

USES AND LIMITATIONS OF ELECTRICAL PROSPECTING FOR WATER SUPPLIES

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One of the many methods employed by the Illinois State Geological Survey in the search for groundwater supplies is the electrical earth-resistivity survey. It is used to locate water-bearing sand and gravel within glacial drift on the uplands and within alluvium in valley flats and lowlands. This program has been in continuous operation since Dr. M. King Hubbert's interest in it in the summer of 1932. Since that time nearly 500 separate surveys have been run, ranging in size from 10-station, 1-acre surveys for farm water supplies to 1000-station surveys on 100 square miles for municipal supplies. The surveys cover practically every physical environment found in Illinois (Fig.1).

Figure 2 shows diagrammatically the theory of the earth-resistivity test and the Wenner electrode configuration used by most investigators. The instruments used by the Illinois Geological Survey resemble closely the commutated direct-current circuits developed by O. H. Gish and W. J. Rooney of the Carnegie Institute of Research, using standard electrode spread. In some of our equipment we have recently substituted the synchronous vibrator for the hand-driven commutator. This provides a somewhat smoother

operation but no noticeable increase in accuracy. Our newest instrument is small, hand commutated, and easily portable. Continuing improvement of field equipment and technique has led to many minor changes in instrumentation, but the operating theory remains the same.

Experience has shown that many of the materials making up the earth's crust can be identified, at least in some degree, by their reaction to the flow of a current of electricity. In this action, which is electrolytic in nature, the moisture of the ground, together with the dissolved impurities, gives to the several materials characteristic resistances, or resistivities, to a flow of current. These characteristics, when recognized, may be used for locating and, to some degree, identifying subsurface formations.

Ordinary moist soils containing moderate amounts of clay or silt with some more or less active electrolytic agent usually have a comparatively low resistance, but sand and gravel, dry loose soil, and solid rock usually have relatively high resistance. These classifications are far too general to be of use, but if we can make initial calibration near a test-hole or well or outcrop where the lithology is known, the resistivi-

