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ADDRESS BY C. G. PAULSEN, CHIEF HYDRAULIC ENGINEER, U. S. GEOLOGICAL SURVEY, PRESENTED AT THE TENTH MIDWESTERN STATES FLOOD CONTROL AND WATER RESOURCES CONFERENCE TOPEKA, KANSAS, 10 A. M., MAY 24, 1955.

Speech meeting

WATER-RESOURCES PROGRAM OF THE GEOLOGICAL SURVEY IN THE MIDWESTERN STATES

The program of basic water-resources investigations by the U. S. Geological Survey in the Midwestern States is a highly coordinated undertaking. It represents a partnership among Federal, State, and municipal agencies that has developed during the past 60 years from the mutual desire to obtain and maintain optimum knowledge of our water resources with a minimum outlay of public funds. The program is sufficiently broad to include investigations of water from all natural sources including the chemical and physical quality of water from each of these sources.

Pattern of Partnership

The pattern of partnership in this endeavor is impressive. In the 14 States 1/ from which representation of this Conference is anticipated, there are more than 3 dozen State agencies, and nearly as many local governmental units such as cities, counties, and water districts, currently cooperating with the Federal Geological Survey on water-resources investigations. Other Federal agencies also are contributing to this joint enterprise. The Corps of Engineers stands out among such agencies, regularly supporting the collection of stream-discharge records at a sizeable network of stations throughout the Middle West. The Soil Conservation Service is currently transferring funds to the Survey for work in 11 of the 14 States. The Bureau of Reclamation also supports certain investigative work in that portion of the 14-State area in which it has authority to exercise its function.

We in the Federal Geological Survey must do our best during the conduct of these joint scientific undertakings to merit the trust and confidence that the many Federal, State, and local governmental agencies place in our policies, capabilities, and personnel. The Survey is dedicated to the partnership approach as the core of the water-resources investigative program. Working together, the Federal Survey, the States, and other participating Federal agencies seek to build a sound and solid foundation of knowledge in the field of water resources and water science. The accomplishments of the program are shaped so that they may be most usable not only to the cooperating agency, but also to all current and potential users. The basic water facts and other products from this cooperative effort are published in either Survey or State publications. In this manner the public has access to all findings.

The average dollar used by the Survey in water investigations in the Middle West comes from many sources. About 31 cents from the State and local governments; about 24 cents is from Federal agencies other than the Survey. The remaining 45 cents is from the U. S. Geological Survey, of which 14 cents represents the Federal program and the balance represents the Federal contribution to the Federal-State program.

It is of interest also to break the average dollar down into the primary types of investigations it supports. Currently, about 65 cents is for surface-water investigations, which are primarily stream gaging. Another 22 cents is being used for ground-water investigations and the remaining 13 cents is for quality-of-water and sediment studies.

Growth of Cooperation

Financial participation in this program by individual States began within 15 years after establishment of the Federal Survey. The first State contribution of cooperative funds for water investigations was made here in Kansas in 1895. Nebraska also began cooperation in that year. By 1921, 11 of the Midwestern States were engaged in cooperative water investigations with the Federal Geological Survey, and the remaining 3 had begun cooperation by 1935.

This continuing growth of cooperative endeavor not only reflects mutual satisfaction with the Federal-State "team" way of doing things, but also an increasing awareness on the part of the citizens of each State as to the importance of making the most of our natural water supplies. It used to be that the local public became really "water conscious" only during the periods of "water adversity," such as local floods or droughts. Now, however, with the rapid communication facilities of press, radio, and television, flood or drought is a subject of conversation almost as soon as the phenomenon occurs, be it 10 or 1,000 miles away. Conversations and group discussions on these topics have become more serious in tone as reports call attention to seemingly more persistent and frequent droughts.

Thus, it is probably only within the past 10 years that this so-called water consciousness has begun to take on nationwide proportions. During this same period nature has probably dealt blows no more violent than in many ages past, but because of the growing population and the concurrent growth of agriculture and industry, each river flood or water shortage tends to wreak more extensive damage on man's homes, farms, and factories.

