DISCUSSION

BERTRAM S. BARNES (Regional Engineer, United States Weather Bureau, San Francisco, California)--Does the author consider his method satisfactory on streams that are principally rain-fed, such as the Ohio? Has it been tried where snow is not a large factor? Would he consider that the success of the method is on account of the presence of snow? Is the pattern of the first six months dictated by the nature and extent of the snow in the same way as the runoff for the second six months? (See p. 96 for reply by the author to these queries.)

THE USE OF SNOW-SURVEYS AS AN AID IN FLOOD-CONTROL OPERATION OF RESERVOIRS

Fred Paget

On the Sierran tributaries of the San Joaquin River, floods are of two types: (1) Winter floods from heavy rains and (2) late-spring floods from melting snow.

In this area heavy rains which may occur at any time from the first of November to the end of April may cause floods while melting snows may cause floods from the first of May until the end of July. The rain-floods can be predicted only a few days in advance at the most, but by means of snow-surveys the floods from melting snows can be foretold many weeks before they occur.

For the control of floods from the Sierras, investigations have been made in the past by several different organizations to determine the degree of protection desirable and the means of providing it.

It is not the purpose of this report to present another such study. Its purpose rather is to draw attention to the information revealed by snow-surveys and to show how this information may be applied to the problem of operation of reservoirs for the control of snow-melt floods and yet allow maximum conservation of water for irrigation and power-purposes.

A review of the statistical data gathered during the past 12 years during which snow-surveys have been made in California reveals a close correlation between snowpack and ensuing runoff which holds promise that forecasts of such floods within an accuracy of ten per cent can be made on many of the streams of the San Joaquin Valley.

With forecasts of this accuracy, snow-surveys make it possible to operate a reservoir for protection from snow-melt floods and yet have it full at the end of the flood-runoff season.

The following study presents the correlation between snow-survey measurements and runoff on the Kings River, and using this stream as an example shows how advance information as to snow-melt runoff may be applied to the dual problem of flood-control and water-conservation in operation of the proposed Pine Flat Dam on the Kings River.

During the course of this study other streams also were investigated and the method described herein was found to apply equally well to all. For the sake of brevity, the discussion herein is limited to the Kings River.

Snow-survey data

Runoff-forecasts from snow-survey of April 1--The water-content of the snowpack in each watershed is determined by taking a mean of measurements at many places strategically located in the watershed.

The main survey is made during the closing days of March and the early days of April. At this time usually the winter's snowpack is all down and the snow-melt runoff is about to start, and from the snow-surveys a reasonably accurate forecast can be made of the total amount of water to be expected during the snow-melt period April 1 to July 31. This forecast assumes normal precipitation on the watershed during April. A correction is made about May 1 if the precipitation in April departs from normal.

Figure 1 shows for the Kings River the presently established relationship between the total discharge at Piedra during the snow-melt period and the water-content of the snowpack in the watershed as measured at the first of April.

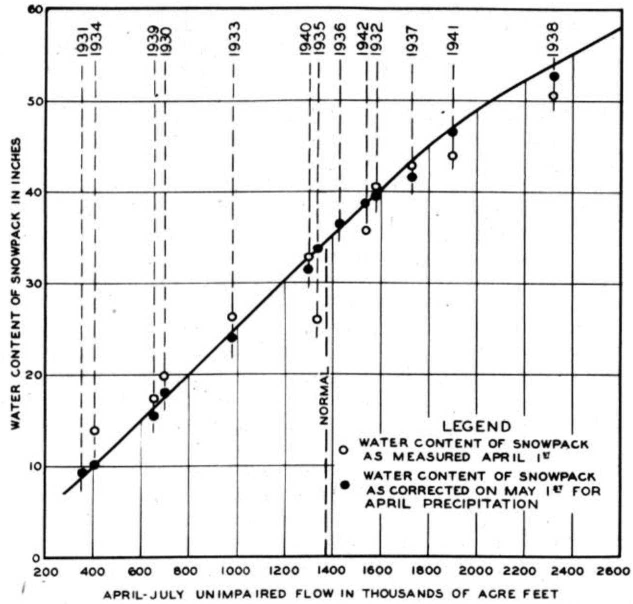


Fig. 1--Relation of snowpack water-content to unimpaired flow of river. Kings River at Piedra

