Seismic Hazard and Risk Assessment - Screening

Bleiswijk 1b - VDB-GT-05 / VDB-GT-06

Version 1

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SUMMARY

For the development of the Bleiswijk 1b licence (until 1 July 200 known as *winningsvergunning Bleiswijk 1b*, and since then *startvergunning Bleiswijk 1b*) a seismic hazard screening *(SDS = seismische dreigingsscreening)* as part of the *Seismic Hazard and Risk Assessment workflow* (Mijnlieff et al., 2023) was performed to confirm (or update) the previously established risks of seismicity during geothermal development of doublet VDB-GT-05/ VDB-GT-06. These risks were established previously by both a Seismic Hazard Risk Analysis Quickscan (Level 1) screening as well as a Location Specific Seismic Hazard Analysis (Level 2) (Tullip Energy, 2023a; Panterra, 2022).

The Seismic Hazard Risk Analysis Quickscan (Level 1) determined whether there is a risk that a soil vibration will occur as a result of geothermal energy extraction using a methodology that has been established by IF/QCon (Baisch at al. 2016) and resulted in a normalized score of 0.29, associated with a low risk (Tullip Energy, 2023a). The location specific Seismic Hazard Analysis (Level 2) also demonstrated that the likelihood of fault reactivation (and possible resulting seismicity) after 40 years of injection is close to that for zero injection (Panterra, 2022). Based on these studies the risk of soil vibration can be considered as negligible.

Out of abundance of caution and because guidelines for seismic hazard analysis have been changing in recent times, this project has been screened again following the latest Seismic Hazard Screening (SDS = seismische dreigings screening) methodology as described in Mijnlieff et al. (2023). This screening exercise reconfirmed the negligible seismicity risk for this project because of:

- the good coverage with good quality 3D seismic data,
- the good matrix permeability with proven injector-producer communication,
- the absence of overlap with other mining activities,
- the absence of overlap with the Ruhr Valley Graben area,
- the absence of with major relevant fault zones,
- the absence of faults with a potential for reactivation in its Geothermal Area of Influence (GT-AoI) as a result of injection.

NEDERLANDSE SAMENVATTING

Voor de ontwikkeling van de voormalige winningsvergunning Bleiswijk 1b (nu startvergunning Bleiswijk 1b) is een seismische gevarenscreening *(SDS = seismische dreigingsscreening)* als onderdeel van de *Seismic Hazard and Risk Assessment workflow* (Mijnlieff et al., 2023) uitgevoerd om de eerder vastgestelde risico's van seismiciteit tijdens geothermische ontwikkeling van doublet VDB-GT-05/ VDB-GT-06 te bevestigen (of bij te werken). Deze risico's zijn eerder vastgesteld door zowel een *Seismic Hazard Risk Analysis Quickscan (Level 1)* screening als een *Location Specific Seismic Hazard Analysis (Level 2)* (Tullip Energy, 2023a; Panterra 2022).

De *Seismic Hazard Risk Analysis Quickscan (Level 1)* heeft de IF/Qcon methodiek gebuikt (Baisch et al., 2016) en geresulteerd in een genormaliseerde score van 0,29, waar is geassocieerd met een laag risico (IPS, 2023). De *Location Specific Seismic Hazard Analysis (Level 2)* toonde ook aan dat de kans op breuk reactivering (en daaruit volgend mogelijke seismiciteit) na 40 jaar injectie dicht de kans van een scenario met nul injectie ligt (Panterra, 2022). Op basis van deze beiden studies kan het risico op bodemtrillingen als verwaarloosbaar worden beschouwd.

Omdat richtlijnen voor seismische gevarenanalyse de afgelopen tijd in ontwikkeling zijn geweest, en uit voorzorg, is dit project ook gescreend volgens de nieuwe Seismische Dreigings-Screening (SDS) methode zoals beschreven in Mijnlieff et al., 2023. Op grond van de volgende observaties bevestigt deze seismische dreigings-screening of SDS het eerdere, volgens de oude richtlijnen vastgestelde, verwaarloosbare seismiciteitsrisico van dit project:

1. 3D seismische gegevens van het project gebied zijn van goede kwaliteit,
2. Het geothermische reservoir heeft goede matrix permeabiliteit met bewezen communicatie tussen injector- en producer,
3. Er is geen overlap met andere mijnbouwactiviteiten,
4. Er is geen overlap met het Roer Dal Slenk gebied,
5. Er is geen overlap met een Major Relevant Fault Zones,
6. Er geen breuken zijn in het geothermisch invloedsgebied (GT-AoI) met potentie tot reactivatie als gevolg van reservoir injectie.

