A METHOD FOR ESTIMATING GROUND-WATER RETURN FLOW TO THE LOWER COLORADO RIVER IN THE YUMA AREA, ARIZONA AND CALIFORNIA—EXECUTIVE SUMMARY

By O. J. Loeltz and S. A. Leake

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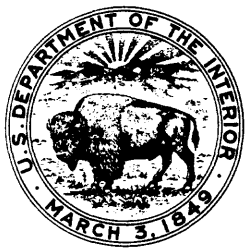

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PREFACE

This report summarizes the development and results of a method for estimating the amount of ground-water return flow to the Colorado River in the Yuma area, Arizona and California. Readers interested in a detailed technical discussion of the method are referred to Loeltz and Leake (1983).

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ABSTRACT

Substantial quantities of water diverted from the lower Colorado River in the Yuma area, Arizona and California, return to a reach of the river as ground-water flow. A method for estimating these quantities involves the computation of ground-water return-flow rates using hydraulic analyses of ground-water flow at 18 cross sections in a reach of the river adjacent to irrigated land in the Yuma area.

The hydraulic-analysis method uses aquifer characteristics and average annual gradients that are based on measurements of river stage and ground-water heads in each cross section. Aquifer characteristics were estimated mainly from the evaluation of aquifer response to changes in river stage.

The average annual return flow for 1975-78 was estimated to be 44,000 acre-feet from lands on the Arizona side of the river and 38,000 acre-feet from lands on the California side. Estimates of total return flow for the Yuma reach compare favorably with estimates made using surface-water-budget and salinity-budget methods.

CONVERSION FACTORS

For readers who prefer to use metric units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
mile (mi)	1.609	kilometer (km)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)

INTRODUCTION

An investigation of the water resources of the lower Colorado River-Salton Sea area by the U.S. Geological Survey began in 1960. The investigation disclosed that along three reaches of the lower Colorado River substantial quantities of water that had been diverted from the river for irrigation were returning to the river as ground-water (subsurface) flow (Metzger and others, 1973; Olmsted and others, 1973). These reaches were later designated as the Parker reach, the Palo Verde-Cibola reach, and the Yuma reach (fig. 1).

The State of Arizona, in a letter dated September 22, 1969, officially protested to the Secretary of the Interior the practice that was being used by the U.S. Bureau of Reclamation in accounting for water use from the main stem of the Colorado River below Lees Ferry pursuant to Article V of the decree by the U.S. Supreme Court (1964). The protest was mainly against the practice of charging diversions from the river less surface return flows to the river as consumptive use to each State. Arizona contended that the definition of "consumptive use" in the decree, which states "'Consumptive use' means diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation," included surface and subsurface return flow. The U.S. Department of Interior agreed that subsurface return flows should be included and immediately sought a means of determining the amount of subsurface return flow creditable to each state.

In 1970, representatives of the U.S. Geological Survey and the U.S. Bureau of Reclamation agreed on the scope and objectives of a project for estimating the amount of subsurface return flow. The project was to be a cooperative undertaking in which the U.S. Bureau of Reclamation would be responsible for the construction, installation, and maintenance of various equipment and features for data collection, and the U.S. Geological Survey would be responsible for the instrumentation, data collection, and determination of the ground-water return-flow quantities. The Task Force On Unmeasured Return Flow to the Lower Colorado River was formed to provide guidance on the scope and objectives of the investigation and to provide an avenue of communication among all interested agencies during the investigation. The task force is composed of representatives of the States of California, Arizona, and Nevada; Federal Indian Agencies; the U.S. Bureau of Reclamation; and the U.S. Geological Survey.