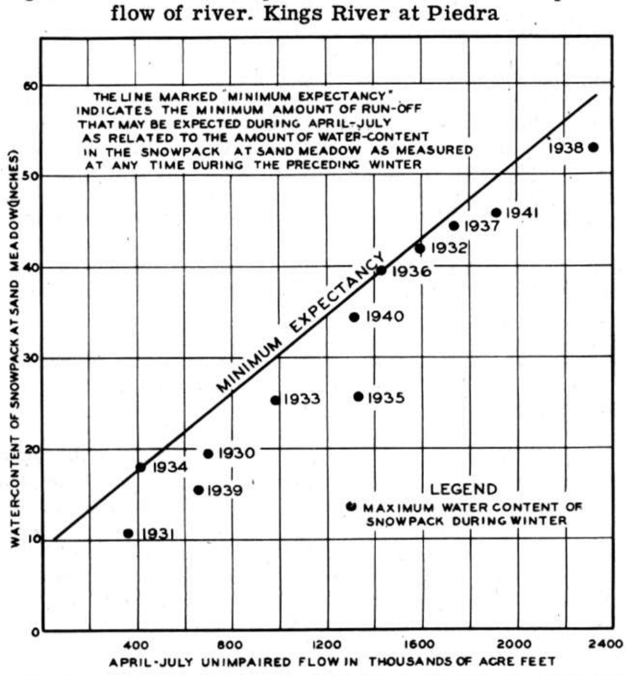


Fig. 2--Runoff-expectancy as indicated by snow-surveys at Sand Meadow, Kings River at Piedra

Inspection of this Figure reveals that during the period of record, forecasts made from this curve early in April would during wet years have had an accuracy within 10 per cent. Forecasts made after the first of May of those years would have had an accuracy within four per cent.

Forecasts in the past have not always been as accurate as the present curve would indicate, but each year yields more data upon which to base forecasting procedure and accuracy continues to improve.

Runoff-expectations indicated by early progress snow-surveys--While final forecasts of runoff cannot be made until the snow is all down, yet some idea of the expectations for snow-melt runoff can be obtained before the first of April by means of progress snow-surveys made from time to time during the winter. For any amount of snow on the ground there is a certain minimum amount of runoff that can be depended upon. Regardless of how much snow may fall later on, any quantity of snow on the ground will produce some runoff. As the season progresses and more is added to the pack, the minimum expectancy increases.

Because of inadequate finances the progress snow-surveys have been limited to one or two key snow-courses in each watershed. Lacking more complete coverage, the records of the progress snow-surveys for the key station at Sand Meadow in Kings Watershed have been used to compile Figure 2 showing the expectancy of runoff for the Kings River at Piedra.

Figure 2 shows the runoff during April to July corresponding to the maximum snowpack measured during the preceding winter. On this Figure, the line marked "minimum expectancy" drawn through the points to the extreme left indicates on the basis of past experience the minimum amount of runoff that may be expected at Piedra during the snow-melt period of April to July corresponding to measurements of snowpack made at Sand Meadow at any time during the winter.

This knowledge of minimum expectancy of runoff as revealed by progress snow-surveys can not be used in the winter operation of a reservoir primarily intended for flood-control, since such a reservoir would be operated during the winter in accordance with a prearranged plan devised to provide protection against rain-floods that might occur at any time. In such a case the snow on the ground at any time during the winter would make little, if any, difference.

However, in the operation of a reservoir primarily devoted to water-conservation the progress snow-surveys will on wet years allow maintenance of some measure of protection against rain-floods longer than would otherwise be done.

When progress snow-surveys indicate the minimum supply from snow will be large enough to satisfy anticipated demands and also fill the reservoir, there would be from then on no object in filling the reservoir before the snow-melt starts. Instead, space may be kept empty to provide a measure of protection against possible late rain-floods, with assurance that the space so kept empty can be filled later on, during the snow-melt season.

Influence of temperature on runoff--Although forecasts of the total amount of runoff can be made, the actual distribution of the runoff from month to month is so dependent upon temperatures that it cannot accurately be determined very far ahead of time. However, by platting a superimposed graph of daily maximum temperatures and daily river-discharges, the trend of the runoff can be foreseen to some degree.

No temperature-recording stations are maintained up in the snow-covered area, but reports on temperature from towns in the San Joaquin Valley serve as a fairly satisfactory index to increasing mountain temperatures.

On Figure 3 is shown for the snow-melt season of 1938 the mean daily flow of the Kings River at Piedra along with the maximum daily temperature at Fresno. For want of a better name, this coupled curve will in this discussion be referred to as a "thermo-hydrograph"

Very little melting of the snowpack is indicated until temperatures at Fresno reach 80°F. Above that the rate of melting increases as temperatures rise and decreases as temperatures drop.

Examining this thermo-hydrograph, it is seen that despite daily variations the trend of the temperatures is upwards as the season advances. This is also true of the runoff until the time when the snowpack is so depleted that increased temperature cannot melt more snow each day. After this maximum point the general trend of the runoff is downward.

