Without advance knowledge of the potential runoff, the three pumps would most certainly have been operated at maximum capacity for at least half of June, exceeding the 11,200 kw limit to a demand charge of $35,000 to the farmers.

The safety factor employed by the project engineer may be noted here. Even though the season's total runoff proved to be more than adeauate for all irrigation needs, and the storage from runoff prior to the peak discharge was equal to the June demand, removal of this storage from the upper end of the valley for deliveries in the area under the pumps would have left the higher areas completely unprotected from a forecast error. However, the cost of running two pumps as a safety factor was considerable, amounting to $10,000. The value of a dependable forecast for the 1950 irrigation season would, therefore, total $45,000 for power costs.

The snow surveys have been used successfully for the last five years as a guide for supplemental pumpage and the acre-foot-per-acre allocation. They have also figured prominently in this season's program.

THE PROGRAM OF SURFACE WATER INVESTIGATIONS IN THE WEST

by
J. V. B. Wells[1/]

The backbone of any surface-water investigation--North, East, West, or South--is the network of stream-gaging stations. Here in the Columbia River basin the Survey operates about 600 stream-gaging stations which in a total drainage area of about 210,000 square miles in the United States represents about one for every 350 square miles. However, the adequacy of the coverage is not told by this generalization. Most of our stations in the Columbia, as in the remainder of the United States, are on the larger streams. In fact, the farther down the ladder we go in size of river, the poorer the coverage. However, all this is another story and without further ado I'll talk about what we are doing with what we do have.

Records of daily discharge at all the gaging stations maintained by the United States Geological Survey are published annually in the Survey's water-supply papers. A few years ago we thought seriously of discontinuing the publication of daily discharge, in favor of other means of disseminating the data. We explored the matter with you folks who use these records and the response was almost unanimous that the publication of the discharges should be continued. Basic daily discharge published in this way can be used for many different purposes and probably will be continued.

Although the formal publication of records of daily discharge serves an essential purpose, it is not the complete answer to the dissemination of surface-water basic data. Two rather fundamental deficiencies have shown up in this procedure--lack of compactness and lack of timeliness.

Compilation Report

In many studies monthly discharge satisfies the requirements but the user finds that he has to consult many volumes of water-supply papers to find all the data he needs. In fact, I imagine many of you have made your own "compilation" reports by tabulating monthly discharge from Geological Survey water-supply papers. Perhaps some have compiled the same figures that others had "compiled" before him. Furthermore, in using these records you have doubtless found many short missing periods breaking up an otherwise continuous record. Also, questions have arisen about the accuracy of the older records which have not been systematically reviewed and revised where necessary. We have been engaged for the past three years on a Nation-wide compilation report to remedy this situation. It has been one whale of a big job. I am glad to report that it won't be long before such a compilation through 1950 will be available for all stations in the West. The compilation report for Part 9 (the Colorado River basin) was published a few months ago as Water-Supply Paper 1313. That for Part 12 in the Columbia River basin is expected to be published this year; those for Parts 10, 11, 13, and 14 are expected to be completed gradually over the next four years. Out in this area Earl Bailey has been project engineer for this work. His territory includes the Pacific Northwest, Alaska and Hawaii.

These compilation reports involve much more than a mere "cut and paste" job. One important feature of the project is the rigorous review given the original analyses and computations. This is particularly necessary for the older records. The old timers did a wonderful job considering the handicaps with which they had to contend. However, new correlation techniques have improved with the years and, for some stations, additional base data permit reinterpretation and recomputation which result in a better final product. All records are examined for major computation errors and tested wherever possible by comparison with all base data such as records of discharge at other stations and weather data. Records that are found to be in need of substantial revision are recomputed or omitted if revision is not feasible. Estimates of discharge are

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made to fill short gaps to complete the continuity of the record, whenever practical. The result is, we believe, the best possible base for all users of stream-flow data. Its completion is being given high priority in our planning. It can be likened to a very necessary housecleaning before the company arrives.

Current Records Center

The other deficiency that many see in the annual report series of surface-water data is the length of time after the close of the water year before the printed report is available. Part of this delay is due to a backlog of work in computing the records which in turn is due to manpower and financial considerations. This we hope to remedy in part and gradually get back on a more current schedule.

However, even if the records were computed within a few months after the end of each water year, the time required in the review and publication would add about a year to that time so that at best the published report would not be available until after the end of the following water year. Although many of us are anxious to receive the streamflow data as soon as possible, I am sure that none of us would want to see the final reports which are used as a yardstick in such important matters as court actions contain errors that could be avoided if time is taken for rigorous review and checking. On the other hand, current records are frequently necessary for some pressing needs but usually great accuracy is not essential for this purpose. Therefore, we have come to the conclusion that we should attempt to work out a procedure so that we can "have our cake and eat it, too."

