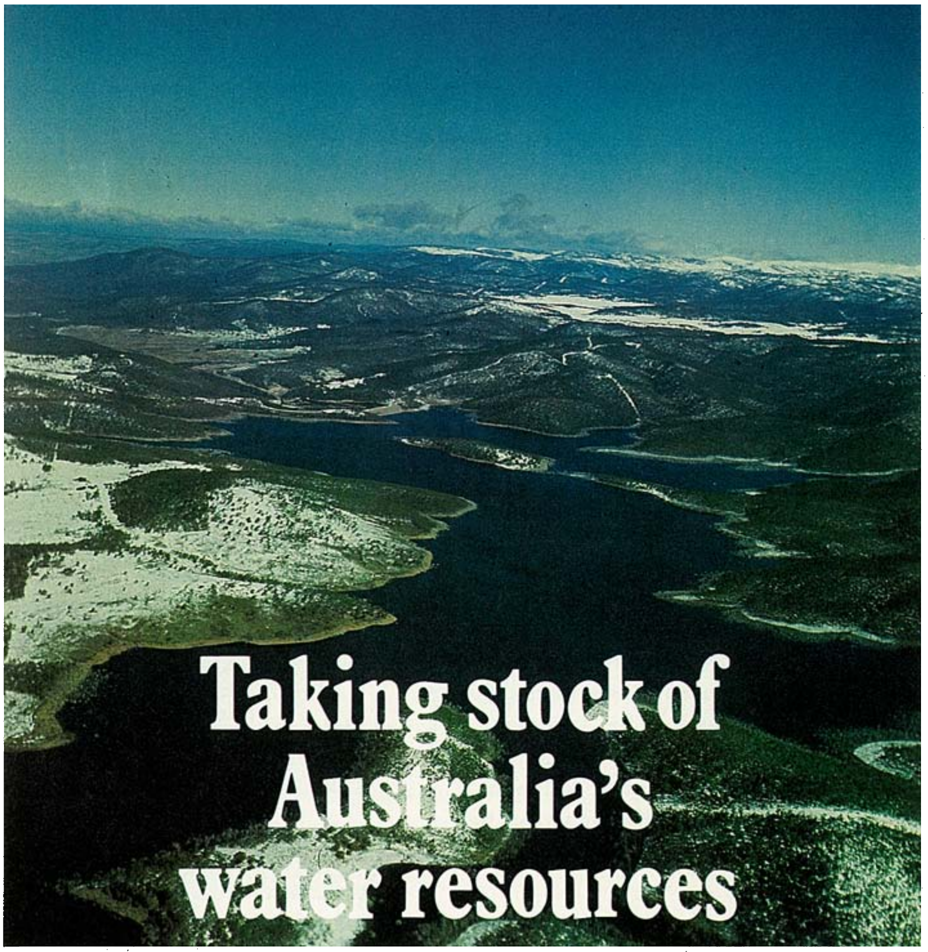


Taking stock of Australia's water resources

Lake Eucumbene gains most of its water from melting snow. However, most Australian streams depend largely upon storms, making their flow extremely variable.

Australia is the driest of the inhabited continents, yet our modern society makes large demands on water supplies for domestic, industrial, and agricultural purposes. The average annual run-off from the Australian mainland has been assessed as the equivalent of only 5 centimetres depth over its surface. The run-off from Africa, the next driest continent, is equivalent to a depth of 17 cm.

To compound the problem of small resources, Australia experiences prolonged droughts, and its lack of high mountains means that it has no permanent snowfields. As a result, stream flows here depend largely on individual episodes of heavy rain, and are consequently extremely variable.

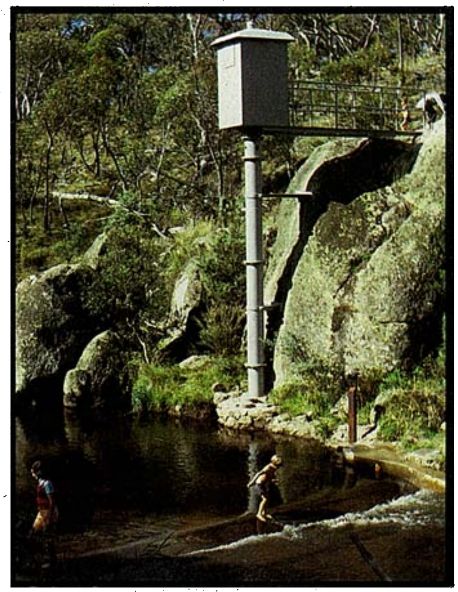
The potential of a stream in providing water can only be estimated if we have good long-term flow information. The Australian water resource authorities have a valuable and extensive network of stream-gauging stations, but it would be an impossible task to place gauging stations on all our rivers. It would also be many years before long-term values could be established.

