Groundwater flows to the San Joaquin River

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Groundwater may represent only a fraction of one percent of the river's total annual flow.

San Joaquin River near Vernalis.

The San Joaquin River is the key outlet for water discharges in the San Joaquin Valley. Wastewater from productive agriculture in the Valley is of prime concern because of its potentially adverse impact on water quality in the river. Intense debate on this issue culminated in the issuance of Water Quality Order 85-1 by the State Water Resources Control Board in 1985. A secondary purpose of this order was establishment of water quality objectives, which could potentially result in regulation of agricultural discharges in the Valley.

In an effort to define these objectives, we constructed a mass balance model that considers all discharges (industrial, municipal, and agricultural) and diversions in a 60.4-mile stretch of the San Joaquin River. As defined here, agricultural discharges include tail-water return flows, accidental spills during cultural operations, subsurface tile drainage, and shallow groundwater flows.

Groundwater flows, unlike other discharges, cannot be directly measured and must be estimated from available data describing variations in shallow groundwater elevations, river stage, and the ability of the soil to transmit water. Alternatively, groundwater flows could be estimated indirectly from mass balance measurements of surface flows. Indirect measurements of this type, however, result in accumulation of errors in measuring surface flows into groundwater flows, resulting in physically unreasonable values. This study represents an attempt to quantify groundwater flows to the San Joaquin River for the stretch from Lander Avenue near Stevinson to Airport Way Bridge near Vernalis, using pertinent data from water agencies describing factors controlling groundwater flow.

Concept

Hydrogeologic features of the river basin in the study area formed the basis of the model. A shallow clay layer 50 to 70 feet below ground surface was considered the lower boundary of the flow system. Although this shallow clay layer is probably discontinuous in the horizontal plane, detailed analyses of wells in the region indicate that deeper confined and unconfined aquifers generally have hydrostatic pressures less than that of the shallow water table and appear to contribute little, if anything, to flow in the river. Moreover, as will be discussed later, increasing the depth of flow by a factor of four or five changes the groundwater flow by an amount less than the probable error associated with estimates of hydraulic conductivity.

East and west boundaries of the flow system ranged from 3 to 5 miles on both sides of the river. Establishment of these boundaries was dependent on the number of available water table elevations required to adequately define the slope of the water table, or hydraulic gradient, toward the river. The cross-sectional area available for flow was determined by the depth of the shallow clay layer below the water table.

To model the flow system, we devised a series of 107 "flow tubes" simulating magnitude and direction of groundwater flow. Flow tubes were assumed to be north-south, east-west, or diagonal combi-

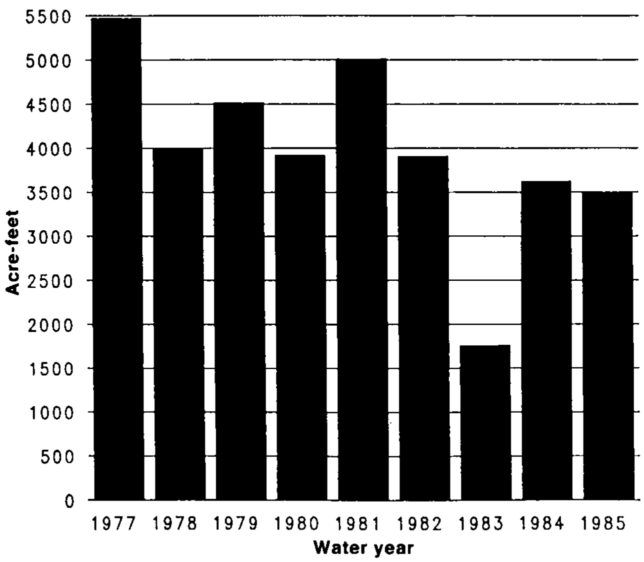

Fig. 1. Estimated groundwater flow in the study reach for the water years 1977-85, using data from a variety of water agencies. The estimates are based on a model incorporating "flow tubes" simulating hydraulic gradients.

