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Preliminary Geophysical Investigation of the Sand and Gravel Aquifers in the Kaskaskia River Valley near Evansville, Illinois

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ABSTRACT
Exploratory geophysical tests were conducted in the Evansville, Illinois, area to determine whether the Kaskaskia River Valley contains sand and gravel deposits large enough to produce 2- to 3-million gallons of water per-day (mgd). The integrated geophysical testing program consisted of 19 reversed seismic refraction lines and 77 electrical earth resistivity soundings.

No extensive areas of coarse grained alluvium or outwash were found west of the Kaskaskia River. East of the Kaskaskia, localized areas of sandy deposits are indicated both north and south of Evansville. Test drilling to confirm the geophysical results is recommended for one area north of Evansville (Beagle Lane area) and one area south of Evansville (Dew Drop Landing Road area). Within the study area, the total area likely to contain coarse grained deposits is probably too small to obtain a 2- to 3-mgd groundwater supply. None of the recommended areas is larger than a similar field 7 miles upstream near Baldwin, which yields approximately 0.5 mgd.

INTRODUCTION
The Randolph County Water Commission (RCWC) is seeking to establish a 2- to 3-million gallon per day (mgd) regional water supply. Both groundwater and surface water supplies are being considered. Because the most likely location for the system's water plant is near Evansville, Illinois, representatives of the RCWC contacted the Illinois State Geological Survey (ISGS) for information concerning the groundwater potential of the shallow sand and gravel aquifer in the Kaskaskia River Valley near Evansville (fig. 1). The required volume of water is relatively large for Kaskaskia River Valley aquifers, which typically support well fields with capacities of only about 0.5 mgd. Regional data suggest that a similar low yield could be expected in the Evansville area; little specific information, however, is available to confirm this expectation.

This report documents exploratory geophysical tests in the Evansville area undertaken to determine whether sufficiently large sand and gravel deposits might be present to produce the required volume of water. The integrated geophysical program used seismic refraction and electrical earth resistivity tests. Maps based on the results of these tests show areas that are more or less favorable for the location of a well field. The maps can guide the location of test drilling in the more favorable areas.

The study area is defined by the 1- to 1.5-mile-wide Kaskaskia River Valley from about 1.5 miles north to 3 miles south of Evansville (fig. 1). It includes parts of Sections 12, 13, 14, 22, 23, 26, 27, 34, and 35 of T5S, R8W, Randolph County. The river has been channelized in the study area so that it flows in a relatively straight northeast to southwest reach through most of the area. Significant sand and gravel deposits most frequently occur in sharp valley bends. The study area is, therefore, terminated near the first sharp bend in the channel both at the north and south edges of the study area.

For most of the river valley within the study area, the modern channel is located along the east edge of the valley. A prominent bluff line that defines the east edge of the valley lies about 0.25 mile from the main channel. The bluff is closest to the main channel at Evansville where the uplands come within several blocks of the channel and bedrock is less than 15 ft below land surface along the river's edge. On the west side of the river, the valley is generally about 0.75 mile wide. A pronounced change in valley morphology occurs at the south end of the study area where the river bends sharply to the southeast. There, the modern river channel crosses to the west side of the valley, hugging prominent bluffs that come to within several hundred feet of the river. On the opposite side of the river, the eastern bluffs recede to about 0.5 mile from the river.

Landforms and sediments in the Kaskaskia River Valley reveal several stages in the history of the valley (fig. 2; Miles 1988). Nearest the river, the modern alluvial deposits have been greatly altered by the channelization and alignment project. The natural materials are primarily silty and clayey alluvium. Some areas of sandy alluvium and outwash are also present in the lower river bottoms. A lower terrace usually several hundred feet away from the river marks the edge of silty backwater lake sediments that were deposited during the latest glacial episode when the river

