

tions. Groundwater in coastal sands and the alluvium of rivers was used during early settlement but the main growth in usage for irrigation has occurred in the last two decades. The Burdekin delta and the Hunter River Valley are examples. In the Murray-Darling River system interest in groundwater was intensified by waterlogging and soil salinization following intensive irrigation of the riverine plains. Water is supplied from the surface, although recent investigations have shown that many areas contain valuable groundwater resources. In the Perth basin, ground and surface water are being used for expanding urban and industrial developments. Groundwater sources now are incorporated into the existing system. Development of new mineral fields in northwest Australia has depended on availability of large quantities of water. Only groundwater has been able to provide the quantities needed.

To meet the increasing demands for water in Australia from new groundwater sources, the main requirement is for groundwater to be economically, socially, environmentally, and regionally managed.

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#### ARTIFICIAL RECHARGE OF GROUNDWATER IN BURDEKIN DELTA, AUSTRALIA

Aquifers underlying the 500-sq km onshore part of the Burdekin delta are among the most prolific in Australia. Annual production of groundwater is mainly for irrigation and is in excess of  $300 \times 10^6$  cu m. Aquifer thickness ranges from zero, where the river crosses a bedrock bar, to 100 m. Mean annual natural recharge has been estimated at  $210 \times 10^6$  cu m, partly supplied by seasonal rains and partly by the Burdekin River which has a mean annual flow of  $10 \times 10^9$  cu m and yet is ephemeral. The seasonal pattern of recharge and pronounced variations in recharge year by year cause major fluctuations in the water table. Intensive pumping has accentuated water-level fluctuations and in 1971, at the end of a dry period, the water table at one point was 5 m below sea level in an aquifer with a mean transmissivity of the order of 5,000 sq m/d. The short-term problem in the delta is severe fluctuation of groundwater levels and the long-term danger is saline intrusion.

Local water boards have been established to build and operate recharge works—the first such substantive program in Australia. Water is pumped from the river into a system of natural and artificial channels and increasing rates of recharge have been achieved. Pumpage for artificial recharge now is approaching  $100 \times 10^6$  cu m/a. Suspended clay in the recharge water precludes recharge through bores without expensive pretreatment.

Since commencement of artificial recharge the system has had sharply declining recharge rates particularly in the constructed facilities, and in 1971 the Australian Water Resources Council initiated a group of research projects: (1) numerical modelling of the groundwater system, which will provide a basis for design and management of the expanding artificial-recharge program; (2) detailed study of unsaturated flow below the recharge pits, including the effects of low-permeability layers on and below the floor of the pits; (3) the role of the sediment load in the recharge

waters in the reduction of recharge rates; and (4) study of the biota of the warm recharge waters and their effect in limiting recharge.

Other studies are in progress on tritium dating of the groundwater to assist in definition of the flow system and on the heterogeneity of the materials around the recharge pits.

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#### GEOLOGIC ASPECTS OF URANIUM RESOURCES OF JAPAN

Uranium minerals are widespread in Japan and are present in various geologic environments. Significant concentrations of the element, however, are limited to dissemination in Tertiary sedimentary rocks of small basins. These sedimentary rocks unconformably overlie Cretaceous to Paleogene granitic rocks.

The major sources of the uranium of the deposits are believed to be intergranular material and micas of the underlying granitic rocks. The average uranium content of the major granitic bodies in Japan ranges from 1.5 to 5.7 ppm, but in the vicinity of uranium concentration, can be as high as 11 ppm or more.

The uranium in the rocks probably was leached by circulating groundwater containing  $\text{HCO}_3^-$  ion. Waters within granitic masses contain up to 8.5 ppb uranium whereas the content in average groundwater is less than 0.05 ppb. The element was transported as uranyl bicarbonate complex and deposited under reducing conditions or was adsorbed in clays and other material.

The primary ore minerals of the Tono mine are uraninite and coffinite, but the major form of uranium concentration here seems to be adsorption in montmorillonite and other materials. Recently, interesting and unique deposits of the element, such as a very close association with zeolite and concentration in traps between reverse faults and the basement granite, were found in this mine.

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#### SUBMARINE PHOSPHORITE DEPOSITS OF CHATHAM RISE NEAR NEW ZEALAND

Phosphorite nodule deposits, with estimated total reserves in excess of  $200 \times 10^6$  tons, are present at an average depth of 350 m on the crest of Chatham Rise. The rise is a broad submarine ridge about 130 km wide and 800 km long extending eastward from Banks Peninsula on the east coast of the South Island, New Zealand, to slightly beyond the Chatham Islands. Preliminary investigations based on exploratory dredging in 1968 by Global Marine Inc. suggest that  $65 \times 10^6$  tons of the phosphorite deposits are concentrated sufficiently to be of economic interest. These more concentrated deposits are mainly in an area of about 4,600 sq km centered 560 km from the South Island.

The phosphate content of nodules ranges from 18.6 to 25.4%  $\text{P}_2\text{O}_5$ , averaging 21.5%. Satisfactory superphosphate can be made from the nodules after they are calcined to reduce their high calcite level. The reactivity of the nodules on the Hoffman and Breen phosphate ore solubility scale is a high 10. Pot trials with rye grass by the New Zealand Fertiliser Manufacturers' Research Assoc. Inc. confirmed the agronomic availability of the phosphate suggesting that finely ground Chatham Rise phosphorite also may have