The time at which the runoff changes from an upward trend to a downward trend is somewhat difficult to determine readily on the thermo-hydrograph platted from the daily data because of the many minor variations. To overcome this difficulty ten-day running means have been worked up for both the daily temperatures and the daily runoff. These are platted on the "ten-day mean" thermo-hydrograph on Figure 4. The flattening of the daily variations makes it much easier to determine the period during which the trend of the runoff begins to decline.

In the operation of reservoirs these thermo-hydrographs should be very helpful. Not only could the daily peaks be foreseen to a certain extent several days in advance, but also the start of the decline in runoff could be recognized in ample time to insure that water needed for storage be not wasted needlessly.

Proposed Pine Flat Dam

The physical characteristics of the proposed Pine Flat Dam on the Kings River are set forth in House Document No. 631, as presented to the Third Session of the 76th Congress by the U. S. Bureau of Reclamation on February 12, 1940. The proposed reservoir with a capacity of 1,000,000 acre-feet will have demands upon it in accordance with the data listed in Table 1. (All data abstracted from House Document No. 631.) Demands of irrigation will be as listed in columns

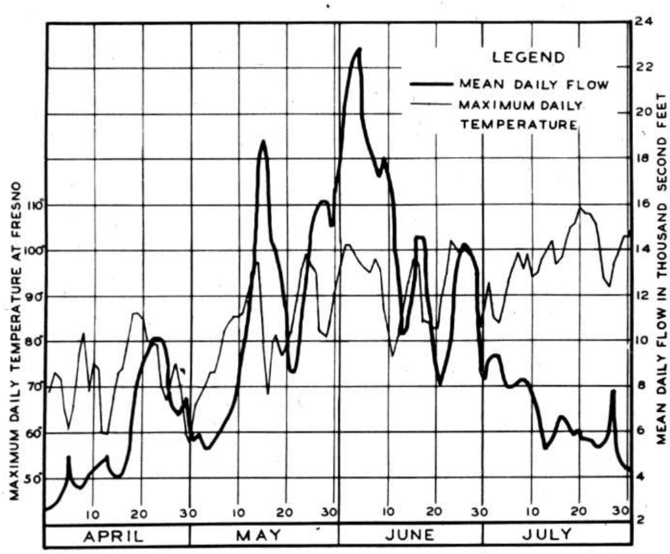


Fig. 3--Thermo-hydrograph, daily for 1938, Kings River at Piedra

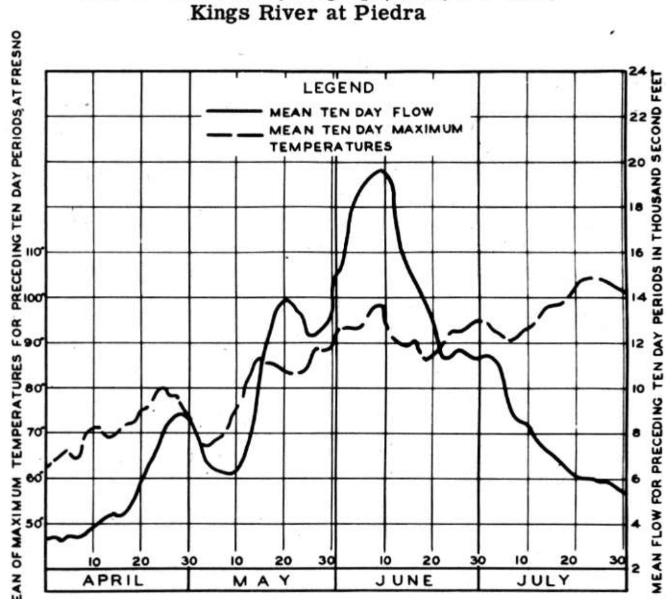


Fig. 4--Thermo-hydrograph, ten-day mean for 1938, Kings River at Piedra

(2) and (3). Power-demand with one of the three units operating (initial development) will be as shown in columns (4) and (5). Maximum allowable discharges will be as listed in columns (7) and (8).

In the following discussion the figures for the flow of the Kings River are as measured at the Piedra Gaging-Station which is situated a few miles below the site of the proposed Pine Flat Dam.

