GROUND WATER RELATED RESEARCH - 1967-1970

Water Resources Research Center
The University of Arizona, Tucson, Arizona

L. G. Wilson, Hydrologist

The ground water related research activities of the Water Resources Research Center have been oriented along two general lines: artificial ground water recharge, using industrial waste effluent and sewage effluent; and natural recharge in an ephemeral stream of southern Arizona, the Santa Cruz River. The research activities, under the direction of L. G. Wilson, have been financed by the State of Arizona, the Office of Saline Water, and the Office of Water Resources Research.

RECHARGE OF INDUSTRIAL EFFLUENT

The general goal of the artificial recharge program of the WRRC is to obtain, via experimentation, rational guidelines for the selection, design and management of economical recharge units for the geohydrological regimen of souther Arizona, concomitant with minimal alteration of native ground water quality. Specific objectives of artificial recharge studies are: (1) to evaluate the effect of various management techniques on intake rates in two experimental recharge facilities, a pit and a well; (2) to observe the mechanics of water flux in stratified sediments overlying the water table during pit recharge; (3) to evaluate changes in the chemical quality of recharge effluent during water movement above the water table and during intermingling with native ground water; (4) to compare the effect of several management techniques during recharge in a well on the chemical quality of a blend of recharge effluent and native ground water; and (5) to examine recent analytical approaches to certain problems in artificial recharge (e.g. hydrodynamic dispersion, mound formation, etc.) in light of field data for recharge in stratified sediments.

The principal recharge site for studies on artificial recharge of waste effluent (and natural recharge of Santa Cruz river water) is located on the WRRC Field Laboratory near the northwestern boundary of Tucson, Arizona. Waste effluent, consisting of cooling tower blowdown effluent from the Tucson Gas and Electric Co., Grant Road Plant, is transported about a mile in a buried pipe line to the Field Laboratory. Artificial recharge facilities include a pit (100 ft x 50 ft x 12 ft; 2½:1 side slopes) and a well (20-inch diameter, 150 ft deep). The well was designed and constructed to combine the features of both a recharge shaft and a recharge well. That is, a section of the well casing was perforated (pre-milled slots) in permeable materials above the water table and separated by unslotted casing from a second perforated region below the water table. By means of a packer assembly and suitable inlet facilities, the upper and lower regions may be recharged independently of each other. Details on the design of the well were reported by Wilson, Fogel, DeCook and Osborne (1969). Appurtenances include a settling pond; three eight inch, 150 ft deep observation wells; 14 access wells, each 100 ft deep, used in conjunction with a "moisture logger" based on the principles of neutron thermalization; a series of piezometer-water sampling wells; a 16-inch, 150 ft pumping well (used during "two-well" tests), located 260 ft downstream of the recharge well; propeller flow meter, gate valves and other control facilities; and two instrument shelters. Laboratory and shop facilities are also located at the Field Laboratory. Preparatory to recharge studies subsidiary investigations were conducted to characterize the quantity and quality of effluent; and to define the geohydrologic framework of the area (depths and textural properties of principal stratigraphic regions, depth to water table, and the hydraulic and storage properties of water bearing materials).

Two pit recharge tests were conducted. The first trial, in 1966, consisted of 142 days of continuous inundation. The second test, in 1968, comprised 15 wet-dry cycles. Quantities recharged by the two management procedures were contrasted. By obtaining water content profiles in the 14 access wells at the site two principal zones of water transmission or "mounds" were deliniated in the region above the water table. During the continuous inundation test three stages were apparent in the history of these mounds; the development stage, the equilibrium stage and the drainage stage. It was possible to relate these various stages to intake characteristics of the pit. Changes in the chemical quality of recharge effluent were observed in the region above the water table (via water samples from piezometer-water sampling wells) during vertical and lateral migration of water from the pit and during the miscible displacement of native ground water. Details of the two studies were reported by Wilson (1969a and 1969b) and Wilson, Osborne and Percious (1969).

Using the experimental, 20-inch diameter recharge well Osborne (1969) conducted a study to compare well and formation head losses during recharge with losses during pumping. The experimental results suggest that it may be possible to estimate the recharge potentialities of an existing well by conducting step-drawdown discharge tests, assuming conditions such as those at the test site.