To help to accomplish our objective we have established the Current Records Center here in Portland with Hollis Orem in charge. Prior to that I believe many of you made arrangements with individual districts of the Surface Water Branch whereby you obtained preliminary data. It is not intended that the Current Records Center will entirely replace that medium but it should go a long way in consolidating the work and speeding up the releases. By taking advantage of the reporting system maintained by other agencies in the Columbia basin and the current discharge measurements made by the district offices of the Geological Survey, the Current Records Center releases daily discharge data on a weekly basis for 57 stream-gaging stations, and change in contents in 16 reservoirs, in the Columbia River basin. To put out these reports on time requires real cooperation on the part of all participating agencies. Everyone in the area has been particularly helpful to Mr. Orem's office. As an example, I might point to the use permitted us of the unique network for reporting hydrometeorological data of the Bonneville Power Administration and the Weather Bureau. In other words, the releases of the Current Records Center really are the results of a fine partnership arrangement among many individuals, private companies, and offices of other public agencies. The data for the Canadian streams are obtained through the fine cooperation of the Water Resources Division of the Canadian Department of Northern Affairs and National Resources. We all realize that these data produced for an early release are not of the same accuracy and reliability as the final records. However, for current needs we feel that the timeliness more than makes up for this. The weekly releases are mailed to 200 users, who report that they find them of considerable value.

The Current Records Center compiles and releases discharge data on a monthly basis for 70 discharge stations, 12 of which are not included in the weekly release. Monthly mean flows for 22 stations are computed in the district offices under less pressure and in general are somewhat closer to the final figures than the data released weekly. Information on storage in 16 of the major reservoirs in the Columbia River basin is included with these monthly releases.

In addition to the weekly releases the Current Records Center is acting as the release agent for the Pacific Northwest Water Resources Summary. This Summary is prepared monthly by Hollis Orem's office--the Current Records Center--from data furnished by the field offices of the Water Resources Division of the U. S. Geological Survey and of Canada. Ground-water conditions and water levels of observation wells occupy a prominent part in this Summary. This morning Mr. Stewart described the graphs and the interpretation of these graphs so far as the ground-water data are concerned. Incidentally, the Ground Water Branch goes to considerable work to make this information available each month.

A special feature of the Summary is the outlook for surface-water runoff during the succeeding month. The outlook for average conditions is based on discharge from base-flow recession at key gaging stations to which has been added additional runoff that on the average can be expected during the next month. The outlook for adverse conditions is based on the assured flow from base-flow recession plus the accretion from additional runoff that can be expected to be equalled or exceeded 19 times out of 20. Much of the credit for the initiation of the project goes to C. C. McDonald of Tacoma, your current program chairman of the Western Snow Conference. He did much to develop the technique for the outlooks as well as the idea of the Summary. The first issue of the Summary was for the month of January 1955. It will be issued monthly but the outlook section will be included only for the period September to March, inclusive--periods when there is normally no snow-melt runoff. Copies of the March Summary were distributed by Hollis Orem earlier in the program and additional copies are available for those who have not already obtained one. If you desire to be placed on the mailing list to receive copies of the Summary, your request may be made to the Current Records Center, P. O. Box 3418, Portland.

So far I have talked mostly about the availability of discharge records at established stream-gaging stations. Now I would like to say a few words about the adequacy of the present network. During the past few years we have come to realize that because of practical limitations we will never be able to operate a long-term stream-gaging station on every stream where surface-water information will be needed. The importance of long-term records has long been stressed by the Survey and will continue to be.

The longer the record, the better we can determine the probability of various flow conditions being repeated in the future. However, the number of requests for data on small streams leads us to believe that areal coverage is equally as important as long-term records, particularly when dealing with flood-peak and low-flow characteristics. Although the mean annual runoff may vary relatively uniformly from place to place, the extremes of discharge may vary widely in only a short distance. A network of short-term gaging stations used in conjunction with nearby long-term stations is believed in many cases to be the practical answer to evaluate these differences--in other words, to estimate long-term flow characteristics at short-term gaging-station sites. However, in actual practice, the application of this philosophy depends on a strong network of long-term base stations to which to anchor. The base stations should be selected by careful hydrologic analysis so that when the need for information at any specific site becomes apparent, a short-term station can be established and correlated with the base station.

For reconnaissance purposes, much information can be obtained at small cost by obtaining peak-flow determinations and low-flow measurements at partial-record stations. The peak-flow determinations would be by means of crest-stage gages and direct or indirect measurements of discharge; the low-flow measurements would be current-meter measurements made under base-flow conditions.

We have been making studies to test the proposed methods of determining which gaging stations should be considered part of a base-station network to be operated indefinitely. The remaining stations would then fall into the general category of short-term stations, to be moved after a relatively short period of time, or project stations, to be maintained for a specific purpose. At the present time the stream-gaging program in the Colorado River basin is being intensively studied under the above system. If this project proves successful similar studies will be made in other basins.

To those who use our records primarily in developing plans for operation, the idea of short-term and partial-record stations may sound impractical. However, those who have been faced with the problem of estimating the low flow or flood flow of a small ungaged stream would probably be glad to swap admittedly desirable continuity of record at a few locations for a lesser amount of basic data at many more locations. It is a case of compromise with the ideal as a matter of practicability.