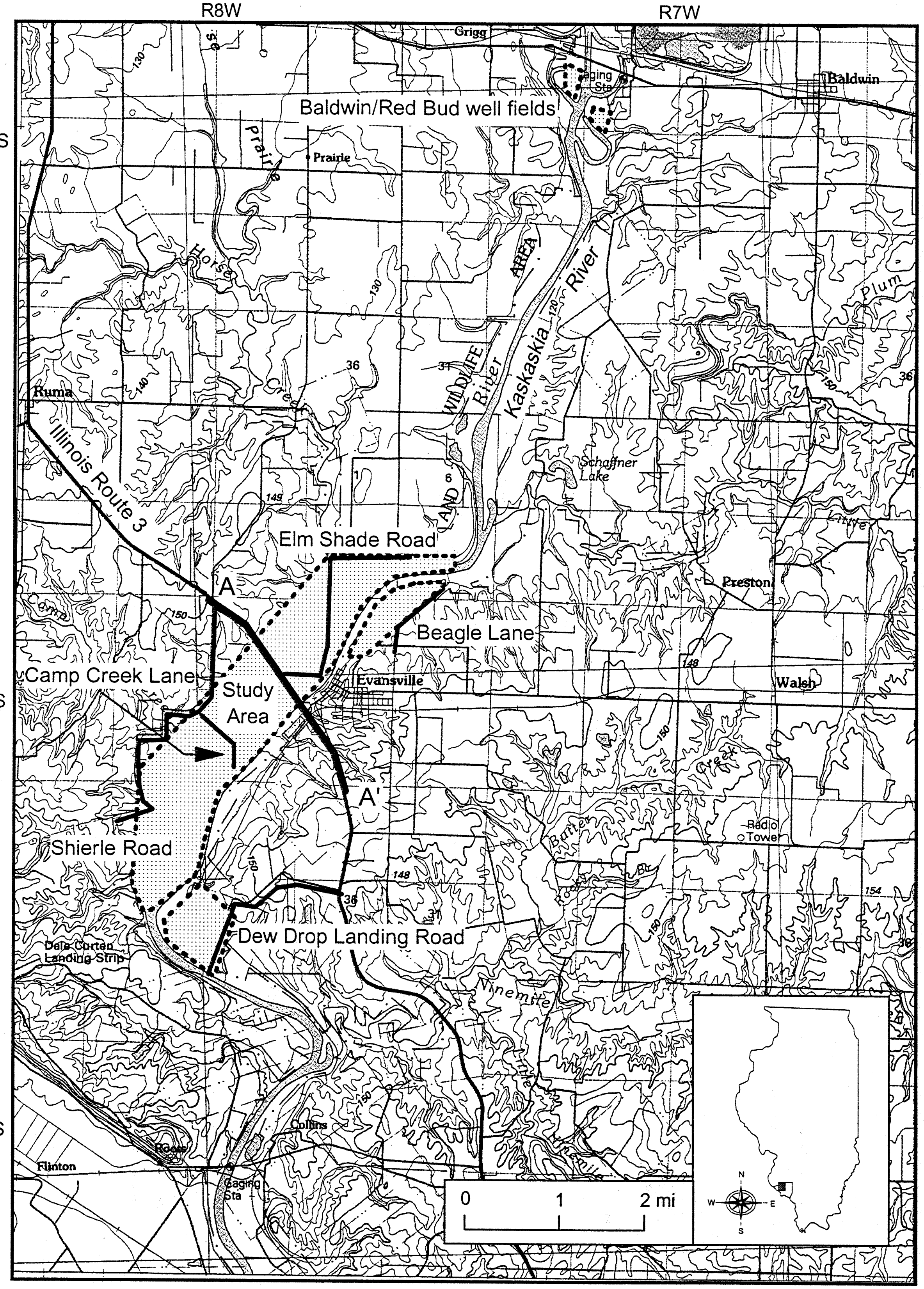

Figure 1 Study area in western Randolph County, Illinois. Base map is part of the Pinckneyville, Illinois, 1:100,000-scale quadrangle map published by the U.S. Geological Survey in 1985. Elevation contour interval is 10 meters. Line A–A′ along Illinois Route 3 locates the cross section shown in figure 2.

