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SUMMARY

Wide application of the term "basin" in Australia indicates the necessity for careful definition as the word is employed in the assessment of water resources. It is the purpose of this paper to define current usage of "basin" and to examine the problems in adopting a consistent nomenclature which will be useful for the future appraisal of groundwater resources.

Geological usage of "basin" comprises topographic, structural, and sediment-filled depressions. Hydrological usage is based on the recharge, movement, and discharge of water. But the hydrologic basin is dependent upon the geologic environment for its physical shape. The three kinds of hydrologic basins are the drainage basin, the artesian basin, and the unconfined-groundwater basin. Related hydrologic terms include "groundwater reservoir", which refers to an area defined by groundwater development, and "groundwater province", which refers to an area of uniform hydrologic characteristics.

Study of water resources within the framework of a hydrologic basin makes possible the evaluation of the hydrologic budget, the estimation of safe yields, the definition and control of problems of contamination, and the proper management of future development. However, application of the hydrologic basin as a study area in Australia may require the division of the country into two hydrologic environments: the influent-stream environment and the effluent - stream environment.

The influent-stream environment comprises the major and interior part of Australia, where recharge to drainage and unconfined-groundwater basins is too small to support effluent streams. Because it is difficult to define topographic and phreatic divides in this environment, drainage and unconfined-groundwater basins may not prove useful as study areas. On the other hand, artesian basins are important sources of supply in this region and are therefore suggested as primary water-study units (Pl.1)

The effluent-stream environment comprises the coastal parts of Australia, where annual recharge is less variable and is large enough to support at least seasonally effluent streams. These streams indicate an excess of groundwater recharge over storage, which excess is available for human development. The phreatic divides generally approximate the topographic divides in this environment, hence the drainage basin may be utilized as a unit of areal study (pl.1).

INTRODUCTION

Geological and hydrological maps of Australia show patchworks of areas labelled "basins". At first glance, it seems that almost every sedimentary unit is termed a "basin", and that each of these contains its own "artesian basin". These labels are not incorrect, but they do suggest that the word "basin" is overworked and that future geological and hydrological usage should be carefully defined. A clearer understanding of what constitutes a hydrologic basin is especially required for the future assessment of Australian water resources.

It is the purpose of this paper to examine the problems of naming hydrologic basins from the standpoints of current usage and meaning, and particularly from the standpoint of usefulness for the appraisal of groundwater resources. As will be seen, this requires an inspection of current geological usage of "basin" as well as a commonsense understanding of the word.

In this paper "groundwater" is used as an equivalent of underground water and therefore includes both confined and unconfined water that occurs within the zone of saturation.

USAGE OF THE TERM "BASIN"

The term "basin" has been used in different, but interconnected senses by geologists. Three usages have been strictly geological; others have been hydrological, but always related in some respect to the geological environment.

Most of these usages have not violated the commonsense meaning of "basin", which suggests a depression that slopes from a rim to a more or less centrally located low point (or, hydrologically, from a margin of recharge to a common point of discharge). However, when the word is loosely applied by geologists to a body of rock of a given age or to a depositional unit of undefined shape or structure, or when it is applied by hydrologists to an arbitrary unit of saturated rock, its significance as a descriptive term is destroyed.

Geological Usage

There are three common geological usages of the word "Basin": topographic (geological in the sense that topography marks the upper limit of the earth's crust), structural and sedimentary.

The topographic basin is an extant depression, which may or may not be related to any structure.

The structural basin, however, is of tectonic origin. "...A regional structural depression of great area which does not have the characteristics of a geosyncline ... a structural low in a still larger structural depression ... a local syncline only a mile or a few miles across" (Russel, 1955, p.294-297). To be tectonically more specific: "... Use the term 'basin' for ovate negative areas within the craton proper" (Krumbein and Sloss, 1951, p.336).

The sedimentary basin is a sediment-filled depression. Whether structural or not, it must perforce have been at one time a topographic basin or it would not have received sediment: "... A sedimentary basin is a topographic depression receiving sediments, and its size and shape are controlled only by the existing topography" (Dallmus, 1958, p.884).

Most Australian sedimentary basins are partly filled cratonic depressions and thus qualify as structural basins as well. However, some, for example the Drummond and Bowen Basins, might be better classed (tectonically) as geosynclines, and a few may deserve more general titles, such as "depressions" or "regions".