1/ Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio Oklahoma, South Dakota, Wisconsin.

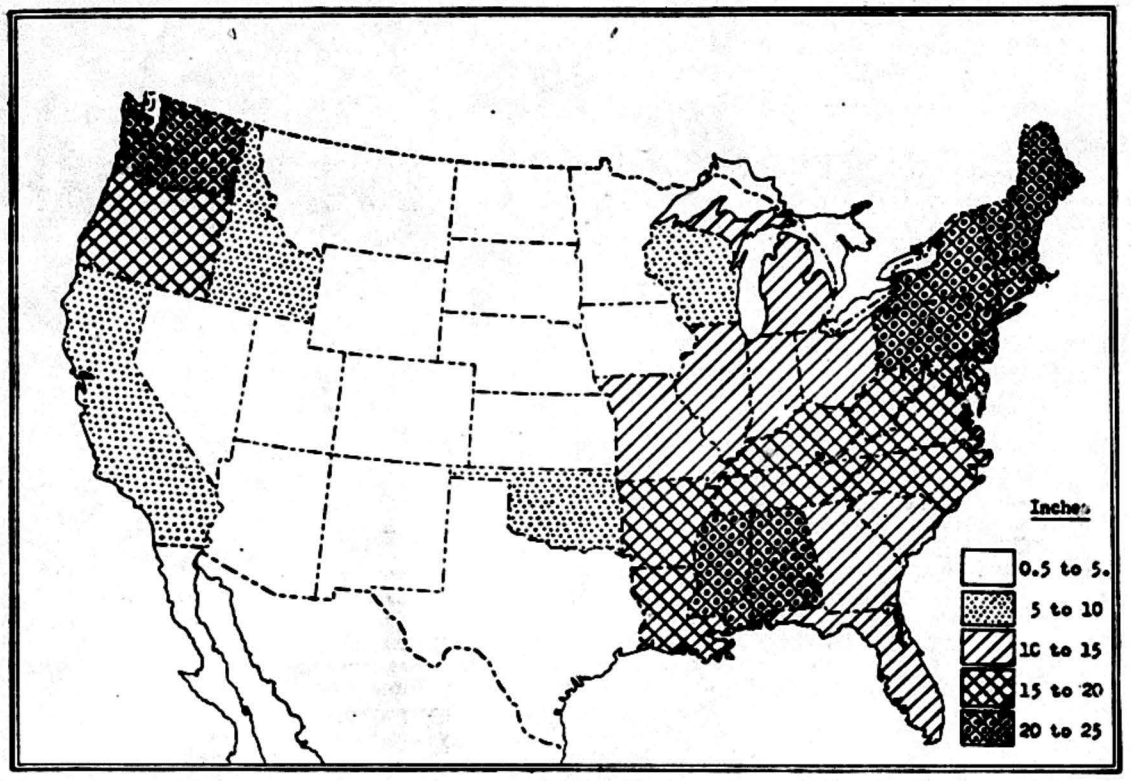

Figure 1. Average annual runoff in the United States, 192[illegible]-45, shown by State averages, in inches (adapted from Langbein and others, 1949).

