"WATER SUPPLIES FROM WELLS"[1] - [2]

By

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It is indeed a pleasure for me to appear before this group of water and sewage plant operators and managers to talk about water supplies from wells. It is a subject vital to all of us, including the population of our country as a whole, although too many people take our water supply too much for granted. It is only when restrictions on water use are necessary that this subject becomes of active interest to the public. We in this group are faced with it each day.

Perhaps a few words regarding the water-supply work of the U. S. Geological Survey would not be out of place. The water-resources investigations of the Geological Survey are conducted by the Water Resources Division through its three operative branches: the Surface Water Branch, the Ground Water Branch, and the Quality of Water Branch. The activities of the Surface Water Branch relate primarily to the gaging of streams and the measurement of water on the surface of the earth. Perhaps many of you are familiar with this phase of our work, for the Surface Water Branch has been engaged for many years in cooperative studies with the State of Montana. The work of the Ground Water Branch relates to the determination and investigation of the waters below the surface of the earth that supply the wells and springs and the low flow of the streams. The Quality of Water Branch deals with the determination of the chemical quality of both surface and ground waters and the silt load of surface waters.

The Geological Survey's investigations relating to water are made by authorization of Congress under the organic act of 1879. Each year since 1894 Congress has appropriated funds specifically earmarked "for gaging streams and determining the water supply of the United States, investigating underground currents and artesian wells, and methods of utilizing the water resources." It is under this directive that we operate, and we have been at work on these problems a long time.

Since 1929 the annual appropriation acts have provided also that a major specified part of each appropriation "shall be available only for cooperation with States and municipalities" on the basis that not more than half the cost of the cooperative investigation shall be at the Federal Government's expense. Such cooperative studies of surface water are being

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made in all of the states and there are similar cooperative ground-water programs in 41 of the states. At present we have no cooperative ground-water work in Montana, although such a cooperative study of surface water has been carried on for many years. At the two past sessions of the Montana State Legislature a bill calling for legislative control of ground water in the State, and including a clause providing for cooperative ground-water studies, has been introduced but failed to pass.

The work in ground water which has been carried on in Montana since 1946 is a part of the investigational program for the development of the Missouri River basin. We have made comprehensive studies in a number of areas and have done reconnaissance work on the geology and ground-water resources of numerous other areas. The areas in which we have made comprehensive studies include the following: Lower Marias area, the valley of the Missouri River from Nashua to the Montana-North Dakota boundary, the valley of the Yellowstone River from Miles City to below Sidney, the Helena Valley, the Townsend Valley - Crow Creek area, the valley of the Little Big Horn River from Lodge Grass to Hardin, and the Gallatin Valley. Our study on the Little Big Horn has been a detailed drainage study, as was our study on the First Division of the Buffalo Rapids Project between Glendive and Fallon. We have assembled a considerable volume of data on many other areas and are getting into a position where we can be of assistance in answering requests for information from many parts of the State.

In the course of our investigations we have at times gathered data which have proved valuable to towns in the area of our study. Several towns have called on us for advice and, although we are not now financed to make detailed investigations aimed toward solving problems faced by municipalities and other water users throughout the State, we as public servants feel obligated to lend assistance within our field to the best of our ability and manpower.

Many factors are involved in making an evaluation of ground-water resources. Our organization employs geologists, engineers, chemists, and physicists who are trained in the specialized study of ground-water resources. The detail of our investigations varies in accordance with the requirements of individual studies and includes the identification of the water-bearing formations that underlie each area and the determination of their depth below the surface, their thickness, lithology and hydrologic properties, the head, temperature and chemical quality of the water in each aquifer, the quantity of water that each aquifer will yield for a limited period and perennially, the yield of wells and their drawdown and interference with other wells, the conditions that will cause encroachment of salt water or other contamination, the available methods of increasing the ground-water supplies by artificial recharge, means of draining land by artificial methods, and methods of conserving our ground-water resources.

In general, we consider ground water as occurring under two distinct conditions--under water-table conditions or under artesian conditions. Of course there are gradational situations as in most natural phenomena.