Hydrological usage

A hydrologic basin is defined by the recharge, movement, and discharge of water. It is bounded by the limits of its area of recharge on the one hand and by its point or area of discharge on the other. Furthermore, because water is a fluid, the hydrologic basin depends upon its geologic environment for its physical shape. The water within a hydrologic basin is also occupying a topographic, structural, or sedimentary basin.

Of course, this definition is oversimplified. Surface water, confined groundwater, and unconfined groundwater may each enter a given area differently, may each move in a different direction, and may each have different points of discharge. Hence, there are different kinds of hydrologic basins.

Drainage Basin

The most used and simplest kind of hydrologic basin is the drainage basin. It is defined by the recharge, movement, and discharge of surface water, but it is geologically a topographic basin. Its boundary is the topographic divide; rainfall on one side of the divide will recharge the surface waters of the basin, rainfall on the other side will not. Movement of surface water through the basin is also controlled by the topography. Discharge (other than by evapotranspiration) is at the lowest point in the drainage basin.

Artesian Basin

An artesian basin has been defined as: "... The whole of an area within which artesian or sub-artesian water may be obtained by boring" (Interstate conference on Artesian Water, 1912, p.IX), and as: "... the whole of an area within which pressure water exists and from which artesian or sub-artesian water is obtained by boring, together with the area occupied by the groundwater contained in the upper and marginal unconfined portions of the water-bearing beds" (Ward, 1946, p.34). The second definition is more complete and more useful.

Geologically, then, an artesian basin is bounded by the extent of its water-bearing strata and approximates, but is generally somewhat smaller than, its containing structural-sedimentary basin, which may include less-permeable basal beds in the intake area and possibly overlying beds in other areas. Topography has a limited role in defining an artesian basin.

Recharge to an artesian basin is limited to the catchment area and includes pluvial and influent water. Movement of water is from points of high potential to points of low potential (Ward, 1946, p.36, 37); differences in potential are due to geologic structure and changes in aquifer permeability. Natural discharge of pressure water is as underflow from the artesian basin or as upward leakage.

Unconfined-groundwater Basin

The margin of an unconfined-groundwater basin is a phreatic divide, rather than a topographic divide or a stratigraphic boundary. The position of this divide depends largely upon geologic structure and the permeability of the water-bearing materials. Topographic control of the divide is possible where the basin occurs in water-bearing materials of relatively uniform permeability and of hydrologically ineffective structures.

Although this last case is not everywhere common, the phreatic divide does tend to approximate the topographic divide, because topography is in most places controlled by the same geological structures and rock characteristics that influence hydrology. The phreatic divide corresponds most closely to the topographic divide where and when the water table is shallow. Thus, there is close correspondence of divides in humid environments and, where rainfall is decidedly seasonal, during the wet season. (See Wisler and Brater, 1959, p.39.).

Recharge to an unconfined-groundwater basin is generally pluvial, but under certain conditions, particularly in arid climates, it may be partly or largely influent from bodies of surface water. In humid environments, the area overwhich recharge takes place approximates the area of the corresponding drainage basin. Thus, where knowledge of the subsurface geology is relatively complete, differences in area due to non-coincidence of the phreatic and topographic divides may be calculated or at least estimated.

In arid environments, factors of rainfall intensity, duration, and distribution; soil moisture content; depth to the water table; perched water tables; and stream-bed permeability may widen the discrepancy between phreatic and topographic divides. Thus, the area of surface-water recharge may have little relationship to the area of unconfined-groundwater recharge.

Movement of unconfined groundwater is from points of higher to points of lower hydrostatic head. Differences in head are due to geologic structure, to changes in permeability, or, more rarely, to topography alone.

Discharge of unconfined groundwater may be to the surface by evapotranspiration or as effluence to springs, swamps, streams or lakes; or by underflow from the basin at the point or cross section of lowest hydrostatic head. Discharge as underflow from an unconfined-groundwater basin provides a source of recharge to another goundwater basin.

Related Hydrological Terms

Terms used frequently in the discussion of hydrologic basins are "groundwater reservoir" and "groundwater province".

A groundwater reservoir is a part of the earth's crust that is significant as a source of water supply at the current levels of technology and economy. It is bounded by the limits of the effects resulting from its development, rather than by the natural phreatic divide. A hydrologic basin may contain none, one, or several groundwater reservoirs; conversely, a single groundwater reservoir may comprise more than one basin or parts of several basins.

For example, a groundwater basin may be incapable of development (i.e. it contains no groundwater reservoir), because of the very low permeability of its water-bearing materials or because of the poor quality of its water. Or it may contain several distinct reservoirs of highly permeable rocks or deposits, which are separated by areas or strata of less-permeable rocks and are therefore capable of development without mutual interference (excepting possible competition for recharge within the basin).