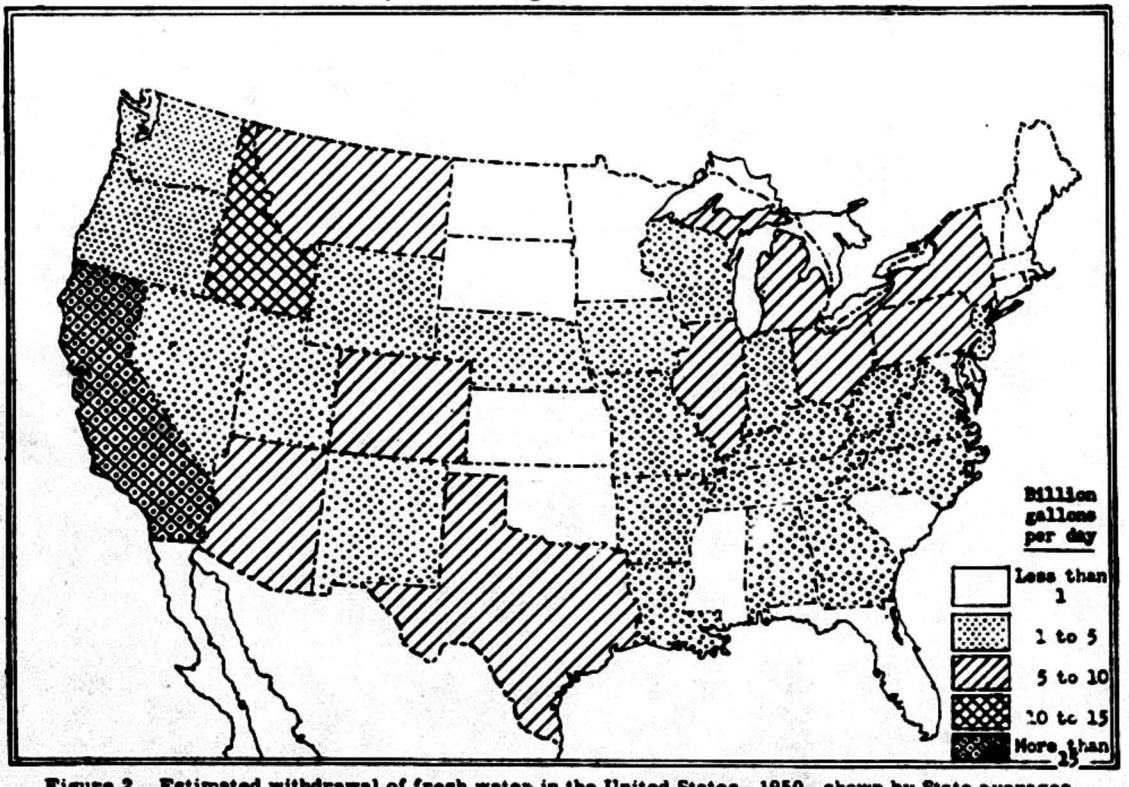

Figure 2. Estimated withdrawal of fresh water in the United States, 1950, shown by State averages, in billion gallons per day (adapted from MacKichan and Graham, 1951).