When under water-table conditions the water is not confined and thus is not under pressure. Under water-table conditions the ground-water reservoir has many of the characteristics of a large surface-water reservoir. The thickness and areal extent of the water-bearing material determine the size of the reservoir. The water is contained in the voids between the rock particles and thus the amount of water that may be stored in such a reservoir is determined by the amount of such space. Under natural conditions the water surface has a gradient or slope, generally more or less in accordance with the slope of the land surface, and the water moves slowly in the direction of the slope. The surface configuration of the water table can be determined by means of holes that penetrate below the water surface. When a well is constructed and pumping begins, the water level near the well is drawn down and a cone of depression is formed. If only a small amount of water is pumped, the cone of depression will be small in permeable materials but a cone is always formed so that the water will drain into the well. Water is actually drained from this cone of depression; or in other words, it is taken from storage. By making carefully controlled tests we determine the amount of water taken from storage within the cone of depression and this, of course, is an approximate measure of the volume of voids between the rock particles. This formation is needed if one is to determine the amount of water in storage in a ground-water reservoir.

The cone of influence will spread as pumping continues until enough water is intercepted to equal the water being pumped from the ground. If the amount of water pumped is increased the cone of influence will deepen and enlarge. This is important to remember when plans are made for additional wells, because if the wells are spaced too closely their cones of influence will overlap and none of the wells will supply as much water as they should without an extra pumping lift; and, of course, it costs money to lift water. This illustration (fig. 1) shows graphically what the situation would be:

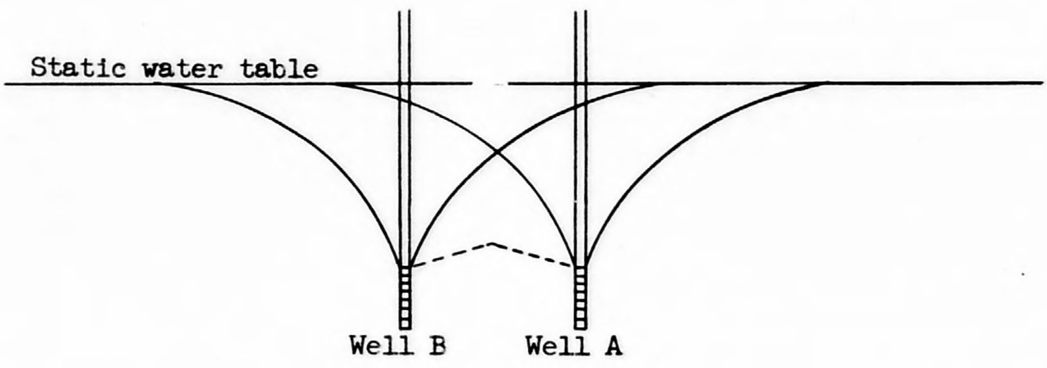

Figure 1.--Solid lines show position of water surface in cone of depression if only one well is pumping. Dashed line shows surface of water in cone between wells if both wells are pumping. With same drawdown the yield of both wells, pumping at same time, will actually be only a small amount more than yield from single well.

Some of you may think that this does not happen very often - but I have seen extreme cases of mutual interference between wells, here in Montana and elsewhere. I have in mind one case in a city which had two wells located about 300 feet apart; there probably was some interference between these two wells when both were pumping. A third well was drilled between the two existing wells. The total yield from the three wells when pumped at the same time is only a small amount more than was pumped from the two wells with the same pumping lift.

In some instances one can use information on the size of the cone of depression to aid in locating wells to induce recharge. By locating wells near streams or other bodies of surface water the cone of depression can be extended to intercept the body of water and obtain additional naturally filtered water with a lower pumping lift. This condition would exist as shown on figure 2.

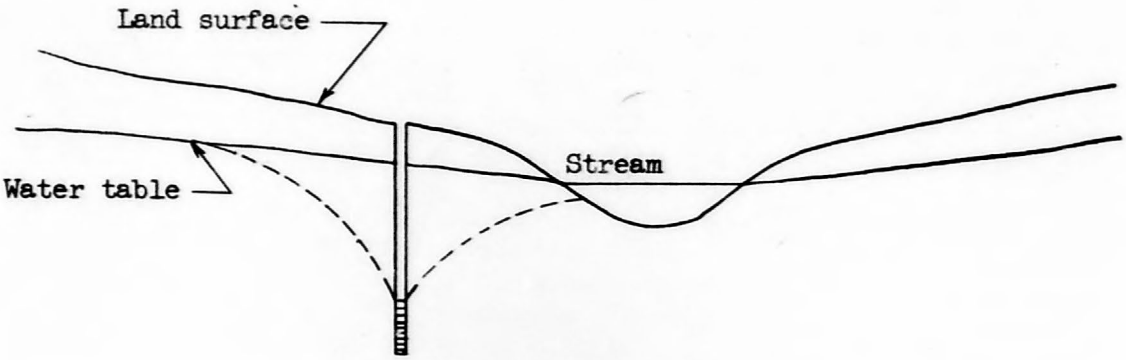

Figure 2.--Well located near stream so cone of depression extends under stream and induces recharge from that source.