Purpose and Scope

The purpose of this study was to develop a method for estimating the amount of subsurface return flow to the Colorado River in the Yuma area. This report presents a method that will permit an accounting

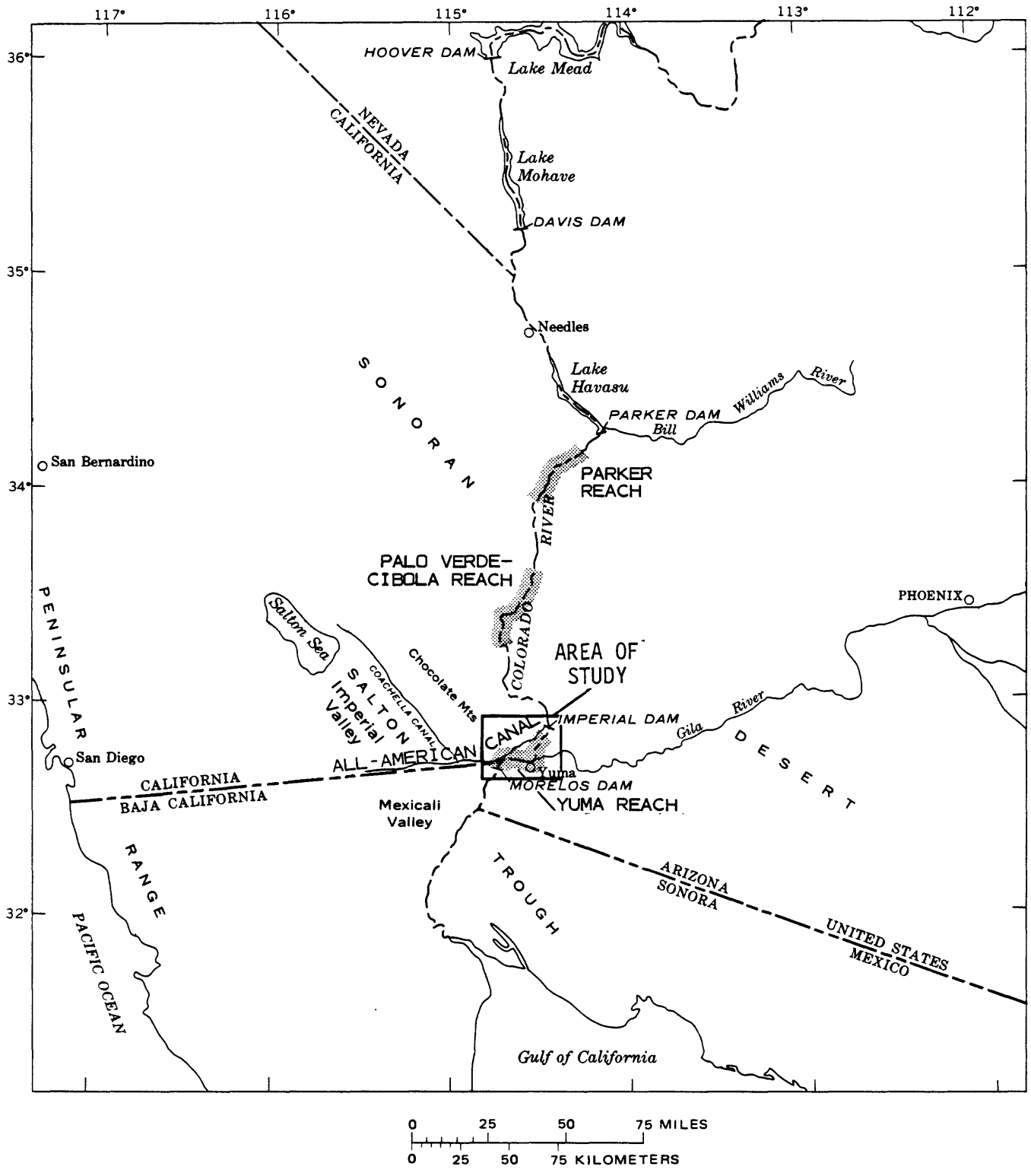


Figure 1.--Area of study.

of ground-water return flows from each side of the Colorado River in the Yuma reach (fig. 1). The estimates of return flow can be used by water-management agencies in determining return-flow credits for the States of Arizona and California.