INTRODUCTION

IPS Geothermal Energy B.V., hereinafter referred to as IPS, operates as a license operator, on behalf of licenser 85 Degrees Renewable 3 & 4 B.V., hereinafter referred to as 85, a geothermal installation for geothermal heat extraction. IPS & 85 intend to realize a geothermal operation within the Bleiswijk 1b geothermal production area (former *winningsvergunning Bleiswijk 1b* and since 1-7-2023 *startvergunning Bleiswijk 1b*). The geothermal production plan (winningsplan Beiswijk 1b) of which was submitted to the Ministry of Economic Affairs and Climate Policy in June 2023 (IPS, 2023). The mining site is located at A.H. Verweijweg (near number 1a as there is no number yet), postal code 2651 LC in Berkel en Rodenrijs (municipality of Lansingerland) in the province of Zuid Holland. This mining location is located within a greenhouse horticulture area. The doublet to be realized in the Bleiswijk 1b geothermal production area concerns a new production well (VDB-GT-05) and injection well (VDB-GT-06), which will produce geothermal heat from the Nieuwerkerk Formation containing the Delft Sandstone and the package of Alblasserdam at 1815-2402 m depth.

Mining activities, including geothermal energy extraction, are associated with risks. Control and mitigation of these risks, such as the possible cause of seismicity, is of great importance in Dutch geothermal projects. Although the consensus is that the risk associated with the type of geothermal energy projects such as in Bleiswijk 1b – VDB 05/06 (i.e., low-enthalpy geothermal energy in matrix-dominated sandstone reservoirs) is low (e.g., TNO., 2019; Professors Panel, 2020; TNO-AGE, 2020), guidelines on how to properly assess this risk have been in development over recent years, resulting in a recent change from the *level 1 screening guidelines* (Baisch at al., 2016) to the current *Seismic Hazard and Risk Assessment* workflow (Mijnlieff et al., 2023). To asses if the previously established low seismicity risk for the Bleiswijk 1b project could change as a result of the new methodology, a full seismic hazard screening *(SDS = seismische dreigingsscreening)* was carried out and described in this report.

Guidelines for geothermal projects

To assess the risk of local seismicity for geothermal installation VDB-GT05/VDB-GT-06, seismic hazard screening *(SDS = seismische dreigingsscreening)* according to the workflow of figure 1 and 2 (Mijnlieff et al., 2023) was carried out.

