

**KEM Innovation/Research Question (max. 4 pages + annex)**

**TITLE** *Liquefaction hazard and risk quantification*

**Objective**

Liquefaction is an effect which can occur in case of large intensity earthquakes (PGA, PGV) in combination with geologically recent uncompacted sandy/silty sediments at shallow depth, especially when these areas are loaded by heavy buildings or structures.

Currently, it has not been unambiguously excluded that liquefaction cannot occur as an effect of the production-induced earthquakes in Groningen. In addition, liquefaction is not part of the Hazard and Risk Assessment (HRA) model that is used to assess the seismic risk caused by the Groningen gas production.

The objective is to develop a module for the HRA model (the version developed by TNO), such that it can be used to evaluate the liquefaction potential above the Groningen field.

**State of the art, background**

Worldwide, much knowledge is available on the occurrence of liquefaction, i.e. the (local) conditions needed to trigger liquefaction and the kind of damage and number of casualties that may result.

In the Netherlands, NAM has conducted research together with partners on methods to quantify the liquefaction hazard and related risks. This has resulted in an assessment method suitable for Groningen and a refined liquefaction potential map of Groningen, eliminating liquefaction as a risk in some areas and pinpointing areas with a higher risk due to the subsurface geology.

However, liquefaction is not part of the HRA model. In addition, the work on a Groningen specific liquefaction method is still ongoing (e.g. Green et al., 2019 and 2020) and new data on the shallow subsurface is continuously collected. Combining these new liquefaction insights and data and implementing these in the HRA model will allow for a more thorough and realistic assessment of the liquefaction potential in the Groningen region.

**Research Question**

1. Is there currently a method available to assess the occurrence of liquefaction in the Groningen region and can it be implemented as a separate module in the HRA model (the version developed by TNO)?
2. Using the liquefaction module, most recent HRA model version and updated subsurface database, what is the liquefaction potential in the Groningen region?
3. Is it possible that for Groningen type earthquakes (PGA's, PGV's) liquefaction occurs, possibly resulting in lateral spreading? This was observed in the Meuse levees as a result of the Roermond earthquake in the Netherlands. If so, what effect can be expected for buildings and infrastructure in Groningen?

**Deliverables expected**

A liquefaction module, that can be implemented in the HRA model (version developed by TNO).

A report answering the above research questions and describing the liquefaction module.

**Timeline**

Start in 2020.

**Expected use**

The results will be the basis for extending the Groningen model train with liquefaction risk assessment.

Results will be used to inform the public and professional community as questions were raised by the public.

Results will help to better define the NPR loading condition to be anticipated in the strengthening program.

**Expertise and tools preferred for the team**

Geotechnical, Geological, Structural, Safety approach.  
Access to Database of liquefaction damages and casualties.  
Experience in writing code.

**Quality assurance, Organisational and communication requirements**

Experienced scientists in collaboration with Dutch groups, active in the field (a.o. NAM funded research).

**References**

NAM, Liquefaction sensitivity of the shallow subsurface of Groningen, 2016. <https://nam-feitenencijfers.data-app.nl/download/rapport/2eaac4bd-95be-42d8-90d2-399eaebd367a?open=true>

Green, R. A., Bommer, J. J., Rodriguez-Marek, A., Maurer, B. W., Stafford, P. J., Edwards, B., Kruiver, P.P., de Lange, G. & Van Elk, J. (2019). Addressing limitations in existing 'simplified' liquefaction triggering evaluation procedures: application to induced seismicity in the Groningen gas field. *Bulletin of Earthquake Engineering*, 17(8), 4539-4557.  
<https://link.springer.com/article/10.1007/s10518-018-0489-3>

Green et al (2020) Liquefaction Hazard of the Groningen Region of the Netherlands due to Induced Seismicity, *Journal of Geotechnical and Geo-environmental Engineering*, in press

M. Korff, Wiersma A., Meijer, P, Kloosterman, F. de Lange, J. van Elk D. Doornbos, 2015, Liquefaction mapping for induced seismicity in the Groningen gas field, *ICEGE paper, Christchurch conference*.

*European Liquefaction project results* (<http://www.liquefaction.eu/>)