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Shear wave velocity for the upper 30 m: Combining a 3D voxel model and seismic CPTS for the Groningen gas field, the Netherlands.

Roula Dambrink (1), Jan Gunnink (1), Jan Stafleu (1), Ger de Lange (2), and Pauline Kruiver (2)

(1) TNO - Geological Survey of the Netherlands, the Netherlands (roula.dambrink@tno.nl), (2) Subsurface and Groundwater Systems, Deltares, the Netherlands

The Groningen gas field in the Netherlands is one of the largest gas fields of Europe and has been in production since the 1960's. Due to the progressive depletion of the reservoir, induced seismic activity has increased in recent years. In 2012, an earthquake of magnitude 3.6 initiated further research in prediction and management of risks related to man-induced earthquakes. Last year the government decided to reduce the gas extraction for this reason. One of the topics of concern is the large difference in earthquake-related damage to buildings which, in addition to the distance to the epicenter, appears to be also related to the composition of the shallow subsurface.

To improve the spatial distribution of Shear Wave Velocities (Vs) in the shallow subsurface, used for hazard prediction, the Geological Survey of the Netherlands and Deltares constructed a Vs_{30} map of the upper 30 m of the gas field. In this map a high-resolution geological model (GeoTOP) is combined with seismic cone penetration tests (SCPT) from the area. The GeoTOP model is a 3D voxel model of the upper 50 m, in which each voxel (100x100x0.5 m) is attributed with lithostratigraphy and the most likely lithological class (peat, clay, fine sand, etc.). To obtain statistical distributions (with mean and standard deviation) of Vs for each combination of lithostratigraphical unit and lithoclass, 60 SCPTs were analyzed. In this way, it was possible to assign a specific Vs to each voxel in the model. For each voxel in the stack of voxels that covers the upper 30 m (i.e. 60 voxels), a Vs value was randomly drawn from the statistical distribution of the lithostratigraphical – lithoclass combination it belongs to. The Vs_{30} for each voxelstack is then calculated using the harmonic mean of the Vs of the 60 voxels. By repeating this procedure 100 times, an (average) Vs_{30} map and the uncertainty in Vs_{30} has been constructed.

Using the procedure described above we were able to delineate zones with distinct Vs_{30} characteristics: areas containing predominantly soft Holocene deposits with low Vs_{30} and areas with predominantly stiff Pleistocene deposits with high Vs_{30}, complemented with the uncertainty in Vs_{30}. The incorporation of the high resolution geological model resulted in a large improvement compared to the previously used Vs_{30}, which was a simple interpolation of Vs30 from a limited number of CPTs and SCPTs. This new procedure also gives the opportunity to study the role of the upper subsurface in site amplification predictions. Using this new method, risks related to gas extraction in urban areas can be better managed and predicted.