HYDRAULIC-CONDUCTIVITY MEASUREMENTS OF REATTACHMENT BARS ON THE COLORADO RIVER

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Construction of Glen Canyon Dam and subsequent hydroelectric power generation has altered the flow regime on the Colorado River, changing physical and chemical characteristics of the downstream flow. The Bureau of Reclamation is the principal agency empowered with preparing an Environmental Impact Statement (EIS) of the impacts of Glen Canyon Dam on downstream resources in Glen and Grand canyons. Interim flow criteria were implemented during the EIS preparation period as required by the Grand Canyon Protection Act of 1992.

Recent work has determined that return current channels along the reattachment bars have become the highest areas of productivity for organic matter of all bar environments as a result of accumulation of organic matter and finer grained sediments during the interim flows (Stevens 1991). Geochemical analysis of groundwater within reattachment bars has indicated that progressive nutrient storage is produced in return-channel environments (Parnell and Bennett 1994). Flow modeling coupled with solute transport modeling is required to model cycling of nutrients between reattachment bar groundwater and the river. Determination of hydraulic conductivity is a necessary variable in the calculation of groundwater velocities used in flow modeling. The pneumatic slug test was determined to be the best method to measure hydraulic conductivity of Colorado River reattachment bars.

Purpose and Objectives

The purpose of this study was to determine the flow and transport parameters of the deposits that comprise reattachment bars on the Colorado River. The primary objective of the study was to determine the hydraulic conductivity of reattachment bar deposits. A secondary objective was to assess the spatial variability of hydraulic conductivity within reattachment bar deposits.

Study Area

The reattachment bars used in this study are located at river miles 43, 72, and 194 relative to Lee's Ferry on the Colorado River in Glen Canyon and Grand Canyon. Reattachment bars form as the river current leaves a constriction of the channel formed by a debris fan from a side canyon flood. The main current separates from the channel at a location referred to as the separation point and reattaches at the reattachment point (Figure 1A). This causes the formation of a recirculation zone with a return current along the channel boundary. Within the recirculation zone a reattachment bar deposit forms with a return-current channel incised along the cliff side of the bar (Figure 1B).

Well Installation

Fifty-eight wells were drilled on transects both perpendicular and parallel to the river on three separate reattachment bars. The wells were installed by pumping river water into a 3/4-inch diameter jetting tool inserted into a 2-inch diameter drive casing. The tool was capped in such a manner that water was forced up and to the side, carrying cuttings through the casing. The casings were driven to a depth of 10 feet for the shallow wells at each cluster, and 20 feet for the deep wells. Wells were assembled using 1.25-inch diameter schedule 40 PVC casing; each well had a 0.0025-cm slot screen 1.5 feet above the total depth of the jetted hole. The well pipe was inserted inside the 2-inch diameter drive casing. The 2-inch diameter drive casing was then withdrawn, allowing the sediment to collapse around the 1.25-inch well casing.

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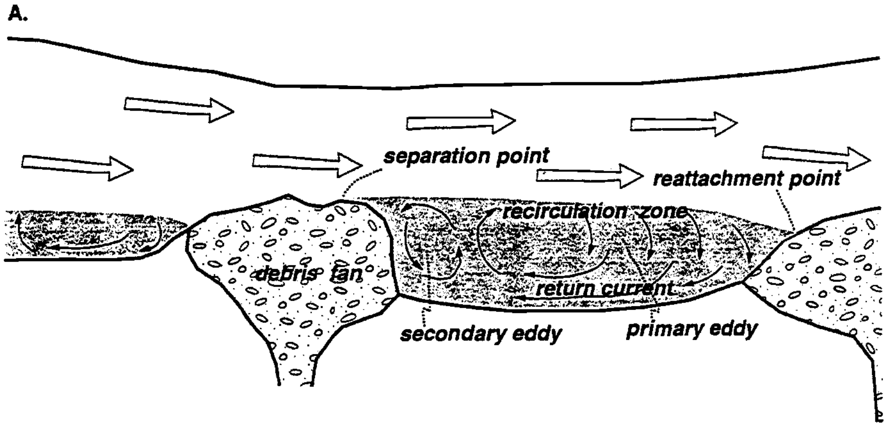

Figure 1A. Recirculation zone currents.

