THE USE AND VALUE OF SNOW SURVEY DATA IN THE OPERATION OF HYDROELECTRIC FACILITIES

by

David R. Campbell
Hydraulic Engineer, New England Power Service Co.
Boston, Massachusetts

As you are all aware, water is an extremely valuable commodity. The supply of potable water for the needs of our ever increasing population, its growing use for recreational purposes, irrigation of arid land and transportation are all very familiar to you. Water is also a very valuable commodity in the generation of electric power, particularly in New England, where the cost of those fuels which are also used to generate power is higher than in many sections of the country because of the large transportation cost to get them to the area. Unfortunately, our supply of water for hydroelectric purposes is limited and it is, therefore, increasingly important that we use whatever is available in the most efficient and economical manner possible.

It has been successfully demonstrated that the most economical power for New England is obtainable from an interconnected power system including both tidewater steam plants and inland hydroelectric stations, and that hydro power realizes its greatest worth when it serves the so-called peak loads of such a power system.

Perhaps a brief explanation of what we mean by peak loads would be useful at this point. First, we must understand one of the fundamental differences between steam generation and hydro generation. A steam plant will continue to turn out kilowatt-hours just as long as you feed in fuel from an unlimited supply. Our hydro plants cannot do this. They can produce only when there is water. Thus, a hydro station may be capable of operating at high capacity for only a few hours, but must then lie idle while conserving its limited supply of water. For this reason, on our System, it is customary, except during brief periods of extremely high river flow, to carry the so-called base load, or constant twenty-four hour requirements of our customers with our most modern and efficient steam plants - those which require the least fuel consumption per kilowatt-hour. As the daily load increases during working hours, when factories and stores are all in operation, we add on our less efficient steam units until, as the load approaches its peak, say during the dark late afternoon hours in winter, when lights, stoves, and television sets go on, we also add on our hydro stations using our precious water to carry load which otherwise would have to be carried by our less efficient steam units, or by similar power purchased from other sources. By so doing, we concentrate our hydro power into these peak periods when it would be most expensive to obtain equivalent power from other sources.

This method of operation is further influenced by the fact that, in the case of the New England Electric System, we use the same water to generate power at several different hydro stations as it flows down the river toward the sea.

On the Deerfield River, for instance, water passes successively through hydroelectric stations at Searsburg, Harriman, Sherman, and so-called Plants No. 5, 4, 3 and 2, with a combined gross head of 1138 ft. Similarly on the Connecticut River the water flows through Moore Station, Comerford, McIndoes, Wilder, Bellows Falls and Vernon, with a combined gross head of 514 ft., as well as several other power developments not belonging to our system. We must, therefore, synchronize our operations to have water available at each of these stations at the time when it is most valuable.

To facilitate this, we have built several storage reservoirs near the head waters of these two rivers, which are large enough to enable us to regulate the flow of the rivers to a far greater extent than would otherwise be possible. These reservoirs include the Somerset and Harriman reservoirs on the Deerfield River, with a combined capacity of over seven and one-half billion cubic feet; and the First and Second Connecticut Lakes, Moore and Comerford reservoirs on the Connecticut River, with a combined capacity of over ten billion cubic feet. This quantity of water when used successively at the various stations on either the Deerfield or Connecticut Rivers represents over 222 million Kilowatt-hours of generation. In addition, the State of New Hampshire's Pittsburg reservoir on the Connecticut River has a capacity of 4 billion, 300 million cubic feet.

To emphasize the value of this stored water: at Harriman, for instance, one inch of runoff from rainfall or snow melt on its 154 square mile net drainage area is capable of producing 5,714,000 kilowatt-hours of generated power at the various plants downriver.

As you can readily see, the ability to predetermine the quantity of water which will become available in the near future both from rainfall and melting snow is of great value in permitting the maximum use of reservoir contents with a reasonable assurance of replenishment, and in providing against excessive waste of the anticipated runoff by spilling it over the various dams.

Operation of the storage reservoirs follows the same general pattern year after year. This consists of a low drawdown in the late winter to accommodate the runoff from melting snow and spring rains. This generally fills the reservoirs by May or June. The drawdown period usually begins in July and continues through the following March with some refilling frequently occurring from rainfall in November.

The rate of drawdown and its timing depend upon such variable factors as load conditions, weather patterns and the availability of power from other sources. The cycle is also considerably influenced by the snow survey data.

Snow measurements are presently taken twice a month, on the 1st and 15th, at twenty-two stations situated at strategic locations throughout the Deerfield and Connecticut River watersheds. Thirteen of these stations are located near the various plants so as to be easily accessible to operating personnel. The others are in selected locations, one in each tributary watershed, which from past experience we found most closely indicated average conditions for the whole area. The results are plotted in chart form for the use of all interested departments. They are also made available to the Corps of Engineers for use in the compilation of snow cover reports which they publish weekly during the spring period in connection with their flood control operations, as well as to the Weather Bureau, and the U. S. Geological Survey.

The New England Electric System dispatching and operating personnel have been forecasting runoff for the spring months for over thirty years, using the semi-monthly snow survey data as it is obtained. The actual mechanics of forecasting were fully explained in a paper presented at the annual meeting of the Conference in 1961 by L. D. Pierce, Assistant Civil Engineer of the New England Power Service Co., whose paper also covered descriptions of our snow equipment and our survey methods. At the risk of being repetitious, however, I believe that a brief review of the forecasting procedure would be helpful at this time.

