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Thresholds for earthquake-induced hydrological changes in sedimentary aquifers: a record from 9 earthquakes and 107 boreholes in central New Zealand

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A dense hydrogeological network in central New Zealand has recorded groundwater fluctuations from 12 years of seismic events. Hydrological data over the past 15 years were assessed in 107 boreholes at depths of 4 – 405 m. Nine seismic events (M$\geq$5.9) occurred at near- to far-field distances of 10 – 913 km, shaking the sedimentary aquifers at a wide range of 10^{-4} to 10^{3} J/m^{3} seismic energy densities.

The earthquakes produced 258 detectable hydrological responses, exhibiting different polarities (rise or fall), amplitudes (2 to 820 mm, -859 to -2 mm) and timescales (15 min to day [s]). Shaking parameters were calculated from 28 proximal GeoNet broadband seismometers, providing local estimates of peak ground acceleration (PGA) and velocity (PGV), Arias intensity, and spectral amplitudes. ShakeMap model solutions, utilising ground motion prediction equations (GMPEs), were also acquired at borehole sites. Continuous oceanic tidal responses of 38 boreholes were derived using Baytap08, with temporal transmissivity and earthquake-induced changes estimated from tidal properties. The earthquake-induced changes to groundwater level and tidal response are used to infer those events which caused aquifer deformation and changes to the groundwater flow regime.

A transient (15 min to 2 hr) / permanent (15 min to day [s]) deformation boundary is observed when shaking reaches $\sim$1 %g PGA. As well as defining thresholds at which hydrological changes occurred, the central New Zealand dataset provided an opportunity to examine aquifer ability in resistance to the effects induced by earthquakes. Where monitoring is dense and continuous, the absence of responses under certain levels of shaking is equally informative and helps delineate causative processes. On-going work utilises data mining to assess the contribution of seismic, hydrological, and geological parameters to earthquake-induced hydrological changes in sedimentary aquifer systems.