An objective of well recharge studies in recent years has been to test the relative effectiveness of various recharge-pumping regimes for mixing recharge effluent and ground water within the water bearing formations at the recharge site. The two principal types of experiments were so-called "single-well" tests and "two-well" tests. These studies were patterned essentially after mixing experiments by Israeli workers. Single-well tests were conducted using a 20-inch diameter recharge well. For two-well tests recharge was initiated in the 20-inch well and simultaneously a downstream, 16-inch well was pumped.

The single-well tests entailed the following recharge-discharge regimens: (1) No-pause tests in which a volume of effluent was recharged, followed by immediate pumping; (2) pause tests in which a finite volume of effluent was recharged and pumping was initiated after a time pause (in individual tests varying from one hour to seven days); (3) pulse tests in which a finite volume of "tagged" effluent was recharged followed by the recharge of a finite volume of "untagged" effluent, after which pumping was initiated. During the tests the fluorescent dye Rhodamine WT and natural differences in chloride ion concentration were used to distinguish effluent from ground water. Preparatory to field experimentation laboratory column studies were conducted to characterize the sorption-desorption characteristics of the dye (Wilson, 1969b). Breakthrough curves, depicting the relative concentration of recharge effluent in pump-back water were prepared from concentrations of the tags during each pumping operation. Percious (1969) examined the breakthrough curves from single-well, no-pause tests to evaluate the dispersivity coefficient of aquifer materials. From the viewpoint of mixing, the most effective single-well method was the pause test in which natural ground water movement augmented the dilution of recharged effluent.

In the summer of 1970 a 14-day, two-well, recharge-discharge test was conducted, followed immediately by an additional nine days of pumping in the downstream well. Recharge and discharge rates were equalized during the test. Five days after the beginning of the test recharge effluent was present in pumped water. Two weeks after beginning the test, the relative concentration of effluent in pumped water was 26% (Wilson, 1970).

The results of single well and two well tests suggest that recharge-discharge techniques may have a role in conjunction with intrabasin transfers of water for quality control of ground water in the Tucson Basin.

RECHARGE OF SEWAGE EFFLUENT

Field investigations on the recharge of sewage effluent were conducted on a grassed spreading area at the Ina Rd. Oxidation Pond site, Pima County Dept. of Sanitation. Facilities installed at the site included: two 100 ft access wells; two PVC sampling wells; shallow suction cups; inlet and outlet flumes; and inlet and outlet water sampling devices. Controlled studies were conducted using instrumented lysimeter columns at the WRRC Field Laboratory.

A series of water spreading studies using treated stabilization lagoon effluent were conducted on the grassed area in 1967 and 1968. Changes in such parameters as B.O.D., C.O.D., nitrogen (organic-N, ammonia-N, nitrite-N and nitrate-N) phosphate, and microorganisms were evaluated during vertical movement of effluent through materials overlying the water table and during recharge below the water table. The salient results of the study were presented by Wilson and Lehman (1967).

The fate of certain trace metals in sewage effluent during soil filtration was studied by Lehman (1968) in instrumented lysimeter columns designed to simulate various water spreading units. The concentration of iron, manganese, nickel, copper, zinc, lead and cadmium were substantially lowered during percolation through eight ft of calcareous soil materials contained in the lysimeters. Strontium concentrations were not reduced. Corroborative studies were conducted in the field by applying effluent to the grassed area near the Ina Rd. oxidation ponds.