In this case one could pump more water with the same drawdown because the well would be fed with water from the river. It actually is somewhat analogous to the previous diagram if one would consider well A as a recharge well into which one poured water at the same rate as one took water from B. You would build up an inverted cone comparable in slope with the cone of depression. In this case (fig. 3) the actual drawdown of well B would be the algebraic sum of the inverted cone of well A and the former cone of well B--or in illustration actually the drawdown would be considerably less for the same amount of water or the well could be made to yield more water with the same pumping lift.

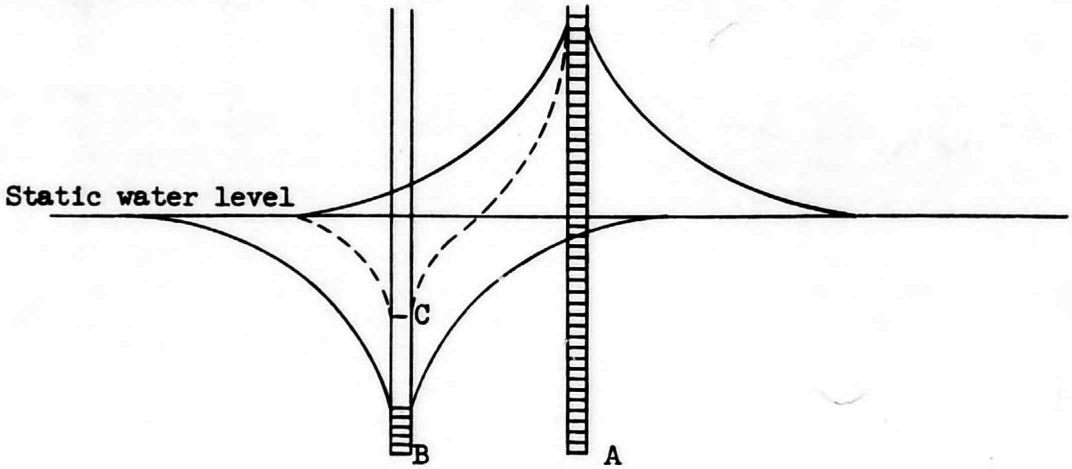

Figure 3.--Solid linesshow cone of discharge for well B and cone of recharge for well A if not operating simultaneously. Dashed line indicates theoretical curve if as much water in injected in well A as is being withdrawn from well B. C is new pumping level for same yield.

You are all practical men, and some of you think that these theoretical data have no practical value. In many places in the country these principles are being used to lower the cost of high pumping lifts and to increase ground-water supplies. On Long Island, N. Y., several tens of millions of gallons of used but uncontaminated ground water is returned to the ground-water reservoir each day, and additional storm water is recharged through infiltration pits. Over-use of water on the Island led to careful studies, because many of the wells were becoming salty and pumping lifts had become excessive. Based on the scientific data collected during those studies, legislation was enacted for conservation of water. Now, for each new well drilled to produce more than 100,000 gallons per day for air conditioning or other use and where water is not contaminated or consumed, a recharge well must be drilled to feed water back into the ground. During the water shortage in New York City a few years ago the wells on Long Island were able to make up for some of the shortage, in part because of this conservation measure.

At Louisville, Ky., during the World War II, industrial use of ground water was extremely large and the ground-water reservoir was being depleted. At two vital industrial plants threatened by a ground-water shortage, treated Ohio River water was purchased from the city supply during the winter months, when treatment facilities were not completely utilized, and fed into the ground-water reservoir where it would be available during the summer when water use was greatest. Other conservation measures put into effect then and later have reduced the net pumpage at Louisville to a safe amount. Large war factories along the Ohio River in Indiana and other States located large-capacity wells close to the river to induce recharge.

