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WEATHER FORECAST NEEDS FROM THE VIEWPOINT OF HYDROLOGY

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Introduction

I think we can all agree that meteorology and hydrology are intimately related. One intuitively would expect, therefore, that meteorologic forecasts would be used extensively by hydrologists--but such is not the case. In fact, meteorologic forecasts are used infrequently by hydrologists, and then only in a quite non-specific way.

It may be worthwhile to investigate how the hydrologist operates with the possibility of noting why a meteorologist's products are so infrequently used. Perhaps we can uncover some avenues of communication that will enhance both the meteorologist's and hydrologist's efforts.

My objectives in this talk are:

(a) To describe some of the hydrologists' work and note how they use meteorological forecasts, and

(b) To suggest what types of forecast information, if available, might prove to be of added usefulness to hydrologists.

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For the purposes of this presentation, let us assume that hydrology includes the study of all aspects of water during the non-atmospheric phase of the hydrologic cycle. Principal sectors of study include:

-- floods and coastal storm inundation

-- water supplies and droughts

-- water quality and sediment

-- ground water

Hydrologists can be characterized as earth scientists primarily engaged in research, data collection and analyses, forecasting or predicting water resource system response to natural events and man-induced stresses, planning and designing water resources developments and water-related regulations. Hydrologists, like meteorologists, deal with an abstract and uncertain future; consequently, they, like meteorologic forecasters, must recognize uncertainty in their projections. Hydrologists rely heavily on probability and statistical theory in quantifying and qualifying their work..

Some comments about usual hydrologic practice and the role of meteorological forecasts are in order.

Flash Floods and Tidal Surges

Forecasts of flash floods or hurricane storm surges obviously are the most used forecasts related to hydrology. These forecasts are used, however, as "watches" and/or "warnings." They are not used to identify floods on specific stream reaches or to predict specific flood levels.

The value of these predictions bears mention. A large part of the average of $2-3 billion and 100 lives lost to floods each year are the result of flash floods and hurricanes. These figures would be far higher were it not for our forecasting efforts. Hurricane Camille in 1969 cost $1.4 billion and 372 lives along the Gulf Coast (Wilson, 1969) and in Virginia (Reid, 1975). The Rapid City, South Dakota flood of 1972 cost $160 million and 245 lives (Schwarz, 1975), the Big Thompson Canyon flood of 1976 cost $30 million and 144 lives (McCain, 1979). The magnitude of these losses demonstrates the practical value of efforts to improve our flood prediction and warning dissemination techniques. Meteorologic forecasts obviously allow more time for flood mitigation efforts.

Large Stream Floods

Large stream floods, for the most part, are predicted from observed climatological and hydrologic data rather than from weather forecasts. In general, flood predictions for large streams are defined by precalibrated computer models that operate on observed values of precipitation, streamflows at upstream points, and other variables. Time is of the essence in this flood forecast scheme, and considerable effort has been expended to establish near real-time data transmission systems. Some of these data observation and transmission systems have become quite complex.

The flood prediction scheme for large streams apparently works sufficiently well that local officials can effectively place emergency plans for evacuation and flood-proofing into effect. It would seem obvious, however, that improved meteorological forecasts would provide an increased length of time for such actions.

River System Management

Hydrologists frequently plan and design reservoir systems to control river flows for such purposes as providing adequate flows for municipal supplies, irrigation, industrial needs, enhancing water quality, recreation, and many other purposes.

Such studies usually define the probability that a reservoir or reservoir system at some future time will fail to control a flood event, or will fail to meet the supply demands. These probabilities are not forecasts in the sense of relating an expected value to a specific time.

A part of the reservoir system design frequently includes defining a set of "reservoir operating rules." These rules are intended to guide the operator on when and how much water to release under various expected future circumstances. The operating rules are intended to optimize some criteria such as downstream flood damage reduction, or likelihood of meeting water supply demands.

These "operating rules" are based upon analyses of past flow records with the assumption that past records are representative of future events.

