FORECASTING SHORT-TERM DISCHARGE FROM SNOWMELT 1/

By

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The State of California, Department of Water Resources, Snow Surveys and Water Supply Forecasting Section, in cooperation with the U. S. Weather Bureau, River Forecast Center, has been investigating the uses of snow sensor data, the possibilities of making effective snowmelt discharge forecasts on a daily basis, and the instrumentation required to effectively produce such forecasts.

Snow sensor data have already been applied by the Department in the following ways to help prepare and update the seasonal water supply forecasts:

1. In February and March, many April-July forecasts are made using aerial marker data. A snow sensor is used with an aerial marker at the same location to obtain the water content and depth. The calculated density is applied to other aerial marker data in the basin to obtain the computed water contents that are used in the forecast procedure.

2. In our present forecast schemes all snow course data are adjusted to the first of the month. This has always been done by using the best available precipitation data. Since most of the precipitation stations are at lower elevations, outside the snow accumulation area, there could be considerable error in the adjusted precipitation factor applied to the snow course data. This adjustment can now be approximated more closely from the change in water content from the nearest snow sensor.

3. During the 1967 snowmelt runoff period, snow sensor data were used in updating the April-July forecasts on a weekly basis. This was the first year the water supply forecasts were updated so frequently; it was also the first year snow sensor data were readily available thereby making such a program more feasible.

These are some of the uses which have already been realized from this type of data. In addition to these benefits for seasonal water supply forecasting, available sensor data have been analyzed to test their application to short-range discharge forecasting.

A primary requirement for effective short-range forecasts is the determination of the amount of snowmelt reaching the stream. This is a function of the hydrologic characteristics of the basin and the quantity of snowmelt. In the past, temperature data usually have been used to estimate the snowmelt data required for stream discharge studies (1). Now, however, by actually measuring the melt at a given site on a real time basis, the snow pillow provides a more direct means of obtaining these data. A comparison of the two methods for determining the melt parameter was made using data acquired during the 1967 runoff season in the Kings River Basin. This basin, located in the Southern Sierra of California, has approximately 1,540 square miles of drainage with more than 50 percent of its area above 8,000 feet. Over 75 percent of the river's annual flow occurs during the April-July snowmelt season.

A computer was utilized to test several hundred modifications of the degree day technique for determining snowmelt from temperature data. The best of these provided the temperature-determined melt parameters used in the comparison study. A snow sensor installation at Mitchell Meadow, located at about 10,000 feet elevation in the Kings River Basin, provided snow pillow melt data for the study. Comparison of the short-range

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forecasts obtained by using the different melt parameters indicated no clear-cut superiority of one over the other. Plate 1 indicates the accumulated discharge error in each of the procedures for the snowmelt period of May 21 to July 2, 1967. It should be noted this is absolute error (the average arithmetic error, of course, approaches zero).

It can be seen that the use of pillow data produced an accumulated absolute error which was only 54 percent of that produced by using temperature data measured at Fresno, California, at an elevation of 330 feet. (Center and top curves shown on Plate 1.) Temperature data at Balch Power House located in the basin at elevation 1,720 feet produced an accumulated error 10 percent larger than that shown for Fresno. Temperature data from Yosemite National Park, located somewhat north of the basin at an elevation 3,970 feet, produced errors in the same magnitude as Balch Power House. Temperature data at Giant Forest, however, showed 15 percent less accumulated error than the pillow. (Bottom curve shown on Plate 1.) Giant Forest is located just south of the Kings River Basin at an elevation of 6,400 feet. Although these results cannot be considered conclusive, they do suggest that with more effectively defined snowmelt, through an adequately located instrumentation system, more accurate short-range discharge forecasts could be produced.

