Report for 2002NE28B: Investigation of Directional Hydraulic Conductivites of Streambed and Their Roles in Stream-aquifer Interactions

- Articles in Refereed Scientific Journals:
  - Chen, X. H., 2003. Analysis of pumping-induced infiltration in gaining streams. Journal of Hydrology 275 (1-2), 1-11. Chen, X.H., and X. Chen, 2003. Effects of aquifer anisotropy on the migration of infiltrated stream water to a pumping well. Journal of Hydrologic Engineering (in press). Chen, X.H., and Y. Yin, 2003. Semi-analytical solutions for stream depletion in partially penetrating streams. Ground Water (in press). Chen, X., and X. H. Chen, 2003. Stream water infiltration, bank storage, and storage zone due to flood stages in channels. Journal of Hydrology (in press). Chen, X. H., and L. C. Shu 2003. Streambed hydraulic conductivity for rivers in south-central Nebraska. Journal of the American Water Resource Association (in review). Chen, X.H., and X. Chen, 2003. Sensitivity Analysis and Determination of Streambed Leakance and Aquifer Hydraulic Properties. Journal of Hydrology (in second review).
- Conference Proceedings:
  - Chen, X.H., 2002. Determination of streambed hydraulic conductivity using extended permeameter methods. American Water Resources Association Annual Summer Conference Ground Water/Surface Water Interactions, July 1-3, 2002, Keystone, Colorado, p. 529-534. Chen, X. H., and Xi. Chen, 2002. Analysis of infiltrated stream water to a pumping well. American Water Resources Association Annual Summer Conference Ground Water/Surface Water Interactions, July 1-3, 2002, Keystone, Colorado, p. 511-516.

Report Follows

Problem and research objectives:
Problem: Streambed hydraulic conductivities and their roles in stream-aquifer interactions. Objectives: 1) utilization of permeameter methods for determination of in-situ streambed hydraulic conductivities in Nebraska's key rivers and their tributaries; 2) collection of streambed hydraulic gradients (their upward or downward directions and magnitude) in various river reaches for determination of the losing/gaining river segments; and 3) development of a stream-aquifer model to evaluate the role of streambed hydraulic conductivity in stream-aquifer interactions.

Methodology:
We developed standpipe methods for measurement of streambed hydraulic conductivities directly in river channels. The standpipes were used to measure streambed hydraulic conductivities along a number of directions over vertical profiles of stream sediments, including vertical, horizontal, and oblique directions. Measurements were conducted in the Platte, Republican, and Little Blues rivers of Nebraska, including 20 transects across the river channels and 198 tests.

This study also includes a modeling activity to analyze the role of streambed hydraulic conductivities in stream-aquifer interactions, particularly the streamflow depletion due to groundwater extraction during irrigation seasons. Semianalytical solutions were developed and MODFLOW and MODPATH of USGS were used for the analysis of stream depletion, bank storage, and the migration of infiltrated stream water to a pumping well.

Principal findings:
Sandy streambeds commonly occur in the Little Blue River, the Republican River, and the Platte River in south-central Nebraska. Low-permeability silt and clay layers locally occur in the river channels. The vertical hydraulic conductivity (K_v) for the top 40-cm sediment of sandy streambeds is usually greater than 20 m/day, and the most common range is from 30 to 40 m/day. It can reach as large as 98 m/day. In contrast, the average K_v for the silt and mud layer is about 1.5 m/day. Statistical analyses indicated that the K_v values of sand and gravel in the Platte and Republican rivers have the same mean but the K_v values from the Little Blue River have a different mean compared to those from the other two rivers.

The sediment of the top 40-cm sand and gravel layers seems to be relatively uniform in grain size by field observation. Nevertheless, anisotropy of streambed conductivity is still determined in it. The ratio of the horizontal to vertical hydraulic conductivity is about 4; this ratio is as large as 7.6 for sand and gravel that contain small shale fragments. These thin and flat fragments have apparently reduced the vertical hydraulic conductivity of the streambed.

The horizontal hydraulic conductivity (K_h) values of the alluvial aquifers in the Republican and Platte River valleys determined using pumping tests are similar to the K_h values of sandy streambed determined using permeameter tests. However, the K_v values of the alluvial aquifers are much lower than those of the top sandy streambed. This is interpreted as the layers of silt and mud in the sand and gravel sediments leading to a stronger anisotropy than a single layer. The K_v values of the sandy and silty streambeds determined in this study provide essential information in the analysis of the anisotropy of interbedded sediment layers. Because the sediments in the rivers are essentially the same materials as the alluvial aquifer, the K_v values of the alluvial aquifer that have been determined by aquifer tests are probably good references for the K_v values of the entire thickness of streambed materials.

Simulations results using stream-aquifer models indicate that in a partially penetrating river, the pumping-induced stream infiltration moves downward beneath the streambed. Thus, the vertical hydraulic conductivity of the sediments in river channels has a significant role in controlling the interactions between groundwater and stream water. Migration of infiltrated stream water in the aquifer is often very slow and it requires a long time for the water to get at the pumping well.