Acknowledgments

The expertise of W. E. Moffitt, geologist, formerly of the U.S. Bureau of Reclamation, was greatly appreciated. His efforts contributed to the development of techniques for installing the piezometers. He also coordinated the test-drilling, construction, and maintenance responsibilities of the U.S. Bureau of Reclamation. E. E. Burnett, geologist, U.S. Bureau of Reclamation, worked many hours in obtaining geophysical and geologists' logs for about 70 test holes in the Yuma area.

D. W. Wilkins, hydrologist, U.S. Geological Survey, was the principal assistant on the project until early 1977. He helped develop instrumentation and operational procedures that were peculiar to the project. He was involved in the construction and operation of the electrical-analog models that were used in the early stages of the study and in the design and adaptation of the digital models that were used later.

METHOD

Return-flow estimates in the Yuma area are made by hydraulic analyses of ground-water flow in regions adjacent to the river at 18 cross sections spaced about 1 mi apart (fig. 2). The hydraulic-analysis method involves computing return-flow rates at each cross section using average annual gradients to the river and estimated aquifer characteristics. The return-flow rates are applied to each subreach represented by a cross section. The computed return-flow estimates for the subreaches are summed for the entire Yuma reach.

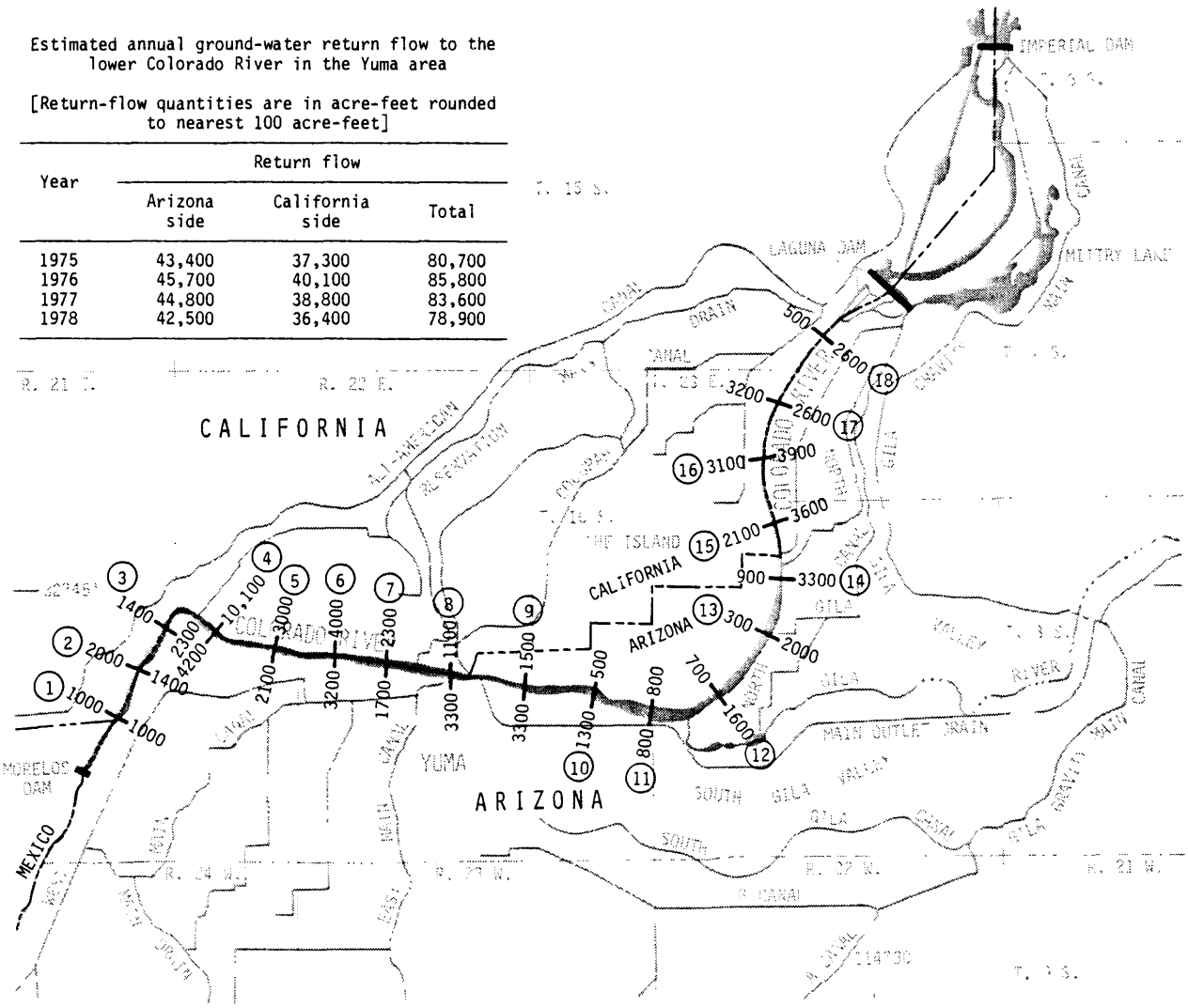
The gradients to the river were determined from heads in the river and the aquifer. The heads in the aquifer were measured in 216 piezometers, 12 at each cross section, open to the aquifer at various depths below the water table. About 40 digital recorders were used to record the heads.