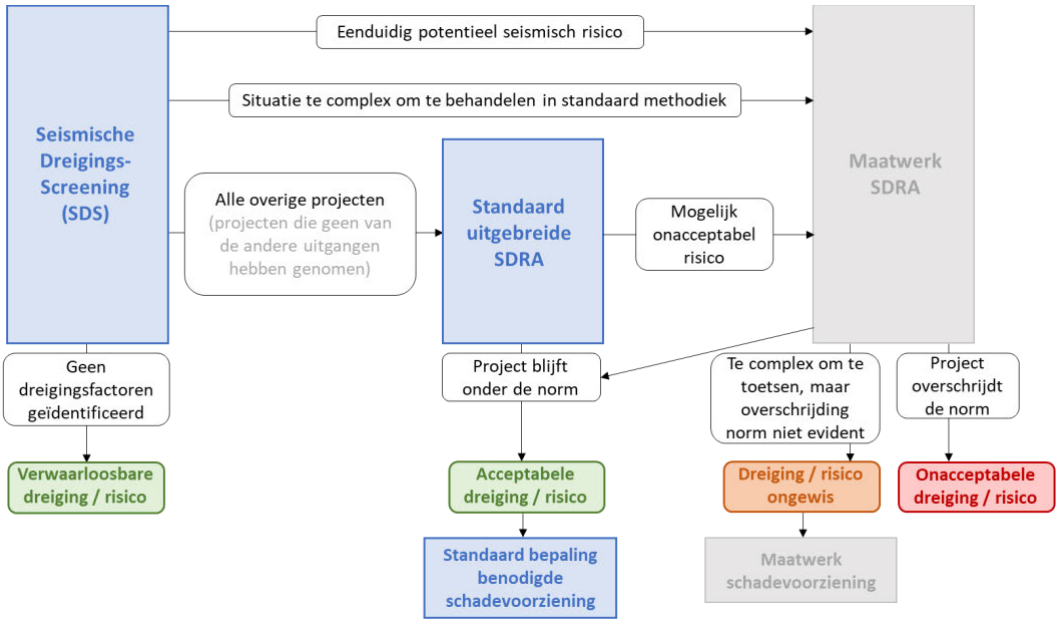

Figure 1. Schematic representation of the SDRA workflow. SDS = Seismic Hazard Screening, SDRA = Seismic Hazard and Risk Assessment (Mijnlieff et al., 2023)

