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Dynamics of an unconfined aquifer

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Most rainwater infiltrates into the ground, where it flows towards a stream slowly within the aquifer. However, the stream discharge increases rapidly during a rain event, and decreases slowly during droughts.

To reconcile these observations, we use a thin tank filled with glass beads to simulate this process in a simplified laboratory experiment. A drilled pipe located above the tank reproduces a homogeneous rain, which infiltrates into the porous medium. Groundwater exits the aquifer through one side of the tank. The resulting hydrograph resembles field measurements: the discharge increases quickly, and decays slowly.

A theory based on Darcy's law and the shallow-water (or Dupuit-Boussinesq) approximation, reveals two asymptotic regimes. At the beginning of a rain event, the river discharge increases linearly with time, with a slope proportional to the rainfall rate to the power of $3/2$. Long after the rain has stopped it decreases as $1/t^2$, as predicted by Polubarinova-Kochina (1962). These predictions compare well against our experimental data.