NATURAL RECHARGE STUDIES

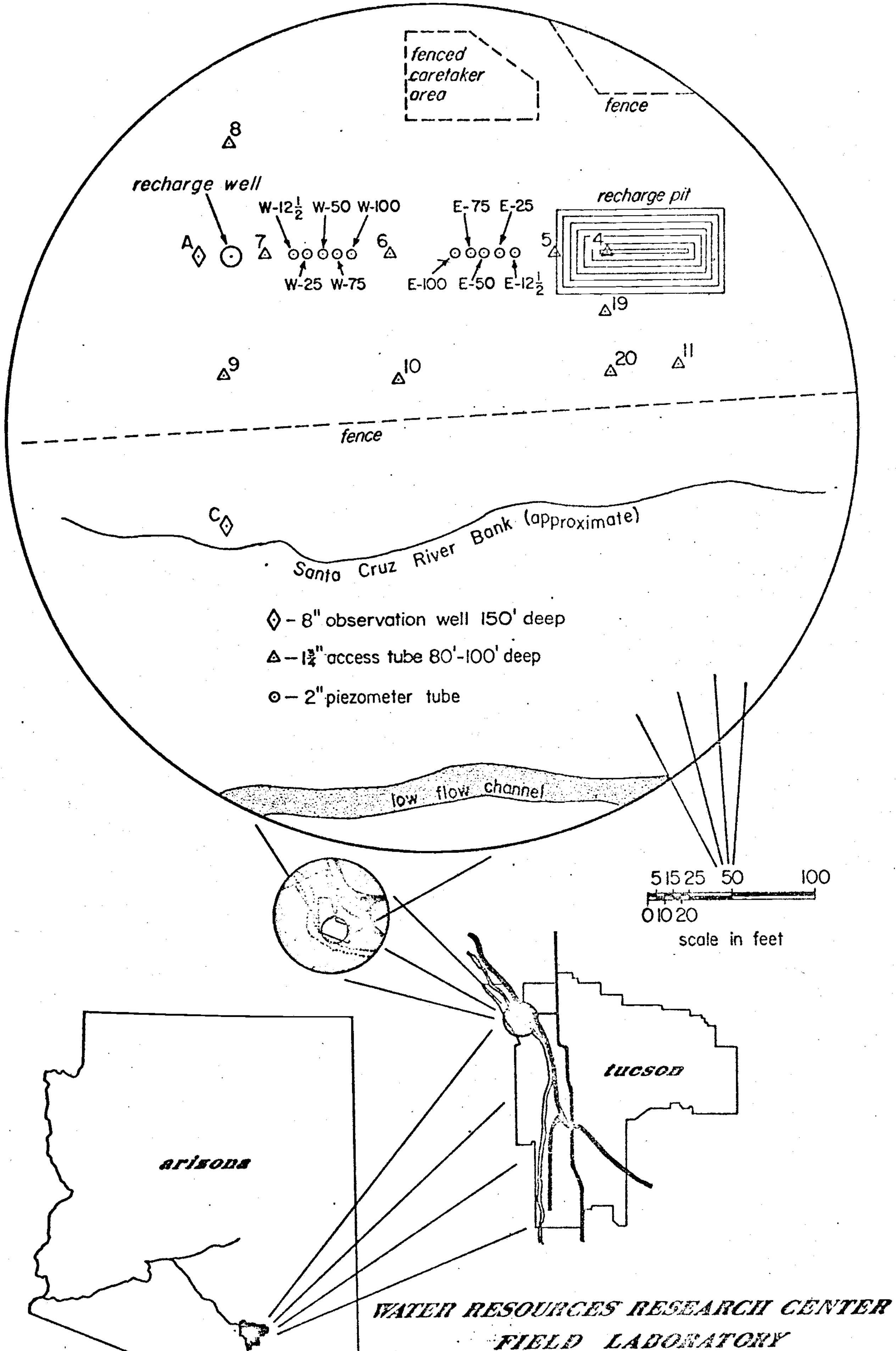
Concurrent with the artificial recharge program of the Water Resources Research Center discussed above, several investigations were conducted into the mechanics of natural recharge. The general objectives of these investigations were two-fold: (1) to study the infiltration phenomena in the stream bed and (2) to characterize the subsurface disposition of infiltrated water in the stratified sediments overlying the water table. Facilities at the WRRC Field Laboratory, located contiguous to the Santa Cruz River, were used for these investigations.

The Santa Cruz River in the reach through Tucson is classified as an ephemeral stream: discharge occurs in response to overland flow and the channel is above the water table. Discharge events occur primarily in the summer and winter months, the two rainy seasons. River water normally contains a heavy load of entrained sediment, particularly in summer flash floods.

Marsh (1968) conducted an intensive investigation to evaluate the effects of suspended sediment and stream discharge, and their interrelationships, on intake rates in the Santa Cruz River. A "lysimeter-flume" was constructed at the Field Laboratory and filled with representative materials from the river bed. A large capacity steel hopper was located upstream of the flume to permit storing and metering sediment into applied water. Three flow rates and three sediment concentrations were combined into 18 trials, conducted in random order. Infiltration rates were determined for each trial. Evaluating the results of these trials Marsh (ibid.) concluded that, "Increasing discharge rates appeared to increase infiltration rates indirectly through the effect of stream velocity on bed erosion and sedimentation. Increasing suspended sediment concentrations were found to be highly significant in reducing infiltration rates."