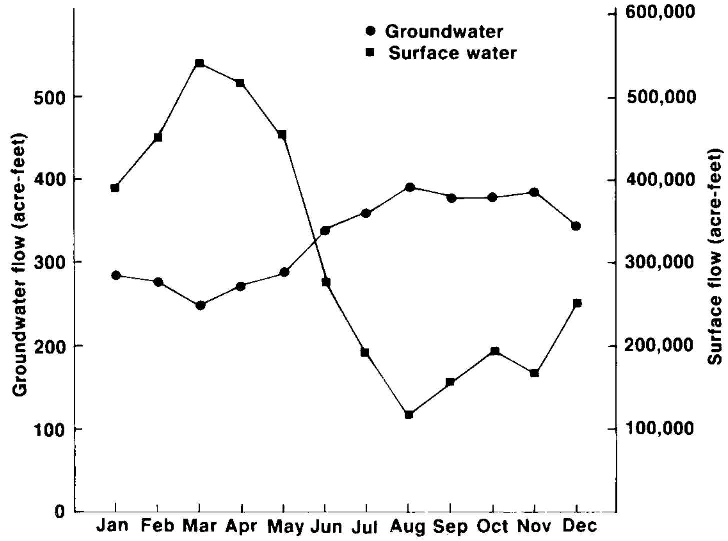

Fig. 2. Surface water flows in the San Joaquin Valley may vary as much as 75 percent during the season, groundwater flows only about 20 percent. Typically, total river flow reaches a peak in the spring, when groundwater flow declines to a minimum.

nations of sections within townships, and each tube was oriented in the direction of the hydraulic gradient and roughly perpendicular to the river. Tubes were adjacent to one another along the entire river reach and can be visualized as rows of squares. The ability of the soil within the flow tubes to transmit water was computed from the average of hydraulic conductivities estimated from available drillers' logs. Estimates of hydraulic conductivity at each logged well were based on a depth-weighted average of conductivities assigned to each soil textural layer. With this hydrogeologic information for each flow tube, it was then possible to determine contributions of groundwater flow to the river.

Model development

A model incorporating the flow tubes was developed to estimate monthly groundwater flows into the river for nine water-years of record (1977-85). Hydraulic gradients, which provide the driving force moving water in soils, were estimated from water table elevations near the river and water surface elevations in the river for each flow tube. Occasionally, hydraulic gradients indicating river discharge into adjacent water table aquifers occurred during high river flows resulting in water surface elevations in the river exceeding adjacent water table elevations.

Groundwater flows within each flow tube were estimated by multiplying the average area of its flow, the average hydraulic conductivity of the area, and the hydraulic gradient. The flows in individual tubes, added together, represented the total groundwater flow into the river.

Annual groundwater flows

While estimates of annual groundwater flow in the 60-mile reach (fig. 1) are subject to improvement, the scarcity of data presently available makes further refinement unlikely. Other analytical approaches currently being investigated, however, could yield somewhat different values in terms of the total groundwater flow. The primary source of uncertainty in the data and the analysis is properly defining the regional hydraulic conductivity of the soil. Assuming physically reasonable maximum and minimum values for hydraulic conductivities in each flow tube results in estimates of annual groundwater flow of at most an order of magnitude larger or smaller than those given in figure 1.

In addition, errors caused by underestimating the depth available to groundwater flow may increase estimated flow by two or three times. Revising estimates of flow depth and hydraulic conductivities to the largest possible values, however, has only a limited effect on groundwater flows relative to surface water flows.

For the nine-year record, the maximum rate of groundwater flow to the study reach was estimated at 90 acre-feet per mile per year in 1977, when a drought occurred in the river basin. The minimum value of about 30 acre-feet per mile per year occurred in 1983, an extremely wet year. Groundwater flow during either year is less than 1 percent of the total flow in the river.

Variations in groundwater flows

Seasonal variations in both groundwater and surface water flows are due in part to operation of Friant Dam in the Sierra Nevada (fig. 2). Typically, total river flow reaches a maximum in the spring while groundwater flow declines to a minimum. Surface water flows, however, vary as much as 75 percent from the annual mean compared with approximately 20 percent for groundwater flows.

In addition to seasonal variations, groundwater flows were substantially different at each rivermile because of local hydrogeologic conditions. Such variations may be of importance in establishing local and regional water quality standards for the river.

River water quality

Establishment of water quality objectives for the San Joaquin River requires careful assessment of all components affecting quality. The groundwater component was of specific concern in this study because it represents a nonpoint, nonmeasured, saline discharge.

Despite limitations in available data necessary to assess the magnitude of groundwater flow to the San Joaquin River, it appears that this flow is only a fraction of one percent of the total annual river flow, and represents less than a few percent of the total agriculturally related discharge into the river. Although average groundwater salinity is relatively high, its impact on water quality in the San Joaquin River appears to be relatively minor.

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