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An approach to construct a Netherlands-wide ground-motion amplification model

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Local site conditions can strongly influence the level of amplification of ground-motion at the surface during an earthquake. Especially near-surface low velocity sediments overlying stiffer seismic bedrock modify earthquake ground motions in terms of amplitudes and frequency content, the so-called site response. Earthquake ground-motion site response is of great concern because it can lead to amplified surface shaking resulting in significant damage on structures despite small magnitude events. The Netherlands has tectonically related seismic activity in the southern region with magnitudes up to 5.8 measured so far. In addition, gas extraction in the Groningen field in the northern part of the Netherlands, is regularly causing shallow (3 km), low magnitude (Mw max= 3.6), induced earthquakes. The shallow geology of the Netherlands consists of a very heterogeneous soft sediment cover, which has a strong effect on seismic wave propagation and in particular on the amplitude of ground shaking.

The ambient seismic field and local earthquakes recorded over 69 borehole stations in Groningen are used to define relationships between the subsurface lithological composition, measured shear-wave velocity profiles, horizontal-to-vertical spectral ratios (HVSR) and empirical transfer functions (ETF). For the Groningen region we show that the HVSR matches the ETF well and conclude that the HVSR can be used as a first proxy for earthquake site-response. In addition, based on the ETFs we observe that most of the seismic wave amplification occurs in the top 50 m of the much thicker sediment layer. Here, a velocity contrast is present between the very soft Holocene clays and peat on top of the stiffer Pleistocene sands.

Based on the learnings from Groningen we first constructed sediment type classes for the Dutch subsurface, each class representing a level of expected amplification. Secondly, the HVSR curves are estimated for all surface seismometers in the Netherlands seismic network and a sediment class is assigned to each location. Highest HVSR peak amplitudes are measured at sites with the highest level of amplification of the sediment classification. Based on this correlation and the presence of a detailed shallow geological model at most sites in the Netherlands, a simplistic

approach is presented to predict amplification at any location with sufficient lithologic information. With this approach based on the shallow sediment composition, we can obtain constraints on the seismic hazard in areas that have limited data availability but have potential risk of seismicity, for example due to geothermal energy extraction.