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THE UTILIZATION OF THE LOCAL WATER RESOURCES OF THE ARID ZONE

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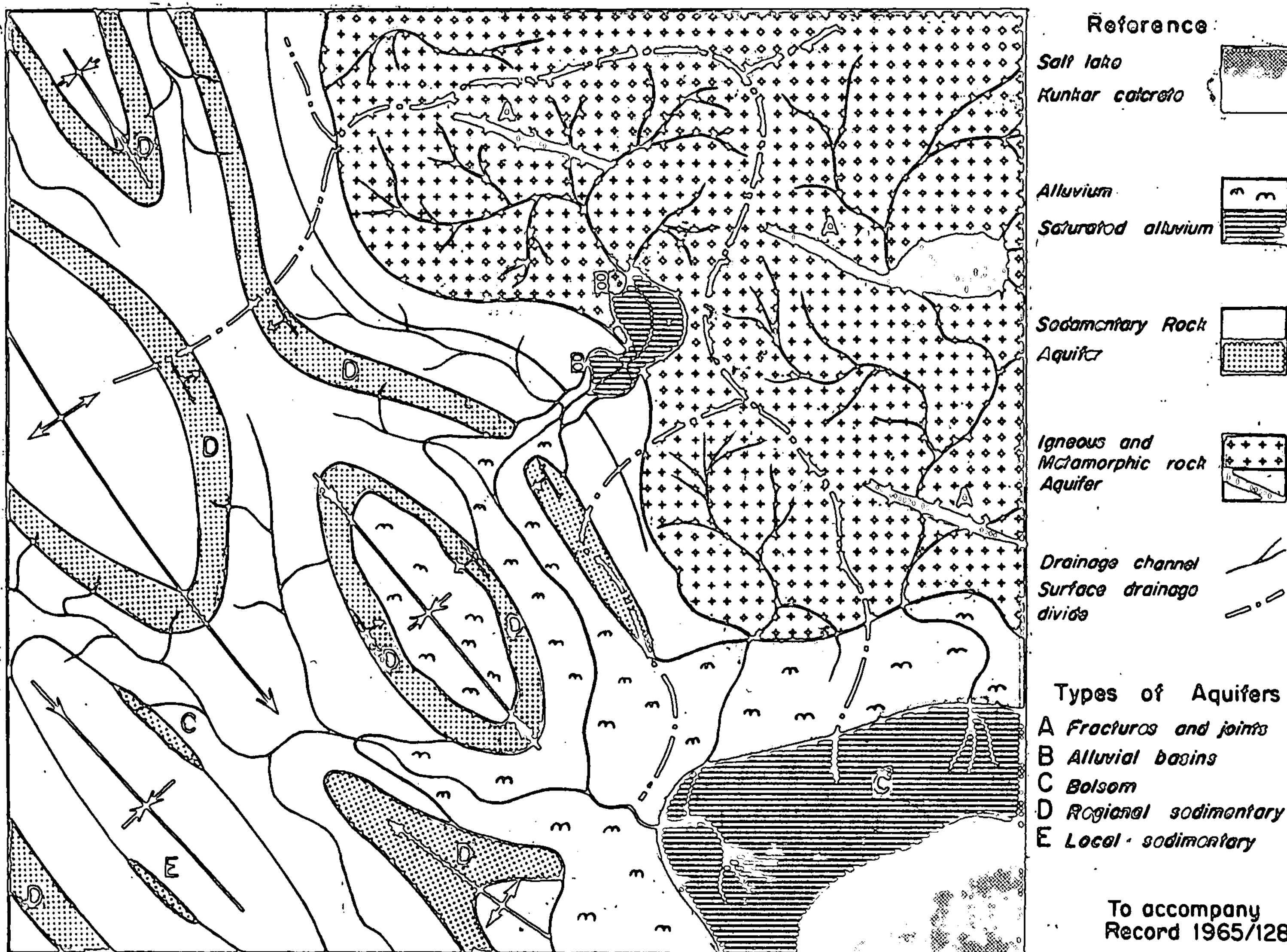

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Fig. 1 Relationship between various types of aquifers within the Arid Zone.

