially hazardous substances. Moreover, small to medium magnitude earthquakes may be induced along pre-existing faults. Disposal of waste water from shale operations by injection in subsurface formation may lead to similar impacts.

Study

In this study, risks are assessed for subsurface operations during the full life cycle of a shale gas project, starting with an exploration phase and ending after decommissioning. Risks assessment was based on a three-component framework: (1) a Markov Chain-type approach to describe the transition from a properly operating shale gas well to absorbing states where detectable incidents effect human health, safety and natural environment, (2) a bow-tie approach to describe incidents that lead to a transition between states in terms of its causes and effects with associated preventive and control measures, and (3) a risk assessment matrix that classifies risks according to their probability of incident occurrence and impacts. Probabilities of incidents occurrence and impacts of incidents are based on available data from shale gas operations in the U.S.A. and Canada. Best practice operations and risk mitigation measures were discussed.

Results

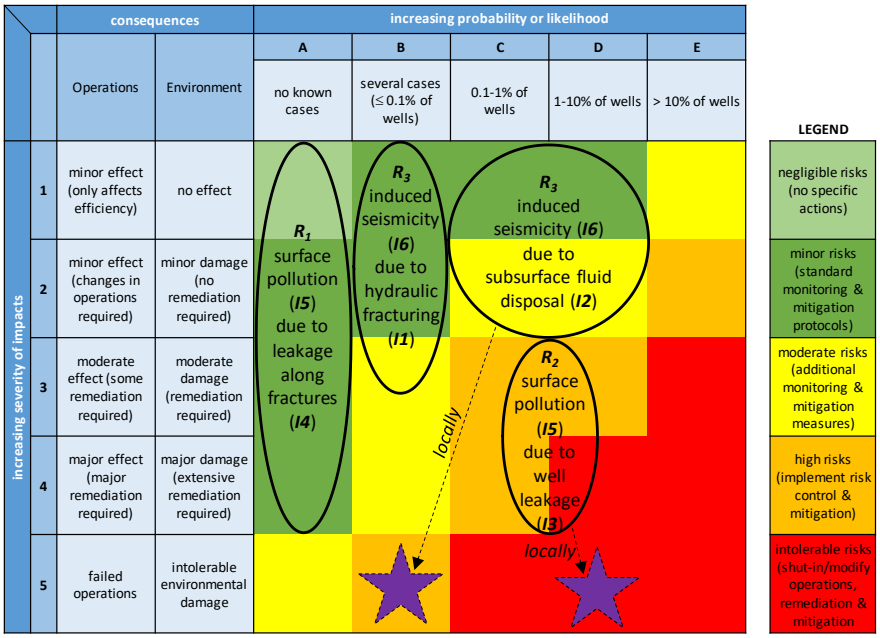
The risk assessment indicates that the main risks of operations in the subsurface are (1) contamination of shallow aquifers, groundwater or drinking water resources due to upward migration of hazardous substances along damaged or improperly constructed wells, and (2) structural damage as a result of induced seismicity associated with waste water injection or hydraulic fracturing. Probabilities are highest for out of zone fluid migration during stimulation or waste water injection, and for along well migration and leakage due to well damage. Decommissioned or abandoned wells are of particular concern. No evidence could be found for leakage along fracture disturbed zones up to drinking water resources if fractured wells are below ~1.5 km depth. Probabilities for problematic induced seismicity (M > 2) during waste water injection or hydraulic fracturing can be high, but impacts vary depending on local geology.

RECOMMENDATIONS FOR MINIMISING THE ENVIRONMENTAL FOOTPRINT OF SUBSURFACE SHALE GAS OPERATIONS

J. TER HEEGE

Science-based Recommendations

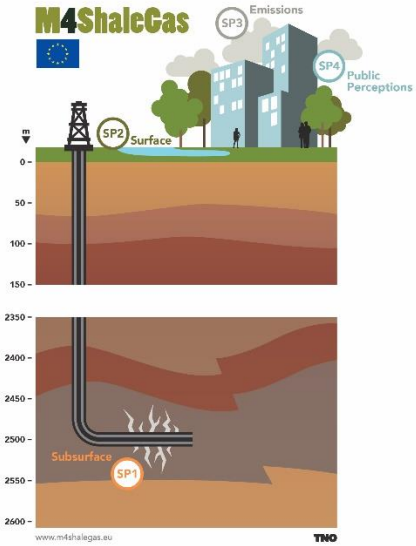
- Where possible, data on subsurface shale gas operations should be transparent and made publicly available to allow independent studies and reviews of environmental impacts and footprints.
- The 'natural baseline' (e.g., seismicity, groundwater composition) needs to be assessed in detail before operations have commenced, and changes during and following operations needs to be assessed relative to that baseline.
- Operations and risk mitigation measures must be tailored to individual sites and acknowledge local geological conditions and properties of shales and surrounding rock formations. In particular, the properties and stress state of the overburden and the faults in the vicinity of wells need to be assessed upfront to avoid or mitigate potential problems with well construction or problematic seismicity.
- Predictive models should be used to assess likely subsurface response to operations and potential impacts before commencement of operations.
- Best practice operations based on lessons learned from North American experience should be used. Where possible, the scale of operations (e.g., number of wells, fracturing jobs) should be minimized.
- Operations must be accompanied by independent monitoring using sensor networks tailored to the project phase. Monitoring should be used in traffic light systems (e.g., for seismicity, leakage) with pre-defined thresholds and mitigation measures that minimize the environmental footprint.
- Specific subsurface operations should focus on: (1) ensuring integrity of well barriers to avoid well leakage, (2) avoid interaction of fracture disturbed zone or injection-induced pressure front with pre-existing faults or offset wells to avoid induced seismicity and well leakage, (3) limit the injected volume of fracturing fluids or waste water in a single formation to avoid damaging induced seismicity.



*Risk assessment diagram indicating the relative importance of the main risks (**R1-R3**) associated with subsurface shale gas operations in North America. Risks for most operations following current practices are indicated by black circles. Locally, risks may be higher than average (as indicated by purple stars), i.e. some regions are more prone to risks associated with induced seismicity and well leakage than others.*

The Project

M4ShaleGas examines the potential environmental impacts and risks related to **shale gas** exploration and exploitation in Europe with the goal to build a technical and social knowledge base on best practices and innovative approaches for **m**easuring, **m**onitoring, **m**itigating, and **m**anaging these impacts.



4 sub-programs:

- SP1-subsurface
- SP2-surface
- SP3-air emissions
- SP4-public perceptions

Funding:
The project that has received funding by the European Union's Horizon 2020 research and innovation programme under grant agreement number 640715.

Horizon 2020 Topic LCE-16-2014:
Understanding, preventing and mitigating the potential environmental impacts and risks of shale gas exploration and exploitation.

Project duration:
1 June 2015 – 30 November 2017

Coordination:

Published December 2017 by M4ShaleGas Consortium