Aquifer characteristics were estimated mainly from the evaluation of the response of the aquifer at each cross section to changes in river stage. Information from geophysical and geologists' logs at the piezometer locations and soil-moisture profiles from about 60 neutron-probe access tubes also were used.

Estimated annual ground-water return flow to the lower Colorado River in the Yuma area

[Return-flow quantities are in acre-feet rounded to nearest 100 acre-feet]

Year	Return flow		
	Arizona side	California side	Total
1975	43,400	37,300	80,700
1976	45,700	40,100	85,800
1977	44,800	38,800	83,600
1978	42,500	36,400	78,900



EXPLANATION

500—2600 / (18) RETURN-FLOW CROSS SECTION—Numbers, 500 and 2600, are estimated average annual return flows, in acre-feet, for subreach represented by cross section for 1975-78. Number, 18, is cross-section number

Figure 2.--Estimated ground-water return flows to the lower Colorado River in the Yuma area.

The hydraulic analysis of the ground-water flow system was done using mathematical flow models run on digital computers. The mathematical models were used to estimate aquifer characteristics and to compute ground-water return flow from each side of the river.

RESULTS

Estimated annual return flows for 1975-78 are shown in figure 2. The average annual return flow for 1975-78 was estimated to be 44,000 acre-ft from lands on the Arizona side of the river and 38,000 acre-ft from lands on the California side. In this report, Arizona and California sides of the river, respectively, refer to the left and right sides of the river facing downstream even though the right side of the river includes land in both States. Although the reliability of the estimated return flows for the reach cannot be objectively determined, the total return flow for the reach estimated by the hydraulic-analysis method is in agreement with estimates made by other methods. The other methods, however, cannot be used to determine the side of the river from which the return flow originates. For comparison, ground-water return flows were computed with surface-water budgets for the Yuma reach. In the surface-water budgets, ground-water return flows to the river are estimated as the differences between known outflows and inflows to the river reach. Additionally, the U.S. Bureau of Reclamation has used salinity budgets to estimate ground-water return flows for the reach from Imperial Dam to the northerly international boundary near cross section 1 (E. E. Burnett, U.S. Bureau of Reclamation, written commun., 1981). The estimates made by the hydraulic-analysis method, the surface-water-budget method, and the salinity-budget method are shown in figure 3.

The results of the hydraulic-analysis method are estimates of the annual return-flow quantities rather than measurements. Ground-water return-flow quantities cannot be estimated to the same degree of accuracy that surface-water return-flow quantities can be measured. The accuracy or reliability of the estimated ground-water return-flow quantities cannot be assessed; however, return-flow quantities for the entire Yuma reach are probably more accurate than those estimated for individual cross sections. A major advantage of the hydraulic-analysis method over the water-budget and salinity-budget methods is that estimates can be made of the amount of return flow entering the river from each side.

