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THE AUSTRALIAN REPRESENTATIVE BASINS PROGRAMME

P. M. Fleming*

ABSTRACT

The Australian representative basins programme is outlined, its history discussed and the influence of the *a priori* conceptual model on the specifications for data collection and processing is discussed. The present status and directions of expansion are briefly touched on.

INTRODUCTION

Rodda (1971) has commented that, in contrast to most national representative basin programmes, those in Australia and New Zealand are rationally planned to sample the hydrological diversity present in their respective environments. The programme in Australia has also been planned from the very first to achieve a uniformity of data-collection techniques compatible with a central data analysis. The concept of uniformity of data collection and central data storage and analysis has posed special problems in Australia because the measurement and assessment of water resources are state and not federal responsibilities under the Australian constitution. In addition, within some states there is a further partitioning of authority with respect to surface and underground water and city water supply.

It is proposed here to review the history of the programme and the concepts involved, which are set out in greater detail in AWRC (1969), and show how these concepts influenced the specification of data-collection techniques, the initial processing of data and its eventual transmission to and storage in a computer archive. Development of the programme has continued, as has the development of the conceptual model. These developments have not, as yet, seriously modified the initial specifications.

* Division of Land Use Research, Commonwealth Scientific and Industrial Organization, Canberra, Australia.

THE HISTORY OF THE PROGRAMME

On the recommendation of an advisory committee on rainfall and runoff relations, the Australian Water Resources Council set up an Advisory Panel on Representative Basins with terms of reference which may be broadly stated as follows:

(i) Development of an objective selection method by which about 100 sample catchments of a reasonably homogeneous nature could be obtained. This group was to collectively represent as wide a range of Australian hydrological conditions as possible.

(ii) Development of recommendations as to the type and quality of the data to be collected and preparation of the data for analysis, together with the primary method of analysis to be adopted.

The first objective was met by devising two new classifications for climate and landscape and then selecting the dominant landscape members in each climate region. The climatic classification was based on median monthly rainfalls available from the data bank used in the Australian Water Resources Council publication, *A Review of Australia's Water Resources (Monthly Rainfall and Evaporation)* (AWRC, 1968). Seasonality was taken into account by the calculation of the ratio of summer rainfall (November to April) to winter rainfall (May to October). If the ratio of the greater to the lesser was less than 1.3 the rainfall was termed uniform, otherwise the region was named after the dominant term. Evaporation was taken into account in the setting of the rainfall limits to different zones. Thus the limits of the arid zone are respectively 254 mm and 380 mm in the winter and summer rainfall zone while the high-rainfall zones are respectively greater than 890 mm and greater than 1400 mm.

The landscape classification was based on an extension of the land-system method introduced by Christian and Stewart (1953). The final form was a map of Australia with a scale 1:5 000 000, showing the relief and land form of Australia, with symbols for rock types of general hydrological significance, and this was issued as an appendix to AWRC (1969). The panel, having determined the broad location in which sampling was required, then asked the Water Resources Council to set up a state working group in each state and territory to provide, in the light of detailed local knowledge, a suggested representative basin in each specified area. A selected basin was to lie roughly in the size range of 25 to 250 km^2, was to contain within its boundaries a complex of land forms, geology, land use, and vegetation which could be recognized on many other catchments of a similar size throughout that particular region.

The advisory panel and its working parties found that in the very flat plain areas, which occupy perhaps one-third of the continent, distinct drainage basins were atypical and not representative, and so such areas were deleted from the programme. It is expected that the final nominations of basins to be included in the project will number 86. The problem of the hydrology of the arid and semi-arid plainlands was referred to another panel, which examined the problems involved and issued a report (AWRC, 1972).

The second objective was approached from the consideration that the method of analysis would determine the type and quality of the data to be collected. A decision was therefore made to recommend that all data from the programme be forwarded to a data-analysis centre and that the analysis method should be based on a deterministic mathematical model. The deterministic model approach was adopted because it was felt that it offered the greatest possibility that analysis of short records from a great variety of hydrological regimes could provide useful information. This was particularly important because, from the selection criteria, it was not expected that many of the representative basins would have any streamflow or climate data from before their selection. Statistical and other types of analysis will be reduced in accuracy for some years after the implementation of the programme, because of the limited data sets.