Table 1

Month	Irrigation-demands		Power-demands		Normal flow of Kings River	Maximum allowable releases Fresno Slough Cap 6,000 second-feet	
						Ground-water low	Ground-water high
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	a-f	s-f	a-f	s-f	a-f		
Jan.	15,000	240	96,000	1,567	71,000	7,000	6,200
Feb.	46,000	830	87,000	1,567	84,000	7,800	6,800
Mar.	107,000	1,740	96,000	1,567	133,000	9,700	7,800
Apr.	183,000	3,080	93,000	1,567	239,000	12,200	9,000
May	244,000	3,970	96,000	1,567	478,000	16,600	10,000
June	259,000	4,350	93,000	1,567	464,000	17,200	10,200
July	259,000	4,210	96,000	1,567	194,000	16,200	10,200
Aug.	214,000	3,480	96,000	1,567	57,000	....	....
Sep.	122,000	2,050	93,000	1,567	23,000	....	....
Oct.	61,000	990	96,000	1,567	25,000	....	....
Nov.	15,000	250	93,000	1,567	26,000	6,800	6,200
Dec.	0,000	0	96,000	1,567	36,000	6,000	6,200
	1,525,000	....	1,131,000	....	1,830,000	....	....

Note: Minimum amount of water in storage required for full power head 120,000 acre-feet.

Outline of operational procedure--Operation of Pine Flat Reservoir during the winter would depend upon the policy adopted for the control of rain-floods which is not a part of this study.

However, under any policy of operation adopted, prior to April 10, when and if the progress snow-surveys indicate that the expectation of runoff during April to July (see Fig. 2) is greater than the total amount required to simultaneously fill the reservoir and supply current demands of irrigation, releases are increased to provide additional empty storage-space.

After April 10, when forecasts of complete runoff become available (see Fig. 1) the operation of the reservoir would be modified as necessary to control it.

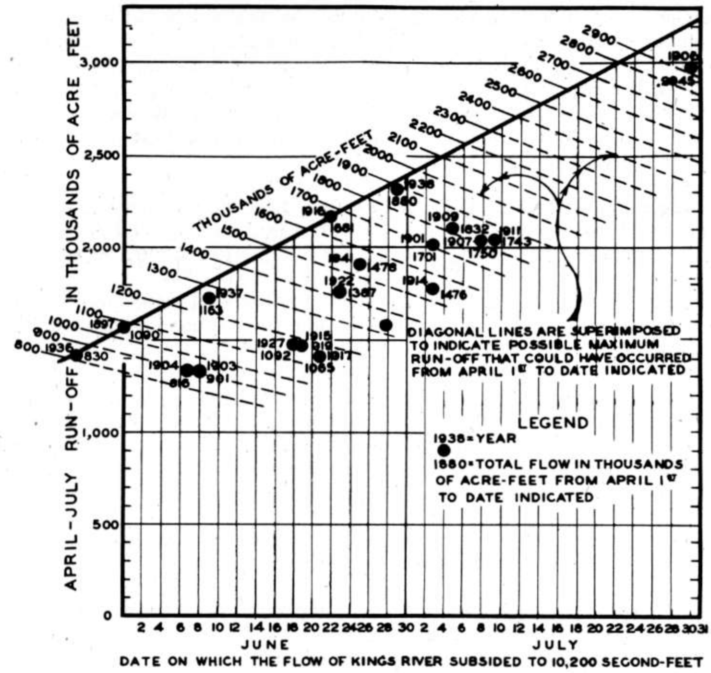
Actual runoff may depart 10 per cent from the forecast, and the manner of its occurrence is subject to wide variations depending upon unpredictable conditions of weather and other factors such as the amount of snow on the watershed, the extent of coverage, and the density of the snow at the end of the winter.

In this study the most unfavorable distribution of occurrence of runoff as disclosed from past records has been used.

Flood-control requires that reservoir-space be provided to take care of early melting, while water-conservation requires that the reservoir be not kept so low that a runoff long drawn out would fail to fill it.

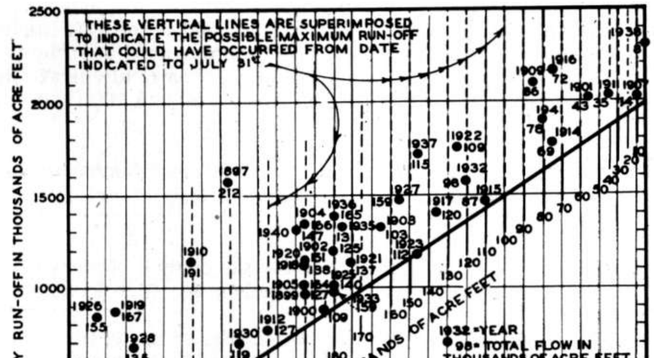
Each year when predetermining an operational schedule, two possible extreme variations in the manner of the occurrence of runoff must be considered. One of these conditions makes flood-control the most difficult and the other makes the filling of the reservoir at the end of the season the most difficult.