Yet in most areas of Australia, records of daily rainfall and climate have been kept since the earliest days of settlement. It is therefore an attractive notion that, if we could use climate data to estimate evaporation and transpiration and link these estimates with rainfall readings, we could calculate the total surface run-off and seepage to groundwater.

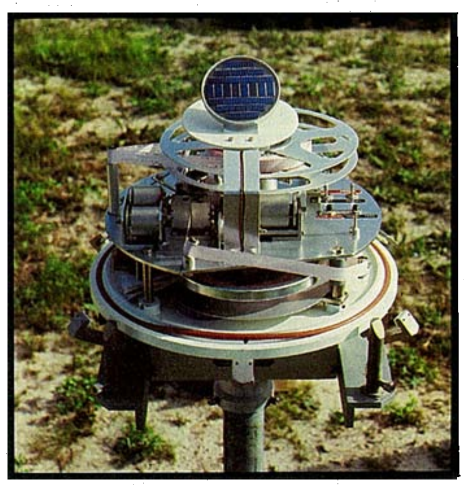
What is needed is a hydrological model that can tie rainfall within a catchment to the stream flow generated in it. This is the aim of the Representative Basins Program, an ambitious project being run by the Australian Water Resources Council (AWRC).

The idea of representative basins relies on similarities between different catchments. When driving along a road through the Australian landscape, repeating patterns occur. Each culvert or creek-crossing drains an area that looks similar to the last or to one a few kilometres back.

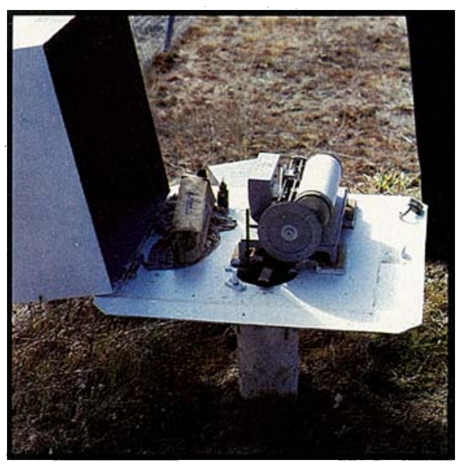
Now, if we can identify the similarities between two catchments that are hydrologically significant — terrain, geology,



This gauging station in the Orroral Valley is designed to register nearly all conceivable floods.



A data recorder designed at the Division of Land Use Research for field operation. When its protective cover is in place, only the solar cell on top is exposed.



A borehole instrumented to record the groundwater level.

land use, soil, and vegetation — we will be in a position to estimate the stream flow of one from the rainfall and stream flow of the other. A reasonably simple model should be able to take account of the variability resulting when the hydrological elements of the catchments are the same but arranged in different ways.

Starting from this idea in 1965, the AWRC has identified 93 basins, ranging in size from 25 to 250 square km, that have been selected as representing a very wide range of Australian landscapes, hydrological conditions, and climate. Each catchment is being instrumented (about 90% of them have been so far) so that the particulars of its water balance can be measured.

Very flat arid and semi-arid plainlands do not, in general, possess distinct drainage basins. Because they cannot be easily accommodated in the representative basin concept, these areas, occupying one-third of the continent, do not come under the program umbrella.

Collecting data

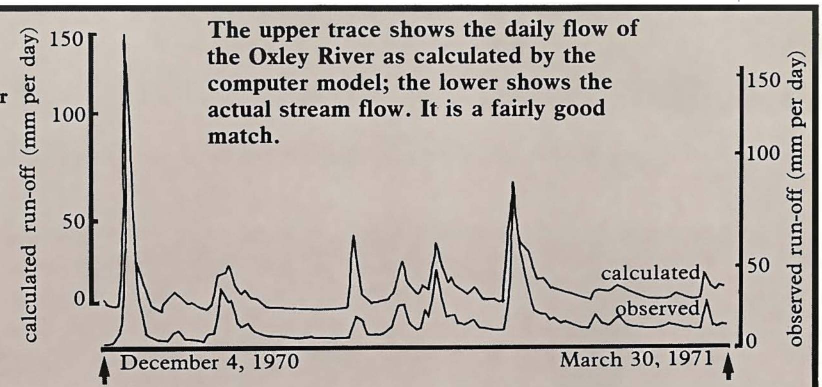
The implementation of the program has involved virtually all agencies associated with the AWRC. The particular State water authorities are undertaking stream-gauging of basins, the Bureau of Meteorology is collecting rainfall and climatological data, and the Geological Survey authorities are investigating geology and groundwater.