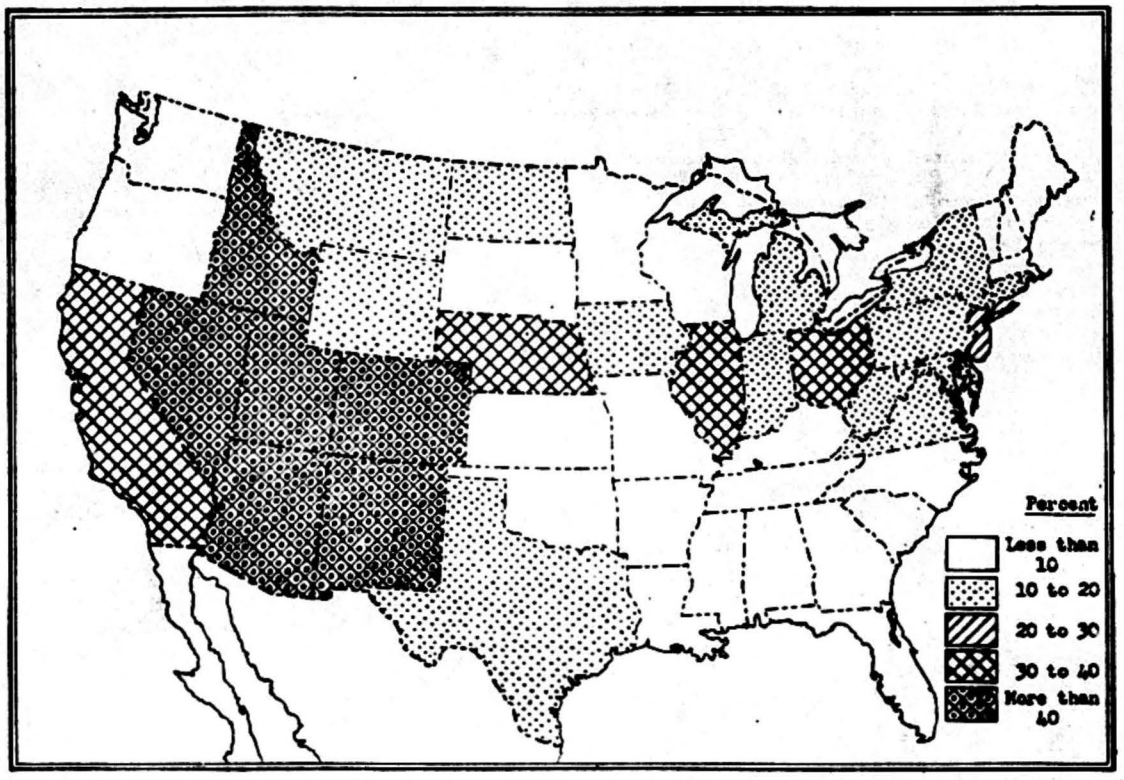

Figure 3. Ratio of withdrawal of fresh water, 1950, to average annual runoff, 1921-45, shown by States, in percent (adapted from Langbein and others, 1949, and MacKichan and Graham, 1951).