Flood-control considerations--Figure 5, compiled from past records, indicates the most dis-



THE INTERSECTION OF THE APRIL-JULY FORECAST WITH THE HEAVY DIAGONAL LINE INDICATES ON THE ABSCISSA SCALE THE EARLIEST DATE AFTER WHICH THE FLOW OF THE RIVER SHOULD NOT EXCEED 10,200 SECOND FEET, AND INDICATES ON THE SUPERIMPOSED DIAGONAL SCALE THE MAXIMUM TOTAL AMOUNT OF RUN-OFF THAT MIGHT OCCUR FROM APRIL 1ST TO THAT DATE. THIS INDICATES THE MOST UNFAVORABLE DISTRIBUTION OF EARLY RUN-OFF FROM THE STANDPOINT OF FLOOD CONTROL

Fig. 5--Runoff-distribution graph, early snow-melt runoff, Kings River at Piedra



THE INTERSECTION OF THE APRIL-JULY FORECAST WITH THE HEAVY DIAGONAL LINE INDICATES ON THE ABSCISSA SCALE THE LATEST DATE AFTER WHICH THE FLOW OF THE RIVER SHOULD NOT EXCEED THE IRRIGATION DEMAND AND INDICATES ON THE SUPERIMPOSED VERTICAL SCALE THE MAXIMUM TOTAL AMOUNT OF RUN-OFF THAT MIGHT OCCUR FROM THAT DATE TO JULY 31ST. THIS INDICATES THE MOST UNFAVORABLE DISTRIBUTION OF RUN-OFF FROM THE STANDPOINT OF FILLING THE RESERVOIR AT THE END OF THE SEASON.

Fig. 6--Runoff-distribution graph, late snow-melt runoff, Kings River at Piedra

advantageous distribution of runoff as affecting flood-control that is apt to occur. Combining both the pre-flood or preparation-period with the flood- or control-period, the Figure shows the earliest date each year that flood-flows from snow have ceased on the Kings River, and indicates to what extent the bulk of the runoff might be concentrated in the early part of the snow-melt season. This is the most critical flood-situation as it restricts to a minimum the time for preparation and control. The Figure also indicates the maximum amount of runoff that might have to be taken care of from April 1 to the end of the flood-period.

Thus anticipating a runoff during April to July of 2,000,000 acre-feet, Figure 5 would indicate that in the case of a very early season all flood-flows might be over and done with on June 16 and that between April 1 and June 16 the total runoff might amount to 1,500,000 acre-feet.

Measures adequate to provide protection against the extreme condition of early runoff as indicated by Figure 5 would be more than adequate should the season be delayed and the bulk of the runoff not occur until later.

Water-conservation considerations--While flood-protection requires that the reservoir not fill until after the river-flows have subsided below the maximum allowable releases, water-conservation requires that the reservoir be full at the end of the snow-melt season. Ordinarily there will be little difficulty in filling the reservoir after flood-danger is over and before the snow-melt finishes.

However, there is the possibility of not filling, if too much space for flood-control is reserved so long that the runoff remaining is not enough to fill the reservoir.

The longer it takes for the flood-runoff to be completed, the earlier the filling of the reservoir must be commenced on account of the greater amount of the total remaining inflow required for current demands and the reduced amount available for storage.

Figure 6, compiled from past records, indicates the latest date each year that flows on the Kings River have exceeded the hypothetical demand of irrigation. For any amount of runoff-forecast, this Figure indicates the extreme length of time during which snow-melt in excess of demands might be expected to occur. The Figure also reveals the maximum amount of runoff which might occur from that date to July 31, thus indicating the balance of the runoff which would occur before the date the flow fell below the irrigation-demand.

Thus anticipating a runoff during April to July of 1,500,000 acre-feet, Figure 6 would indicate that in the case of a very late season flows in excess of the demands of irrigation of 4210 second-feet might occur until July 16 and that from July 16 to July 31 the total runoff might amount to 100,000 acre-feet, and conversely that the flow from April 1 to July 16 might amount to 1,400,000 acre-feet.

If the operation of the reservoir is adjusted to insure filling, should this condition of maximum delayed runoff occur, filling is also assured under all conditions of earlier completion of the runoff.

Operational criteria--The criteria of operation for the control of snow-melt floods on each stream would be different. Those which suggest themselves for Pine Flat Reservoir are:

(1) Prior to April 10, as soon as progress snow-surveys at Sand Meadow indicate a minimum expectancy of runoff during April to July more than sufficient to fill the reservoir and supply the demands during April to July, releases should be increased to provide additional empty storage-space.

