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GUEST EDITORIAL

A MORIBUND SCIENCE?

Dr. Earl Bardsley
Department of Earth Sciences
Waikato University

There is something wrong with hydrological science in New Zealand. The hydrological equivalent of contributions to high temperature superconductivity are not emerging from our universities and research institutes. That is not to say that a research frontier in the water sciences no longer exists, it's just that we don't want to look for it.

The current malaise could be related to the needs of the regional councils in their role as water regulatory authorities in an agricultural nation. Their necessary overseeing of environmental legislation has generated a utilitarian kind of hydrology which has spread to the universities and research institutes—the latter needing to appear relevant to the national economy, and the former feeling an obligation to groom their hydrology students for jobs in regional councils. A few university environmental science courses even go so far as to include lectures on the Resource Management Act.

The loser in this arrangement is the development of hydrology as a science in New Zealand. The loss is evident at many different levels—from recycling the same presentations through twenty years of Hydrological Society conferences, through to a preoccupation with zero-information "analyses" such as graphical flow separation and the use of one-off hydrological models.

Consider, for example, a recent investigation where it was desired to model the monthly variation of hydraulic head in a confined aquifer. The aquifer supplies water to users during the summer months, so it is not too surprising that the head values are lowest at this time of year.

It turned out that the seasonal variation of head values could be matched quite well just by rainfall (assumed to represent recharge) and monthly groundwater abstraction. However, there is a worry here in that the real story might be quite different. The seasonal variation of effective rainfall is such that the water available for recharge is at its lowest during the summer—at the same time as maximum abstraction. Also, the maximum abstraction coincides with the time of lowest water table, so the lower summer head values might be just a reflection of the decreased weight of near-surface water.

These multiple possibilities are irrelevant from a utilitarian viewpoint in that the water abstractions act as a proxy for all the other seasonal variables. But all the scientific information is lost in the flick of a scale parameter, justified in hindsight by an empirical data match.

The same pragmatic philosophy is evident in the use of random variables as a proxy for hydrological extremes. The selected distribution which generates the "variables" is useful as a compact means of describing the data histogram. However, it does not follow that a good fit to the histogram means that the data can be analysed as if they really were random variables from the distribution concerned. Even allowing a general random variable model, there will always be an infinity of other distributions which could match the histogram just as well, but having highly-divergent behavior beyond the largest and smallest data points.

Far from being a scientific analysis, the distributional approach is more a time-honoured way of generating design values sanctified by straight-line data plots on elastic graph paper (or elastic transformations on arithmetic graph paper).

In the statistical literature, a probablility distribution may be specified as a starting premise for further development—such as the derivation of improved estimation techniques. This is fine in the formalised world of mathematics, but it would be naive to uplift those techniques and laud them as a corresponding advance in hydrological method. Even given the reality of a particular statistical distribution, it has never been demonstrated that formal estimation techniques are significantly more accurate than subjective fitting of the mathematical predictive functions concerned.

It is unfortunate that the random-variable model has evolved over time from a temporary working hypothesis to a belief statement of reality. Apart from halting the scientific study of flood and drought sequences in alternative frameworks, the rigorous application of probability distributions has created paradoxes like the smallest events being able to provide information on the frequency of the largest.

These points are not mere ivory-tower quibbles. The return period of the drought associated with the recent electricity crisis was evidently calculated on the basis of all droughts in the record being akin to random variables from the same distribution. That is, the New Zealand hydro system may be vulnerable to nature because it is being operated by a belief in the truth of this highly idealised model. It would seem much wiser to suppose that droughts are caused by something, and allow for the possibility that the conditions which gave rise to this winter's drought may still be operative. This in turn opens the way for a full scientific study of the processes leading to low hydro inflows, including the possibility of developing predictive techniques.

Just as a multitude of probability distributions can accurately describe a given histogram, so too can a multitude of hydrological models describe a more complex data sequence. That is, the "models" are not models at all, but simply a more compact way of presenting the original data.