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THE UTILIZATION OF THE LOCAL WATER RESOURCES OF THE ARID ZONE

INTRODUCTION

The water resources of the arid zone are fully utilized in the cycle of nature; they can only be used by man if he breaks into this hydrological cycle at some point and diverts water to his own benefit. Therefore the problem is social as well as scientific. No policy has yet been formulated, in Australia, for the exploration of water in arid zones; social scientists have conflicting opinions on it, and the Australian Water Resources Council (1963) has publicly recognized that we do not yet have enough basic data for such a formulation.

This paper examines some of the aspects of the use of water, by describing breifly the resources which could be available the use which may be made of them, and some of the problems which can be expected.

THE RESOURCE

The Availability of Surface Water

The amount of surface runoff resulting from a storm will obviously depend on the hydraulic characteristics of the catchment, which in turn, are largely dependent on the topography and the surface geology. They vary from catchments in sand plain in which there is little or no runoff, to those in igneous and metamorphic terrains, in which runoff is very high.

Only for a few short periods during the year does enough rain fall to give surface runoff; so the availability of surface water will depend largely on the design of conservation works. Also, a catchment at least thirty times as large as that in a temperate zone would be needed before surface conservation could be contemplated.

The Availability of Groundwater

Useful quantities of groundwater are stored beneath the surface of the ground within aquifers - rocks which store water, and which allow its movement through interconnected fractures and intergranular spaces. The geological structure and the geomorphology of an area determine the extent of aquifers and their hydraulic behaviour. Five different types of aquifers which commonly occur in the arid zone are shown in Figure 1. They are:

1) Fractures and joints, mainly in igneous and metamorphic rocks. Individual fractures and joints are narrow, planar openings in rock, which can only store small quantities of water. Unless many of the individual openings are interconnected they are unreliable aquifers.

2) Alluvial Basins - small basins filled with unconsolidated alluvium and sediment. They are associated with single drainage systems and store moderate quantities of groundwater. Recharge is by infiltration along the bed of the drainage channels, and the ratio of the groundwater stored to recharge is less than 10. The groundwater which is used at Lorna Glen and Wiluna, W.A., is withdrawn from basins of this type.

3) Bolsoms, or large basins filled with unconsolidated lacustrine and marine sediment and with piedmont deposits, formed by the coalescing of individual alluvial fans. Commonly they are basins of internal surface and groundwater drainage, which terminate in salt lakes at the foot of the piedmont deposits. Recharge is usually available from several drainage systems and the ratio of groundwater storage to recharge is 100. The bolsom to the north of the Western MacDonnell Ranges, N.T., is 100 miles long and 30 miles wide.

4) Regional sedimentary aquifers, or permeable sedimentary rocks of wide areal extent, which will function as a regional aquifer system even if they have been structurally deformed. Recharge to the aquifers is by infiltration from many drainage channels as they cross outcrops of the sedimentary rocks. The ratio of groundwater storage to recharge is 1,000. The Wooramel and the Moogooloo Sandstones in the Carnarvon Basin, W.A., the Cambrian limestones of the Barkly Tableland, N.T., and the Mereenie Sandstone of the Amadeus Basin, N.T., are aquifers of this type.

5) Local sedimentary aquifers are thin porous and permeable beds of limited areal extent, which are within a sequence of impermeable sediments. They may store moderate quantities of groundwater, but the amount of recharge which they receive may be low.

Water Quality

The surface runoff from catchments within the arid zone will normally contain less than 100 parts per million of dissolved salts, but much larger quentities of suspended clay and silt. Providing that the latter can be removed, the water will be suitable for all purposes, although its turbidity may make it undesirable for domestic consumption.

Commonly within arid zones both surface drainage and groundwater basins are basins of internal drainage, and this has an adverse effect on the quality of the available groundwater.

Much information has been made available by the United States Bureau of Agriculture and the Geological Survey on the suitability of water for domestic, industrial, and agricultural use (Hem , 1959, and United States Department of Agriculture, 1954). Within the arid zone particular attention should be given to the limits which they have recommended because much of the groundwater is unsuitable for many uses.