(2) After April 10, when complete snow-survey forecasts become available, the criteria are:

(a) To assure of filling, assume that the forecast may be ten per cent high with runoff continuing until late in the season (as indicated by Fig. 6). During the time that the outcome of the runoff is in doubt do not allow the reservoir to empty beyond a point that it would be impossible to fill it under such a delayed distribution of runoff.

(b) To safeguard against flood assume that the forecast may be ten per cent low with heavy early runoff (as indicated by Fig. 5). During the time that the outcome of the runoff is in doubt do not allow the reservoir to fill beyond a point which would result in its overflowing during the flood-period should such conditions of early runoff eventuate.

(c) Follow this intermediate course, protecting against possible flood and assuring of filling, as long as possible. When the point is reached beyond which both conditions cannot be satisfied, the thermo-hydrograph (Figs. 3 and 4) should indicate whether the runoff is going to be less or

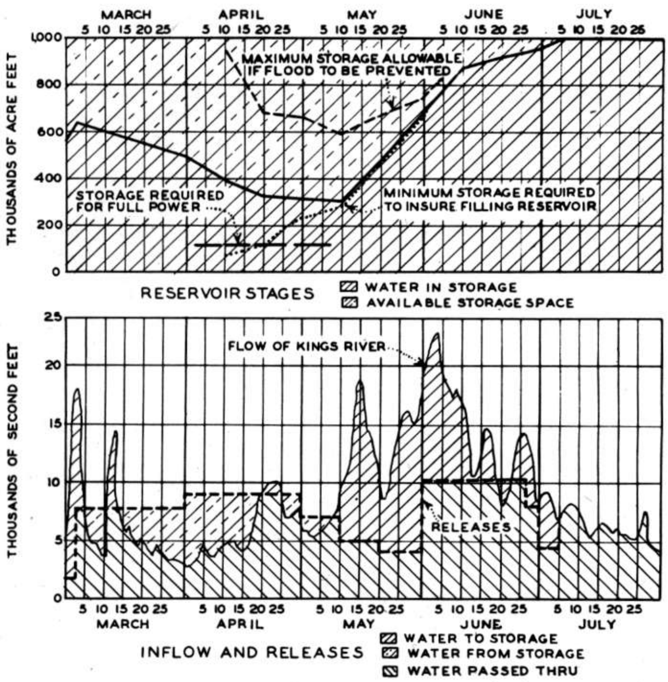


Fig. 7--Operation-chart, Pine Flat Reservoir, 1938-forecast, ten per cent low

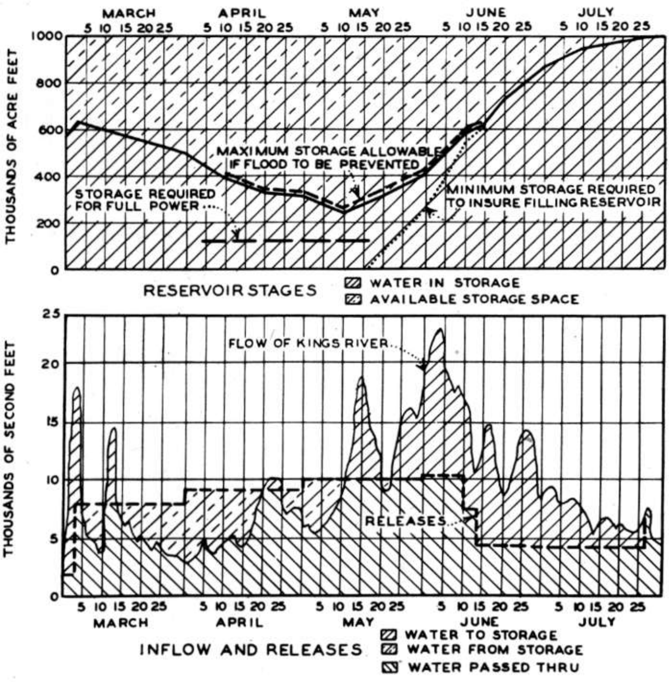


Fig. 8--Operation-chart, Pine Flat Reservoir, 1938-forecast, ten per cent high

greater than the forecast, and the operation during the last part of the season can be properly adjusted to the existing situation.

Application of operational criteria--The system outlined above has been worked out in detail covering the year 1938 for which snow-records are available. During the entire record of the Kings River the flow during the snow-melt period of 1938 was exceeded only in 1906 for which no snow-records are available.

In the hypothetical operation of Pine Flat Reservoir during 1938, as outlined hereafter, it has been assumed that the ground-water table of the agricultural lands was high, having been brought up by the preceding wet year of 1937. The allowable releases are thus limited to those shown in column (8) of Table 1.

