Velocity profiles extension for the seismic station of STEIN

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This report summarizes an update of the site characterization summarized in GeoExpert ag (2009). In particular, the velocity profile is extended at depth, by keeping the surface velocity profile from the site-characterization fixed within a limited range. The applied method is the Hybrid Heuristic Search algorithm (HHS), an inversion technique that estimates P- and S-wave velocity profiles using the H/V curve from earthquakes (Nagashima et al., 2014). It is based on the diffuse field theory proposed by Kawase et al. (2011) and can be applied at sites characterized by different levels of seismicity (Nagashima et al., 2014, Chieppa et al., 2023).
The HHS inversion algorithm was applied at more than 50 sites of the Swiss Seismic network to improve the resolution of the subsurface. At these sites, the P- and S-wave velocity profiles were estimated by inverting the H/V curve from earthquakes that were computed by using the S-wave arrivals of local and regional earthquakes, recorded around each investigated area. The chosen sites were selected according to the availability of passive and/or active site characterization investigations (Michel et al. 2014, Poggi et al. 2017, Hobiger et al. 2021). This information was used to define the initial seismic velocities, thicknesses and densities of the shallowest layers of the initial velocity model. Ten deep layers are added at the end of the shallow layers to improve the resolution of the subsurface. These layers adjust during the inversion and explore the parameter space with a variability of 100% from the initial value attributed to the seismic velocities and to the thicknesses. The initial thickness of these layers is set to 50 m, the density is constant using the half-space value found in site characterization investigation and the P- and S-wave velocities are set to increase with depth up to a maximum of 6200 and 3500 m/s, respectively. The search for the best model is performed by the HHS algorithm according to the shape of the H/V curve from earthquake recordings and the initial parametrization.
Some variability is also allowed to the shallowest layers to fit the inverted H/V curve at high frequency. For the shallow layers, first a variability of 20% is allowed to the seismic velocities, thickness and density values and then, if the fit between the estimated H/V curves and the H/V curve from earthquakes is not good, this value is raised to 50% for all layers above the half-space from site characterization analysis.
A visual selection of the best models is then performed by comparing the inverted H/V curves with that obtained from earthquakes. In case all estimated H/V curves from inverted profiles fit the H/V curve from earthquakes over the entire frequency range, a second criteria is applied. This criteria considers the fit of Rayleigh- and Love-wave dispersion curves from the inverted profiles to those from site characterization analysis, which are not used as input by the HHS algorithm. In case of STEIN station, using 20% variability the inverted models fit the H/V curve from earthquakes and the Rayleigh-wave dispersion curve (Figure 1). A rather good fit is obtained for the empirical amplification function.
The final models, calculated according to the equations used for the computation of V_P (Nagashima et al., 2021), are shown in dark gray in Figure 1. In Figure 1, we show (*a*) H/V curves from earthquakes, (*b*) inverted velocity profiles down to 4 km and (*c*) their zoomed-in view down to the depth available from site characterization. In the same figure, we also show (*d*) the synthetic and measured Rayleigh -wave dispersion curves, and (*e*) the SH-wave transfer functions from the inverted velocity profiles along with the amplification function obtained from empirical spectral modelling (ESM, Edwards et al., 2013).
The quarter-wavelength (QWL) representation is shown in Figure 2 for the estimated velocity models of Figure 1. According to the quarter-wavelength computed at depth (Figure 2 – top

row) and taking into account a frequency which is half the fundamental peak (f_0 = 0.8 Hz), a conservative estimate of the reliable investigation depth for the site of STEIN is equal to 2463 m. We might also extend a maximum depth of investigation to two times the QWL value (4927 m), as the QWL approach can be considered conservative.

Network: CH
Station Name: STEIN (Stein am Rhein, SH)
Installation date: 29.08.2003
Type of instrument: Trillium Compact 120s (HHZ, HHN, HHE)
Swiss Strong Motion Network (SSMNet): no
Type of site characterization measurement: -
Depth of site characterization analysis: 75 m
Number of layers in the site characterization profile: 10
Number of recorded earthquakes: 303
Resulting Vs30 and uncertainty: 369 ± 10 m/s
Resulting depth of engineering bedrock (H800) and uncertainty: 87 ± 51 m.
Soil class according to SIA261: C
Soil class according EC8: B

