DISCUSSION OF PAPERS PRESENTED IN SESSION 2  
(APPLICATION OF STATISTICS) *

Reporters, R. P. Ibbitt

Session 2 (a)—Chairman, G. Kienitz

Papers presented were the review by M. Sugawara (vol. 2, p.111); P. Hutchinson (presented by G. H. Jowett) (vol. 1, p.203); A. N. Mandeville and J. C. Rodda (vol. 2, p.120); A. J. Raudkivi and N. Lawgun (vol. 1, p.269).

C. Toebes (to M. Sugawara):
In your review paper you expressed your concern that no papers on experimental design are to be presented. I share your concern and although design of within-basin experiments is sufficiently covered in the literature, the design of the establishment of representative and experimental basin networks, or of a research basin as such, is a long overdue study topic. We have made a new approach to network design in New Zealand but we are still struggling with the most satisfactory design of an experimental basin. I believe that experimental design and the development of mathematical models should go hand in hand.

M. Sugawara:
I agree with this. Most standard techniques are inappropriate. New techniques must be developed. The techniques ought to start very simply. The development of new techniques would have to be in the light of new knowledge but could be tested by numerical experiments using Monte Carlo methods and digital computers.

G. J. Blake:
Do you completely condemn the Thiessen polygon method, for if this is the case then many estimates of mean basin rainfall will have to be revised. Perhaps Dr Sugawara has used an extreme example and for practical purposes the usual reasonably even spacing of raingauges within a catchment would not cause large errors.

M. Sugawara:
I agree but I should like to point out that Thiessen polygon estimates are still no better than the arithmetic means of gauge catches and the latter method is easier, particularly if the Thiessen polygon method makes allowances for altitude effects.

J. Rodier:
I agree with Dr. Sugawara. In my experience, provided the raingauges are evenly distributed over the plains and zonally distributed in the mountains, there is little difference between the arithmetic mean and the Thiessen polygon method.

J. Martinec (to G. H. Jowett):
I should like to point out that the increased variation of precipitation data measured in winter can usually be attributed to snow. At the same time it should be kept in mind that winter data are also subject to a systematic error since standard raingauges underestimate the amount of snowfall.

G. H. Jowett:
The standard error given in Dr. Hutchinson's paper assumed that the data were homogenous. Obviously snowmelt was one example of inhomogeneity—positional changes in the raingauge sites being another. I suggest that such effects should be treated as separate cases.

J. Rodier:
I suggest that Fig. 3 shows bias in the form of the standard error used; there is a smaller error for the gauges which have caught less and were presumably situated in the plains. If this is so, it would imply that the distribution of the standard error is dependent upon the raingauge network and that a regular or a zonal distribution of raingauges might overcome this problem.

* The discussion was recorded by reporters, one for each session, and is therefore not a verbatim transcript. It is possible that some discussion has not been reported a fully as it occurred but every attempt has been made to record the essential facts. Trivial questions concerning simple explanations were not recorded.
Discussion (Session 2)

G. H. Jowett (to J. C. Rodda):
I should like to point out that Drs Hutchinson's and Rodda's papers both attempt to answer the question of how to estimate the true mean rainfall for, say, 10 raingauges. The question raises two problems with different and conflicting answers. Dr Rodda's approach obtained gauge weighting factors by numerical integration of the trend surface. This was one type of approach to which the Thiessen polygon method also belongs. Dr Hutchinson, on the other hand, obtained gauge weightings by minimizing the statistical error caused by random variation between rainfalls. The two approaches produced two different sets of weights, and now we have the still-unanswered problem of reconciling them.

M. Sugawara:
The treatment of rainfall as a random variable is inevitable.

J. P. B. M. Ouma:
How were the raingauges placed, and has relief had a significant effect upon raingauge placement?

J. C. Rodda:
In placing the gauges an attempt has been made to define homogeneous regions. Three maps have been constructed showing altitude, aspect and slope steepness. Superposition of the maps upon each other defined homogeneous regions within the basin. Gauges were then randomly placed in the 13 or 14 largest regions.

P. J. Grant:
Were any tilted gauges used?

J. C. Rodda:
All the data used in the study were from horizontally placed gauges. Tilted gauges have been installed, but the data obtained are not yet sufficient to allow any conclusions to be drawn.