Hypothetical operation is shown covering two different situations. In the first example the forecast is assumed ten per cent low; in the second example the forecast is assumed ten per cent too high.

The stage of the reservoir during the winter would be dependent upon the program of operation adopted for the control of winter rain-floods. In this study, in order to supply a starting point the water in storage in Pine Flat Reservoir on March 1, 1938, is arbitrarily assumed as being 568,000 acre-feet.

Operational charts for 1938 are given on Figures 7 and 8. That on Figure 7 shows how the reservoir would have been operated under the foregoing criteria had the forecast been ten per cent low. That on Figure 8 shows the operation had the forecast been ten per cent high. In neither case is hindsight used.

Division of Water Resources,
California Department of Public Works,
Sacramento, California

DISCUSSION

JAMES E. JONES (Department of Water and Power of the City of Los Angeles, California)--The author of this report has presented a correlation between snow-survey data and the runoff of the Kings River in California. The example used shows how the advance information as to snow-melt runoff may be applied to the dual problem of flood-control and water-conservation in the operation of reservoirs in a water-system supplied from natural runoff.

Figure 1 is a starting point fairly familiar to all using snow-survey data for purposes of forecasting stream-runoff.

Figure 2 presents a view that may be required when the season in question is one of subnormal temperatures, or has been preceded by years that would cause great losses from the water-content of the snow-field by reason of the heavy recharge to the underground water. This expectancy must be, to a large degree, based upon a knowledge of the basin held by the forecaster as a matter of historical experience.

Agreement with the statement "Although forecasts of the total amount of runoff can be made, the actual distribution of the runoff from month to month is so dependent upon temperatures that it cannot accurately be determined very far ahead of time" is made as a matter of experience.

The use of the maximum daily temperature at Fresno to plot the "thermo-hydrograph (Figs. 3 and 4) is believed capable of refinement by the use of the daily mean, due to the melting of the snow-field being more probably a result of the effect of both maxima and minima.

The Department of Water and Power of the City of Los Angeles has followed the practice for two years of plotting the mean temperature at Long Valley against the flow of the Owens River and has found that nearly a week's advance notice has been obtained of changes in stream-flow.

Experience has shown that the range between the maxima and minima temperatures at Long Valley is not uniform, having many wide and narrow belts. The melting of the snow-field is believed to more closely follow the mean temperature than either of the two extremes.

The demands upon a reservoir may be of several characters, but the treatment under a mass-curve can be set out according to the special conditions. The plan is usually set by May 1 of each year, but the progress-surveys will have determined to a large measure the season's operations.

Figures 5 and 6 give the approximate early and late dates of snow-melt runoff. These graphs are new to the writer and their construction was not clear from the report as submitted.

Under date of July 2, 1943, FRED PAGET, in reply to a request for data as to the construction of Figures 5 and 6, made the following statements:

> "The heavy diagonal line of Figure 5 determines for any amount of forecast the earliest date by which time the flow from the watershed might fall for keeps to a stage that the outlet channels could safely carry, and also indicates the maximum total amount of water that under such conditions would have to be taken care of up to that date. The heavy diagonal line of Figure 6 determines for any amount forecast the last date upon which the stream-flow might be expected to be greater than the amount required for irrigation, and also the amount of water that could have runoff up to that date."

The heavy diagonal lines are drawn through those record years, as plotted, that most nearly fill the condition of being extreme cases, the other years being disregarded in the construction of the curves.

In the letter of July 2, 1943, Mr. PAGET continues as follows:

> "Referring to Figure 5: The position and slope of the superimposed diagonal lines are determined by the critical black points. The lines are put on to fit the worst conditions. The solid black circles marked by the numerals were first plotted and then the diagonal lines superimposed to fit. The actual slope of the lines does not matter much since in this study it is only their intersection with the heavy line through the points at the extreme left that are considered when using the curve. The same remarks apply to the vertical superimposed lines of Figure 6."

It is considered that by the presentation of Figures 5 and 6, their construction having been clarified, this report will be a worthwhile addition to the working technique of the stream-flow forecaster.

H. P. BOARDMAN (Nevada Cooperative Snow-Surveys, Reno, Nevada)--This paper is very interesting and, I think, makes a strong case for snow-surveys as an aid in flood-control where one or more reservoirs of considerable capacity are available.

The graph on Figure 1 shows excellent harmony between the actual unimpaired or natural flow and the snow-survey water-content corrected for precipitation during April. No statement is made as to whether the indicated snowpack water-content for each year is an average of those for all snow-courses or is obtained by weighting them according to altitude-zones, or by some other system.

