Report as of FY2007 for 2006HI138B: "Fate and Transport of Contaminants in a Stream-Aquifer System"

Publications

Project 2006HI138B has resulted in no reported publications as of FY2007.

Report Follows

Problem and Research Objectives

Streams and rivers transport sediments, natural organic matter, and land-applied chemicals. Many drinking water wells located on riverbanks induce a portion of the river water to flow to well screens through the aquifer. The pumped water is a mixture of groundwater and induced infiltration water. This process is known as riverbank filtration. River water contaminants are removed through straining, colloidal filtration, chemical precipitation, sorption, and microbial degradation. Also, dilution is possible if the respective contaminants in surface water are lower in concentration than those in groundwater. Riverbank filtration is a viable and low-cost water treatment technology for water utilities. As this natural filtration process works somewhat differently than engineered filtration systems, knowledge of the dynamic behavior of the system for various flow regimes of the river is important for safe and sustainable operation. Knowledge of changes in water quality due to bed clogging and scouring would enable the utilities to deal with filtrate quality during flooding or periods of heavy sedimentation. Scouring and clogging of the stream bottom affect the rate of infiltration and the fate of the soil-resident or percolating contaminants. A clogged streambed would have a slower infiltration rate and a more reduced condition than a normal streambed. Scouring during floods can introduce oxygen-rich water into the aquifer, thus disturbing established redox conditions. It is not easy to study these processes in field settings because of high velocity in streams during high flow events and because of our inability to measure redox and clogging processes accurately.

The objectives of this project are as follows:

1. To retrofit a recirculating flume to serve as a model stream channel and attach a column to the stream bottom to simulate conditions in an aquifer under the riverbed (the bed will contain sediments similar to that found in stream bottoms)
2. To study the impact of velocity profile on the scouring and deposition processes of particles
3. To study the redox conditions in the column as a function of stream velocity, particle deposition rate, natural organic matter content of the recirculating water, and the travel distance
4. To examine the effect of channel bed scouring on the change in the redox conditions of the upper portions of the column and its impact on water quality

Methodology

Retrofitting of Flume/Column

A small recirculating flume (15-cm wide), available in the Hydraulics Laboratory of the Civil and Environmental Engineering Department of the University of Hawaii at Manoa , was retrofitted for this research. The flume can be tilted to change the bed slope. A mechanically operated flap controls the water level on the bed. A 10-cm-diameter column attached to the bed of the flume channel simulates the porous media that are typically present between the river and the well screen. A peristaltic pump draws water at a set rate from the bottom of the column. A layer of silica sand simulates the riverbed. A pump provides water at the upstream end of the flume, and the drainage water from the flume is recycled back. Clogging of the bed is simulated by adding fine particles such as silica into the flow stream. Scouring is simulated by increasing the flow velocity by enhancing the channel bed slope.

Velocity Profile and Scour/Deposition Study

The sediment composition and flow velocity in the recirculation system can be adjusted to have distinct particle distributions in the flow systems. For each set of experiments, the corresponding heads in piezometers at various depths below the channel bed will be examined. Effort is being made to use a recently acquired particle image velocimetry system to obtain the velocity profile in the flume. The velocity profile obtained from laboratory measurements will be used to calculate bed shear stress for the channel.

The boundary shear stress, using calculated shear velocity and the density of water, is a good indicator of whether a particle can be lifted from the bed.

Clogging of the streambed due to particle transport into the column of aquifer sand can be examined using measurements of the flow resistance (or head loss) in the column. For an unclogged column with uniform material, the head gradient is generally linear. However, if fine particles accumulate on the channel floor, most of the head loss will be experienced in that zone.

Redox Dynamics

Water samples collected from the channel and various sampling ports in the column will be analyzed for dissolved oxygen, oxidation-reduction potential, dissolved organic carbon (DOC), and selected redox-sensitive species such as nitrate, nitrite, ammonium, iron, and manganese. Frequent measurements of the velocity profile and the size distribution of the flowing particles will give a good indication of the small particle load in the flow stream. Head loss due to particle clogging of the column surface will be correlated with the sizes of the flowing particles. Redox parameters of the flowing water and the sampled water will be correlated with the velocity profile in the channel, particle size distribution, DOC in the channel water, and water extraction rate through the column.

*Scouring Effect on Redo*x

Once a redox regime in the column is established based on a flow regime in the channel, DOC content of the water, and the sediment load in the channel water, conditions in the channels will be changed to that of incipient scour. We will examine head loss in the column and monitor select redox parameters in the column. Following a given period of disturbance (i.e., simulation of a flood passage), we will examine the time needed to re-establish a redox condition that is conducive for denitrification and for the degradation of other chemicals.

Principal Findings and Significance

The construction and retrofitting of the flume were completed. Other tasks have not been initiated as the flume was not ready until recently. A no-cost extension has been requested, and other tasks will be carried out in the next reporting period.