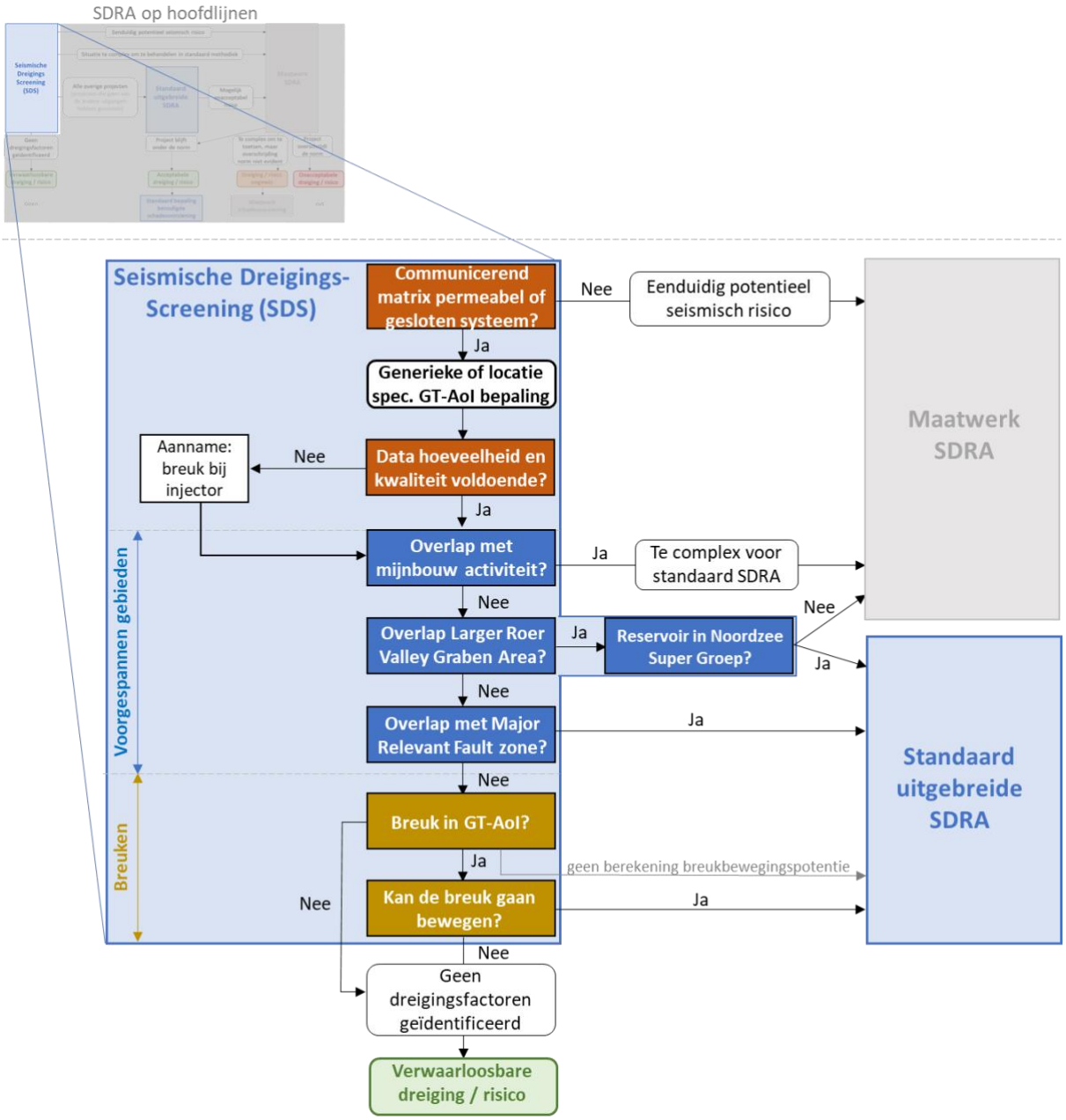

Figure 2 Schematic image of the SDRA showing the steps within Seismic Hazard Screening (SDS) in more detail (Mijnlieff et al., 2023)

With the argumentation in Table 1 the questions in the Seismic Hazard Screening (SDS) decision tree (Figure 2) were answered to arrive at the bottom green box labelled *Negligible Hazard / Risk* (Verwaarloosbare dreiging/ Risico).

Table 1: Answers and argumentation for the Seismic Hazard Screening (SDS) workflow (Figure 2) leading to the negligible risk assessment.

Decision tree question	Answer Y/N	Argumentation or reference
Reservoir communication in a closed or matrix permeable system?	Yes	Reservoir is the NieuwerKerk Formation with well-established matrix permeability and injector-producer communication in nearby wells.
Sufficient data coverage and quality?	Yes	Covered by good quality (high signal to noise ratio) 3D seismic survey, where horizon identification is easy and faults up to the seismic resolution can be identified.
Overlap with mining activity?	No	Nearest historic oil and gas activity at > 3.3 km distance to nearest influence area of mining activity
Overlap with Larger Ruhr Valley Graben?	No	Doublet VDB-GT05/06 is located in the West Netherlands basin, more than 48 km away from the nearest end of the Ruhr Valley Graben
Overlap with major relevant fault zone?	No	No relevant faults have been identified in the Schieland Groep in the Netherlands. The closest major relevant fault zone in the overlying Rijnland Groep is still more than 43 km away from the GT-AoI of doublet VDB-GT05/06
Is there a fault in the geothermal area of influence?	Yes	Plotting the Geothermal area of influence (Mijnlieff et al., 2023) on the top Nieuwerkerk Formation thickness map shows one faults exists within the Geothermal area of influence of doublet VDB-GT05/06
Can the fault slip?	No	Mohr-Coulomb Monte-Carlo simulation in a location specific seismic hazard assessment by Panterra (2022) for injector VDB-GT06 shows that the likelihood of fault reactivation after 40 years of injection is close to that for zero injection.

Results

Permeability system

The reservoirs of the Nieuwerkerk Formation have a well-established matrix permeability (Panterra, 2021). In the nearby geothermal heat extraction project of Bleiswijk 1b, stable production pressures and flow rates in the past years have shown good pressure communication in the Nieuwerkerk formation (Willems, 2012).

Geothermal Area of Influence

The determination method of the Geothermal Area of Influence (GT-AoI) is described in the new *Seismic Hazard and Risk Assessment for geothermal projects in The Netherlands* report by Mijnlieff et al (2023). This GT-AoI is defined by the zone within two buffers around the production and injection well at reservoir level (Mijnlieff et al, 2023). Because of the maximum deviation of these wells is 38°, buffers were established around the well TD. The buffer around the production well is 300 m (Mijnlieff et al, 2023). The buffer around the injection well is 0.7 x horizontal distance between producer and injector at well TD: *0.7 x 1074 = 752 m* (Panterra, 2021). The GT-AoI is the area that envelops these buffers (Figure 3). Note that the GT-AoI of VDB-GT05/06 overlaps with the GT-AOI of nearby doublet VDB-GT07/08. The *Seismic Hazard and Risk Assessment – Screening* of VDB-GT-07/08 is described in in separate report (Tullip Energy, 2023b).