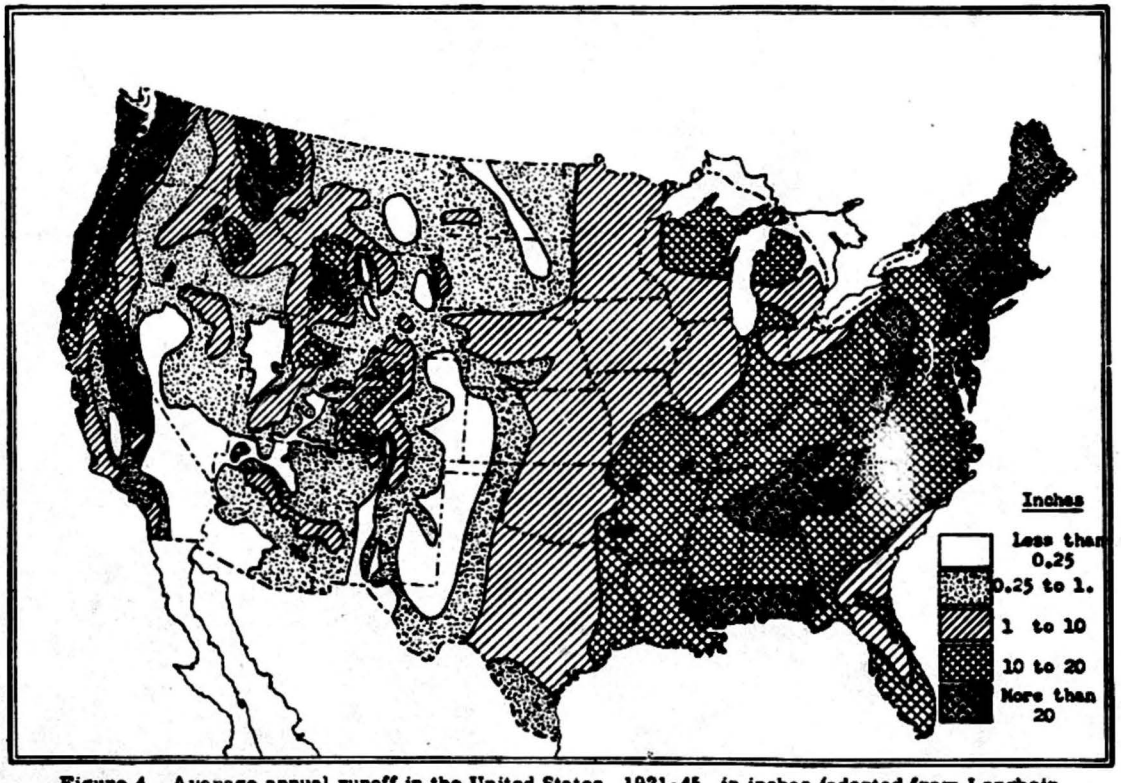

Figure 4. Average annual runoff in the United States, 1921-45, in inches (adapted from Langbein and others, 1949).

Development of the Federal Program

The steady growth of cooperative investigations with the States and municipalities and with other Federal agencies has resulted in an aggregate program of great nationwide value. By its nature, however, it is not without certain deficiencies of balance and gaps in coverage. This is inevitable because each segment of the cooperative program is dependent upon local as well as national need and local as well as Federal financing. The Geological Survey has had in recent years a fairly substantial federally financed activity directed toward removing these deficiencies. It tends to give the overall program optimum value to both the Federal government and to the States.

Fundamental hydrologic research has high priority in this all-Federal activity. Scientific progress in basic water-resources investigations is maintained only through a continuing well-coordinated effort directed toward the discovery of new principles and the development of improved techniques. Also with high priority are measurements and interpretations pointed toward defining the hydrology of large interstate basins as well as of the Nation as a whole.

Water Shortages Versus Total Supply

Let us look for a moment at the subject of water shortage. A reconnaissance study of public water-supply shortages in the summer of 1953 indicated that in the Midwestern States 53 percent of the shortages were caused by demands exceeding the supply, 27 percent by inadequate treatment and distribution facilities, and the remaining 20 percent by combinations of these causes. These percentages correspond closely to the figures for the Nation as a whole. Analysis of hundreds of public water shortages that have occurred during recent years indicates that many of the shortages were the result primarily of planning on the basis of inadequate hydrologic data.

What are the limiting amounts of water available, and how do these amounts compare with the present and future use of water? For the sake of this comparison, we have chosen figures for average annual runoff in each State (see figure 1), and have added the State figures to reach a regional total of water available to the 14 Midwestern States in a year of average runoff. The total is then compared with the combined municipal, rural, industrial, and irrigational use of water in 1950 (see figure 2).

We find that the maximum amount of water available to the 14 Midwestern States in a year of average runoff would amount to about 300 million acre-feet, or average 270 billion gallons a day. By comparison, the amount of water withdrawn from streams, springs, and wells in the entire region during 1950 was only 14 percent of this amount. In the State having the lowest ratio of water use to runoff, the water use was about 2 percent of the runoff, as compared with nearly 40 percent in the Midwestern State having the largest ratio of use to runoff (see figure 3). The President's Materials Policy Commission in 1952 estimated that for the country as a whole, withdrawal of water would almost double between 1950 and 1975. During this period water use would probably continue to increase in each one of the Midwestern States experiencing a growth in population, industry, or agriculture by irrigation.

From a first glance at these simplified and generalized figures, it might appear that major increases in water use could be absorbed without encountering very difficult problems, especially when it is recalled that the same water is often used two or more times as it proceeds downstream, provided it is not evaporated or heavily polluted, so that the actual net percentages used are less than the figures given previously. On the other hand, having made comparisons using average figures for runoff, we have not taken into account the fact that precipitation and runoff vary greatly in their occurrence with respect both to time and place. For example, during the water year ending September 30, 1953, the flow of the Kansas River here at Topeka reached or exceeded the 37-year average flow on only 6 of the 365 days. For the year ending September 30, 1951, measurements at the same station showed above average flow on 192 of the 365 days, and the annual flow for that year was more than 4 times the average annual flow. Examples of equal or greater contrast could be cited for many parts of the Nation.

