Impact of shale gas production on water resources in Noord Brabant, the Netherlands

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Abstract
The possible future exploration and production of shale gas in the province of Noord Brabant may have a considerable effect on water resources and therefore has to be studied. This study shows that the yearly water demand for drilling and fracking ranges from 0.58 to 1.35 Mm3/y. This is comparable to a major industrial water extraction. This amount cannot be supplied by local water distribution networks unless major adaptations are done. Also local surface water resources are insufficient, especially in the summer months. The vast amount of wastewater which is produced during the drilling and fracking will probably have a high salinity. Assuming a high salinity, the wastewater cannot be treated by the existing municipal wastewater treatment plants (WWTP) in the area or discharged in local surface waters. According to current Dutch mining regulations it is also not possible to inject the waste water in the deep subsurface. The only option is therefore special wastewater treatment and extensive water reuse. Eventually rest products (brine) will have to be transported and, if possible from an ecological standpoint, discharged into the sea.

Introduction
In order to guarantee the availability of safe drinking water in the Netherlands, groundwater sources need to be protected. New activities in the subsurface need careful consideration because of the possible impact on the groundwater quality and availability. The possible future exploration and production of shale gas in the province of Noord Brabant may have a considerable effect on water resources and therefore has to be studied. The main purpose of this study is to assess both the water demand during drilling and fracking stages and wastewater production during shale gas production from the Posidonia Shale Formation (Lower Jurassic) in Noord Brabant. An inventory of water resources has been carried out. Also the main options for the disposal or treatment of wastewater have been outlined.

Methods
Because only limited information from deep (> 2000 m) boreholes are available the assessment is based on scenarios developed in a previous stage by the Dutch Ministry of Economic Affairs. Based on the spatial distribution of so called ‘sweet spots’ within mature shale layers (see Figure 1), geological fault patterns and estimations of development rates, a long term 49-years forecast of water demand and wastewater production can be made. To achieve this, a geodatabase is designed to hold the spatial and temporal data. Using ArcGIS 10.1, Spatial Analyst and the ModelBuilder functionality a set of tools is designed to model the spatial and temporal distribution of well fields for the production of shale gas in Noord Brabant. Using index numbers from literature, the water demand and wastewater production can be determined.
The inventory of water resources is based on recent information from both the local water company Brabant Water, local water boards and the province of Noord Brabant. Options for wastewater disposal or treatment are drawn from literature.

**Results**

The results are clearly presented in the form of maps, graphs and video animations in ArcGIS showing the development on a yearly basis over a period of 49 years. The results of the study show that the water demand is only a small portion (0.39%) of the total yearly drinking water production in the study area and is comparable to the yearly abstraction of a large industrial water user.
The 49-years forecast for water demand is based on the up scaling of earlier studies by Halliburton (2011) and Godderij et al. (2014). In the first 33 years, shale gas production sites will be developed by drilling and fracking. From year 1 through 16 the water demand is approximately 1.35Mm³ per year. From year 17 through 33 the water demand will be less, 0.58 Mm³ per year (see Figure 2). The water demand has been compared to the regional water resources, i.e. drinking water from groundwater sources, surface water and WWTP effluent (Figure 3). During winter surface water is available but in the summer this will be insufficient. Due to the effects of climate change it is projected that there will even be more frequent and intensive shortages of surface water in the future. Because of the dense drinking water distribution
network, this water source may be appealing to oil and gas companies. However, this study shows that drinking water supply cannot be guaranteed during high peak demands. Also in most of the foreseen shale gas production areas the sustainable capacity of the groundwater abstraction plants is insufficient.

![Figure 3 Potential water shortages (light red) per municipality in m³/year during the first development period (year 0-16)](image)

During and after development of the production sites solid and liquid waste will be produced. The total amount of drill cuttings is estimated at 340,000 to 460,000 m³. This solid waste needs to be transported, treated and reused if possible. However, some of the cuttings may contain radioactive material or heavy metals limiting the possibilities of reuse.

After fracking a part of the used water flows back to the surface (Lutz et al., 2013). This part is estimated at 15% which amounts to 1.45 Mm³ during the total construction period in the first 33 years. Depending on the type of fracking technique this amount may be higher, 4.35 Mm³ in case of a ‘slick water’ fluid instead of a viscous fluid. Along with the produced gas or oil so called formation water will be produced from the shale. Based on assumptions made by the Dutch Ministry of Economic Affairs (Godderij et al., 2014 and Halliburton, 2011) we estimate a total of 3.6 Mm³ of formation water during the whole production period of 49 years, see figures 4 and 5 (Cirkel et al., 2014). However, a comparison with actual figures from Pennsylvania shale gas wells (Lutz et al., 2013) indicates that this amount may be higher, up to 34.2 Mm³ in the same period.
The discharge of flowback and formation water in surface waters or treatment by WWTP’s is not feasible from an ecological perspective and due to management regulations of the WWTP’s. The main concern is the high salinity which is estimated at 55-70 g/l (Verweij, 2003). Deep injection in the subsurface is also not possible due to regulations and possible risks of induced seismicity and leakage. Through new
treatment techniques the saline water may be reused for fracking purposes. However, supply and
demand will not be equal over time. Eventually rest products (brine) will remain which has to be
transported, treated extensively and, if even possible from an ecological standpoint, eventually
discharged in the sea.

Conclusions
Using ArcGIS it was possible to model the spatial and temporal distribution of water demand and waste
water production related to the possible production of shale gas in Noord Brabant. The possible future
exploration and production of shale gas in the province of Noord Brabant may have a considerable effect
on water resources. The produced wastewater (with diluted salts, metals, natural radioactive compounds
and hydrocarbons) is a potential threat to the environment. Also ground and surface water sources which
are used for drinking water production may be at risk. The management of the waste water from possible
shale gas production in the future needs to be scrutinized.

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