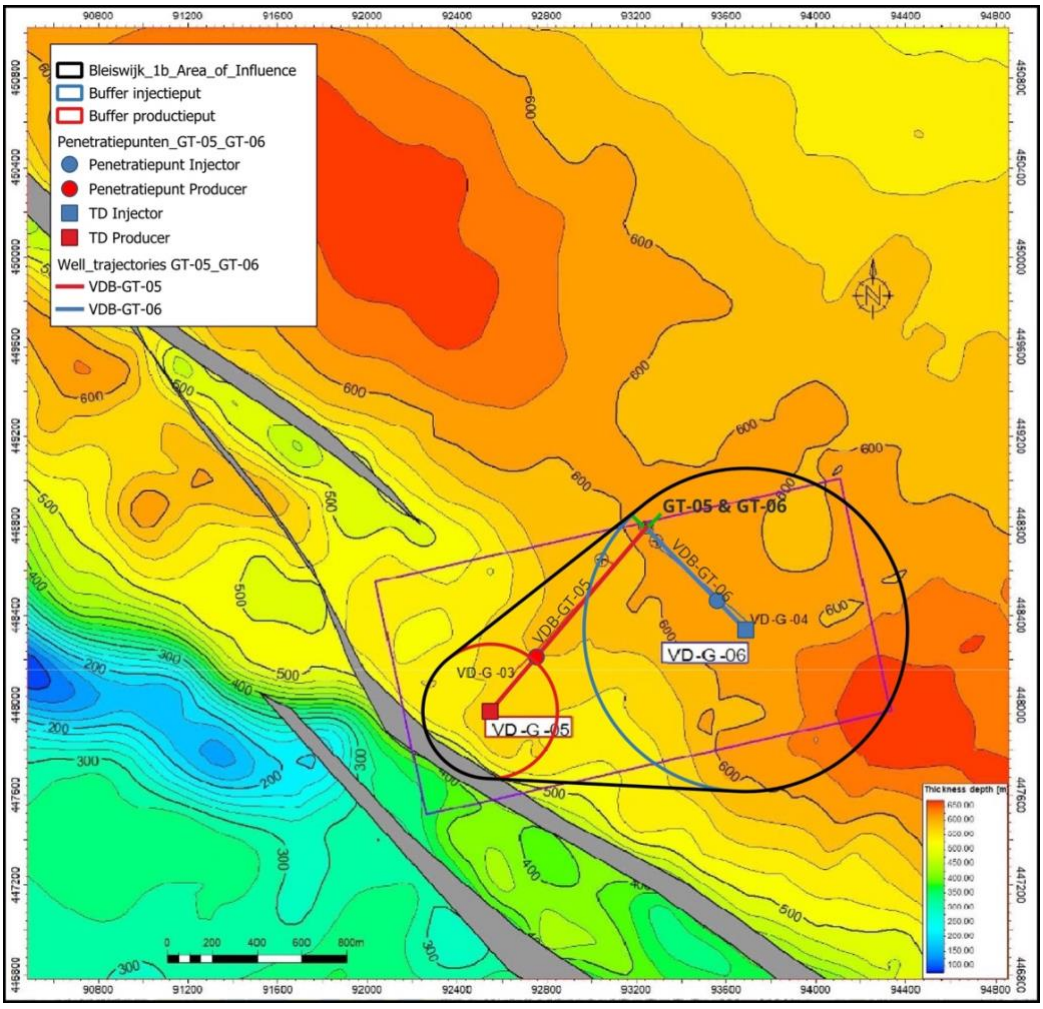

Figure 3 Geothermal area of influence according to methodology of Mijnlieff et al (2023) plotting on the top of Nieuwerkerk Formation thickness map with identified faults in the area (IPS, 2023).

