

existing native water, and air entrainment or dissolution of gases in interstices of the porous medium.

A comprehensive study of factors affecting artificial groundwater recharge should include laboratory determinations of the relation of the various causes of hydraulic-conductivity reduction. Problems pertaining to the effect of water quality in relation to the lithologic environment of a recharge system also should be studied in the laboratory.

A laboratory facility has been designed and equipped to provide means of testing flow through porous media columns. Any quality of recharge water from distilled water to activated sludge, can be constituted in quantities providing for indefinite term tests. Flow can be through repacked or field cores under constant flow or constant pressure.

A flow-test data acquisition and computation system provides punched tape data storage and real time computation and plotting of intrinsic permeability changes with column depth and time.

Water quality data are taken during the test, and characteristics of the porous media and suspended solids are determined. Accumulation of material in porous media interstices is visually observed with scanning electron microscopy.

The data are analyzed to relate the physical, biologic, and chemical effects in the porous media flow system with the objective of obtaining data that can be transferred to field situations and thus develop more economical artificial-recharge systems.

SUN, REN JEN, U.S. Geol. Survey, Washington, D.C.
HYDRAULIC FRACTURING AS TOOL FOR DISPOSAL OF WASTES IN SHALE

The growth of modern society and technology requires an increasing level of protection of the environment, and waste disposal is a growing problem, particularly for radioactive and toxic industrial wastes.

The injection of wastes mixed with cement grout into thick shale formations is a promising method for effectively immobilizing wastes in a nearly impermeable medium. Hydraulic fracturing serves as a tool to increase the permeability of shale during the grout injection. Ion exchange and adsorption agents can be added to the grout when it is mixed. After hardening of the grout, the injected wastes will become an integral part of the shale and remain there as long as the shale is not subject to erosion.

Problems concerning the safety of the method are phase separation and orientation of the hydraulically induced fractures. During hardening of the grout, phase separation may occur, that is, some liquid may separate. In such an instance, the mobility of wastes in the separated liquid may be greatly retarded by the very low permeability and high ion-exchange capacity of shale. If the separated liquid reached a groundwater reservoir, the concentration of contaminants would be greatly reduced further by dilution in the native groundwater.

In bedded shale there is a great difference in tensile strength between the direction normal to and parallel with bedding planes. This difference in tensile strength may favor the formation of fractures along low-angle bedding planes within a zone of limited vertical extent. However, not all shale formations produce bedding fractures, therefore before construction of a waste-disposal plant it is necessary to test the site by water or nontoxic grout injections tagged with radioactive isotopes to judge whether a "zone" of fractures can be induced parallel with the shale bedding planes. Injection

pressure, movement of the ground surface, and gamma-ray logs made in observation wells are used to interpret the orientation of the hydraulically induced fractures during the site-selection tests. A case history of hydraulic fracturing at West Valley, New York, illustrates the method of selection of a site.

Waste disposal through an injection well is conducted in multiple-layered injection stages. The first injection starts from the deepest depth, then the injection zone is plugged by cement, and the second injection will be started about 10 ft above the first one. The repeated use of the injection well distributes the high cost of construction of injection and monitoring wells over many injections, thereby making hydraulic fracturing economically feasible as a tool for the disposal of certain types of wastes.

WALKER, WILLIAM R., and WILLIAM E. COX,
Virginia Polytechnic Inst. and State Univ., Blacksburg, Va.

LEGAL AND INSTITUTIONAL CONSIDERATIONS OF DEEP-WELL WASTE DISPOSAL

Deep-well injection of wastes is subject to two levels of legal and institutional constraints. The first consists of regulatory procedures established by state and federal legislation. Waste injection has traditionally been regulated by the states through use of a variety of statutory constructions and administrative organizations. Federal control over subsurface disposal has essentially been limited to radioactive wastes, but influence currently is being extended into the general area of underground waste management. The apparent intent of the Federal Water Pollution Control Act Amendments of 1972 is the subjugation of state regulatory procedures to federal standards, with actual administration of controls ultimately to remain with the states.

The second level of constraints consists of the property rights of adjacent landowners. These adjacent rights are important because injected wastes do not respect property boundaries and therefore may produce conflict with certain aspects of property ownership. The most obvious type of infringement involves injurious contamination of property interests by the injected waste. A more indirect case of contamination may involve the pressure-induced migration of naturally occurring pollutants such as mineralized water. Another potential type of pressure-related interference with property consists of structural damage from seismic activity initiated by injection. In some jurisdictions, even the unauthorized occupation of underlying space without measurable damage to the landowner may constitute a violation of property rights. The courts in most states have not been confronted with all these issues, but the party adversely affected by injection generally will be able to invoke a variety of legal actions, including nuisance, negligence, and trespass. In addition, some states accept the concept of strict liability regarding hazardous activities and the escape of deleterious substances, with the result that the injured party is relieved of the requirement of proving fault.

WARNER, DON L., and DONALD H. ORCUTT,
Univ. Missouri, Rolla, Mo., and Wapora, Inc., Washington, D.C.

INDUSTRIAL WASTEWATER-INJECTION WELLS IN UNITED STATES—STATUS OF USE AND REGULATION, 1973

Recent inventories of industrial wastewater-injection wells in the United States show that at least 250 wells have been completed to date (March 1973) in 24

states. Available data have been obtained and analyzed concerning site geology and geohydrology, waste character, well construction, surface equipment, and operating programs and regulatory requirements for each well. Brief environmental impact statements for the wells have been developed where sufficient information could be obtained to allow this assessment.