The details of the deterministic model and its interaction with the data-collection specifications will be dealt with in detail later. However, arising from this modelling decision were a number of political ones. As previously indicated, there is a state responsibility for water resources and so state working parties were set up to co-ordinate selection and implementation of the scheme. In general each state water authority will bear the cost of the design, installation and operation of the stream-gauging facilities. In some special cases, basins gauged by authorities such as the Sydney Water Board are being used. These authorities are also members of the appropriate state working party.

Under the Australian constitution, meteorological and climatological observations are collected by a federal agency, the Bureau of Meteorology. The bureau was therefore invited to take responsibility for the instrumentation and data collection in respect of rainfall and climatic observations. In a similar manner, but for reasons of scientific expertise and convenience of federal funding, the Commonwealth Scientific and Industrial Research Organization Division of Land Research (now Land Use Research) was invited to maintain the central data file and develop the deterministic-model method of analysis. The administration and co-ordination of the whole programme was given to officers of the Department of National Development (now Water and Soils Division, Department of Environment and Conservation) of the Australian Government.

By 1969, the selection of basins and implementation of the programme had been effectively completed, so the original advisory panel was terminated. However, continuing development of the programme was considered to require supervision and co-ordination, so a new Advisory Panel on the Operation of the Representative Basins Programme was set up and meets approximately twice a year to review progress. This panel has sought to interest other groups in specialized research fields in becoming associated with the project. The Division of National Mapping of the Department of Minerals and Energy (formerly Department of National Development) is co-ordinating a programme of aerial photography and mapping of representative basins. The School of Geography of the University of New South Wales is carrying out geomorphological research on a group of basins, whilst the Bureau of Mineral Resources is providing groundwater monitoring and geological investigation of the other basins. It is hoped and expected that other groups will join the programme in the future.

THE CONCEPTUAL MODEL AND DATA SPECIFICATION

Details of the initial, *a priori*, conceptual model are given in AWRC (1969) and the basis for development in Chapman (1968). It was based on a critical review of existing and proposed deterministic mathematical models, and some modelling experience with existing models – in particular the Boughton model (Boughton, 1966) and the Stanford model (Crawford and Linsley, 1966). The early and critical decisions were:

(i) That the approach should be by way of a 'lumped parameter' model using averaged catchment parameters computed for a single hypothetical point, with a movement to a limited number of sub-catchments as a refinement.

(ii) The wetting cycle, including infiltration, should attempt to simulate the basic physical processes, which meant a time increment of less than 15 minutes for this phase at least.

(iii) The drying cycle, including moisture redistribution, should account for the variation of major vegetation types in respect of evaporation characteristics and rooting zones and perhaps the diurnal pattern of evaporation. This meant a time increment of one day normally and perhaps one hour coming out of a wetting cycle.

These critical decisions then determined what were the essential minimum observational requirements and the frequency of such observations. The primary measurements may be summarized as follows from statements in AWRC (1969):

(i) Streamflow – "recorded by a continuous chart recorder or digital event recorder sampling at 15-minute or shorter intervals . . . a permanent control is essential, and preferably an artificial control . . . ".

(ii) Precipitation – "A minimum of four daily-read rainfall stations . . . but not biased by the availability of competent observers. . . . At least one pluviograph which samples rainfall at not more than 15-minute intervals".

(iii) Climate – At a point within or close to the basin a climate station should be established which observes sufficient climate elements to allow the calculation of evaporation by the combination formula. The desirable observations are hourly temperature, humidity, wind-run at 2 metres, and sunshine hours or integrated total global solar radiation. In fact, standard climatological observations at 9 a.m. and 3 p.m. of wet-and-dry-bulb temperatures, daily maximum and minimum temperatures, daily totals of wind-run and radiation are accepted as the minimum standards. As far as possible an evaporimeter is being added as an additional evaporation index.

Additional desirable secondary measurements are listed in AWRC (1969), including – amongst the most important – water quality, groundwater estimates and soil moisture.