On the other hand, where a phreatic divide crosses relatively permeable rocks, development on one side of the divide may cause the divide to shift toward the undeveloped or less developed side. Thus, recharge from the adjoining hydrologic basin is "pirated" and the groundwater reservoir comprises more than one hydrologic basin.

A groundwater province is an area or region of uniform hydrologic characteristics. It may refer to a related group of hydrologic basins. Often, it is applied to relatively large areas which are not readily classified as hydrologic basins of one type or another, or where such classification is pointless. For example, separation into basins may be pointless in areas of crystalline (igneous and metamorphic) rocks where saturated deposits of soil or alluvium are too thin, too discontinuous, or too impermeable to form significant aquifers. Groundwater recharge, movement, and discharge is here almost completely controlled by local patterns of joints, fractures, or other secondary structures. The areal evaluation of recharge, etc., therefore, has little relationship to what occurs at particular well sites.

THE USEFULNESS OF THE HYDROLOGIC BASIN CONCEPT

Because the three kinds of hydrologic basins generally overlap or merge, to the confusion of the investigator, and because each kind is ultimately defined in terms of geologic factors, the value of the basin concept as a tool for the areal study of water resources may be questioned. Certainly, reconnaissance or inventory type investigations which have the object of collecting basic underground-water data, can be as efficiently performed within political or map areas. The same is true to site-testing investigations.

However, if the object of the investigation is some phase of water management, the hydrologic basin concept is extremely valuable. All surface-water investigations, by nature and application of results, are of the water-management type.

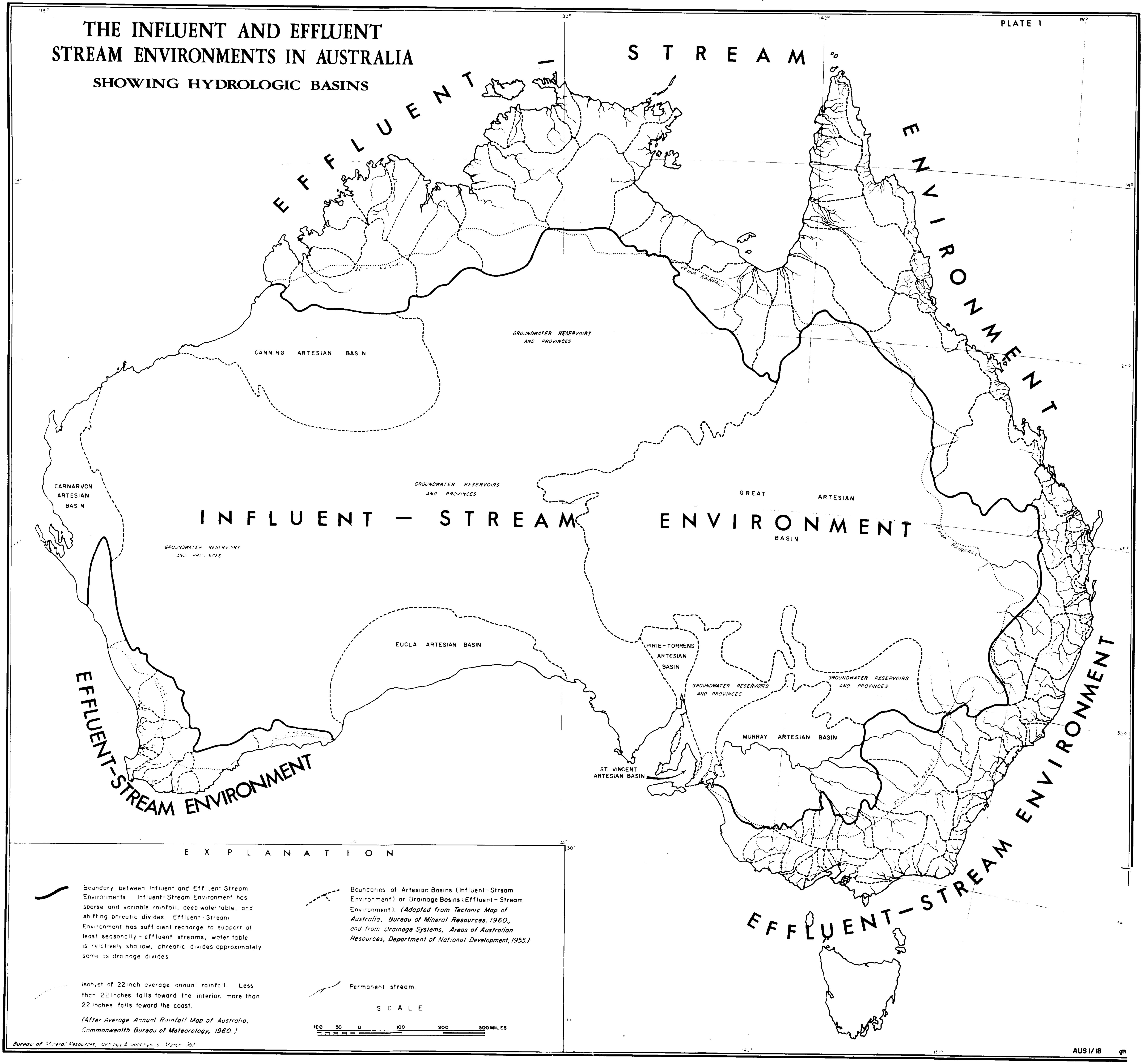
PLATE 1
THE INFLUENT AND EFFLUENT
STREAM ENVIRONMENTS IN AUSTRALIA
SHOWING HYDROLOGIC BASINS
EFFLUENT – STREAM ENVIRONMENT
INFLUENT – STREAM ENVIRONMENT
EFFLUENT-STREAM ENVIRONMENT
EFFLUENT–STREAM ENVIRONMENT
CANNING ARTESIAN BASIN
GROUNDWATER RESERVOIRS AND PROVINCES
CARNARVON ARTESIAN BASIN
GREAT ARTESIAN BASIN
EUCLA ARTESIAN BASIN
PIRIE-TORRENS ARTESIAN BASIN
ST. VINCENT ARTESIAN BASIN
MURRAY ARTESIAN BASIN
22 inch RAINFALL
EXPLANATION
Boundary between Influent and Effluent Stream Environments. Influent-Stream Environment has sparse and variable rainfall, deep water table, and shifting phreatic divides. Effluent-Stream Environment has sufficient recharge to support at least seasonally-effluent streams, water table is relatively shallow, phreatic divides approximately same as drainage divides.
Boundaries of Artesian Basins (Influent-Stream Environment) or Drainage Basins (Effluent-Stream Environment). (Adapted from Tectonic Map of Australia, Bureau of Mineral Resources, 1960., and from Drainage Systems, Areas of Australian Resources, Department of National Development, 1955.)
Isohyet of 22 inch average annual rainfall. Less than 22 inches falls toward the interior, more than 22 inches falls toward the coast.
(After Average Annual Rainfall Map of Australia, Commonwealth Bureau of Meteorology, 1960.)
Permanent stream.
SCALE
100 50 0 100 200 300 MILES
AUS 1/18