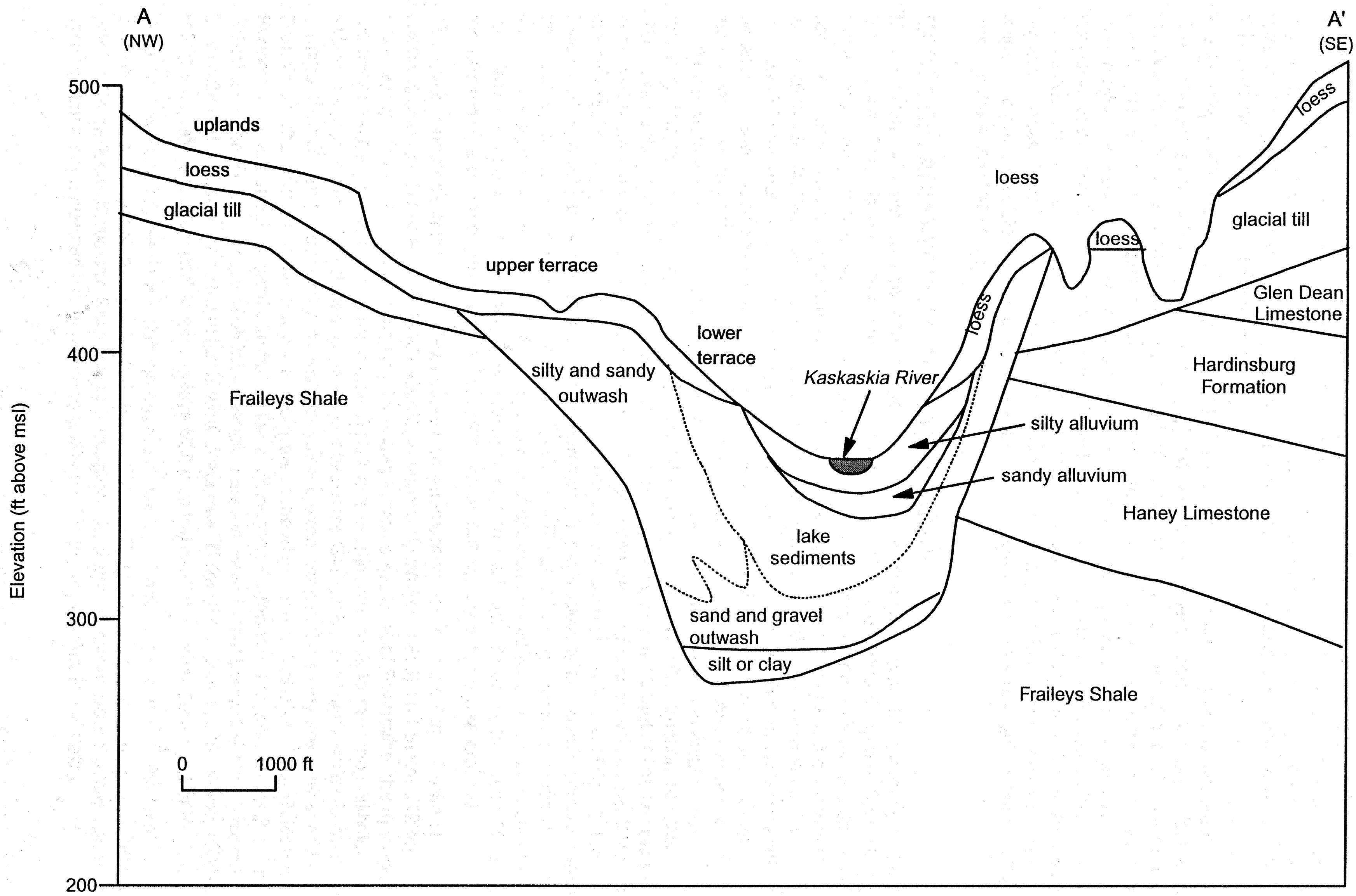

Figure 2 Generalized northwest–southeast cross section along Illinois Route 3 shows the sediments within the Kaskaskia River Valley. Location of cross section is indicated as line A–A′ on figure 1. Surface features are from Randolph County Soil Maps; deeper features are interpreted from available well and boring records.

was dammed by outwash sediments (Willman and Frye 1970). These silty lake deposits once blanketed the area within the lower terrace, but have since been eroded near the modern channel. A higher, usually broader terrace containing sandy outwash marks the edge of an old, high stage in the river that developed during the peak of Illinoian glacial meltout. Above this upper terrace, the upland soils are formed in till from the Illinoian glaciers and loess from Illinoian and Wisconsinan glacial times (Miles 1988).

The geophysical testing in this study targeted the coarse grained materials in the river valley. These materials are of two types. The first is sandy alluvium in the modern valley deposits near the river. The most favorable locations for well fields are where these alluvial deposits are thick and extensive. The second type of coarse grained deposit is sandy outwash in the upper terraces. At one time, the sandy outwash probably filled the valley. Although most of it was eroded, remnants of the sandy outwash deposits still underlie the younger deposits in some places within the valley. Areas where these deep remnant deposits are thick and extensive or where they are directly overlain by modern coarse grained alluvial deposits are also favorable for locating well fields. The geophysical tests can delineate areas of both types of coarse grained materials if they are present within the study area.