The proof of the method is in its operation, and on this score the model is doing well.

Automatic recorders take readings of stream height at least every 15 minutes, and the stream flow is calculated from them. At least four rainfall stations within a catchment take daily readings and one of them records rainfall at 6-minute intervals.

The climate station in each catchment records standard meteorological data — daily maximum and minimum temperatures, daily totals of wind-run and radiation, and wet- and dry-bulb temperatures at 9 a.m. and 3 p.m. Some stations are more elaborate and record hourly values, and some possess evaporimeters as well.

The mass of data is transferred to the CSIRO Division of Land Use Research at Canberra on magnetic tape, where it is processed and added to the computer data bank. Currently this data bank contains data from 67 basins and the total information exceeds 10 million words of computer store. This represents more than 2000 station-years of data. The data bank, which is available to all researchers, is already a resource of considerable national value, and is being drawn on by workers in universities and other research institutions.



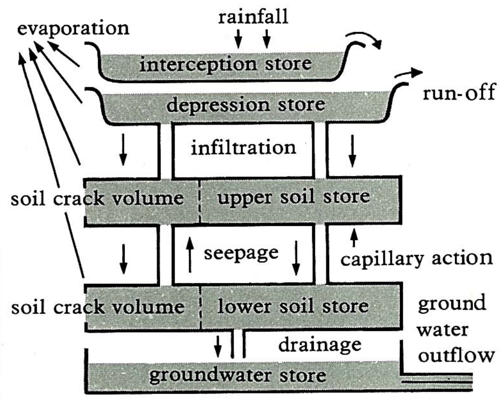
How good is the computer model? **The upper trace shows the daily flow of the Oxley River as calculated by the computer model; the lower shows the actual stream flow. It is a fairly good match.**

Mr Neil Body, Mr Mick Fleming, and Mr Jim Goodspeed are the scientists at the Division responsible for development and use of the data bank. As Mr Body sees it, the acquisition of data in the first 10 years, and the development of computer programs to edit, manipulate, transfer, and store the data, were far more difficult than anybody originally expected. They have required the efforts of hundreds of people throughout Australia, but the results are now beginning to show.

From the beginning, the Division has been involved in some way in nearly every aspect of the Representative Basins Program. It operates and maintains one of the representative basins, the Upper Yass River basin. Part of its role has been to develop instruments that enable the data to be processed by digital computer. Mr Goodspeed was responsible for designing equipment that translated existing charts into digital form. He also produced an instrument for logging field data, which punched the data directly onto paper tape ready for the computer.

Mr Body and his colleagues now have before them the challenging task of developing and refining the computer model that will allow the data bank to be put to work. The model will provide simulated stream-flow records from ungauged catchments, given appropriate input data. It will also be used to refine the semi-empirical design methods used by engineers for small structures such as weirs and culverts.

A diagram of the computer model



The Australian Representative Basins Model (ARBM) is basically an arrangement of five different water stores that simulate water storage in the field. Formulas, derived from physical theory and experiments, link the stores.

It is estimated that, on average, $400 million is spent each year on such flood-mitigation structures in ungauged catchments.

Five moisture stores

The model has evolved over time, incorporating new research findings as more has been learnt about the physical processes involved in water percolation and run-off. But the basic idea behind it is fairly simple, and a schematic version of it is shown in the diagram. It has five moisture stores, or 'tanks', and water moves between them as shown. Formulas, derived from physical theory and experiments, link the stores and approximate what goes on in the field.