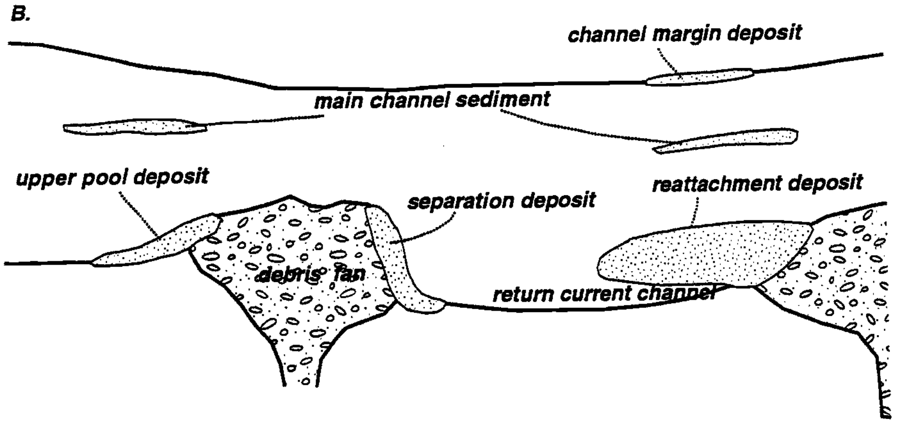

Figure 1B. Recirculation zone deposits (after Schmidt and Graf 1991).

Slug Tests

The slug test is a timely and cost effective method of obtaining a reliable estimate of aquifer parameters. However, in highly transmissive aquifers, data acquisition with a mechanical slug test is impractical because of the rapid recovery of the water level after slug removal. An alternative to the mechanical slug test is the pneumatic slug test. Detailed analysis shows that there is no statistical difference between estimates of hydraulic conductivity between these two methods (Levy and Pannell 1991).

The pneumatic slug test is conducted using a pneumatic wellhead, which consists of a 4-inch diameter PVC pipe with ports for air injection, an air gauge, and transducer emplacement. In addition, the wellhead is equipped with a 4-inch ball valve to release air pressure. The wellhead is equipped with a reducer and metal clamps to attach the wellhead to the well pipe. Data are recorded using a pressure transducer and a 2-channel datalogger. Use of the datalogger allows for the rapid acquisition of data in a short time.

The pneumatic slug test uses air to lower the elevation head of water in a well, replacing it with a pressure head. The air can be compressed, or it can be supplied by a simple bicycle pump. Head change is read off the air gauge, which is calibrated in inches of water. After a new static water level has been reached, the datalogger is initiated and the air pressure is released by turning the ball valve. The head change within the well is measured with the pressure transducer and recorded by the datalogger, producing a head change versus time curve (McLane et al. 1990). Three tests were conducted at each well in order to assure statistical validity of hydraulic conductivity values at each site.

Slug Test Analysis

All slug tests were analyzed using the Bouwer and Rice method for unconfined aquifers (Bouwer and Rice 1976). The Bouwer and Rice method uses an empirical equation relating the effective radius over which head difference between the static water level of the aquifer and the well is dissipated, to the geometry of the well and the aquifer. The solution is achieved by fitting a line to the straight line portion of the drawdown versus time curve (Figure 2). The value of y is then substituted into the Bouwer and Rice equation, yielding a value for hydraulic conductivity. The Bouwer and Rice solution had particular utility for this study because the wells were partially penetrating, with a 1.5-foot long screen in an aquifer with approximately 40 feet of saturated thickness.

Because hundreds of aquifer tests were conducted, solutions were accomplished using an automated well analysis program. Because there were two well geometries, shallow and deep, the only variables changing between wells were static water level and initial head difference. This enabled the solutions for hundreds of trials to be obtained in hours, rather than days.