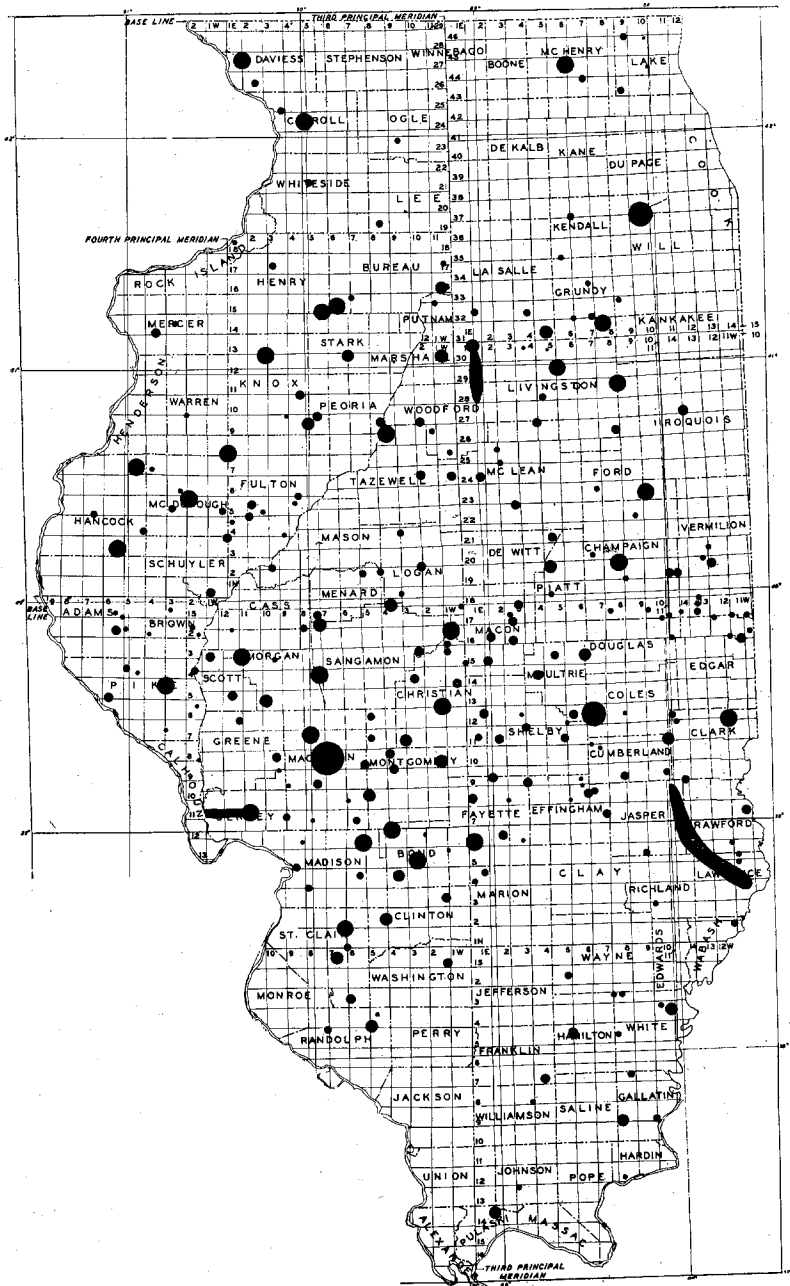


FIG. 1.—Distribution of earth-resistivity surveys, 1932-1956.

ties can be made meaningful, and a reasonably accurate analysis can be made as to the type and position of the underlying material.

Electrical prospecting for water-bearing deposits of sand and gravel is necessarily limited to the areas where such deposits could be expected to occur. In areas where the bedrock is at the surface, the search for these deposits is confined to creek flats and stream beds, both recent and ancient. In areas where glacial drift has been deposited, additional water-bearing lenses and beds of sand and gravel can and do occur anywhere throughout its entire thickness. In one area the local water supply is derived from a near-surface freshwater sandstone which has been found to be mappable by electrical methods. With this exception, electrical exploration for water-bearing beds has been confined to the unconsolidated material lying above bedrock.

Resistivity work in Illinois falls into five resistivity provinces (Fig. 3). Province 1 includes about 25,000 square miles and lies in an east-west belt across the state. It is within this area that electrical prospecting is most effective, as suggested by the number of surveys indicated on Figure 1. The glacial drift ranges from 0 to 400 feet in thickness but averages about 100 feet. The drift is chiefly underlain by rocks of the McLeansboro formation of Pennsylvanian age. These rocks are mostly low-resistivity shales with generally thin beds of limestone and sandstone which do not appear to raise the resistivities an appreciable amount. The glacial drift, which is chiefly clay and consequently has low re-

sistivity, contrasts sharply with the high-resistivity sand and gravel or bedrock. The water-bearing zones in these bedrock layers are usually poor water-producers, and the water is considerably less desirable both in quantity and quality than water in the drift.

Province 2 comprises an area of about the northern one-fourth of the state where glacial drift, that is thin in the west and thick in the east, lies over fresh-water-bearing sandstones and limestone. Commercial quantities of water can usually be obtained from the bedrock formations without considering the glacial drift or its sand and gravel content. At many places, however, excellent water supplies are developed from the sand and gravel within the drift or in the flats of streams. Electrical prospecting is effective though it is used but little in this province.

Provinces 3 and 4 are areas where bedrock crops out at the surface, and electrical prospecting for water-bearing sand and gravel is confined to the beds of rivers and streams, both present and ancient. Away from stream beds in these areas the production of groundwater for public and private use depends, at least in northwestern Illinois, on the well encountering crevices in limestones or freshwater-bearing sandstones. In the southern part of the state the only potable water from the bedrock occurs in sandstones and limestones that are very near the surface in an area of outcrop. Undesirable qualities of water almost invariably appear to increase with depth.

In the stream valleys, local erosion has not, with the exception of the Cache River bottom, resulted in

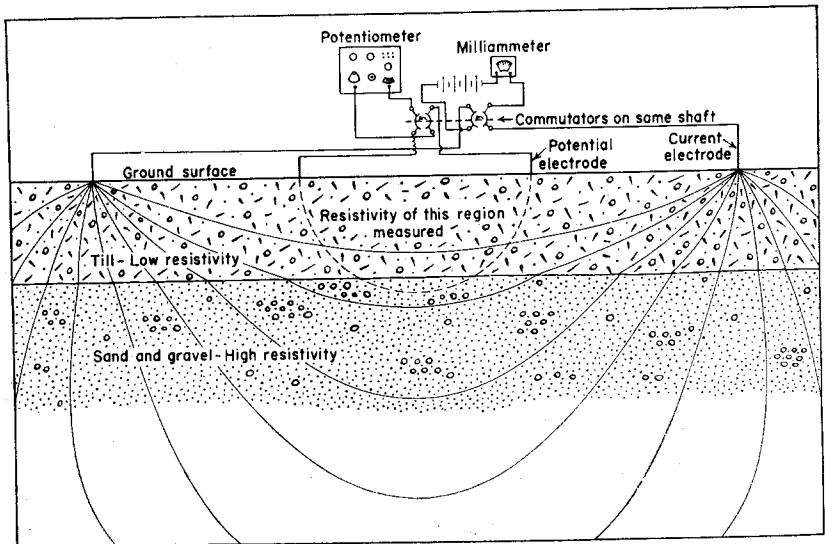


FIG. 2.—Diagram showing resistivity instrumentation and electrode separation.

enough alluvial fill to furnish commercial supplies of water. Electrical prospecting is successful in these provinces where the alluvial fill is sufficiently thick.