The forecaster of the spring runoff begins with the water content of the snow on the ground as of February 15th. To this he adds the average precipitation for the period from February 15th to June 1st. The total thus obtained is then adjusted to allow for variation from the normal, as follows: If the previous summer and fall had less than average rainfall for the period from June 1 to November 1, a correction amount of 42 per cent of that deficiency is subtracted from the expected available water for runoff. If the precipitation for that period was greater than average, however, a correction amount of 18 per cent of the excess is added to the expected runoff total.

A smaller percentage of excess precipitation is used since heavy rainfall runs off relatively quickly and is not so apt to be available as ground water to affect the spring period. As the season progresses after each semi-monthly snow survey, the figures are adjusted as shown on the tabulation now appearing on the screen (See page 197).

Column 1 shows the 15-day interval being considered. Column 2 gives the actual precipitation for that interval and Column 3 the total actual precipitation since February 15th. The next column shows the average total precipitation from February 15th to date, and Column 5 the variance of the actual precipitation from the average. Column 6 gives the predicted spring runoff figure as adjusted by adding or subtracting the variance from normal experienced thus far. The next two columns show runoff conditions, Column 7 showing the actual runoff for the period since February 15th, and Column 8 the remaining runoff expected, which is obtained by subtracting the actual runoff from the forecast in Column 6. Column 9 shows the actual contents of the reservoir under study in inches of water on the drainage area, and the last column shows the amount of runoff available for use in excess of what is needed to fill the reservoir. For example, at Harriman, which can hold 14 inches of the water, on March 15 we subtract the present contents from 14 inches and subtract the remainder, which is what is needed to fill, from the predicted total of 20.88 inches. This gives us 9.6 inches of water available for generation with a reasonable certainty of still being able to fill the reservoir.

The figures below the table show the original prediction which was made on February 15th, using the average precipitation, the snow on the ground at that time, and the adjustment based on the previous 5 months' rainfall. As you see, the prediction was 22.2 inches and the actual runoff 21.9 inches, which is pretty good forecasting. Of course, we are not always so accurate and on occasion have missed badly. In many springs a combination of mild, windy days and cold nights have caused much of our snow cover to literally disappear from evaporation.

By equating the increase or decrease in the water content of the snow at each interval with the actual precipitation and runoff, we also get some indication of the timing of the expected runoff , which is useful in gaging the possibility of light or heavy runoff during the spring ice breakup enabling us to take the necessary precautions for passing river ice at the various plants, according to the climatic conditions existing at the time.

Over the past 35 years, on the Deerfield River watershed, the average maximum water content of the snow cover was about 7.5 inches, varying from a low of 3.3 inches in 1957 to a high of 13.6 inches in 1958. As of March 1st, the average is about 6.5 inches and our average precipitation for March, April and May is about 13.5 inches, or a total of about 20 inches of available water. Runoff generally amounts to about 95 per cent of this or about 19 inches. The figures for the upper Connecticut River watershed are generally comparable. Only Somerset Reservoir, which has a capacity of thirty-six inches on its drainage area, is capable of holding all of this water. Harriman can hold 14 inches of runoff from its drainage area, the Connecticut Lake Dams 20 inches, and the other reservoirs decreasing amounts. For this reason, we must plan on holding what we can and speeding the rest on its way, by generation to the limit of our ability, and the remainder by spilling.

It is an interesting coincidence that very seldom have we had heavy snow cover and heavy precipitation in the same spring. When this does occur, however, the fact that our reservoirs have been drawn down in anticipation of spring flows helps materially in flood control by reducing and delaying the peak flows. This was dramatically illustrated in the flood of March 1936. In a paper published in the Transactions of the American Society of Civil Engineers, Mr. W.F. Uhl of Chas. T. Main, Inc. pointed out that no water was wasted from Somerset and Harriman during that flood and no release was made until a week after the crest on the main stream, thus reducing the peak at Shelburne Falls, Mass., from some 72,000 cfs to 48,000 cfs, or a reduction in flood stage of 3.3 feet.

In conclusion, may I say that the beauty of a blanket of fresh snow is well appreciated in New England and, I'm sure here in Canada as well, but apart from its recreational and aesthetic values, and despite the difficulties and inconveniences it sometimes brings, snow to us is an important natural resource, made more so by the many dedicated men in our industry who by diligence and years of painstaking application to the problems involved have earned the right to sing softly to themselves when the flakes start falling, "Every Time it Snows, it Snows Pennies from Heaven."

SPRING RUNOFF FORECAST - FEBRUARY 15-JUNE 1 - HARRIMAN

1960

1	2	3	4	5	6	7	8	9	10
	Actual Precip. 1960 for the Interval	Actual Precip. 1960 Feb. 15 to Date	36 Yr. Ave. Precip. to Date	Act. Ave. Precip. 2/15 to Date	Exp't R/0 2/15 to 6/1	Act. R/0 to Date	Present Exp't R/0	Present Reservoir Contents	Exp't Use or Spill before 6/1" Elev. 14.00"
Feb. 15					22.20				
15-29	2.66	2.66	1.59	+1.07	23.27	.80	22.47	7.07	15.54
March 15	1.04	3.70	3.76	- .06	22.14	1.26	20.88	2.72	9.60
15-31	1.91	5.61	6.01	- .40	21.80	2.25	19.55	1.46	7.01
April 15	3.77	9.38	8.39	.99	23.19	11.79	11.40	8.29	5.69
15-30	2.61	11.99	10.55	1.44	23.64	18.93	4.71	11.61	2.32
May 15	2.46	14.45	12.69	1.76	23.96	20.85			
15-31	1.20	15.65	15.12	0.53	22.73	21.94			

Water 2/15	5.88
Ave. Precip. 2/15 - 6/1	15.12
	21.00
Correction	+1.20
	22.20