In many areas, satellite data relay systems are being installed at great expense to provide water management and flood forecast data to improve adherence to these operating rules. In actual operations, however, the circumstances, on occasion, result in some deviations from the rules. Let me note two examples--one for a drought condition in Washington, D.C., suburbs of northern Virginia, another in the major Easter 1979 floods at Jackson, Mississippi.

Occoquan Reservoir, Virginia

The Occoquan Reservoir provides the water supply for much of the northern Virginia suburbs of Washington, D.C. During the summer of 1977, deficient rainfall forced managers to initiate measures to accomplish drastic reductions in water use--an unpopular edict for politically sensitive decisionmakers. U.S. Geological Survey (USGS) and National Weather Service (NWS) experts provided analytical assistance in assessing the likelihood of meeting water needs with or without invoking even more stringent restrictions.

Part of the analytical assistance provided by John Schaake of NWS (1979) included an assessment of the effectiveness of utilizing NWS long-range (30-day) forecasts to assess the likelihood that the more stringent restrictions were needed.

Concurrently, Robert M. Hirsch of the USGS (1978) was assessing the potential failure of meeting demands based on an analysis of data for streams supplying the reservoir. Interestingly enough, the runoff forecast based on weather forecasts and the runoff forecast based on observed flow records both suggested less than a 10 percent chance that the more extreme regulations would be needed, and in fact, based on these corroborating studies, they were not used. Reliable long-range weather forecasting in this case would have made it possible to make the decision based on the forecasting facts rather than relying on probabilities.

Floods in Mississippi

During Easter week of 1979, floods occurred along the Pearl River at Jackson, Mississippi. Ross R. Barnett Reservoir is located on the Pearl River, a short distance upstream from Jackson. During the flood-causing storm, which lasted several days, a variety of decisions concerning alternatives for reservoir operation could have been made. The reservoir operators were forced to manage the system under extreme uncertainty because of lack of reliable short-term weather forecasts. The operators knew that if outflow was kept too low, the reservoir capacity could be exceeded. Yet, to increase outflows would inflict additional flood damage in Jackson. They kept the reservoir as low as possible by continuing releases. The record shows that the reservoir filled to within about 0.1 foot of the blowout plug which, if reached, would have allowed uncontrolled reservoir releases. It is doubtful if any more effective operation of Ross R. Barnett Reservoir would have been possible, even with perfect forecast information. However, it would be interesting to seek the operators' thoughts on the value of a highly reliable short-term weather forecast in order to provide a basis for decisionmaking on the proper reservoir releases.

Data Collection

One area of hydrology where forecasts are utilized extensively by USGS is in planning and carrying out data-collection work. Forecasts are used to plan wide-scale synoptic areal surveys of the baseflow of streams. If accomplished at the appropriate times, baseflow (or "ground-water contribution) without the effects of direct or surface water runoff can be obtained. As a result, much can be learned about the aquifers. Another area is water-quality sampling in a basin to determine background levels of contamination and/or sediment concentrations from various parts of the basin. In such cases, it is desired to eliminate the storm runoff effects which interject the impacts from other man-made and and natural inputs.

What is Needed in the Future?

To be most useful, hydrologists need forecasts that recognize spatial variability that are unbiased and that have a specified degree of uncertainty. Relating forecast information to normal is insufficient. For example, one of the challenges to meteorologists for the future is to provide forecasts that say "we have a 95 percent confidence that, during the next 12 hours, 90 percent of the basin will have between 1½ and 2 inches of rain, and 10 percent will have 2½ to 3 inches."

Now that there is recognized a widespread acid rain problem, another challenge for the meteorologist is to predict the quality of precipitation.

Summary

In summary, I have attempted to convey to you that in current hydrologic practice, weather forecasts are used only in non-specific and obtuse ways.

I do not know if this lack of application of meteorological forecasts reflects a weakness on the part of hydrologists, or if a more reliable hydrologic product results from analyses of observed data.

Doubtless, reliable and properly qualified weather forecasts could be of benefit to hydrologists. The science of weather forecasting is improving; and it would appear worthwhile for hydrologists and meteorologists to reevaluate the potential for increased utilization of improved forecasts in hydrologic analyses.

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