Certain generalizations are possible regarding the quality of groundwater stored in the five groups of aquifers illustrated in Figure 1. This is because geology is a common factor in hydraulic behaviour and in processes of solution and adsorption, which determine the chemical character of the water.

1) Fractured rocks contain groundwater of very variable quality. The better quality water is available from aquifers in a position to receive local recharge.

2) The recharge mounds adjacent to the surface drainage channels which cross small alluvial basins contain groundwater suitable for domestic consumption. Away from the recharge mounds the quality will deteriorate rapidly until it is unsuitable for irrigation.

3) The piedmont deposits contain saline water in the vicinity of the salt lakes. The quality improves rapidly as the distance from the lakes increases, so that much of the groundwater is suitable for most purposes. Unless there is a physical connection between aquifers in the alluvium and those in the unconsolidated sediment, the groundwater stored in the latter will only be suitable for stock.

4) The opportunity for groundwater to move through a regional sedimentary aquifer and its lithology are the main influences on the chemical quality of the groundwater which it contains. Local or rapid variations are rare, and groundwater of similar quality is available over large areas.

5) The quality of the water in the sandstone aquifers of limited areal extent is variable and depends on the availability of local recharge and the chemical character of the surrounding sediments.

The Hydrological Cycle

The hydrological cycle may be expressed in terms of the following equilibrium statement:

Available water = (surface inflow - surface outflow)
+ (subsurface inflow - subsurface outflow)
+ (precipitation - unnecessary evaporation and evapo-transpiration)
+ (imported water - exported water)
+ change in surface storage
+ change in groundwater storage

This quantitative description of the cycle can be applied to an area of any size, even to the Arid Zone as a whole. However, it has more meaning if it is used to describe the movement of water within an area which is defined by natural hydraulic boundaries - surface drainage divides and the impermeable boundaries of groundwater basins. It is convenient to consider a groundwater basin and its associated catchment area, or surface drainage basin, as the basic hydrological unit.

The movement of water by a canal or a pipeline from one hydrological unit to another can only be justified when the local resources have become inadequate to meet the requirements of an important industry (usually a mining industry) or town (such as Broken Hill, Kalgoorlie, or Tennant Creek).

Obviously initial development should be directed to the use of both surface and subsurface outflow from particular hydrological units. Such development will ultimately be limited to the combined amount of surface and subsurface inflow, and by the ability to make better use of water which is lost in unnecessary evaporation and evapotranspiration.

UTILIZATION OF THE RESOURCE

The purpose for which the water resources of the arid zone are used depends on social and economic factors, which cannot be evaluated by the hydrologist. However, he can expect that they will be used according to a pattern established in other arid zones. The methods used to provide water must be suited to the arid zone, and will be limited by the resources available.

The Pattern of Utilization

All arid zones have examples of regions which have passed through one or more of the following overlapping stages in the utilization of their water resources, by the establishment of:

1) a nomadic pastoral industry
2) a sedentary pastoral industry
3) a mining industry
4) supplementary agriculture to support the pastoral industry
5) intensive agriculture
6) a manufacturing industry

Ordered development in such stages does not move rapidly, and is dependent on a parallel rise in technology to overcome the problems which occur with development. This is illustrated by the progress made by the Hohokam Indians in Arizona, who started in 1100 AD with primitive water-spreading methods, and by 1400 AD, had developed a system of canals to divert water from the Gila River to irrigate 240,000 acres. The project was abandoned because they were unable to deal with the problem of waterlogging (Skibtzke et al., 1961).

In Australia's arid zone, the principles of nomadic pasture management were used by Sir Samuel Kidman and others at the turn of the century. The change to the present sedentary form of pasture management came with the technical ability to construct permanent water supplies. Within the last ten years small areas have been established in central Australia and in Western Australia in which supplementary fodder crops and vegetables are grown by irrigation. The exploitation of mineral resources has resulted in the intensive use of the water resources available in the vicinity of individual mines.

If some of the known occurrences of oil and particularly of gas within the arid zone prove to be commercial, the local production of cheap fuels may stimulate further development.