Province 5 is the area radiating out from East St. Louis where glacial ponding from the west caused all the streams to deposit their loads of silt along with normal amounts of sand and gravel. This silting extended up practically all the streams emptying into the area and in fact covered most of the low-lying portions of the upland. We believe this silt, or the clay suite with it, has a masking effect over known deposits of sand and gravel, preventing in some manner their detection by electrical methods. The hilltops and hillsides which remain effective sites for electrical exploration are rarely useful in the study of potential groundwater supplies.

In the study of electrical prospect-

ing a simple guiding rule is as follows: the larger the volume of water needed, the larger the water-bearing deposit must be and therefore the easier it is to detect. The nearer the surface the deposit lies, the simpler is its detection.

The electrical earth-resistivity method of prospecting in Illinois is used most effectively where a large volume of water is needed, where geologic factors are favorable, and where the radius of permissible prospecting is fairly large, say within one to five miles of the point of use. For instance, a village whose minimum needs are 100 gallons per minute must have an aquifer 10 to 20 feet in thickness. Such a thickness is usually detectable within 100 feet of the surface. Test-hole sites are then chosen and where tested are usually favorable, thereby eliminating the drilling of many test-holes on a random basis. This work reduces the

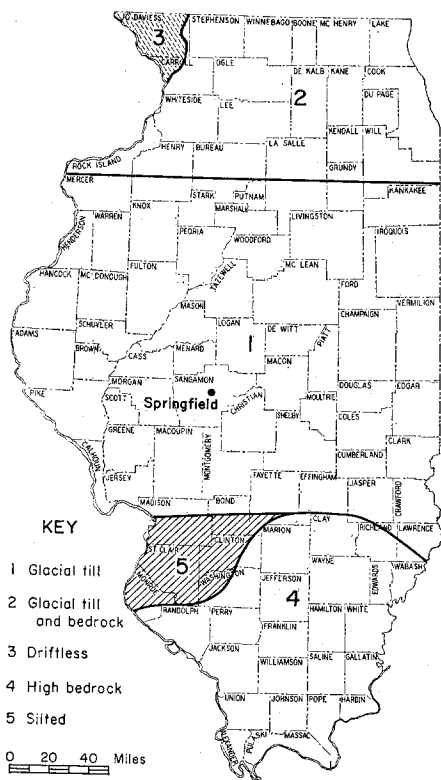


FIG. 3.—Generalized earth-resistivity provinces in Illinois.

area of consideration for test-drilling by about 95%.

The method is least effective on small-volume supplies, such as for individual dwellings or farms, where the area of prospecting is severely curtailed for economic or political reasons, as for instance, the perimeter of the village park or a farm barnyard, usually already drilled many times to no avail. No amount of prospecting of any kind will turn up a thick bed of water-bearing sand in the midst of several sandless, dry test-holes, although this is frequently

expected. A residential or farm supply that needs only five or six gallons of water per minute could be supplied from two or more feet of gravel at any depth, yet two feet of clean gravel could not be detected electrically if it were only ten feet from the surface. It is also true that, if a sand 20 feet thick underlies a house or barnyard, the chances are that it has already been found. A very frequent problem is that in which sand has been encountered but the driller was unable to construct a sand-free well. The right solution here is proper well construction, not further exploration for more sand.

In a year of normal rainfall the Illinois State Geological Survey conducts 40 to 50 earth-resistivity surveys, about one third of them for municipalities; in a drouth year there may be as many as 70, about one fourth for municipalities. Many of these surveys in the past discovered new well fields and many more are seeking extensions of old supplies.

The high level of discoveries, nine of ten for municipal and commercial supplies, is commendable, especially because other methods have frequently failed to find a water supply. There has been an increasing tendency on the part of consulting engineers to call for an electrical earth resistivity survey and a study of ground-water possibilities before final evaluation is made of the estimated cost of municipal and commercial water systems.

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