and remain within the drinking standards of the U.S. Public Health Service.

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ARTIFICIAL RECHARGE—STATE OF THE ART

The largest potential reservoir for the storage of potable water is that which exists in the unsaturated zone. Utilization of this space for the storage and retrieval of potable water is a multifaceted problem which requires application of the best talent from the scientific community. Considerable research has taken place in artificial recharge since the last international symposium on the subject at Reading University, England, in 1970. An increasing demand for economic water supplies created by larger populations indicates a need for much greater research efforts in the near future.

Artificial recharge has many similarities to liquid-waste disposal through deep wells. In both, the problem is to place liquid into a permeable lithologic unit at an economic rate, to predict movement, and the chemical reactions and physical changes that take place while the liquid is in the reservoir. Differences between the two operations are principally in the type of fluid injected and the ultimate objective. In artificial recharge the objective is to store and retrieve water of good quality; in waste disposal the objective is to store permanently water of objectionable quality. In both artificial recharge and liquid-waste storage, the nature of the storage must be known, particularly that of the unsaturated zone. The techniques of investigation for recharge and waste disposal are generally the same.

Water commonly is recharged by surface spreading through basins, induced recharge from adjacent streams and lakes, or through injection wells. Research in recharge through basins has been dominated by mathematical models based on idealized conditions and empirical relations, derived by experimental sequencing of recharge operations, and operational controls in the pretreatment of recharge water. Recharge by injection wells has been undertaken in a variety of hydrologic environments, for example in Israel where efforts have been directed toward the analyses of diffusion and dispersion of the injected water. Much research in the United States has been directed toward the movement of bacteria and organic matter through an aquifer and in the chemical modeling of changes in recharged water as it moves.

Much more research is needed on the basic properties of aquifers, particularly in the unsaturated zone, and on all aspects of recharge water quality. Research and the utilization of data produced are increasingly the responsibility of interdisciplinary teams which consider the geologic, hydraulic, geochemical, bacteriologic, engineering, geophysical, and economic aspects of the system.

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HYDROGEOLOGIC STUDIES AT A SUBSURFACE RADIOACTIVE-WASTE MANAGEMENT SITE IN WEST-CENTRAL CANADA

Nearly all radioactive wastes produced in Canada are stored or disposed of at 2 waste-management sites in shallow Quaternary deposits in south-central Canada. The oldest site and the one which has received most of Canada's radioactive waste is at the Chalk River Nuclear Laboratories (CRNL) in east-central Ontario. The newest site is at the Whiteshell Nuclear Research Establishment (WNRE) in southeastern Manitoba. Both waste-management sites are operated by Atomic Energy of Canada Limited.

Hydrogeologic studies were conducted at WNRE to predict the subsurface behavior of radioactive contaminants, which at some future time possibly could enter the groundwater zone. The site is composed of Quaternary deposits of clayey till above a sandy artesian aquifer which overlies the Precambrian bedrock. The bedrock is 50 ft below ground surface. At present there is no significant contamination of the subsurface hydrologic environment. Hydrogeologic information is being used to facilitiate the design and operation of the waste-management facilities and to assess long-term storage and disposal capabilities of the area.

The hydrogeologic investigations involved 3 main parameters. These are (1) expected residence times of radionuclides which may enter the groundwater flow system, (2) anticipated travel paths and discharge processes, and (3) suitability of the hydrogeologic environment for physical manipulation to achieve greater containment capabilities.

Hydrogeologic studies conducted during the past 5 years have involved field and laboratory techniques such as geologic test drilling, mapping of hydraulic head distributions using wells and piezometers, field permeability tests using single well response tests and long- and short-term pumping tests, mapping of natural hydrochemical patterns in the groundwater zone, tritium tracer experiments, groundwater age dating using $C^{14}$, and mathematical modeling using digital-simulation programs. Comparisons of the results from the studies indicate that we have attained a reasonable level of predictability in our understanding of the hydrogeologic environment in the area.

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HYDRODYNAMICS OF MOUNT SIMON SANDSTONE, OHIO AND ADJOINING AREAS

The Mount Simon Sandstone (Cambrian), the most favorable stratum for waste injection in Ohio, presently accepts about $250 \times 10^6$ gal of industrial waste per year. Concern has been expressed about the transport of these fluids by natural hydrodynamic flow.

The potentiometric surface map of the Mount Simon reservoir of Ohio has a form which mirrors the structural configuration—highest values are in the deeper part of the Appalachian basin and lowest on the Indiana-Ohio platform. Flow direction in central Ohio is indicated to be west or northwest. Head difference is 2–7 ft. Porosity and permeability data combined with this information (Darcy's law) yield velocities of less than 6 in./year.

Because the assumptions involved in determining velocity in this manner are questionable, the resulting values should be considered rough approximations. Nevertheless, the calculations generally show that transport of injected fluids by hydrodynamic flow is not presently a serious hazard in Ohio.

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DAN REGION, ISRAEL, SEWAGE-RECLAMATION RECHARGE PROJECT

The Dan Metropolitan Region, Israel, consists of about 1 million inhabitants, about 50% of whom live in the city of Tel Aviv and the rest in surrounding communities.

The industrial, economic, and commercial growth of this region has been rapid in recent years and the ef-