The adoption of a continuous deterministic mathematical model required the computer manipulation of all data involved in the modelling process and suggested that only a minimum of data should be acquired and held in manuscript form. The panel recommended, as a matter of principle, that each data-collection agency should be responsible for the collection, editing, quality control and processing to appropriate computer storage medium, of all its data. Data should be transmitted to the data-analysis centre in accordance with the appropriate standards for the interchange of data on computer media (AWRC, 1971).

Prototype streamflow data should be transmitted as instantaneous discharge rates, and usually with variable time increments between observations. In periods of rapid change the time interval should not exceed 15 minutes. Virtually all stream-gauging authorities now have a computer filing system for their internal use, and process strip-chart data with a strip-chart-conversion unit of the type described by Goodspeed and Savage (1968). Because this unit samples stage-height data in accordance with the variable-time-unit concept described above, most transfers to the end of 1973 have been in the form of stage-height data, and a separate rating curve has been supplied as well. This form, unfortunately, requires additional processing at the data centre.

The use of a physically meaningful infiltration expression, even if it were to be applied to lumped parameter data as indicated above, meant that the model input required that the hyetograph should be available at 6-minute intervals. The Bureau of Meteorology takes daily or storm totals from the daily-read raingauges and calculates a weighted-mean catchment rainfall. The pluviograph or pluviographs are analysed to provide an adopted mass curve of rainfall which is then adjusted to the daily or storm total, and this is the data transmitted on a fixed 6-minute interval starting at midnight but with compression of zero records.

Data for the estimation of evaporation for most basins will be the standard climatological observations. These are collected, processed and stored on magnetic tape by the Bureau of Meteorology and transmitted on magnetic tape in the format of grouped observations for each day. They are stored in data archive as well as a derived value of potential evaporation based on an appropriate estimation formula. The preferred method is the McIlroy version of the combination formula (McIlroy, 1968). It was shown by Chapman (1970) that in an arid environment a diurnal distribution function for daily evaporation was desirable, and a simple function based on daylength was derived to synthesize hourly evaporation data (Fleming, 1970).

Thus a deterministic model has been developed from an *a priori* consideration of the processes taking place on a watershed. This model has then been used to specify in detail the time and space characteristics of the data to be collected in the programme, for analysis in the model. These data specifications, and the intended use of the data in a computer model, have lead in turn to specifications on the transmission of data from the processing authorities to the central data bank, and while these transmission formats have had limited use to date for representative basin data they have had considerable use in other AWRC projects.

MODEL AND PROGRAMME DEVELOPMENT

It was indicated in the previous section that Chapman (1970) had found that a realistic diurnal distribution of evaporation was desirable in arid conditions. It has also been found that the data for proper application of the McIlroy combination formula are not usually available in the early periods of streamflow records. This is mainly because of the requirement of recording net or incoming solar radiation. It is believed that net radiation will never be a routine measurement at climatological stations in Australia, although it is hoped integrated solar radiation will be. The areal energy balance can be satisfactorily estimated from daily or particularly hourly totals of incoming solar radiation (Fleming, 1972). It is also expected that most climatological stations including automatic ones will record evaporation from a screened U.S. Class-A pan as another evaporation index.

The initial model proposed the use of the truncated series solution for one-dimensional infiltration, or Philip equation (Philip, 1957a, 1957b). This was modified in its actual application (Chapman, 1970) by testing whether infiltration capacity in each interval exceeded the available supply, and if so a new set of initial conditions was calculated for the next interval. The sorptivity constant was made a linear function of initial moisture content, although Philip (1957b) had suggested that in soils with a very steep wetting-front gradient the relation should approximate a square-root function.

The usefulness of the Philip equation was further enhanced by the development (Talsma, 1969) of field techniques for measurement of sorptivity, S, and saturated hydraulic conductivity, K. The second Philip constant, A, is approximately $\frac{2}{3}K$. Chapman (1970) reported investigations of the influence of model time interval, in the wetting mode, on the optimized solutions of S and A, the constants in the Philip equation. These seemed approximately constant from 1 hour to 0.1 hour, although detailed examination of the computations indicates that preponding infiltration and linear reduction in sorptivity was the dominant process.