Similarly, observation and measurement of the various factors of the hydrologic budget, which balances water gains against water losses (Rasmussen and Andreasen, 1959, p.3), is only practical within a hydrologic basin.

Estimates of safe yield require certain knowledge of the contributory area, type, and quantity of recharge; the volume of stored water; and the type and amount of discharge; all of which can best be learned through basin study.

Problems of bacteriological or chemical contamination of water, because they are so dependent for solution on knowledge of water movement and of dilution by recharge, are best defined and controlled through basin-wide programs.

Finally, the management of future development, which includes the problems of safe yield and contamination as well as that of balancing the effects of optimum pressure-water, unconfined-groundwater, and surface-water withdrawals, is only possible within the framework of a hydrologic basin.

APPLYING THE HYDROLOGIC BASIN CONCEPT

The major problem of applying the hydrologic basin concept in Australia is inherent in the fact that the margins of the three types of hydrologic basins generally do not exactly coincide. Hence the question, which type of basin is to be studied? It is important, in examining this problem, to remember that the ultimate object of study should be the overall water resources of an area - not resources of pressure water alone, nor unconfined groundwater, nor surface water.

A possible step toward solution of this problem is accomplished by the division of Australia into two hydrologic environments: an influent-stream environment and an effluent-stream environment (plate 1). This division is essentially based on the occurrence of surface water, but is modified to follow the boundaries of extensive and important sedimentary basins. It is intended as an aid for organising and assessing available data and for planning future investigations. It is not intended as a dictum to be followed by field investigators who have discovered more practical hydrologic boundaries for their particular study areas.

