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Field Trials of Periodic-Sinusoidal Slug Tests for Aquifer Properties and LNAPL Transmissivity

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Background/Objectives. Periodic oscillations of a solid cylindrical slug in a well can create water-level fluctuations represented as a series of sine waves that will propagate to nearby observation wells. Timed movement of the slug is converted to a series of short-term pumping/injection rates that, with recorded pressure head fluctuations in all wells, serve as inputs to aquifer test analysis software to obtain aquifer transmissivity, storativity, and other hydraulic properties. Trial tests performed in 2010 on a glacial outwash aquifer at a USGS research site produced aquifer transmissivity values within 10% of those determined via performance of a 45-hour constant-rate pumping test (Lundy, 2014). The objective here was to extend the application of the oscillating slug method to estimate LNAPL transmissivity using similar software, given a suitable method for separating the LNAPL response from the aquifer (water table) response.

Approach/Activities. Additional trial tests were performed at the USGS research site and two other sites using control and observation wells containing both LNAPL and groundwater. Recorded head fluctuations were filtered to remove low-frequency background noise to improve separation and identification of the sine-waves representing the aquifer response, and smaller amplitude waves believed to represent the LNAPL response. To estimate smaller oscillating pumping/injection rates for the LNAPL, we assumed the repeating sine-wave sequences represent a steady-state condition. Trial tests at three LNAPL sites have now been performed, representing the moderate-K glacial outwash aquifer, a low-K regolith (saprolite) on metamorphic bedrock, and a high-K limestone karst aquifer in a tidal environment. We speculate that low-amplitude, low-frequency LNAPL waves revealed in a second filtering are delayed relative to the water table waves by hysteretic changes in LNAPL saturations; this relationship deserves further testing to confirm.

Results/Lessons Learned. During initial testing at groundwater-only wells, filtering pressure head response from small background water table fluctuations is necessary. When both LNAPL and groundwater are present, at least one additional filtering step is needed to separate the LNAPL and aquifer responses. Filtered data are filtered a second time, and when tidal influences are present, a third filtering may be needed. Multiple filtering reveals a smaller-amplitude, longer-period sine wave oscillation, here attributed to LNAPL flow. The delayed secondary response by the aquifer is not clearly observed when mobile LNAPL is absent. A longer LNAPL wave period requires a longer duration of the field test. Varying the rate of insertion and withdrawal of the slug to find an optimum rate is done before the test. Adjusting the rate in the middle of the test creates more background noise that requires additional filtering to remove. Assuming different, but steady-state pumping/injecting rates for both fluids, successive approximations of the ratio of aquifer/LNAPL transmissivity are used to estimate LNAPL rates, producing LNAPL transmissivity values more comparable to transmissivity values calculated using baildown test data.