GEOLOGIC AND HYDROLOGIC BACKGROUND

Records from 38 wells, borings, and test holes in the study area were available for study at the ISGS. These records show that in the study area the unlithified sediments filling the Kaskaskia River Valley range in thickness from less than 10 to about 100 feet. In the Evansville area, most domestic water wells that use the sand and gravel aquifer are completed in sand at depths of about 25 to 35 feet. Very few wells or borings completely penetrate the entire thickness of unlithified sediments. Most of the records for wells completed in the bedrock provide very little detail about the unlithified materials. Consequently, the composition and extent of the deeper sand and gravel deposits are not well documented. The most complete description of the unlithified materials was reported in the log for the bridge boring for the Illinois Route 3 river crossing. The boring, located on the east side of the valley in the NW, NW, Section 24, T5S, R8W, encountered 20 feet of silty clay loam to sandy clay loam, above 15 feet of fine to coarse sand and gravel, above 12 feet of clay, above 18 feet of coarse sand and gravel, above 7 feet of gravelly clay loam, above limestone bedrock. Geologic information on file at the ISGS for the Evansville area suggests that although large variations in the thickness and composition in these units can be expected, the basic sequence found in the Route 3 boring is probably typical for the valley. The typical sequence includes an upper unit of alluvium, a middle unit of silty or clayey lake deposits, and a lower unit of glacial outwash or till. In the Route 3 boring, the lower 15 feet of the alluvium is sand and gravel, and most of the glacial outwash is very coarse grained.

The shallow bedrock in the study area consists of sedimentary rocks of the Pope Group of Mississippian age (Weibel et al. 1993). Geologic reports by Weller (1913) and Sutton (1934) provide most of the published geologic information for the area. East of Evansville, the uplands are underlain by the Glen Dean Limestone. Distinctive karstic sinkholes form in the unlithified sediments above these limestones. A clastic unit below the Glen Dean, the Hardinsburg Formation, is primarily shale and is generally not seen in surface exposures in the study area. West of the Glen Dean, the bedrock in the study area consists of the limestone and shales of the Golconda Formation, which stratigraphically lie below the Hardinsburg Formation. The principal unit of the Golconda is the Haney Limestone Member, which is present several feet below the land surface at Evansville and probably forms the uplands west of the river. Below the Haney lies the Fraileys Shale Member. Shale, probably part of the Fraileys Shale, is exposed in stream beds west of the river.

No published reports give details concerning the shallow groundwater potential in the local Evansville area. Regional studies by Horberg (1950) and Pryor (1956) agree that groundwater potential in the lower Kaskaskia River Valley is marginal. Both studies recommend that site-specific investigations be conducted before locating a well field in the Kaskaskia River Valley.

Two well fields have been developed in a shallow alluvial aquifer near Baldwin, about 7 miles upstream from Evansville (fig. 1). There, municipal wells for Baldwin and Red Bud were constructed in an abandoned channel of the Kaskaskia River. Shallow, coarse grained alluvium overlies deeper coarse grained outwash with little or no intervening fine grained deposits. This configuration of deposits is particularly favorable for developing a municipal well field. The Baldwin and Red Bud well fields, located in a moderately productive aquifer within the Kaskaskia River Valley, together produce about 0.5 mgd.

The ISGS conducted two geophysical studies (Reed 1977, 1987) in the Baldwin area of the Kaskaskia River Valley. These two studies and a separate resistivity study closer to Red Bud (Poole and Heigold 1981) helped define favorable areas for siting the Red Bud well field. In these studies, electrical earth resistivity surveying demonstrated that the alluvium is highly variable but that favorable locations could be found.

Preliminary geologic site investigations were conducted in the Evansville area by ISGS geologists in December 1941. Data from shallow auger drilling and resistivity tests as well as field observations were collected, but no report was prepared (the report is on file at the Groundwater Resources and Protection Section, ISGS). Some of the field observations and resistivity data were incorporated into the present study.

GEOPHYSICAL STUDY

Method of Investigation

Two types of geophysical tests, seismic refraction and electrical earth resistivity soundings, were used in this study. The seismic tests define the depth to bedrock, which is also the thickness of the overlying glacial and alluvial deposits. The resistivity tests locate sand and gravel deposits within the alluvium and outwash. Because of the variable nature of the bedrock lithology, the resistivity tests alone do not indicate reliably the thickness of the shallow deposits. However, when the two tests are used together, both the thickness and nature of the glacial and alluvial deposits can be inferred.