Experiments with the algorithm at very short time intervals, less than one minute, have shown that the tendency for the equation to give very high infiltration capacities close to zero time made the algorithm quite unusable with small time steps. Recent published results of theoretical infiltration (Mein and Larson, 1972, 1973; Smith, 1972) have examined in detail the behaviour of the wetting front under the three modes of infiltration – ponding, preponding and nonponding as defined by Rubin (1966). Whilst the approach of Smith would appear to have the greater generality, that of Mein and Larson produces an infiltration algorithm based on the Green and Ampt equation. The Green and Ampt equation contains parameters which can be related to the factors S and A (Talsma, 1969; Fleming, in press). The latest version of the Representative Basin or Chapman model therefore incorporates the Mein and Larsen approach. Under most conditions it is expected that the optimum solution for the parameters *S* and *A* will not be significantly different from the Chapman modification of the Philip equation. Further, field testing of the values will still be possible using the Talsma technique.

It is a characteristic of the Chapman model that it generates rainfall excess at the hypothetical average catchment point only by overflowing the depression store, taking no account of interflow. The initial tests of the model (Chapman, 1970) have been in an arid environment, and have involved storm rainfall excess only. It is still intended that those hydrograph characteristics most difficult to justify physically, for example interflow and delayed flow, will be incorporated through a hydrograph function acting upon a time-distributed rainfall excess.

The model works in a continuous mode, that is it not only considers rainfall events, but also estimates initial soil moisture conditions for each wetting event by simulation of soil moisture depletion by evaporation between rainfall events. The evaporation algorithm used is similar to Boughton (1968) and is based on the concepts set out in Fleming (1964, 1972).

Baseflow is generated from a simple groundwater discharge function, and recharge of groundwater occurs as a result of simulation of water movement through the soil profile. The problems associated with water movement through the soil profile to the regional groundwater reservoir and depletion by evaporation have exercised the attention of the Advisory Panel on the Operation of the Representative Basins Programme. Accordingly, the AWRC have set up an Advisory Panel on Soil Moisture Measurement which is expected to report to the council shortly, and the AWRC can be expected to issue a published report in its Hydrological Series.

The late G. M. Burton, a member of the Advisory Panel on the Operation of the Representative Basins Programme, has shown for the southern tableland region of New South Wales that midslope bores are a sensitive index of baseflow discharge from regional groundwater (unpublished records in Bureau of Mineral Resources). It has therefore been recommended that in all representative basins with a significant groundwater component, at least one and preferably two midslope bores be installed to provide an index of regional groundwater level. Bores to Burton's specifications have been installed in the Upper Yass and Orroral Valley Representative Basins. The Bray Drain Representative Basin, which has a major groundwater contribution, has an extensive network of piezometers, lysimeters and soil moisture monitoring stations.

Thus both model and overall programme development are continuing to respond to theoretical developments and ideas generated from associated or complementary studies, even in advance of actual data and results from the programme. However, the current status is that stage-height data of appropriate quality are available from some 75 basins. Adequate rating curves are not yet available except for low stages, but in approximately 40 percent of cases this is associated with artificial low-stage controls. The authorities concerned have indicated that rating of representative basins will have a high priority.

Climatic and rainfall data of preliminary assessment quality are available from 23 basins, and by December 1973 it was expected that some 120 station-years of data would have been transmitted to the central data-analysis centre. It is planned that by 1975 all except the most remote basins will have adequate rainfall and climatic data collection systems. However, some 30–35 basins are expected to require automatic climate stations, and these will have to await the results of proving trials of small automatic weather stations.

CONCLUSIONS

The Australian representative basins programme was initiated with two primary aims:

(i) To classify and select from the whole range of hydrological diversity present in Australia, representative basins at a scale significant for water resources development.

(ii) To select an analysis technique adequate to deal with this diversity, and then ensure that a uniform and appropriate data-collection specification was applied to all basins.

Within the Australian political environment this has required the co-operation of a considerable number of state and federal departments and agencies. This co-operation has been achieved and is continuing with the guidance of the Australian Water Resources Council. All the data-collection agencies have adopted computer processing of the basic data, and all basic data exchange is occurring on computer-compatible media – usually on magnetic tape in a nationally adopted format (AWRC, 1971).

It is believed that the programme has already made significant contributions to the attitudes of Australian water authorities to data collection and processing and the concept of hydrological modelling. It is hoped that the forthcoming analysis of data from the programme will make an even greater contribution.

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