With respect to geographic variations in runoff, all of us are aware that the Middle West spans a section of the country that progresses climatically from humid in the eastern and southeastern parts to semiarid in the western part. In each of the States of South Dakota, Nebraska, Kansas, and Oklahoma, the average annual runoff in the wettest section of the state (more than 2.5 inches of runoff) is 10 or more times the average runoff in the driest section of the same State (see figure 4).

In this brief discussion of comparisons of runoff with water use, we have omitted consideration of nonwithdrawal uses of water. These include water for navigation, flood control, hydroelectric power, recreation, fish and wildlife, and dilution of municipal and industrial waste. Although such uses do not withdraw water from streams, such operations and activities do require minimum quantities or levels to be maintained in order to function satisfactorily.

There is one source of water in the Midwest that is so large that it should be mentioned. It is located adjacent to six of the States represented here. We refer to the Great Lakes. The total water contained in the Great Lakes is more than 50 times the average annual runoff of the midwestern region. However, even if this source were to be tapped much more extensively than at present, the average annual quantity withdrawn could not exceed the natural discharge of the Lakes without withdrawing water permanently from storage in the Lakes and from some of the water-bearing formations which are adjacent to the Lakes.

Those of us who have responsibilities in the field of water supplies face the future of steadily increasing water use with somewhat mixed feelings. Both assurances and discouragements lie on the horizon. There is not as yet any proved means of appreciably increasing our total water supply. Yet in most areas in the Middle West there is still a wide margin between supply and demand. We know that American ingenuity and engineering can and will harness more and more of the total supply for the steadily increasing demands. However, we have learned also that ingenuity and engineering are effective only when adequate hydrologic data are readily available.

Trend Toward National Appraisals of Supply

From our increasingly water-conscious Nation come many demands for better overall definition of the country's water resources. Industrial mobilization, for example, requires a knowledge of quantity and quality of water available at all likely plant sites. The economy, even in time of peace, is requiring the diversion of waters across many political boundaries and even between major river basins. Interstate and international water problems are thus growing in magnitude. They have long been recognized and dealt with in the West, but they are still relatively new to many parts of the humid East.

In view of this trend toward regional and national analyses of availability and use of water, the investigational program in recent years has included a number of studies designed to clarify the public understanding of the overall water situation. A report on annual runoff in the United States was prepared in 1949 based on streamflow records from 1921 through 1945. In 1951 an inventory report was published on estimated water use in the United States, by source, major type of use, and State. The results of the many cooperative investigations in every State in the United States were of fundamental importance to the successful preparation of these two reports of National scope, as were also the records obtained at key stations maintained as part of the Federal program or by funds transferred from other Federal agencies.

Another major effort in analyzing and compiling water data for the Nation as a whole was recently completed with the publication this year of 2 volumes containing nearly 1,800 chemical analyses and related information about 1,315 of the larger public water supplies in the United States. The collection of water samples for this study was begun in 1950, and most of the analyses were made in 1951 and 1952. Many of the analyses included were made by laboratories of State agencies, municipal waterworks, and commercial establishments. The success of this undertaking is a tribute to the cooperative spirit and assistance of all who participated.

Two more groups of reports now being prepared, which will ultimately describe all the river basins in the country, are a series of streamflow compilation reports and a series of flood-frequency reports. The compilation reports include a re-evaluation and compilation through September 1950 of all streamflow records from the beginning of Survey stream gaging in 1888. Included also are some records computed from data collected by other investigators and organizations prior to 1888. The present work of compilation is part of the all Federal activity of the Survey.