Seismic refraction Seismic refraction surveys record the seismic energy from a small, buried charge of explosive. The energy radiates in all directions through the ground. Some energy travels down to the bedrock surface, where it is refracted back up to the ground surface (fig. 3). The returned energy is recorded by a series of sensors laid in a line near the explosive charge. The recorded information is used to calculate the depth to the bedrock surface beneath the charge and sensors.

The seismic refraction field configuration consisted of a line of 24 single 14-Hz geophones placed at 50-foot intervals for a total of 1,150 feet. Charges were shot at the center and at both ends of the geophone line. Longer profiles of investigation were created by aligning consecutive geophone lines end-to-end along the profile. Generally, adjacent lines were located such that the holes for the end charges were 10 ft apart. Charges were placed in 5-foot-deep boreholes and varied from 0.3 to 1 lb of Kinepak explosive. Data were recorded in digital format for later processing using SIPT, a ray tracing interpretation program (Scott 1977). Seismic data are tabulated in appendix A.

Electrical earth resistivity In the electrical earth resistivity procedure, an electric current is applied to the ground through two current electrodes, and the potential difference is measured across a pair of potential electrodes (fig. 4). Apparent resistivity is calculated based on the measured potential drop, applied current, and electrode spacing (Dobrin 1976). Resistivity depth soundings are obtained by systematically increasing the separation between the electrodes, which increases the effective depth of the resistivity measurement. Apparent resistivities measured at increasing electrode separations are related to the resistivity of the earth materials at increasing depth. Units of resistivity reported in this study are ohm-feet.

The Wenner electrode configuration was employed in this study using a computer controlled Terrameter SAS 300C resistivity meter and ABEM Multimac control system. In the Wenner electrode configuration, the electrodes are laid out in a line with the current electrodes positioned at the outside ends and the potential electrodes forming an inner pair. The spacing between electrodes remains equal as the configuration is expanded from the center point. In this study, the electrode separation was increased in 10 and 20 foot increments to a maximum of 200 feet. Thirteen readings were obtained at each station.

The resistivity data obtained during this study were analyzed quantitatively using an analysis technique developed by Zohdy and Bisdorf (1975). The technique converts apparent resistivity soundings from each location into a sequence of layers representing types of earth materials of varying thickness and calculated resistivity. Resistivity data are tabulated in appendix B. Although this technique provides only one of many geoelectrically equivalent solutions for a given resistivity data set, prior knowledge of the geologic conditions in the study area helps to compensate for this shortcoming (Heigold et al. 1985).

In general, sand and gravel deposits have higher resistivity values than do clay or silt deposits. Gravel has even higher resistivity than sand. Silt or clay in a sand deposit reduces the overall resistivity of the unit. Limestone, the predominant bedrock lithology in the area, typically has a high resistivity and is difficult to differentiate from sand or gravel. Seismic testing is used to locate the top of bedrock, so that high-resistivity limestone can be distinguished from high-resistivity sand and gravel deposits.

Results

Data from four long, exploratory geophysical profiles combining seismic refraction lines (fig. 5) and resisitivity soundings (fig. 6) were gathered to establish a framework for more detailed work. Three lines were on the west side of the river (Elm Shade Road North and South, and Camp Creek Lane). One line (Dew Drop Landing Road) was on the east side of the river. These lines established that, for the most part, the sediments along the Kaskaskia River are thicker west of the present river channel, but that thick sand and gravel deposits are of limited extent. An exception is at Dew Drop Landing Road, where the buried river channel is very deep on the east side of the river for several hundred feet east and north of the present river. Farther from the present river, the buried channel is shallower and approaches the more common depth of 50 to 60 feet.

Two miles south of Evansville, west of the river, the area north of Crooked Creek was investigated in more detail. The river valley is widest north of Crooked Creek. Four resistivity stations were

