

Progress report Seismicity studies Heiligerlee

15 June 2018

KNMI

19 November 2017: observed an unusual seimic signal which was later (mid December 2017) determined as an event that occured in the Heiligerlee cavern field. This initial location was close to HL-K at a depth corresponding to the depth of the cavern. Large uncertainty (>500m) in all directions. The location of the quake was not precise enough to indicate a cavern and a precise depth because (1) determining arrival times was ambiguous and (2) a 3D velocity model was not included in the analysis.

A revised report by KNMI dated 5 March 2018 identified four events in a time lapse of 60s. The preliminary epicentre of the main event was situated on top of the Heiligerlee salt dome at a depth of maximum 1.5 km. The location was based on manual picking of P and S-wave arrivals and a 1D velocity model.

Further studies needed and currently ongoing:

- Acquire the local 3D velocity model and use it to locate the Winschoten events with greater accuracy.
- Determine the magnitude and/or seismic energy of the 19 November 2017 Winschoten events.
- Perform a moment tensor inversion of the events (at least the largest one) to assess whether the moment tensor contains a large isotropic component.

Reviewed the design of a dedicated seismic monitoring system in Heiligerlee to supplement own network. Indicated to keep a closer watch on the Heiligerlee cavern field until the local seismic netowork is in place.

Gasunie

December 2017, following the observed event of 19 November 2017: reviewed production data and carried out sonar in HL-K. Revealed no anomalies.

Cooperation with AkzoNobel on further investigative work.

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December 2017 / January 2018, following the observed event of 19 November 2017: engaged with specialist consultants Arup (principal consultant on seismology) and DEEP.KBB (consultant specialized in salt mining/leaching). Next to that, the micro-seismicity experience of Hengelo was incorporated (supported by Salt technologies consultant K-UTEC).

Cooperation with Gasunie on further investigative work.

Started 4 streams of investigative work:

- 1. Review of production data and execution of sonar in HL-H. Production data did not reveal anomalies. Sonar HL-H revealed an anomaly at a depth of approx. 1060-1080 m.
 - Review of a falling of a pipe string in Hengelo which caused a seismic event: The estimation of the seismic moment of the event and the kinetic energy released by the fall can give insight on the correlation between seismic and kinetic energies. This will help in the modelling of the effect of a falling block in HL-H.
 - A suite of sensitivity analyses are currently ongoing to estimate the effects of different sizes/shapes of a falling block in HL-H in terms of magnitude of induced seismic event.
 - Consequently, a block size comparable with the anomaly found by sonar measurements will be modelled to better investigate whether this could be related to the 19/11/2017 event.

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- 2. Literature review and modelling studies.
 - Generally two types of seismic events: micro-earthquakes and blocks falling. They differ in terms of frequency content and source focal mechanism.
 - Seismic hazard can be anticipated through analysis of the magnitude-frequency distribution of seismicity → Need to detect and locate events with magnitude down to -1.
- 3. Recognition that a more accurate local seismic network is necessary to supplement the KNMI network. Network design was completed and reviewed by KNMI, specialist contractor subsequently appointed (Magnitude/BakerHughes).
 - Network comprises four geophone string positions at HL-B, HL-K, HL-G and HL-H and one hydrophone string at HL-H. Expected location (x,y,z) accuracy in the cavern field approx. 50-60 m and detection limit magnitude -1
 - Installation currently ongoing, expected operation Q4 2018. Modular extension of the network possible if necessary / required.
- 4. Risk assessment / bow tie analysis (to be completed once seismic measurements are available)
 - Following results of all of the above streams, initially primarily the literature survey, a (preliminary) list of top events is made along with a bow-tie model.

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Current status:

Completed: Literature review and KNMI report review

Ongoing: Further KNMI work and modelling of falling block and development of seismic monitoring network.