Data Quality

The Bleiswijk 1b – VDB 05/06 project resides in the West Netherlands Basin which is almost entirely covered by good quality 3D seismic data (Fig 4). data in the *Geothermal Area of Influence (GT-AoI)* has a high signal to noise ratio, with easy horizon and fault identification (Fig 5).

Figure 4, 3D seismic coverage in the West Netherlands basin (NLOG, 2023a), with Geothermal Area of Influence and well trajectories of GT-05 and GT-06.

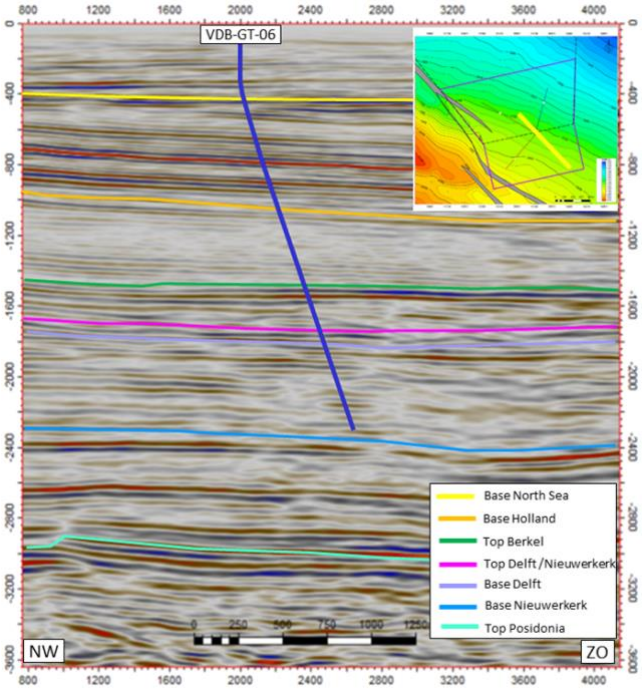

Figure 5 NNW-SSE seismic cross section along the existing injection well VDB-GT06, showing the good seismic quality (IPS, 2023).

Overlap with Oil and Gas fields

Figure 6 shows there is no (historic) oil or gas activity overlapping with the GT-AoI. The nearest oil or gas activity, as published for SHRA screening (NLOG, 202b), is the abandoned Berkel oil and gas field with the closet point of its buffer zone at 3.3 km distance from the southwestern border of the GT-AoI of doublet VDB-GT05/06.