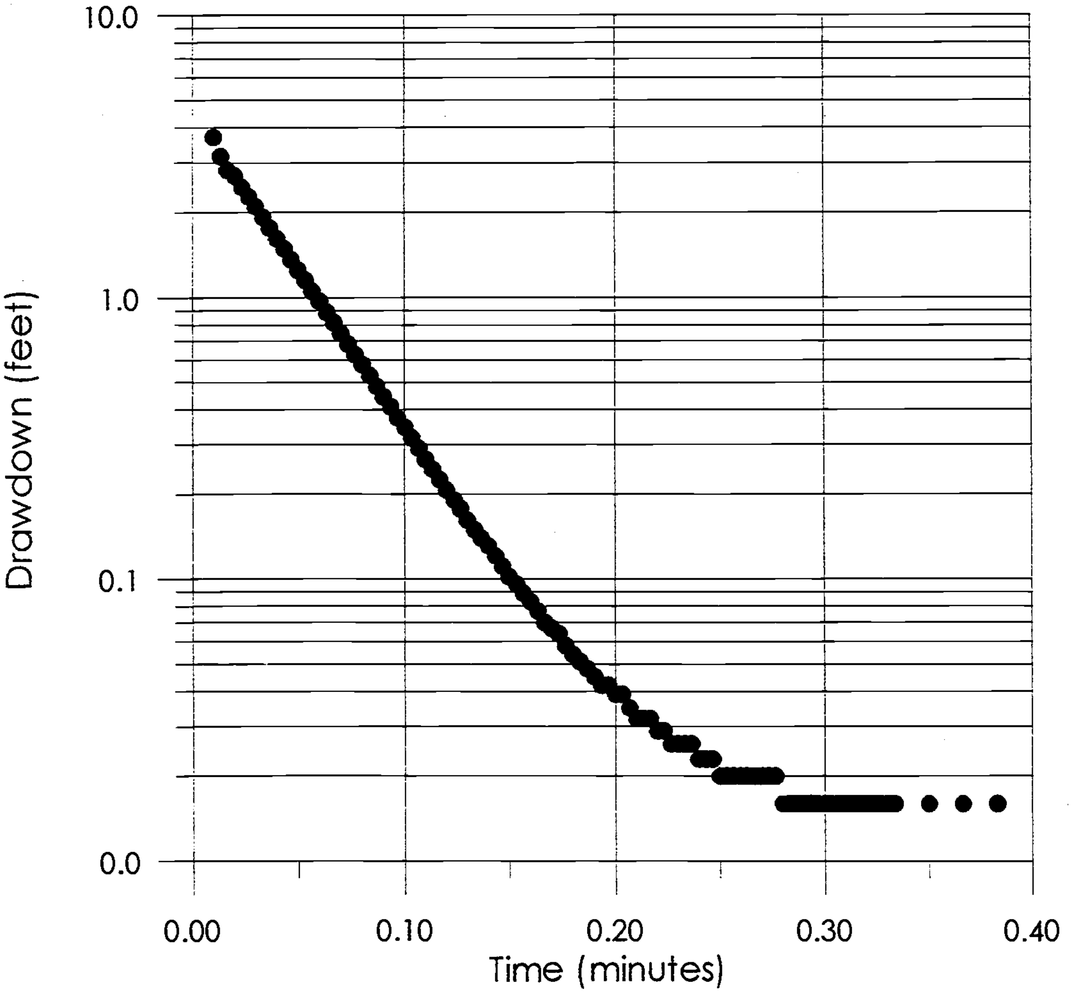

Figure 2. Time versus drawdown curve.

Summary

The values of hydraulic conductivity obtained in the study indicated a spatial variability across the reattachment bars. The largest values of conductivity were generally located at wells in the beach face. Lower conductivities were obtained for wells in the mid-beach and return-current channels. This corresponds roughly to the Schmidt and Graf model for eddy driven deposition of sand bars. In their model, the coarsest sediments would be located in the beach face where the currents are highest; these are the locations of the highest hydraulic conductivities. The lowest hydraulic conductivity values are located in the return-current channel wells where the eddy current was the slowest when the sediments were deposited.

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