In addition, information concerning the current state laws and programs for regulation of wastewater injection has been obtained and evaluated.

WILSON, W. E., J. S. ROSENSHEIN, and J. D. HUNN, U.S. Geol. Survey, Tampa, Fla.

HYDROLOGIC EVALUATION OF INDUSTRIAL-WASTE INJECTION AT MULBERRY, FLORIDA

An injection well was completed in 1972 at a chemical plant at Mulberry, in central Florida, to inject highly acidic industrial waste into limestone. The plant produces sodium fluosilicate from the reaction of sodium chloride with fluosilicic acid, a byproduct of nearby phosphate processing plants. The resulting liquid waste, which is to be injected into the subsurface, has a high chloride content and a pH that is generally less than 2 and at times less than 1.

The cased injection well is finished as a 6¼-in. open hole in limestone, from 4,040 to 4,984 ft below land surface. The injection-well annulus has two monitor wells, one open near the base of the Floridan aquifer from 1,254 to 1,264 ft, and the other open below the Floridan aquifer from 2,755 to 2,788 ft. Before injection tests were made, geophysical logs and a tracer test were run on the well. The radioactive-tracer test indicated that several permeable zones are exposed in the open hole.

The native fluid, sampled prior to injection, and the waste fluid are markedly different in density, chloride content, and temperature.

Two injection tests were run in the fall of 1972, using the waste fluid. The results of the first test were inconclusive because of inadequately controlled injection rates. During the second test, waste fluid was injected for 118 hours at 270 gpm and pressure readjustment was observed for 5 days. Injection pressure measured at the surface increased for the first 31 hours, and then decreased for the remainder of the injection period. The decrease in pressure after 31 hours is attributed to the net effect of reactions that occurred in the injection zone during the test. Dissolution of limestone by the low pH waste substantially increased the permeability of the rock adjacent to the well bore and increased the density and temperature of the injection fluid as it moved into the injection zone. These changes coupled with the unavailability of direct bottomhole pressure measurements in the injection well and the lack of water-level measurements in an observation well finished in the injection zone complicated the evaluation of test results. As a result, only a general estimate of injection-zone transmissivity could be made.

Where acidic wastes are to be injected into a carbonate zone, evaluation of natural conditions would be facilitated by the use of fresh water as the injection fluid during initial tests, and by measuring bottomhole pressure in the injection well and water levels in observation wells open to the injection zone.

YAMAMOTO, SOKI, Tokyo Kyoiku Univ., Tokyo, Japan

UNDERGROUND WASTE DISPOSAL AND ARTIFICIAL RECHARGE IN JAPAN

Private companies at 3 sites—in Tsuruga, Kanazawa,

and Yamagata—have had success with artificial recharge wells. These sites are all on alluvial fan deposits.

In regard to waste disposal into deep zones, some underground treatment of liquid wastes from petrochemical industries in the Setouchi district and other locations in Japan has been done. An experimental study has been made in the Hachimantai and Ootaki geothermal areas, where there has been underground injection of thermal saline water into production wells. Both these geothermal areas are used for electric generation by means of geothermal vapors.

MID-CONTINENT SECTION REGIONAL MEETING

OCTOBER 3-5, 1973

ASSEMBLY CENTER, TULSA, OKLAHOMA

HOST: TULSA GEOLOGICAL SOCIETY

THEME: PETROLEUM EXPLORATIONIST'S CHALLENGE—THE ENERGY CRISIS

General Chairman: MERRILL J. REYNOLDS, Ceja Corp., Tulsa

Program Chairman: MARTIN W. SCHRAMM, JR., Consultant, Tulsa

Key Speakers: W. R. WALTON, Amoco Production Co., Tulsa, Significant properties of sandstones—aims to exploration and exploitation; and K. W. KLEMENT, Univ. Texas at El Paso, El Paso, Texas, Comparative lithostratigraphy of major carbonate reservoirs in the world

For information regarding advertising, exhibitors, hotels, preregistration, etc., contact DON OTT, GeoData Corp., 1420 Thompson Bldg., Tulsa 74103.

TENTATIVE PROGRAM SUMMARY

AMSDEN, T. W.: Porosity and permeability in Silurian carbonate rocks of Hunton Group, Anadarko basin, Oklahoma

BERG, O. R., and J. G. COLE: Stratigraphic analysis of Cherokee Group, Pennsylvanian (Desmoinesian), north-central Oklahoma

FERRIS, C.: Prospecting for reefs by gravity

FROST, J. G.: Algal bank complexes of Mid-Continent

HODGSON, R. N.: Interpretive techniques using exploration data base/application processing systems

KEMPF, J. H.: Structural relations of Arbuckle and Ouachita facies

KRUMME, G. W.: Source changes during Marmaton, northeast Oklahoma

REEDER, L. R.: Liquid industrial waste storage by underground injection

SHELTON, J. W., H. R. BURMAN, JR., and R. L. NOBLE: Depositional and directional features of a braided-meandering stream

STONE, D. G.: Spectrum extrapolation to increase resolution

TAYLOR, J. A.: Hunton fields in Anadarko basin, Oklahoma and Texas

VISHER, G. S.: Reconstructing a Pennsylvanian delta system

AAPG DISTINGUISHED LECTURERS, 1973-1974

GERMAN MÜLLER, Heidelberg University (choice of three papers)

1. Stages of Transformation of Carbonate Sands into