Of course, some of you men from cities using surface water may wonder why Ohio River water wasn't used. Ground water has many advantages for industrial and municipal use. Its temperature generally is more uniform, and lower in the summer, than that of surface water. Ground water has a generally cooler and more uniform temperature. The temperature of the Ohio River at Louisville, Ky., ranges from 32°F to 85°F; the ground water distant from the river is a uniform 58°F, and even that induced from the river fails by 15 or 20 degrees to rise as high as that of the surface water. Ground water is also more uniform in chemical quality, which is important for make-up water which enters into manufactured products. Facilities are adjusted for a constant treatment and seldom have to be changed. Much of the water used by industry is for cooling purposes and summer, when the well water may be 20 to 30 degrees cooler than stream water, is the time when most cooling water is needed.

Several towns in Montana that have standby wells to supplement surface sources have found that freezing of water mains can be prevented in excessively cold winters by using the wells during those periods. Surface water is then just at freezing temperature while water from the wells normally will be 45 to 50 degrees, or warmer.

I have talked at some length about water-table wells. Now perhaps we should consider the other type - the artesian wells. Some towns and cities in the State have artesian wells; some are quite deep and others are fairly shallow. To many people any deep well is artesian, while to others it is not artesian unless it flows. Actually, we consider a well as artesian if the water rises in the well above the level at which it is encountered. For a well to be artesian there must be a confining bed so that the water will be under some pressure. Such conditions are sometimes found at shallow depths; thus, a well need not be deep to be an artesian well. Of course, all flowing wells are artesian wells because the water is under pressure great enough to force it to the surface. (See fig. 4.)

The level to which water will rise in wells penetrating the artesian aquifer is called the piezometric surface. This surface is not flat but slopes away from the intake area. When this surface is above the land surface flowing wells can be obtained. The only place where recharge can enter the artesian aquifers is in the intake area where erosion has removed the impermeable confining bed; this is one of the most important differences between water-table and artesian conditions. The water-table reservoir can take in additional water practically anywhere from the direct rainfall, snow melt, irrigation seepage, or streams flowing across the area. One can readily see why such great importance is placed on water-table wells for large supplies. Of course the artesian aquifers have great importance for they often are the only source of water, carrying water as many of them do from areas of greater precipitation out under dry lands. It is questionable if much of North and South Dakota could have been settled as early as they were had it not