The subsurface disposition of influent seepage from the Santa Cruz River during flow events in the Winter 1965-1966 was studied by Wilson and DeCook (1968). Water content profiles were obtained in two transects of access wells perpendicular to the river. These profiles clearly manifested the growth of extensive mounds in the zone of aeration during inland migration of recharge waves, and the subsequent dissipation of the mounds during the decline of recharge. Similar profiles were obtained by Wilson (1968a) during runoff events in the Santa Cruz River for the Winter 1967-1968. Because of the vast amount of water in storage within the mounds of the zone of aeration during recharge it was concluded that water content changes in the zone of aeration, and related long-term drainage, should be accounted for during water balance studies and aquifer testing in the Tucson Basin.

During pit recharge trials in the summer of 1968 it was observed that river recharge from several runoff events effected a dilution of recharged effluent within the zone of aeration (Wilson, 1968b). This observation suggested that the dilution potential of influent seepage in ephemeral streams may be used to advantage in certain waste disposal or recharge operations in a geohydrological environment such as that at the research site. An obvious advantage of such in-situ conditioning of effluent is that the expense of above-ground mixing facilities is obviated.



WATER RESOURCES RESEARCH CENTER
FIELD LABORATORY
The University of Arizona

FIGURE 2

REFERENCES

Lehman, G. S., Soil and grass filtration of domestic sewage effluent for the removal of trace elements, Unpublished Ph.D. dissertation, Dept. of Watershed Management, The University of Arizona, 1968.

Marsh, J. A., The effect of suspended sediment and discharge on natural infiltration of ephemeral streams, Unpublished M.S. thesis, Dept. of Watershed Management, The University of Arizona, Tucson, 1968.

Osborne, P. S., Analysis of well losses pertaining to artificial recharge, Unpublished M.S. thesis, Dept. of Hydrology, The University of Arizona, Tucson, 1969.

Percious, D. J., Aquifer dispersivity by recharge-discharge of a fluorescent dye tracer through a single well, Unpublished M.S. thesis, The University of Arizona, 1969.

Wilson, L. G., Quarterly reports submitted to the Office of Saline Water, U. S. Department of the Interior, Grant No. 14-01-0001-630 (mimeo), 1965.

Wilson, L. G., Quarterly reports, submitted to the Office of Saline Water, U. S. Department of the Interior, Grant No. 14-01-0001-630 (mimeo), 1966.

Wilson, L. G. and G. S. Lehman, Reclaiming sewage effluent, Progressive Agriculture in Arizona, 19 (4), 22-24, 1967.

Wilson, L. G., Quarterly reports, submitted to the Offics of Saline Water, U. S. Department of the Interior, Grant No. 14-01-0001-630 (mimeo), 1967.

Wilson, L. G., and K. J. DeCook, Field observations on changes in the subsurface water regime during influent seepage in the Santa Cruz River, Water Resources Research, 4 (6), 1219-1234, 1968.

Wilson, L. G., P. S. Osborne and D. J. Percious, Dilution of an industrial waste effluent with river water in the vadose region during pit recharge, Paper No. 68-727, Presented at 1968 Winter Meeting American Society of Agricultural Engineers, Chicago, 1968.

Wilson, L. G., Quarterly reports, submitted to the Office of Saline Water, U. S. Department of the Interior, Grant No. 14-01-0001-630 (mimeo), 1968a.

Wilson, L. G., Quarterly reports submitted to the Office of Saline Water, U. S. Department of the Interior, Grant No. 14-01-0001-1805 (mimeo), 1968b.

Wilson, L. G., Observations on water content changes in stratified sediments during pit recharge, Paper presented at the 50th Annual Meeting, American Geophysical Union, Washington, D. C., 1969a.

Wilson, L. G., M. M. Fogel, K. J. DeCook, and P. S. Osborne, The design of an experimental artificial recharge well at Tucson, Arizona, Annals of Arid Zone, 8 (2), 267-274, 1969.

Wilson, L. G., Quarterly reports submitted to the Office of Saline Water, U. S. Department of the Interior, Grant No. 14-01-0001-1805 (mimeo), 1969b.

Wilson, L. G., Quarterly reports submitted to the Office of Saline Water, U. S. Department of the Interior, Grant No. 14-01-0001-1805 (mimeo), 1970.