FUTURE DECISIONS

Collection of data may be the major expense associated with making future return-flow estimates using the hydraulic-analysis method. The data-collection costs will be related to the amount of data needed to satisfactorily estimate ground-water return flows. A preliminary study of data needs indicates that future computations of average annual heads and

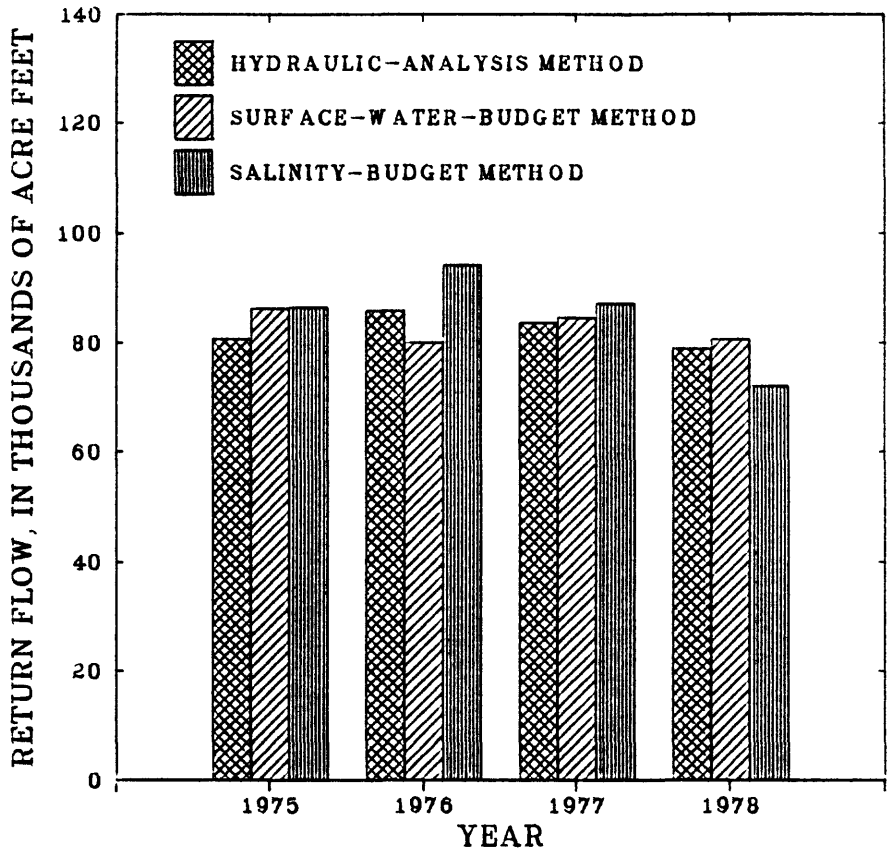


Figure 3.--Comparison of estimated annual return flows in the Yuma reach, 1975-78.

gradients will require fewer data than were needed for the development of the method. The study points out the need to evaluate the costs and the return-flow estimation errors associated with various levels of data collection. With this information, a decision can be made regarding the proper level of data collection.

Future estimates of return-flow quantities can be made with the hydraulic-analysis method using the existing data-collection network and the mathematical models provided that the hydrologic regimen of the area is similar to that of 1975-78. Future conditions that might cause problems with the method or necessitate further analysis prior to application of the method are (1) increased ground-water pumping near the cross sections, (2) high river stages that inundate land around the piezometers, and (3) channelization of the Colorado River that causes significant changes in the river-surface elevations along the Yuma reach. Any future application of the method, therefore, should include an evaluation of changes of the hydrologic regimen in the Yuma area. If and when such conditions occur to the extent that the hydraulic-analysis method cannot provide reliable return-flow estimates, alternate methods must be used.

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