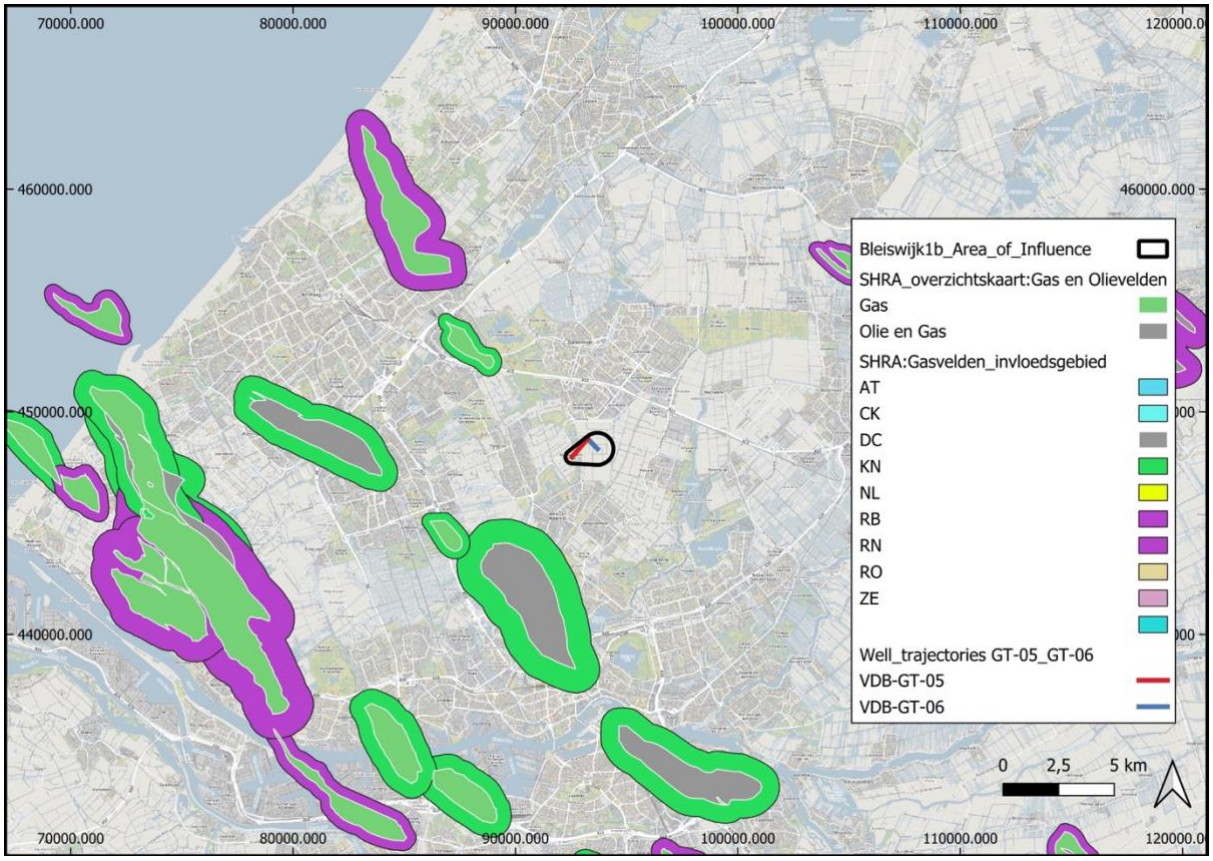

Figure 6 Map showing: 1) Gas and gas producing oil fields onshore The Netherlands, 2) Gas field AoI's (coloured by stratigraphic level) 3) GT-AoI of the Bleiswijk 1b - VDB 05/06 Project

Overlap Ruhr Valley Graben or Major Relevant Fault zone

Doublet VDB-GT05/06 is located in the West Netherlands basin, where the boundary of its buffer zone, as established by the GT-AoI determination, is located 48 km away from the nearest point of the Ruhr Valley Graben area (Figure 7). The Nieuwerkerk Formation, containing the reservoirs used for heat production by doublet VDB-GT05/06, is part of the Schieland Groep. Therefore, only major relevant faults of the Schieland groep are relevant for this assessment, and such faults have not been identified (Figure 7). For reference, the nearest fault in the overlying Rijnland Groep is located north of the GT-AoI at a distance of 43,7 km.