However, additional parameters must also be considered. Assuming a set of pillows allowed a very precise determination of past melt, how accurately can a forecast be made? Inasmuch as any forecast involves events which have not yet occurred, the forecast must include a temperature outlook through the period of interest. The unitgraph characteristics of a typical basin may determine whether or not a comprehensive data collection system should be considered. If a one-day forecast is required (as Plate 2 illustrates), the volume of flow in a particular basin which can occur during the forecast day is 97 percent dependent upon the melt which has already occurred and which we can measure. Three percent of the flow on this day will be a function of the air temperature during that time period. If a forecast is needed for a second day (plate 3), 65 percent of the flow is dependent upon the melt and the remaining 35 percent is a function of the intervening air temperatures between the beginning and the end of the forecast period. By the third day (Plate 4) 47 percent of the flow is dependent upon the melt, and the remaining 53 percent is a function of the air temperatures. These ratios of predetermined flow to temperature dependent flow continue to become more dependent upon air temperatures the farther away in time a forecast is required. Therefore, in determining whether or not data sensors would be useful in short-range discharge forecasting, the unitgraph characteristics must be evaluated. Such evaluation will assist in determining what instrumentation will be effective for a given forecast period.

Assuming that the necessary instrumentation exists in a particular basin and future temperature can be adequately evaluated, how effectively can a short-range forecast be produced? If snowmelt was the only moisture input to the basin, the error in discharge forecasting should be similar to the error in discharge measurement. However, the dramatic effect spring and summer thunderstorms can have on stream discharge is well known to hydrographers in Sierra regions. Weather radar facilities can identify and determine areal distribution of these storms but cannot quantitatively evaluate the amount of precipitation that these thunderstorms deposit (2). Just how significant is this precipitation? Let us again consider the spring 1967 snowmelt runoff season on the Kings River. Basin percolation and moisture losses were already being satisfied by snowmelt, and excess snowmelt was reaching the streams. Precipitation occurring during the melt period had to meet none of the normal losses and was nearly 100 percent effective in generating additional stream discharge. Under these conditions and with no basic change in the temperature regime, thunderstorm activity in the area above 10,000 feet (approximately 385 square miles) could produce an area average of one-half inch of rainfall per day (a small quantity for thunderstorms). This would increase the full natural inflow into Pine Flat by about 5,000 second-foot-days as indicated by the solid center line in Plate 5. If this precipitation amounted to 1.00 inch per day then the hydrograph would appear as the dashed upper line in Plate 5. From this it can be seen that thunderstorms over the upper portion of the basin can change the magnitude of flow by a very significant amount.

At present, there is no way of adequately measuring thunderstorm precipitation or forecasting future thunderstorms. This means that during a thunderstorm situation an error in the forecast volume could approach 50 percent of the normal snowmelt flow. This complication raises some very serious questions as to the effectiveness which can reasonably be expected from daily snowmelt forecasts. The instrumentation costs in minimizing to a

Plate 1

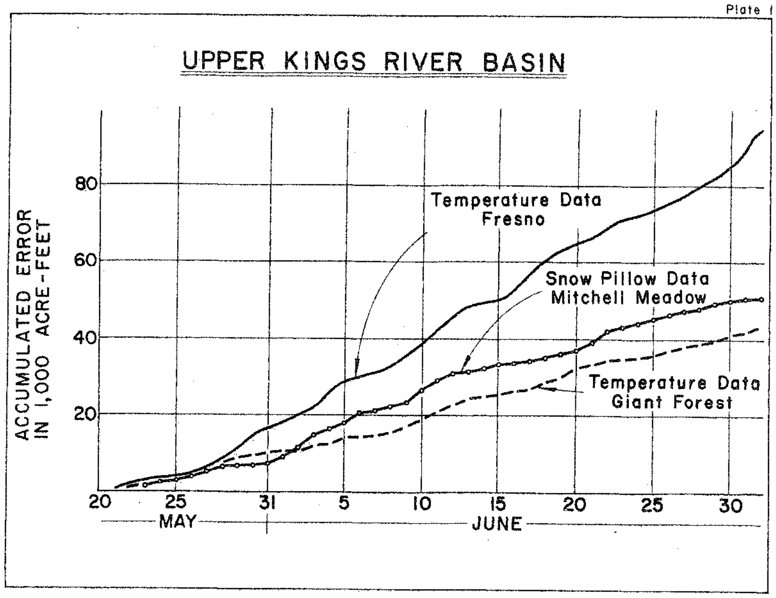
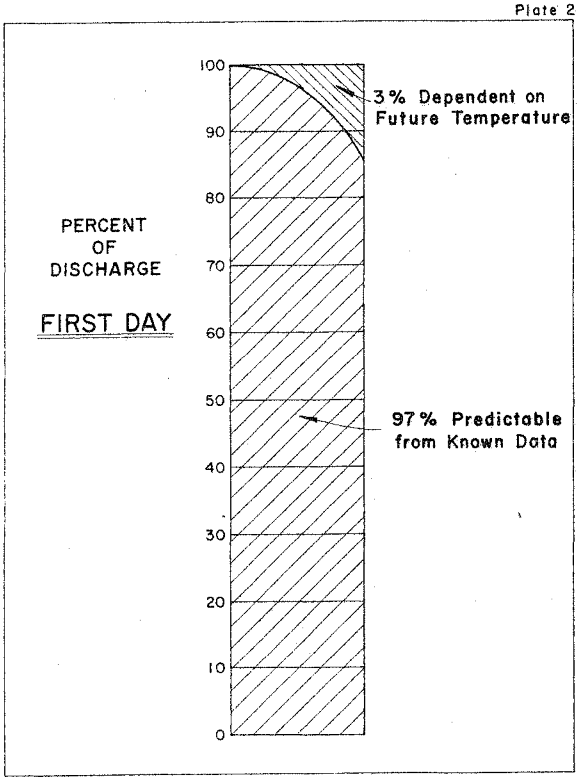