The Utilization of Surface Water or Groundwater

Within the arid zone there are two factors which favour the use of groundwater rather than surface water. They are:

1) the high rate of evaporation
2) the relatively higher cost of conservation works for surface storage schemes.

These factors should not however preclude the conservation of surface water for artificial recharge projects.

The conjunctive use of surface water and groundwater in one particular hydrological unit may be of dubious merit in an arid zone. The deliberate retention of a large portion of surface runoff may slow river-flow down to a speed at which silt can be deposited over some intake areas, reducing their permeability. Moreover, there are usually one or more aquifers farther downstream which would depend on surface outflow from the hydrological unit for their recharge.

H owever, it is unreasonable to assume that significant aquifers, containing groundwater of suitable quality, will be available in all catchments. It would be desirable to restrict the conservation of surface water to those catchments where groundwater is not available, or is of poor quality; and possibly to such low-cost projects as water-spreading and the watering of stock.

Therefore the first stage in planning should be to differentiate between those catchments which are suitable for groundwater development, and those which are suitable for the development of surface water. Such planning would avoid the direct competition for runoff by the two methods of conservation, and possible misappropriation of resources in areas of greatest demand.

This is a logical policy, but it might be difficult to establish where the policies for land tenure are not flexible, and where development is undertaken without an adequate understanding of the available resources.

Limits to Utilization

The annual water requirements of the pastoral industry are modest. It is estimated that less than 15 acre feet of water would be required for maximum utilization of each 30 square miles of native pasture. This is small when compared to the total rainfall on the 30 square miles, and it is one which normally should be achieved by simple conservation works, if sufficient groundwater is not available.

The quantities of water required for agriculture, industry, and town supplies are large. The requirements may be difficult to satisfy unless the need can be established where the resources are available. There are few catchments in the arid zone capable of supplying them from surface storage. Only three of the five groups of aquifers illustrated in Fig.1 are likely to yield sufficient water; they are the regional sedimentary aquifer (type d), the bolsom (type c), and the alluvial basin (type b).

It was stated that the yield of a surface storage or of an aquifer is ultimately limited to a proportion of the rainfall over the appropriate catchment. Consumption in excess of this yield will deplete the quantity of water in storage; normally management practices are designed to use storage as a buffer to provide a continuity of yield. In many aquifers the ratio of groundwater storage to recharge is sufficiently large to permit depletion for a number of years.

The Mining of Groundwater

The use of stored water, in the knowledge that it cannot readily be replaced, is known as the mining of groundwater. This practice is used in the High Plains region of Texas and New Mexico to provide water for agriculture.

The mining of groundwater is condemned on the grounds that it is being denied to posterity but it can be justified on the following grounds:

1. the establishment of industries which would otherwise not have been possible;

2. where industries with small water requirements will replace those with large ones, and where new sources of water are likely to become available as a result of advances in technology.

3. to support the mining of a non-renewable resource, such as b ase metals.

4. when the geometrical structure and the hydraulic behaviour of an aquifer system is such that the water which is lost, by outflow and evaporation, cannot be diverted to more beneficial uses, unless storage is depleted.

PROBLEMS ASSOCIATED WITH UTILIZATION

Our ability to utilize a water resource obviously depends on our ability to solve the associated technical problems, which will increase in magnitude and number as more intensive use is made of the resource. Those which face the hydrologist in the development of Australia's arid zone are:

1. a lack of the basic data, which are a necessary prerequisite for planning the efficient utilization of this meager resource.

2. a lack of experienced hydrologists; particularly of those who are able to use sophisticated techniques

recently developed overseas, such as the use of analog and digital computers for the storage, analysis and interpretation of data.

3. the problem of communication between the many disciplines concerned with hydrology. Scientists and engineers reared in one discipline do not necessarily comprehend the language and logic of others.

4. technical problems associated with the construction of efficient, large diameter, multi-aquifer bores.

5. the suppression of evaporation, which could be overcome by mastering the South African techniques for the construction of sand-filled storages.

6. the control of siltation by the use of suitable conservation measures in the catchment area.

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