The Influent-Stream Environment

The influent-stream environment comprises the major and interior part of Australia (pl.1). Rainfall, the ultimate source of recharge to all types of hydrologic basins, averages less than 22 inches annually over this region. This sparse rainfall is seasonal, occuring during summer in the north and during winter in the south, and is highly variable in amount (Australia, 1954).

Recharge to drainage and unconfined-groundwater basins is small, because in addition to evaporative loss, a large part of rainfall is required to replenish the soil-moisture deficiency (amount of depletion from the maximum amount of water than can be held by molecular adhesion to the surfaces of soil grains), which has developed during the preceeding eight months, before either runoff or groundwater recharge can occur. As a result, the water-table is generally far below the land surface, even during wet periods, and streams are generally influent. The only perennial surface-water drainage system in this environment is that of the Murray River, which itself is an influent stream for part of its course (David, 1950, p.11 and 56).

It is difficult to determine phreatic divides in this environment, for the great depth of the water table makes their positions susceptible to control by buried structures and the variability of recharge causes unpredictable shifts in location. They may range in position, depending upon recharge, from near the topographic divides (which, due to low relief, are not prominent) to the stream courses themselves (which may serve as the major sources of groundwater recharge). Hence, the usefulness of both drainage and unconfined-groundwater basins as study areas is decreased.

Study of unconfined and locally confined groundwater in this environment is probably best limited to groundwater reservoirs, each of which comprises an aquifer or a group of related aquifers. Recharge to these reservoirs, as infiltration and underflow, may be estimated more accurately than recharge to an unconfined-groundwater basin of uncertain and changing size and shape. Where the major aquifers are crystalline rocks or the water resources are so small as to preclude development, areas of study should be ground-water provinces.

The influent-stream environment also encompasses major artesian basins. Catchment areas for some of these occurs near the boundaries of the environment, where recharge is relatively higher and more regular than toward the centre. For this reason, the artesian basins are generally more capable of supplying large quantities of water in this environment than are many of the overlying groundwater reservoirs. Thus, the artesian basin is suggested as a primary water-study unit. However, overlying groundwater reservoirs should be assessed as parts of the overall groundwater resources of the basin area.

A tentative division of this environment into artesian basins and areas of groundwater reservoirs and provinces has been made in plate 1. Artesian basin names have been based on recent nomenclature for sedimentary basins (Irving, Smith, and Walker, 1958; Australia, 1960, Tectonic Map). Subdivision of the areas of ground-water reservoirs and provinces is left to investigators more able to appraise the hydrological characteristics of these regions.

The Effluent-Stream Environment

More plenteous rainfall to coastal parts of Australia results in considerably more recharge to drainage and groundwater basins than in the interior. Except in the south-east, however, rainfall is seasonal and the year is divided into a period of depletion and a period of replenishment. It is the regularity and volume of the annual recharge that distinguishes these regions from the influent-stream environment. Generally, recharge is here sufficient to support seasonally effluent streams and, in most drainage basins, a major stream that is permanent in at least its downstream reaches (See pl. 1.).

Seasonally or permanently effluent streams indicate a groundwater reservoir that is annually recharged to overflowing and hence has an excess of water available for human use. Therefore, withdrawal of groundwater, even during dry seasons, has the effect of providing more storage room for recharge and of decreasing the amount of rejected recharge.

In this environment, the water table is relatively high and the phreatic divide generally approximates the topographic divide. Estimates of recharge, rejected recharge, safe yield, etc. can be made for the drainage basin, utilizing surface-water measurements, and applied to the coincident unconfined-groundwater basin.

Several artesian basins occur in this environment, but they are generally of smaller areal extent than those in the influent-stream environment. It is possible that quantitative appraisal will prove that some of these basins, particularly along the northern and western coasts, are of greater importance as sources of water supply than the overlying unconfined-groundwater basins. Therefore, the approach toward study of this hydrologic environment must remain flexible.

More generally, however, the unconfined aquifers are of equal or greater importance for future development than the artesian systems. Hence, the drainage basin, adjusted for watershed leakage (as underflow), is suggested as the study unit in this environment. A tentative division of the effluent-stream environment into drainage basins has been made in plate 1. The basins should be named after major streams. The underlying artesian aquifers, where present, may be assessed as to quantity of underflow, using artesian potentials across the area of the drainage basin.

Perhaps some areas in eastern Australia should be termed "groundwater provinces", because the major aquifers are fractured crystalline rocks and do not show a basin-wide response to groundwater recharge and discharge. However, I am not familiar enough with the spacing of fractures or the non-occurrence of saturated mantle and alluvium in these areas to make a distinction from the drainage basin classification.

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