Plate 2



THIS PLATE SHOWS THE RATIO OF PREDETERMINED FLOW TO TEMPERATURE DEPENDENT FLOW.

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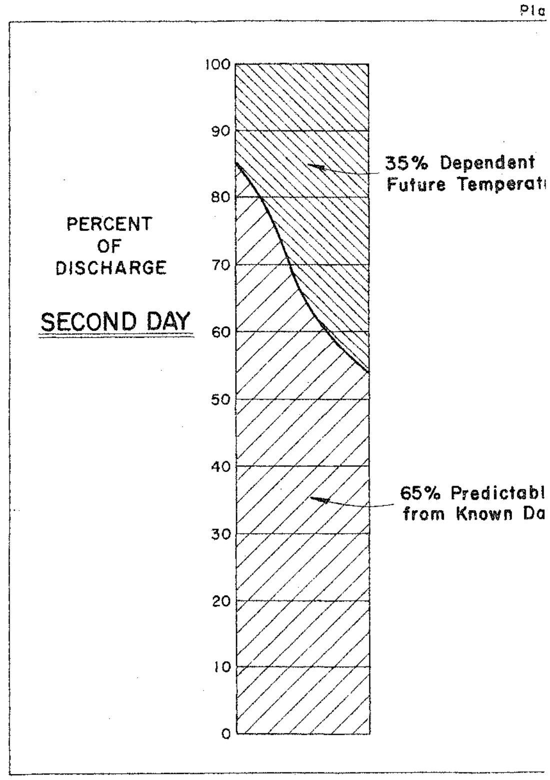

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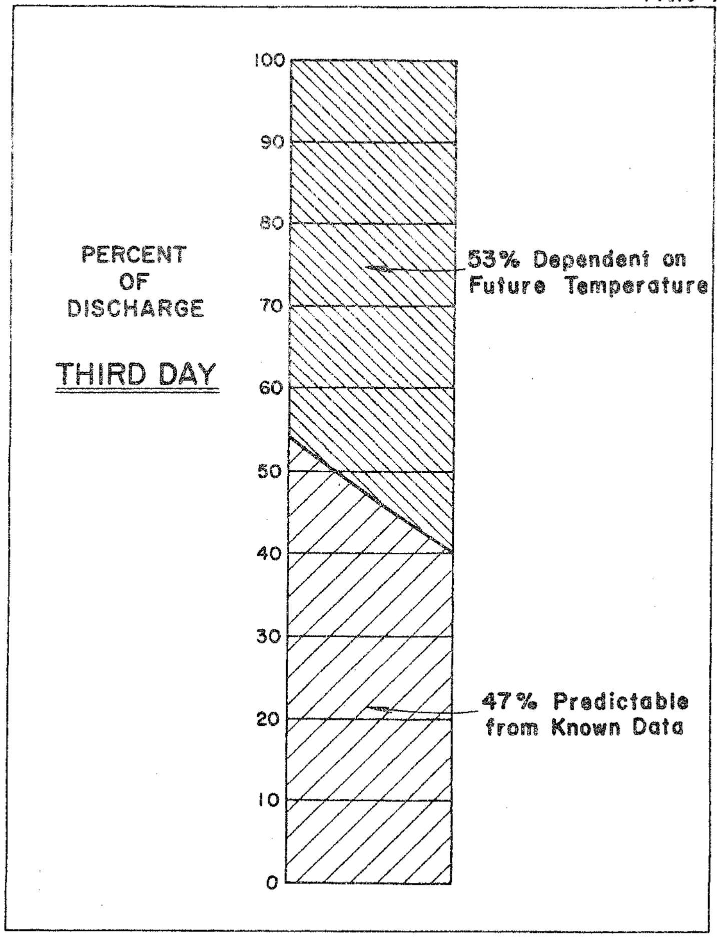