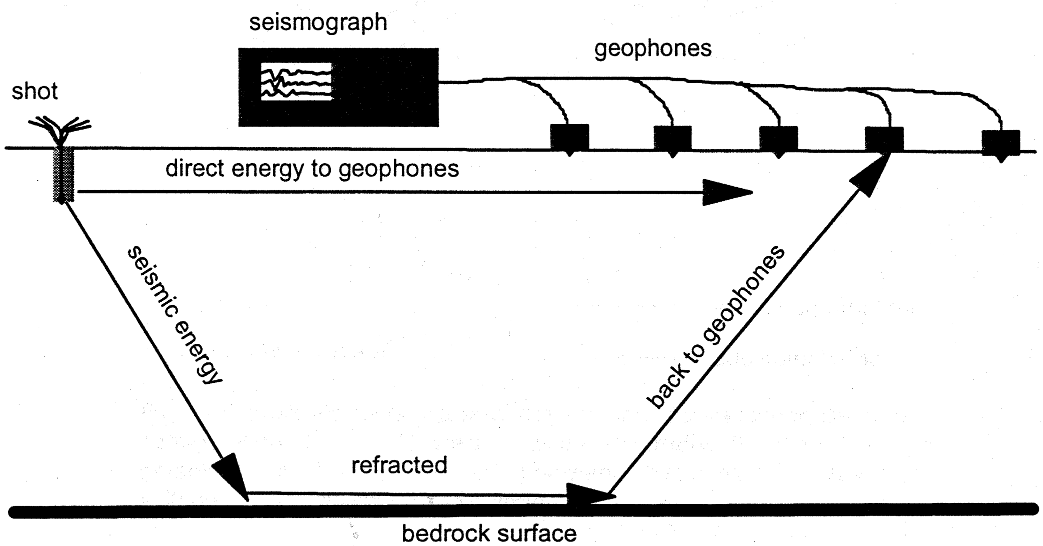

Figure 3 Sketch of seismic refraction field operation.

occupied in this area near Shierle Road (fig. 7). Results from these stations indicated that the river sediments are fine grained, except for a ridge of surface sand. The prominent, north–south sand ridge is probably a dune or river bar that remains from an earlier high water stage of the Kaskaskia River. The fine sandy deposits of the sand ridge do not extend very deep into the alluvium.

On the east side of the river, south of Evansville, 25 resistivity stations were occupied in the river bend west of Dew Drop Landing Road (fig. 7). The highest resistivity values recorded in the entire study area were obtained from two stations nearest the river on the extreme western edge of the Dew Drop Landing Road area. These readings suggest that coarse grained alluvium and/or outwash is present from the ground surface down to bedrock in the river bend. Moderately high resistivity values were recorded at several other stations. Some of the high resistivity values are caused by shallow bedrock along the north rim of the Dew Drop Landing Road area. At other stations, however, high resistivity indicates that shallow sandy alluvium is present to depths of about 40 feet. In some places, the shallow sandy alluvium may be connected to a deeper layer of coarse grained alluvium or outwash. The general geologic conditions in the southern area are shown in a pair of west–east cross sections (fig. 8).

North of Evansville, on the west side of the river, 12 resistivity stations were occupied between Horse Creek and Route 3 (figs. 6, 9). These include a series along the north–south part of Elm Shade Road, aligned approximately parallel to the river, and another series in the river bottoms immediately south of Horse Creek. In general, the resistivity data in this area imply the absence of sand and gravel deposits. Low resistivity readings dominated the unlithified materials. High resistivity values, indicating coarser materials, were found at one station at the confluence of Horse Creek and the Kaskaskia River and at a few stations along Elm Shade Road near the Kaskaskia River.