It is noted, by examining a recent California Cooperative Snow-Surveys report, that the Kings River Basin snow-courses, numbering 21, range in altitude from 5,500 to 11,400 feet and that of the 19 whose normals have been established the average of April 1 water-content normals for courses from elevations of 9,000 feet up is 38.1 inches, from 8,000 to 9,000 is 33.9 inches, and below 8,000 is 23.7 inches. The straight average of all 19 course normals is 31.7 inches which is somewhat under the water-content value where the normal flow-line intersects the adopted curve. The average of normals for the mid-zone, 33.9 inches, checks very close to this intersection. Also a fair curve for the uncorrected points of April 1 would intersect the normal discharge-line at about the same water-content value.

Since of the 19 snow-courses there are seven from 9,000-foot elevation up, seven below 8,000 feet, and five in the intermediate zone, the straight average might seem to give a good representative water-content value for the whole basin, but if the combined areas of the middle and upper zones are more than twice the lowest zone-area, that should raise the value of the whole basin normal above the straight average of all 19 normals.

Of course, some years the snowpack is not the same proportionately over the whole basin; for instance, this year, 1943, the zone below elevation of 8,000 feet averages more than 25 per cent lower in percentage of normal than the higher zones.

The three Kings River precipitation-stations listed in the above snow-survey report are at elevations 6,775, 1,300, and 500 feet, so there might be some question as to the quantitative correction to apply to the snow-water content of April 1, on account of abnormally high or low precipitation during April at these low-altitude stations, to obtain points for the adjusted graph for May 1.

However, I think enough has been said to show that for this basin the snow-surveys afford a very good criterion for estimating the runoff during April to July.

Figures 3 and 4 show a very good correlation between distant valley temperature and the runoff resulting from an evidently nearly parallel temperature at the snow-fields, with a natural lag of a few days between a temperature high or low and the corresponding high or low runoff-rate. This relationship holds as long as there is sufficient snow left to have a pronounced effect on the runoff, even for several weeks after the peak-flow has been passed in the case of the year 1938. The lag as seen on Figure 3 seems to be less at times of high discharge than at low stage probably because of greater velocity of flow, requiring shorter time for the effect to travel down to the gaging-station.

The correctness of the statement in the third paragraph under "Water-conservation considerations" is not clear to me. For instance, referring to Figure 5, assuming total runoff during April to July to be 2,000,000 acre-feet and that, case 1, the flow does not fall below 10,200 second-feet until July 9 (similar to the year 1911) or, case 2, that with the same total during April to July of 2,000,000 acre-feet the flow drops to 10,200 second-feet by June 16. In the second case the peak-flow would probably be passed considerable earlier than in the first case. The danger of flood-rains would probably be passed by the middle of May. In order to be sure and have the reservoir full at the latest practicable date, could not the filling be started at a later date in case 1 than in case 2? Something would depend on the low point in the reservoir from which filling would start. But in case 1 where the flood-flow lasts until July 9 there should certainly be more remaining acre-feet left to flow after June 16 than in case 2. Then why should it be necessary to start filling earlier in case 1?

Such great difference in time of falling below the flood-stage would naturally be due to effect of temperature. Assuming normal spring precipitation in both cases, the shape of the thermograph would determine the shape of the hydrograph as in Figure 3. That being the case, if strongly subnormal temperature occurred in April and May indicating delayed melting and runoff, would that justify early filling of the reservoir if snow-surveys had given assurance of ultimate total runoff?

As a matter of fact, I believe that prolonged sub-normal temperature, -5°F or more, during May will result in some actual loss of surface-runoff.

The graphs of Figures 7 and 8 for hypothetical operation of the Pine Flat Reservoir for the year 1938 look reasonable, both leaving the reservoir full at the end of July, which should be expected in a high year as was 1938.

SOME ACCOMPLISHMENTS IN SNOW-SURVEYING

W. W. McLaughlin

Snow-surveying, as it is now understood, means a determination of the amount of water stored in the mountains in the form of snow and ice. The depth of snow and its compactness are incidental factors not essential in attaining the main objective.

The measurement of snow for the purpose of estimating the amount of water that would result from its melting has been made use of at various times for a long time. During the past 30 to 40 years occasional determinations of water-content of the snow have been made by means of melting samples. The so-called "stake" method of snow-surveying and the melting of snow-samples have been replaced by the present method known as the "course" method. In this latter method samples of snow are taken, by means of a hollow tube, through the full depth of the snowpack at approximately the same place each year and year after year. The core of snow is of such diameter that one ounce in weight of snow is equivalent to one inch in depth of water. In other words, the melting of the snow-samples is replaced by weighing the samples and the conversion of this weight directly into water-content.

Prior to the winter of 1935-36 snow-surveying by the course method was in progress in