Throughout the Midwestern States, extensive investigations of ground-water resources are being made in cooperation with State and other agencies concerned with water resources. These investigations provide information on a vast source of water about which in many areas comparatively little is known. The ground waters of the Midwestern States are receiving increased attention as a dependable source of water supply for the reason that the large hold-over capacity of the ground-water reservoirs provides a source to supplement supplies derived from surface-water sources during periods of deficient runoff. Furthermore, the ground waters are generally of uniform quality, of relatively low temperature, and require only minor treatment in order to protect their sanitary quality. They are, accordingly, especially valuable for industrial and municipal use where available in adequate quantity and suitable quality. The results of these investigations of ground-water resources as well as the results of other Survey water studies and research are published in the series of the United States Geological Survey Water-Supply Papers, and as publications of the cooperating agencies.

In addition to preparing scientific reports on the results of normal investigative operations, the Survey has been called upon many times in the past 5 or 6 years for special types of water information for use of governmental committees or commissions concerned with water policy or legislation. In most of these cases, the results have been published by the requesting organizations. These groups include the President's Water Resources Policy Commission (1950), the President's Materials Policy Commission (1952), the Public Lands Committee (1950), House of Representatives, and the Interior and Insular Affairs Committee (1952), House of Representatives.

Last year President Eisenhower appointed a committee composed of the Secretaries of the several departments interested in water, whose principal task is to recommend to the President a comprehensive and specific national water-resources policy. Until some definite national policy is adopted, the several States are handicapped in deciding upon programs that will harmonize with the national policy without unduly prejudicing their own particular interests.

Special Studies

Much of this talk has been devoted to national and regional aspects of water investigations. We would like to balance this picture to some extent with a few references to studies and reports that cover more limited areas of the Midwest and that represent activities that are still somewhat new to us either in scope or form of presentation.

Within the past year several water publications have appeared in a new large-format series, called Hydrologic Atlases. This new series is designed for material more suitable for presentation in major chart form on 22-by-27-inch sheets than for inclusion in the existing series of book publications. Atlas number 4 is a State map showing the configuration of the water table in Nebraska, prepared in cooperation with the Conservation and Survey Division of the University of Nebraska. Used in conjunction with topographic and geologic information, this map will be an aid in locating water supplies and can be of special help to local, State, and Federal authorities in planning for the full development of the water resources of Nebraska. The most recently published Atlas, number 5, is a map of the Louisville area, Kentucky, showing contours on the bedrock surface. This bedrock surface is the lower limit of the alluvial gravel, sand, and clay deposits from which are obtained the principal ground-water supplies in the area.

During the past 3 years the Geological Survey has prepared and published, generally as part of its Federal program, a group of widely used evaluation reports on the water potential of 17 metropolitan areas, including Louisville, Ky., Detroit and Grand Rapids, Mich.; Minneapolis-St. Paul, Minn.; Kansas City and St. Louis, Mo.; Youngstown, Ohio; and Milwaukee, Wis. A report on Indianapolis, Ind., is about to go to press. These reports have been prepared at the request of the Business and Defense Services Administration of the U. S. Department of Commerce, in order to provide information of value for national-defense and related purposes.

It should be mentioned that in the case of each of these 17 metropolitan-area water-resources reports, the results of Federal-State cooperative investigations of many previous years, and the key data-collection sites maintained by cooperative work for the Corps of Engineers and other agencies, furnished the backbone of the long-term and the quantitative records contained in the reports. However, in the course of summarizing all available information for these reports, certain inadequacies of data became very evident, and these deficiencies could be remedied only in part prior to report completion, because of lack of time and the limited amount of Federal-program funds available to finance these supplementary studies. In making plans for future reports of this type, an effort is being made to anticipate and eliminate deficiencies in data in advance of report preparation insofar as such work is part of a project being conducted with Federal funds, or is mutually agreed upon by cooperating officials as a logical part of Federal-State cooperative investigations.

One water study now being conducted in North Dakota has a type of objective rather new to Survey water investigations: An inventory of saline water resources. The study in North Dakota follows a nationwide reconnaissance study of saline waters and a study of the saline waters of Texas. These studies are parallel in time and supplementary in purpose to extensive research being conducted by universities, research institutions, and private companies into the economical conversion of salty and brackish waters to fresh water, this research program being financed and coordinated by the Department of the Interior as authorized by Congress in 1952.