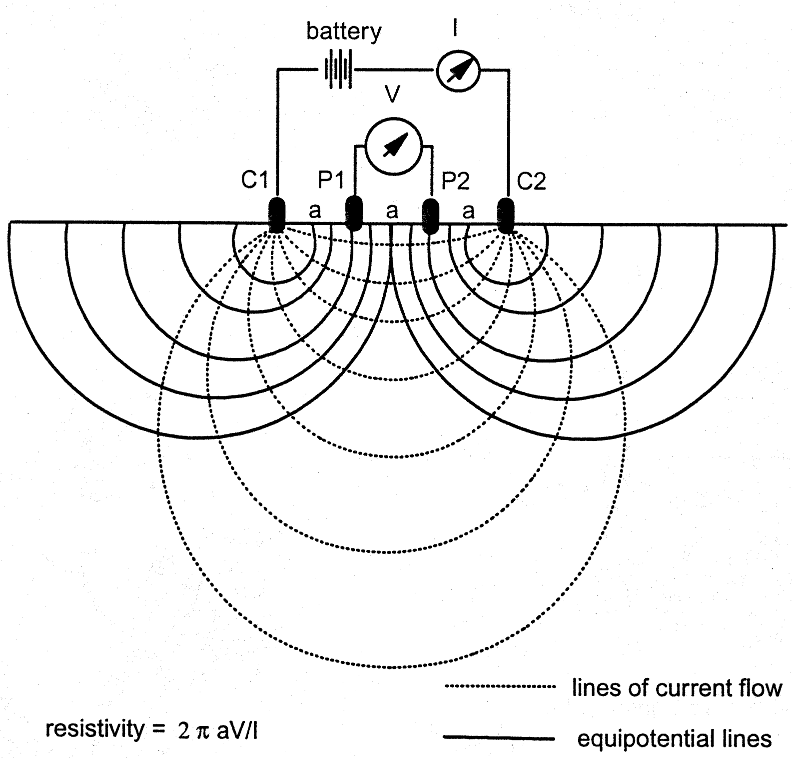

Figure 4 Basic elements of a resistivity meter and the Wenner electrode configuration. C1 and C2 are the current electrodes; P1 and P2 are the potential electrodes; a is the spacing between electrodes; V is measured voltage; and I is the impressed current.

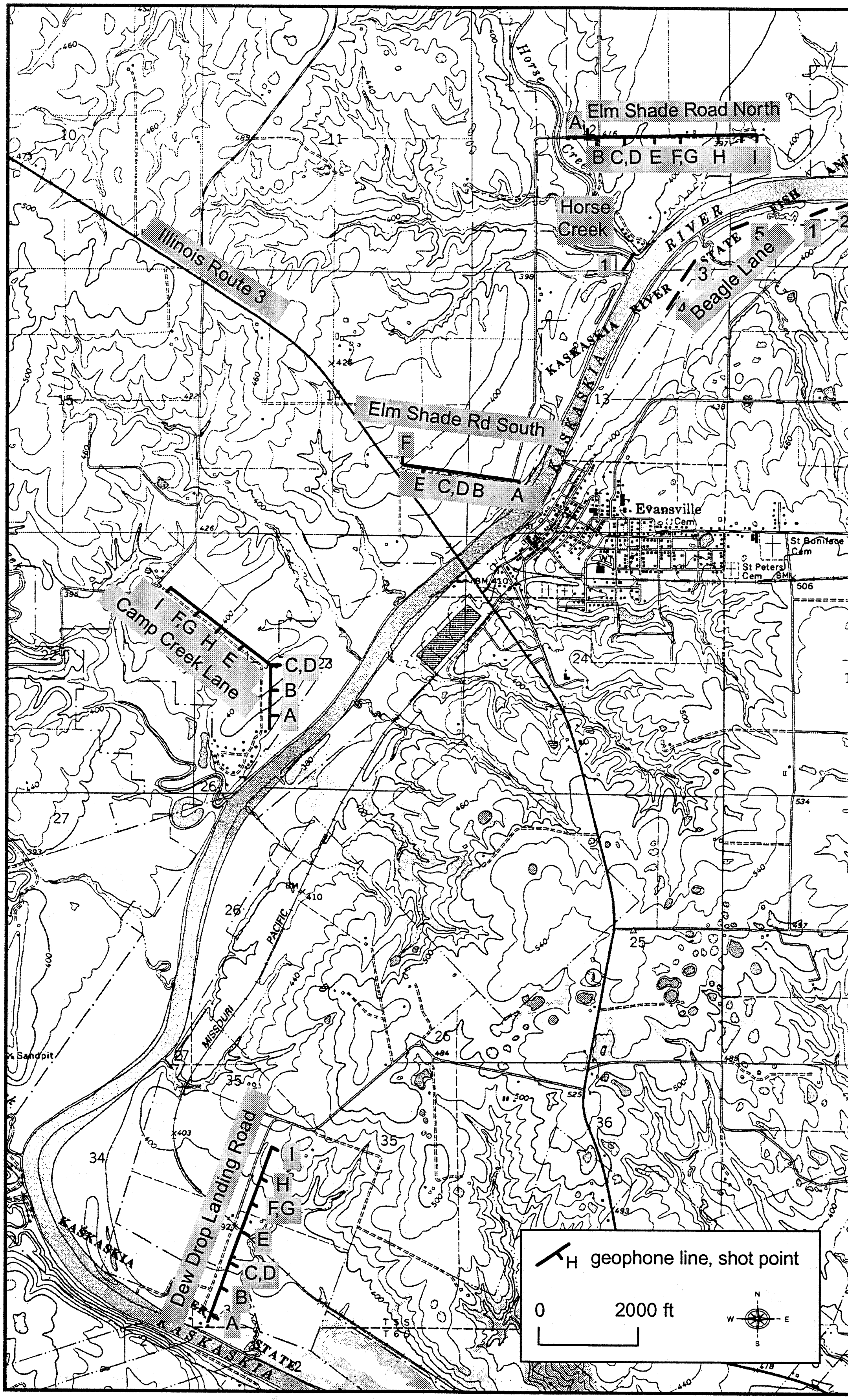

Figure 5 Location of seismic lines in the Evansville study area. Locations of the lines and shot points are shown. Base map is from the Evansville 7.5–minute topographic quadrangle map. Contour interval is 20 feet.