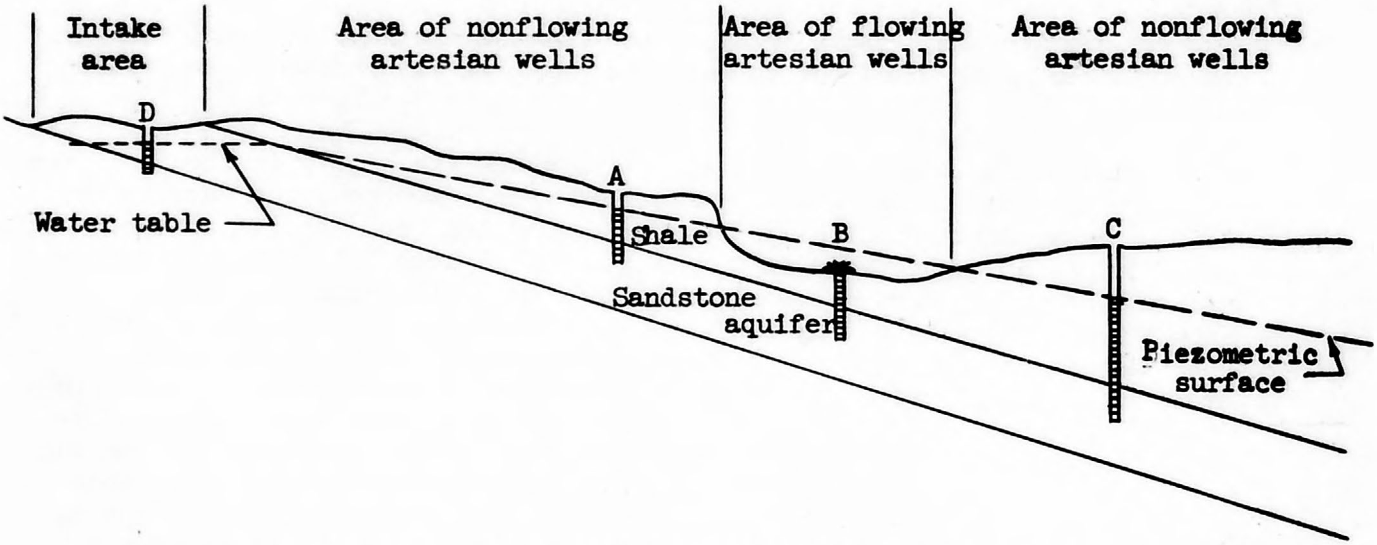

Figure 4.--Diagram showing artesian conditions. Well A is a relatively shallow artesian well, water rises to line showing piezometric surface, thus has shallow pump lift. Well B is a flowing artesian well since it is located on land below the level of the piezometric surface. Well C is a deep artesian well which has a high pump lift. Well D is located in the intake area for the sandstone aquifer and is a water-table well.

been for the presence of the great artesian aquifers which were developed to furnish the only water supply available for many miles.

When water is taken from an artesian aquifer, either by pumping or permitting free flow from wells, there is a decrease in water pressure. The pressure decrease is transmitted rapidly, at the speed of sound, throughout the entire body under pressure, but because water is yielded from storage as the pressure decreases the decline lessens with distance from the well. In general, however, the zone of pumping influence around a well under artesian conditions is much larger than it is around a well under water-table conditions. Thus, the proper spacing of artesian wells is even more important than for water-table wells. I know of instances where water-level recorders on observation wells more than a mile away from a pumped well indicate to the minute when the pump is started or stopped because there is a corresponding marked rise or decline of the water level in the observation well.

Recently, while working in an area in Montana, one of our men had occasion to obtain some data from officials of a town that obtains its water from an artesian well. During the course of conversation it was mentioned that the town needed more water and had just awarded a contract for a new well. The site initially selected for the well was about 20 feet from the existing well. However, a short test was made and it was found that the proposed well would be only about 40 percent efficient. That is, it would produce only about 40 percent as much water as would a well located beyond the immediate zone of influence of the existing well. Needless to say, the new site was located some distance away.

In operating a municipal water system where the supply is obtained from wells it is good business to keep trace of your resources, the same as in banking or any other business. Besides preserving good records on depth of wells, materials penetrated in drilling, and complete information on the well construction, records should also be kept on the amount of water pumped from each well and on the water levels in the well field. It may seem useless to some persons to make a measurement of the static water level each morning before the pump is turned on and also record the pumping level just before the pump is turned off, but many, many times this information has proved to be of great value, far in excess of the cost of making and recording such measurements. The first few months of record may show nothing, but as the record becomes longer it also becomes more interesting and valuable. I know of instances where the yield of wells had declined and new wells were drilled, but if records had been available they would have shown that new wells were not needed. The screens of the existing wells were slowly becoming clogged and could have been cleaned at a cost small in comparison with the expense of drilling new wells, equipping them with pumps, and connecting them into the system. In some cases, of course, such records show an actual overdevelopment of the aquifer, and thus the need for drilling additional wells some distance away or to a different aquifer. In many ways our ground-water reservoirs are like a bank account. One may have a very large account, but if withdrawals continue to exceed deposits the principal will decline and may be exhausted eventually. If withdrawals of water from an aquifer continue to exceed recharge, even though a great amount of water may be in storage, the supply is not truly perennial. If this situation is known well in advance, intelligent plans can be made to develop additional sources in plenty of time.

As mentioned earlier, recharge can enter an artesian aquifer, only in the limited area where it is exposed and where the confining bed is not present. Under water-table conditions, recharge can take place over the entire ground-water reservoir. This is a very important fact to keep in mine when large, continuous water supplies are needed. This is why, the Nation over, the amount of water pumped from unconsolidated sands and gravels, which are the most common water-table aquifers, far exceeds the amounts taken from artesian aquifers. In general there is more space between the rock particles in unconsolidated materials than there is in consolidated rock. Thus, the unconsolidated aquifers can store more water in a given volume of reservoir.

We have discussed ground water in general and possibly you will be interested to know something about the ground-water situation in Montana. Ground water is without doubt one of Montana's most valuable and least known and appreciated natural resources. Without ground water, the distribution of the population, the economy, and the potential development of the State would be very different. As an example: Nearly the entire rural population and more than 80,000 residents of 78 communities, now using ground water for domestic purposes, would be restricted to localities where water is available from streams or springs. The stock-raising industry is virtually dependent on ground water; it also would be restricted to areas adjacent to lakes, springs, or perennial streams. The low flow of most streams is dependent on ground water, and this flow (which represents ground-water discharge) virtually governs all irrigation and power developments along the streams that are not provided with adequate storage reservoirs.