The point can be illustrated by the analysis of pumping-test data. If the standard Theis model does not apply, there are any number of mathematical variations on themes of leaky aquifers, spatially-variable aquifers, head or flux boundaries and so on. Just keep trying different models and stop at the first one that fits, then present the particular geological assumptions as the truth in the inevitable report. Similar approaches can be (and are) taken in the application of rainfall-runoff models.

What is worse, a whole vocabulary of dishonesty has arisen to mask these dubious modeling endeavours with a cloak of scientific respectability. There are numerous occasions when the arbitrary use of specific probability distributions has been justified with phrases like "the data were found to follow the whatsit distribution". Among the worst offenders are the captions for model-generated figures—inevitably the assumptions are left out. When did you last see the caption "Finite-element generated groundwater flow net, calculated on the assumption that all hydraulic conductivities are exactly known", or "Magnitude-return period plot, assuming all floods are EV1 random variables"?

While allowing that there is cause for concern with model interpretation, some will argue that all that is needed is to "collect more data" and the truth will inevitably emerge. The reality is that there is no reason to believe that any "true" hydrological model is uniquely defined by the measurements which can be generated from it.

If this is indeed the case, then there are just two paths open. We can carry on as before citing the past as precedent (Smith and Bloggs did it this way in *their* report). Or we can assert the scientific foundations of the hydrology and attempt a whole new approach.

Without getting too philosophical, a valid scientific alternative would be to seek to reject as many hypotheses as possible, on the basis that advances are made by refutation rather than verification. Instead of seeking a unique model to fit the data, find as many plausible models as possible that do *not* work, and think a little about why this might be. Then, find out how many different model configurations *do* fit the data, and attempt to deduce just how much hydrological information can be extracted.

If we are to have a "new" hydrology to replace the current utilitarianism, then it is up to the universities to put as much emphasis on scientific philosophy as on hydrological technique. Indeed, it could be argued that the wimpish attitude of our hydrology academics has been a major contributing factor to the downward spiral.

It would be unfair, however, to put the blame on the academics alone. Teritary-level hydrology in New Zealand has suffered by having its various subdisciplines fragmented and appended to different established departments. There is not even one university department based on water science, so there can be no output of real hydrology graduates and no location for the moral high ground of hydrological science. The country is not the better for it.

EDITOR'S COMMENT

Dr Bardsley has presented some thought-provoking comments on hydrology in New Zealand. While I cannot quarrel with his caveats on the limitations and misuse of models, I do feel pressed to present an alternative viewpoint to that expressed by the overall tone of the editorial.

The comparison of hydrology with high temperature superconductivity is not a fair one. Hydrology must cope with natural landscapes of great diversity, with interactions between meteorological and geological processes, and with a variability and heterogeneity that is a world away from the controlled laboratory conditions and mathematical physics of superconductivity research. Even the science of fluid mechanics, which comprises but a part of the scene with which hydrology must cope, and which is underpinned by well-defined equations, cannot adequately manage the multiplicity and range of scales present in natural flows.

Hydrology *is* a utilitarian and practical science. There is nothing wrong with saying that, and hydrology has a valuable contribution to make as a utilitarian science in practical situations. Certainly fresh approaches are needed, however. An example of a possible advance in this direction which, in my opinion, has great potential for both education and professional practice is the ongoing development by National Institute of Water and Atmospheric Research (NIWA) scientists of their time dependent date archive and analysis software (TIDEDA) for personal computers. Hydrology is a data-oriented science. All the methods and models that are taught by academics or used by practitioners must be judged against the patterns and processes revealed in hydrological data. Part of the staleness in hydrological analysis that Dr Bardsley rightly criticises is due to difficulties in assimilating and working with large and unwieldy datasets. But technology has now brought the vast hydrological archive within reach of students, researchers and practitioners. Data can now be summoned up in a variety of forms and rapidly visualised with TIDEDA's processes and graphics. Ideas and models can be generated, tested and rejected, modified, or accepted with an ease and speed not possible in the days of printed data summaries and mainframe computers.

Many other issues are raised by Dr Bardsley in his interesting and stimulating editorial. His comments will undoubtedly inspire many readers to express their opinions on these issues; correspondence is invited.