A. J. Raudkivi:
Greater accuracy in the analysis of the raingauge network is needed but the information required to do this should come from a better knowledge of the spatial distribution of precipitation rather than from detailed studies of the statistical errors involved.

M. Sugawara:
I had some data on raingauge weights from trend surface analysis using different assumptions from the ones used by Dr Rodda and I concluded that the technique could be unreliable. I suggest that it might be better to divide the region into small parts and then use simpler trend surfaces.

J. Waugh (to A. J. Raudkivi):
I question the reliability of Professor Raudkivi's method when short-interval data are used. There are often short periods within a storm during which no precipitation occurs, followed by short periods of intense precipitation. The approach by Raudkivi and Lawgun would consider such an event as a series of storms.

A. J. Raudkivi:
Our model will handle this situation if we adjust the zero precipitation periods.

M. Sugawara:
This paper gives an interesting and simple model that gives good results. I believe that there is considerable scope for improvement, however.

Session 2 (b)—Chairman, L. Y. Nilsson
Papers presented were by V. Klemes (vol. 1, p.219); P. G. Franke and W. Bechteler (vol. 1, p.246); R. M. Rice (vol. 1, p.253). The paper by W. G. Strupczewski (vol. 1, p.236) was not presented.

G. N. Alexander (to V. Klemes):
I have a diagram (not produced here) which shows the position of the Gumbel (type 1)
point and the times produced by the Frechet, Weibull, gamma and log-normal distributions. From the diagram it appears that the Weibull distribution might best account for the position of the points shown in your diagram.

V. KLEMES:
Your diagram uses the skewness squared for the abscissa and it is therefore difficult to see if your contention is correct. The use of two parameter distributions is not always a good thing since they have a built in relationship between the second moment and skewness. I recommend the practice used in the USSR of having three parameter distributions which avoids this built in relationship. In particular the gamma distribution raised to some power would remove negative skewness.

H. N. HOLTAN:
What is the implication of your work to engineering design?

V. KLEMES:
Engineers tend to fit empirical formulae to whatever data they have. In particular I am interested in the effect upon dam design that the use of different distributions would have. Usually little is known about the tails of distributions, yet this is the important factor in design. My work is an attempt to throw some light upon this area of ignorance.

M. SUGAWARA:
"Negatively skewed distribution of runoff" is an interesting numerical experiment; however, I am doubtful about its physical meaning because of the large sampling error that can occur in the estimates of skewness.

M. SUGAWARA (to P. G. FRANKE and W. BECHTELER):
The paper presents an important theme. In order to obtain information about water resources long records are needed. But if the records are inhomogeneous then biased estimates would be obtained. Consequently it is better to use short-term homogeneous records. However, there are difficult problems involved with using time series of limited length, and sampling errors must be considered. I think that more information could be obtained by separating out the inhomogeneous parts of the record and then analysing them for systematic and stationary random components.

J. P. B. M. OUMA (to R. M. RICE): Has catchment texture been included in your preliminary studies, and if so, was it significant or not?

R. M. RICE
Originally 28 variables had been considered and drainage density had been included as a measure of catchment texture. However, initial screening had revealed that drainage density was highly correlated with area and was consequently an insignificant variable and had not been included in the later tests.

J. P. B. M. OUMA:
I have had similar experiences but I suggest that if there are significant differences in slope within a catchment, then circularity and texture are better variables than your hypsometric ones.

G. J. BLAKE:
I have been involved in a study similar to Dr Rice's but we used a different level of significance (0.8). Dr Rice used 0.7. As in Dr Rice's work, the technique was not found to be a very successful one, and subsequently we used regression analysis to determine significant catchment variables.

G. H. JOWETT:
Although Dr Rice and Mr Blake have had no success in using the factor analysis method, this should not mean that the approach should be eliminated in hydrological research. It is an excellent technique if appropriately used. I agree with Mr Blake that if no success is achieved with factor analysis, regression analysis would be the most useful approach.

M. SUGAWARA (comments on Dr Strupczewski's paper):
I consider his work excellent but the paper is rather long and difficult to understand. I had some misgivings about certain aspects at first, but in correspondence with Dr Strupczewski all area of doubt has been cleared. I believe that the paper represents a solution to a very difficult statistical problem and I hope that the work will be widely applied in hydrology.