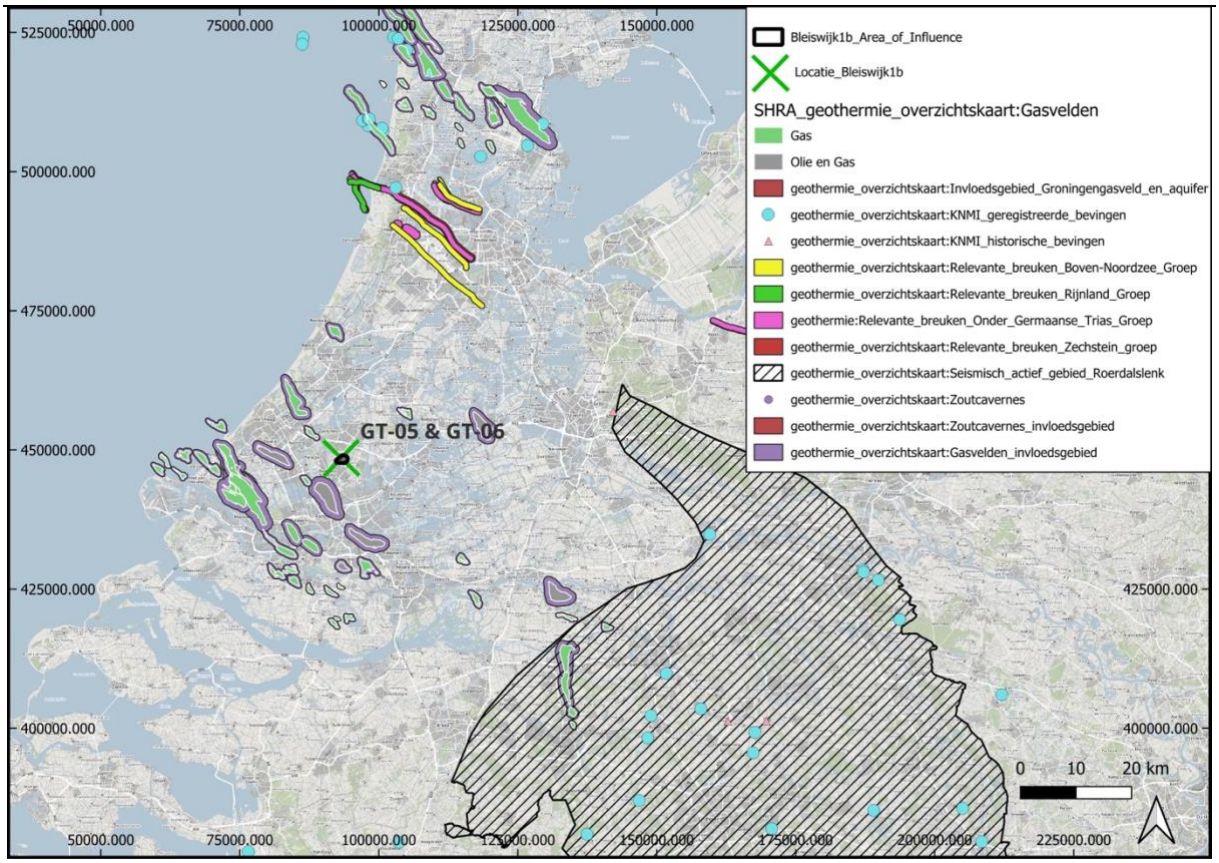

Figure 7: Map showing all tectonic earthquakes, the seismically active Larger Ruhr Valley Graben Area and the "major relevant fault zone trajectories including their uncertainty bandwidth (NLOG, 2023b).

Fault in geothermal area of Influence

One fault to the south of the producer well GT-05 was identified to be present just within the boundary of the Geothermal area of influence of doublet VDB-GT05/06 (Fig 3). The geomechanical behaviour of this fault was studied and modelled in the Location-Specific Seismic Hazard analysis for VDB-GT-06 by Panterra in 2022. This analysis demonstrated that the Shear Capacity Utilisation after 40 yrs at 220 m3/hr at 15°C is < 1 in 98% of the cases, a result similar to the result prior to start injection. Therefore, Mohr-Coulomb Monte-Carlo simulation has shown that the likelihood of fault reactivation is close to that of a zero-injection scenario (Panterra, 2022), translating to a negligible probability for fault activation.

Moreover, the expanding cold-water pool around injector VDB-GT06 would most likely reach producer VDB-GT05 well before it would reach the nearest fault (fig 3). In that scenario, producer VDB-GT05 would start to produce the injected cold water, leading quickly to a situation where no longer heat that can be economically extracted. This would result in the end of the project life and shut in of doublet VDB-GT05/06. After shut in of the injector, the cold front ceases to migrate to the fault and the injected could water will very slowly start to reheat, without the ability to reach the nearest fault and exert incremental stress to that fault.

Conclusions

Following the new Seismic Hazard Screening (SDS = seismische dreigings screening) method as described in Mijnlieff et al., 2023, this project has a negligible seismicity risk, because project benefits from these observations:

- There is good coverage and quality with 3D seismic data,
- There is good matrix permeability with proven injector-producer communication,
- There is no overlap with other mining activity,
- There is no overlap with the Ruhr Valley Graben,
- There is no overlap with a major relevant fault zone,
- There is no fault in its geothermal Area of Influence (GT-AoI) with the potential of fault reactivation as result of the proposed injection.

Therefore, the Seismic Hazard Screening (*seismische dreigings screening or SDS*) assessment according to the guidelines of Mijnlieff et al. (2023) confirmed negligible seismicity risk for this project as per previous analysis under the old guidelines.

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