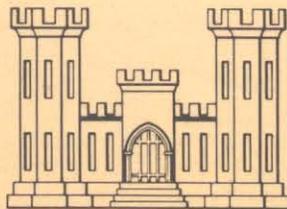


SUMMARY REPORT
OF THE
SNOW INVESTIGATIONS

SNOW HYDROLOGY



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PREFACE

During the past three decades, increasing demands upon the water resources of this country have resulted in the construction of many projects for the control of our river systems, thus bringing about a need for a better understanding of the natural processes which govern their flow. This knowledge is necessary for both the economical design and efficient operation of engineering works required for river control. In response to this need, the field of hydrology has also experienced a large growth, but most of this increased knowledge has been concerned with the hydrology of rainfall. Methods of computing snowmelt and snowmelt runoff have been largely based on empirical relations derived from very limited data. To promote a more fundamental understanding of snow hydrology for project design and streamflow forecasting, particularly in the western part of the United States, the Corps of Engineers and the U. S. Weather Bureau initiated the Cooperative Snow Investigations. Activation and sustaining support of the program resulted primarily from the efforts of Mr. G. A. Hathaway of the Corps of Engineers and Mr. Merrill Bernard of the U. S. Weather Bureau (deceased). Following the cooperative phase of the investigations, the Corps of Engineers continued the work.

The snow investigation program was organized to meet specific technical objectives in the field of snow hydrology for both agencies. In order to meet these objectives, fundamental research in the physics of snow was needed. An extensive laboratory program was established, and observations were gathered over a period of several years at three headwater locations, having differing conditions of climate and physical environment. Data obtained from the laboratories have been processed and published. Analysis of these data forms the basis for the basic relationships and methods of application derived for the solution of snow hydrology problems. These in turn have been utilized by the Corps of Engineers in specific applications to project design or operation. These applications include: (1) the derivation of maximum probable and standard project floods, which partly form the basis of project design; (2) the development of procedures for forecasting seasonal runoff, which are used primarily in connection with regulation of multiple-purpose reservoirs and appraisal of flood potential; and (3) the formulation of procedures for hydrograph synthesis of snowmelt or rain-on-snow events, which are used as the basis for forecasting streamflow at reservoir projects and river control works, and for flood fight operations.

Some specific developments in snow hydrology which have resulted from the work of the snow investigations are: (1) experimental evaluation of the coefficients of snowmelt, in terms of appropriate meteorological parameters, for each of the several processes of heat transfer to the snowpack; (2) methods of applying thermal-budget indexes of snowmelt to drainage basins; (3) derivation of general snowmelt equations which are applicable to drainage basins according to their physical characteristics; (4) determination of the reliability of snow courses

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and precipitation gages, as related to their site characteristics; (5) evaluation of each component of the hydrologic balance in areas of snow accumulation, and application of the water-balance technique to procedures for forecasting seasonal runoff volumes; (6) experimental determination of the liquid-water-holding capacity of the snowpack and transmission of heat and water through the snowpack, with methods of application of results to basin hydrologic studies; (7) methods of synthesizing streamflow hydrographs for areas involving snow; (8) investigation of the general features of atmospheric circulation as it affects moisture and energy input to drainage basins, and the use of upper air data in estimating snowmelt; (9) derivation of an index procedure for forecasting spring-season snowmelt runoff by use of low-elevation winter runoff, without recourse to direct measurements of precipitation or snow accumulation. Under the Civil Works Investigations of the Corps of Engineers, work on two projects was accomplished in conjunction with the snow investigations program. Under Project CW-170, a radioisotope-radiotelemetering snow gage was developed which transmits daily readings of snowpack water equivalent by high-frequency radio from remote gage sites to a base receiving station. Under Project CW-171, a training program for engineers of the Corps was organized, whereby methods being developed within the investigations could be put to use prior to the completion of formal research papers and a general summary of the investigations. Also under project CW-171, certain features of the investigations were developed, including an electronic storage routing analog which is applicable to general hydrologic use. The results of the individual investigations within the snow program have been reported from time to time in the various technical publications of the program.

This report, which summarizes the work of the Snow Investigations, is intended as a reference on snow hydrology. Although the information in the report was developed mainly from studies of mountainous areas in the western United States, the basic relationships derived are applicable to all regions in which snowfall is of appreciable hydrologic concern. The information is intentionally presented in considerable detail, in order that the practicing hydrologist who has need for it may thoroughly understand the fundamental relationships involved and the derivation of the methods given. Accordingly, the report not only includes technical background material necessary to a general understanding of the subject matter, together with methods and examples of application, but also includes some material not essential to application itself. Also, there is some duplication of material among chapters to provide completeness of presentation for individual subjects. Use of the report as a simple handbook or manual of procedure is not intended, and little attempt has been made toward the condensation and generalization that characterize works of that kind. Work on the report has been accomplished under the general supervision of personnel of the office of the North Pacific Division, Corps of Engineers, U.S. Army, including Mr. F. S. Brown, Head, Engineering Division; Mr. Mark L. Nelson, Head, Water Control Branch; and Mr. Oliver Johnson, Head, Hydraulics and Hydrology Section.

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