Looking Ahead

In this discussion we have attempted to review briefly, with particular reference to the Middle West, the growth and importance of joint water investigations, the increase in water consciousness, the nature of water shortages, and some local, regional, and national aspects of water investigations within recent years. What courses of action lie ahead of us? The prospect is as challenging as it is diverse and complex.

At the outset we know that the future program must continue to be based on a strong foundation of water data, collected at key stream stations and observation wells throughout the country, and interpreted in terms of water availability and quality. Only by providing for the continuation of long-term records at key sites will we be able to keep abreast of trends in water availability and the presence and mathematical frequency of normal and abnormal conditions at the key sites, and to gain by correlation the long-term significance of special short-term investigations at any other sites. With respect to stream-gaging stations, we have during the past year given increased emphasis to an evaluation of our station networks with the objective of determining key stations, and stations of more transient value which may be replaced by stations in areas where few or no stream data are now being obtained. It is this aspect of evaluation that is one of the relatively new and most challenging phases of our basic data-collection program.

The second broad challenge, but by no means of lesser importance, is hydrologic research. Data alone are no more of a structure of understanding and knowledge than a pile of bricks is a house. The data must be correlated and equated through interpretative studies and research before the principles governing the occurrence of water can be understood. It is unfortunate, but probably true, that we have barely scratched the surface in this field. The hydrologic research that is needed is a composite of many phases of activity. In some we receive the benefits of research by other agencies and institutions, but in others we must necessarily blaze our own trails.

Some of the studies that should be, or are being included in our research program are:

1. The movement of water through saturated and unsaturated earth material, particularly with respect to its relation to the mechanics of natural and artificial recharge, characteristics of streamflow, movement of fluid wastes, and salt-water encroachment and intrusion.

2. The relation of land-treatment and water-conservation measures to floods and other streamflow characteristics.

3. The mechanics of aquifers, especially with respect to the factors affecting the subsidence of the land surface in areas of large withdrawal of ground water.

4. The relation of the chemical quality of water to its geohydrologic environment.

5. The relation of sediment characteristics of streams to geohydrologic and physiographic factors.

6. The radioactivity of natural waters.

The last-mentioned item, radioactivity, brings to mind the fact that this "atomic age," with all its potentially beneficial aspects, presents a new factor which has an important bearing on the safe utilization of water. The waste from nuclear-energy reactors, dangerous even in minute traces, if released could contaminate water supplies beyond acceptable limits of tolerance. Consequently, the establishment of a nuclear-power industry involves assurance of the safe and efficient disposal of the various types of nuclear waste in the hydrologic environment. Such safe disposal requires a much more exact knowledge and prediction of the movement of those wastes in surface streams and in ground water than has been necessary in previous water-supply and waste-disposal work. The movement of nuclear-energy wastes cannot be studied effectively without more of the basic knowledge and understanding of the actual movement of ground water, thermal layering and merging of currents in streams, the influence of sediment movement on waste dispersal and deposition, chemical reactions and ion exchanges, etc. Studies of these principles and factors are bound to become increasingly important to our program of water-resources investigations.

A third challenge is really a combination and extension of the first two, and is, in effect, the final stage of accomplishment of the objective of all water-resources investigations: To determine and appraise the quantity, quality, and availability of the Nation's water resources. In other words, for any given area, State, or basin, or the Nation as a whole, there is the need to determine the availability of water from both currently used and potentially usable sources, whether they are on the surface or underground. There should be a full understanding of the present and potential hydrologic relationships between these sources. Only then will all of us be in a position to answer fully for the Middle West, or for any other region, the basic, oft-repeated question: How much, where, when, and of what kind?

We sincerely believe that this objective can be reached most successfully by a program of investigation having as its central component a continued and strengthened pattern of Federal-State cooperation.

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