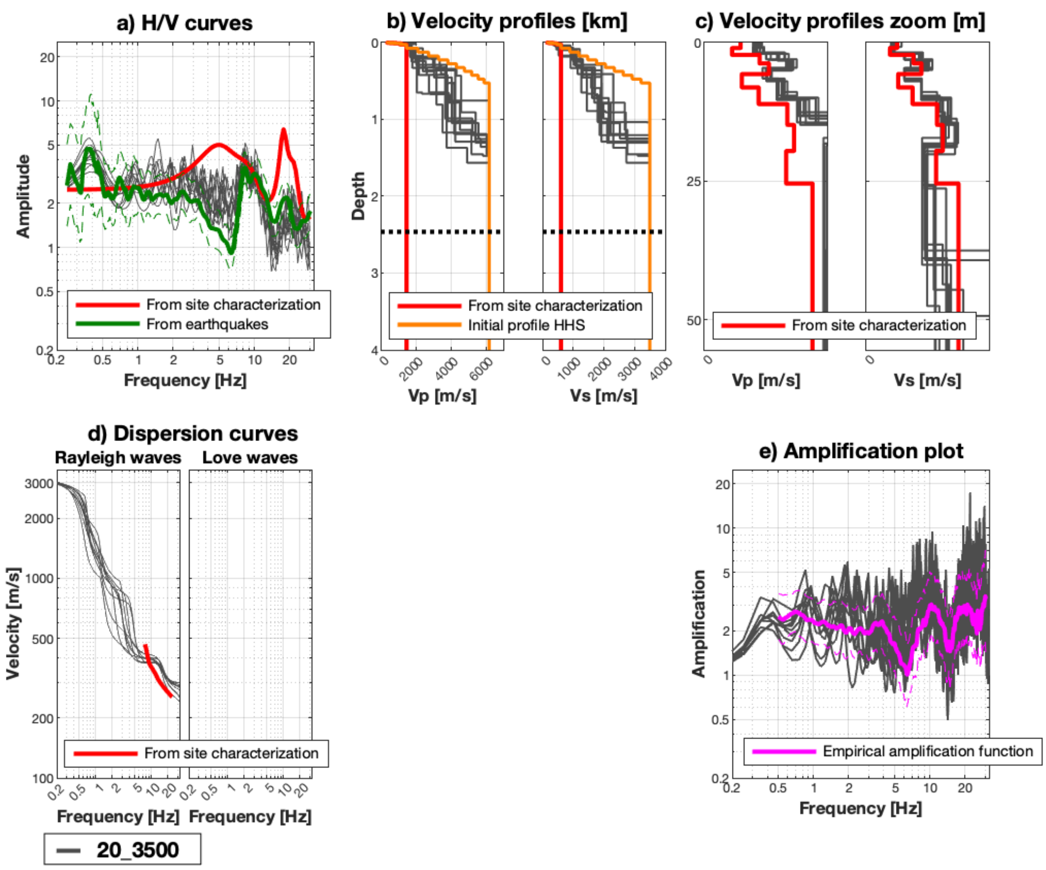

*Figure 1: Estimated models from the HHS inversion for seismic station STEIN. The models estimated by the HHS algorithm are shown in dark gray. In the velocity profiles plots (b), the dotted and dashed horizontal lines correspond to the QWL depth at a frequency of 0.5*f_0 (= 0.4 Hz) and to 2 times the QWL depth, respectively.*

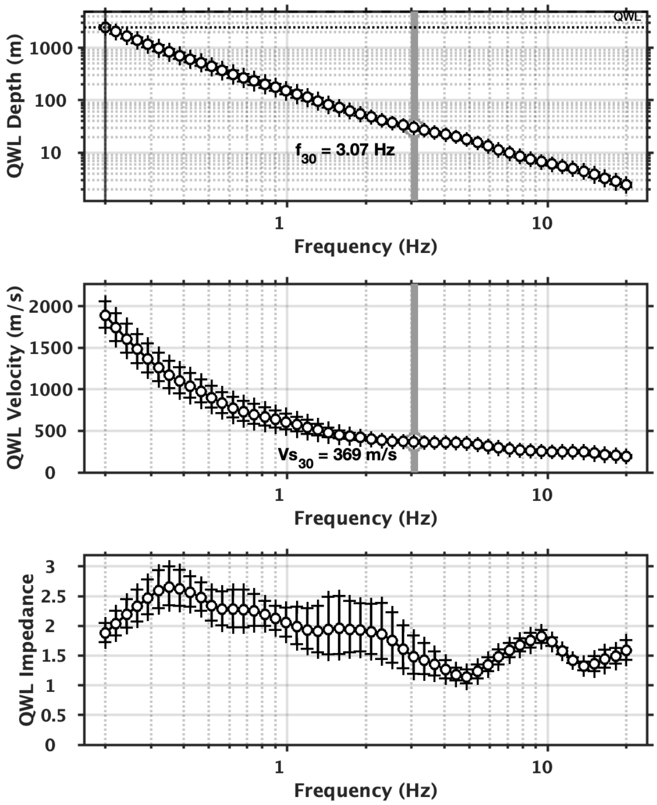

Figure 2: Quarter wavelength representation for the best models generated by the HHS inversion (top: depth, center: velocity, bottom: inverse of the impedance contrast). The grey band and the grey circle mark the frequency (top row) and the V_s (central row) at 30 m depth. The dotted and dashed horizontal lines in the top row correspond to the QWL depth and to 2 times the QWL depth at a frequency of 0.4 Hz (vertical solid line in black), respectively, as defined in Figure 1.

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