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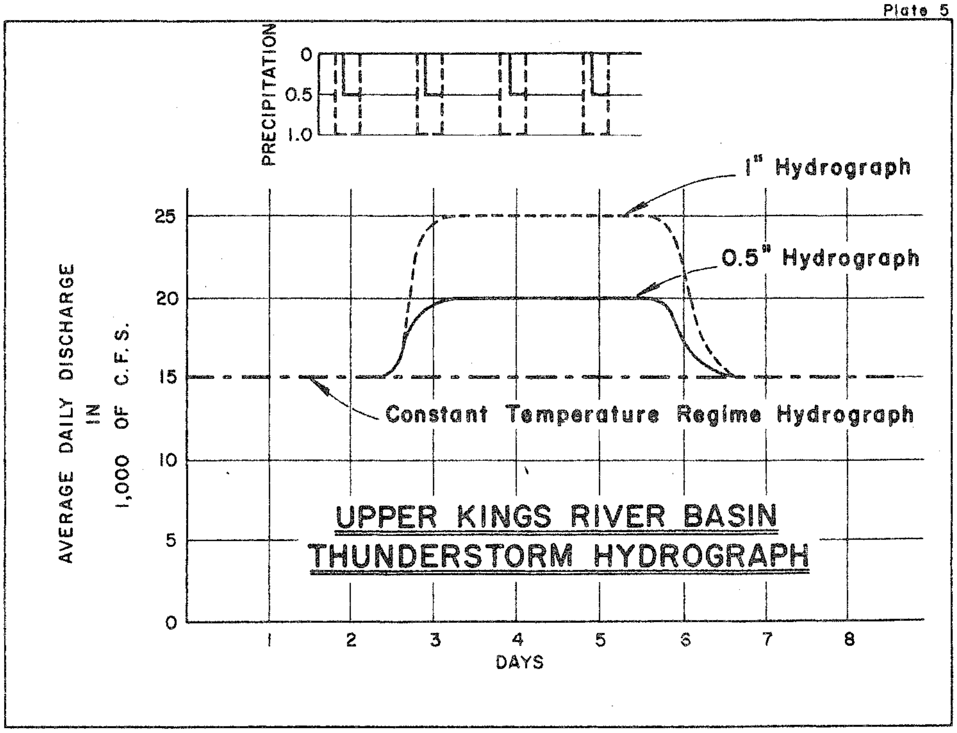
Plate 5



practical degree this portion of the error for a single basin could easily exceed an initial cost of $100,000 and an annual maintenance cost of $10,000.

In summary, snow sensor data are being used advantageously in long-range water supply forecasting and, as sensor networks increase in scope and number, the value of these data to the forecaster will undoubtedly increase. However, their application in the area of short-range discharge forecasting is not so apparent. The accuracy of any short-range discharge forecast procedure basically is determined by the snowmelt and surface flow unitgraphs for each particular basin. But consideration must also be given to present limitations in accurately predicting future temperatures and precipitation at high elevations and the great effect these parameters can have on short-range discharge. Thus, it seems that the most helpful discharge forecast may be several flows which express a probability range tailored to the hydrographer's needs.

REFERENCES

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