Evaluation Reports

One of the difficulties in setting up a base-station network in an area such as the Colorado River basin or Columbia River basin is the distortion of relationship caused by much regulation and diversion of surface and ground water and the accompanying return flows. Adequate consideration to the effect of such man-made changes that have been or are likely to be made are required before we do attempt to estimate the future from the past. The evaluation reports on the Yakima, Rogue, Flathead, and Big Wood River basins that were published a few years ago in Geological Survey circulars were planned to be of aid in such studies. They contain an inventory of reservoirs and canals that affect the flow at the various stream-gaging stations in these basins. These reports were in the nature of pilot projects to see if further reports on other basins would be worthwhile.

Because of the greater need for other types of reports nothing much further has been done along this line except in the Yakima River basin where the surface-water report is being consolidated with a report on the geologic and ground-water factors that affect the representatives of the discharge records at each gaging station. For example, at some stream-gaging stations the underflow in the form of ground water amounts to several percent of the total flow passing the station during low-water seasons. This effect will be evaluated in the forthcoming Water-Supply Paper on the Yakima. Comments you may have on the merits of this type of report would be welcome.

The realization that the discharge that passes a gaging station may not be a representative sample from which we can logically predict future conditions leads us to a somewhat different and perhaps more realistic conception of accuracy. We do not propose to lower the accuracy of the discharge records at most of our gaging stations as the present accuracy is needed in hydraulic studies involving storage volumes, gains and losses between stations, and for legal and compact purposes. However, for streams where the principal objective is to estimate the future from the past and where a flow correlation with a long-term station may result in a standard error larger than that which we had previously hoped to obtain, it may be that we should consider the size of this error in relation to the possible errors in our predictions of the effect of man-made changes. It might not then look so large.

Hydrologic Analysis

I think we have now reached the stage where the number of stream-gaging stations and length of available records afford enough basic data to make areal analysis of these data not only possible but very much worthwhile. The compilation reports mentioned earlier set the stage for such work. As soon as the work on the compilation reports draws to a close, we expect to turn some of our efforts to flood-frequency analysis. This will be done on a regional or areal basis in order to permit the greatest possible application. Further, the areal approach tends to reduce the effect on the results of the chance occurrence or nonoccurrence of an extremely high flood during the period of record at a particular station. Thus it enables us to make the best estimate possible of the magnitude and frequency of floods to be expected in the future at all points in the area. Not only do we expect to obtain greater reliability but by making the data available to all we expect to reduce the amount of "spade work" necessary by the user of the records.

Another type of analytical report that we find urgently needed pertains to low-flow analysis. Flow-duration tables have wide usage among hydraulic engineers but are not generally available unless each user computes his own--a long and tedious task. A compilation of flow-duration data by years and by the month of the year would present the stream-flow data in a more compact and usable form. The usefulness of flow-duration data for simultaneous periods of record in developing flow relations between two gaging stations is being investigated and appears to have much merit especially in areas where flow relationships do not vary materially with the season of the year.

If the position of the relationship curve changes with the season of the year, as is apparently the case in snow-fed streams in mountainous country, duration-curve data on a monthly basis may prove useful in correlation.

Perhaps the most useful type of low-flow analysis for natural-flow streams are low-flow frequency studies on an areal basis. Such a study gives the annual frequency at which, on the average, various low flows can be expected to recur. The frequency of minimum daily flow, minimum 7-day flow, 30-day flow, and flow for longer periods can be computed. In making such low-flow frequency studies it is not sufficient to let each record speak for itself for in many cases there are longer records that they can be tied to by correlation techniques. Thus we are back to the adequacy of the base network of stream-gaging stations to be used as anchors for such regional low-flow analysis.

Low-flow analysis will probably not be started on a National scale for several years although an increasing amount of this type of work is being undertaken on a small scale in various parts of the country. Not only will such delay give us time to complete the compilation of monthly discharge and flood-frequency projects but will give us time to perfect the techniques that will be used. Although we have been working on the problem of techniques for several years we find that much more study of the problem remains to be done.

Equipment Development

I think perhaps you people would be interested in some of our current activities in the field of equipment. We have under contract an electronic device to automatically integrate our recorder charts and to punch cards giving mean daily gage heights and mean daily discharge. The cards would then be fed through another machine for listing the data therefrom. If this is successful it will eliminate many valuable man-hours of our technical people and be much more rapid and perhaps even more accurate than the present laborious method. As another project we are actively exploring several avenues of accurately obtaining river-stage data without the necessity of stilling wells. We are also exploring a number of possibilities for more accurate and more effective and efficient ways of measuring stream velocities and channel cross sections. We are greatly encouraged as a result of our investigations to date along these lines and expect to reach the contract stage in the very near future for engineering models on some of the more promising devices. I could go on and on with the subject but perhaps the equipment items mentioned are the ones of most interest to this group. It is probable that the group we have assigned to this work will be talking in the future with some of you folks, as we desire to get the best thoughts of all interested parties to the end that the very best job will be done in the interest of all.

Summary

To summarize, let me say that we don't propose to sell the stream-gaging program short but we do feel that a mass of daily discharge figures in hundreds of water-supply papers is not the sole answer to the question of surface-water data availability. The time has come to make a better presentation of what is available and to consider if the expanding need for surface-water information can be satisfied, in part, by something short of long-term stream-gaging stations.