The present use of ground water in Montana is only a small part of the potential use. It is a paradox that so little is known about this valuable natural resource. The following statements regarding ground water in Montana are based on published reports, on unpublished data that have accumulated during the past few years, and on observations made during the reconnaissance of the geology and ground-water resources of numerous areas in the State. Because virtually all our work has been east of the Continental Divide, information on the western part of the State is even less complete.

Nearly all the major streams in Montana flow for long distances in valleys underlain by 20 to 400 feet or more of unconsolidated gravel, sand, and clay. These unconsolidated materials locally offer possibilities for development of large supplies of ground water for municipal, industrial, or irrigation use. The best possibilities for development of large supplies are in the west and central parts of the State, but good possibilities exist also along the Milk, Musselshell, and Yellowstone Rivers, and along the Missouri River below Fort Peck and above Great Falls. Between Havre and the confluence of the Milk and Missouri Rivers, the Milk River occupies a former course of the ancestral Missouri River. This part of the Milk River valley is underlain by about 100 feet of unconsolidated material and, in some places, wells penetrating this material are capable of furnishing more than 1,000 gallons per minute. Because the aquifer is recharged by the Milk River and also by the percolation of irrigation water applied to large acreages of land in the valley, much greater use of ground water is possible in this area without serious depletion of this ground-water reservoir. The hydrologic conditions are similar along the Missouri River downstream from the confluence with the Milk River at least as far as Poplar and possibly to the State line.

The unconsolidated deposits underlying the valley of the Musselshell River above Melstone are reported to be as much as 50 feet thick and some 500 gallon-per-minute wells exist. The unconsolidated fill underlying the Yellowstone River valley is as much as 100 feet thick near the mouth of the river, but is considerably thinner upstream. Some large-capacity wells are present in the lower valley but the potential use is much greater than present use.

In the western part of Montana, several intermontane basins are underlain by thick and very permeable unconsolidated deposits. The basins we know most about are the Gallatin, Helena, and Townsend Valleys, but there is reason to believe that the Beaverhead, Three Forks, Deer Lodge, Missoula, Jocko, and Bitterroot Valleys and parts of the Flathead Valley may offer good possibilities for development of large ground-water supplies. Test drilling in the Gallatin Valley has shown that parts of the valley are underlain by more than 400 feet of very permeable water-bearing gravel that is capable of yielding extremely large supplies of good quality water. Because the recharge to the ground-water reservoir in this and in other intermontane basins in Montana, is great, the serious depletion of these aquifers is unlikely. Recently I have received reports on wells drilled near Dillon in the Beaverhead Valley which yield more than 2,000 gallons per minute, wells in the Missoula, lower Jefferson, and Flathead Valleys which yield more than 1,500 gallons per minute, and many other large-yield wells in the above mentioned basins. All these reports confirm my belief that large supplies of ground water not only are available--their development is starting.

Several bedrock aquifers that are potential sources of moderate to large supplies of ground water underlie much of Montana east of the divide. Throughout large areas these aquifers, although present, are so deeply buried by overlying material that their depth is greater than the present economic drilling limit for water. Among the aquifers from which large supplies may be obtained locally are the Kootenai, Heath, and Embar formations, the Tensleep sandstone, and the Madison limestone. Although these bedrock aquifers may prove valuable locally, the potential development of these sources of ground water is nowhere near as important as is that of the unconsolidated deposits.

As I have indicated, we have great undeveloped ground-water resources in Montana. The present use that is being made of ground water in Montana is only a small part of the potential use, but this use is increasing rapidly. If Montana is to avoid the costly problems that have resulted in other States from haphazard development and local overdevelopment of ground-water reserves, now is the time to start careful studies to evaluate the resource in quantitative terms, rather than after the problems have become critical. You men are in a position to start gathering data on ground water. If each of you will carefully record all pertinent data on municipal and industrial ground-water developments made under your supervision, these data will prove very valuable in the future when water shortages may become critical. If you have any problems with which we may be able to help you, feel free to call upon us and we will do our utmost to assist you within the limits of our authorization and ability.