Rain falling to the ground first encounters foliage, from where it drips or runs down stems to the ground, but leaving a proportion behind in the 'interception store'. Rain reaching the ground enters the soil, but if it falls faster than it can be absorbed, water begins to fill depressions in the surface, the 'depression storage', until it overflows and creates surface run-off. Within the soil the absorbed water begins to saturate the upper soil store (considered as the top 30–60 cm) where the roots of most grasses and crops are located. The lower soil store, to about 150 cm deep, is the region explored by the roots of trees and other deep-rooted vegetation. Water seeps down to the lower soil store, but as the upper soil store dries out, it can also rise by capillary action. Water also drains from the lower soil store into the groundwater store, which keeps the stream running during dry spells.

An important feature of the Australian Representative Basins Model (ARBM) is that each store is an amalgam of the conditions from the whole catchment. The model finds the capacity of each store, and this single value, or 'lumped parameter', is accepted as the effective average for the catchment, despite the multiplicity of different areas with different characteristics.

The capacities of the stores are found by comparing observed and predicted stream flows and determining the sets of values that give the best match. Actually, the model involves 12 lumped parameters (representing, as well as store capacities, such factors as evaporation, infiltration, and drainage), and it is not always easy to find the best set of these, since they depend upon one another.

A gauging station on a bushland stream.

The model demands a very large quantity of data; in particular, rainfall readings need to be taken in the field every 6 minutes. These almost-continuous data are necessary because the model is trying to simulate the physical process of water infiltration. This process can change rather quickly, as the rate at which infiltration takes place depends on the initial moisture content of the soil and how much has already infiltrated. However, if no rain is falling the model does not have to operate on a 6-minute interval; in non-rain periods on wet days it uses a 1-hour period and on dry days one of 24 hours.

The amount of data in the data bank

Rainfall at 6-minute intervals	831·8	station years for 151 stations in 55 basins
Daily rainfall	941·5	station years for 62 basins
Stream discharge	206·2	station years for 32 basins
Evaporation	370·6	station years for 54 stations in 42 basins

Although the amount of data is considerable, only 49 basin-years of data for 12 basins can be used for computer modelling (because sometimes meteorological data are not available at times when hydrological data are, and vice versa). Nevertheless, the proportion of complete data is steadily increasing.

Nevertheless, the proof of the method is in its operation, and on this score the model is doing well. The parameters for all the basins analysed so far, except perhaps one, seem to be fairly stable — they don't change radically from one rain-storm to the next or across seasons. The researchers prefer to say that their model is in this respect fairly 'robust'.

The one exception was the Warrambine representative basin, where run-off behaviour differed very much between summer and winter. The problem lay in the soil type, a deep cracking clay, which was normally dry and cracked in summer but almost impervious by the end of winter. The scientists therefore developed a special cracking-soil model, which successfully limited simulated run-off at Warrambine in summer to the few occasions when the cracks were effectively filled. At the same time, it preserves response to winter rain.

Refining the model

The model has been used by a number of other researchers to help solve hydrological problems.

The Snowy Mountains Engineering Corporation has built it into its urban run-off model and has applied it to simulate the effect of urban development at Albury–Wodonga. The model has also been used to compute the size of retarding basins and floodways necessary to handle run-off from adjacent rural land.

At the moment, Mr Body and his colleagues are investigating the relations between model parameters and other physical descriptions of catchments. They are also trying to determine how sensitive the model is to variations in catchment parameter values.

In particular, the researchers are investigating the information that can be extracted from the 1: 100 000 series of topographic maps produced by the Division of National Mapping. These maps are based on a fairly uniform interpretation of aerial photographs coupled with field observations, and thus offer a simple and effective way of obtaining land data. Indeed they seem more useful than Landsat photos, although the scientists are examining them also. Landsat appears to be particularly good for monitoring land use changes.

The maps are at present being analysed to investigate the spread of measured characteristics among groups of adjacent catchments. They are divided into 4-square-kilometre sections, and the dominant land cover, geology, slope, and so on are recorded for each section and filed in a computer data bank. Indexes of similarity are derived, and the first test will be to see how close hydrologically are basins with similar index values.

The CSIRO scientists hope that the refined model and the parameter relations will allow confident prediction of the effect of land use changes, without the detailed field experimentation usually involved (such as was necessary for the Shoalhaven catchment study described in the article on page 8).

Andrew Bell

More about the topic

The representative basins model applied to four catchments. D. N. Body and M. J. Goodspeed. *Proceedings, Hydrology and Water Resources Symposium, Institution of Engineers Australia, Perth 1979*, 1979, 138–44.

The Australian representative basins programme. P. M. Fleming. *Journal of Hydrology (N.Z)*, 1974, **13**, 21–3.