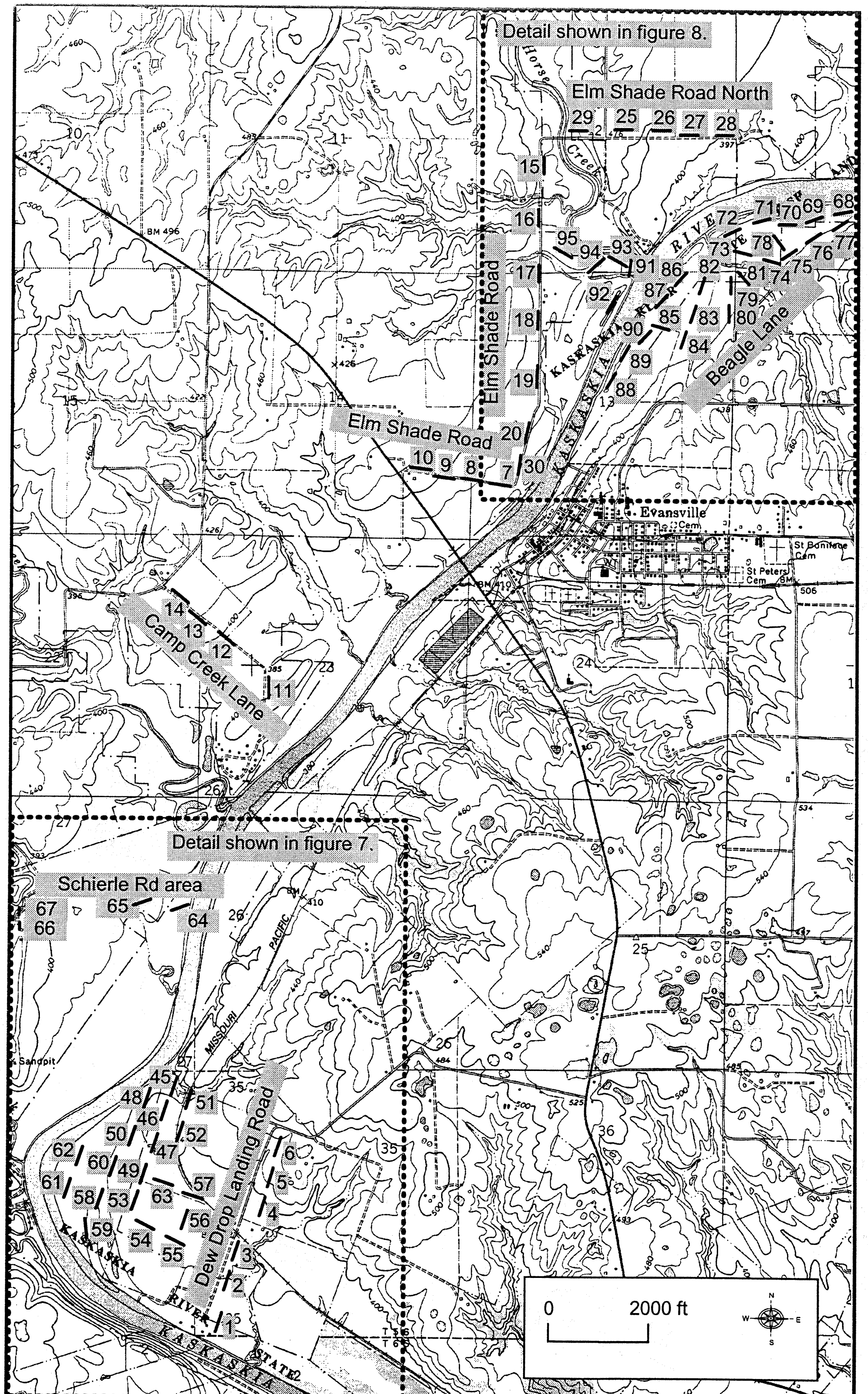

Figure 6 Location of numbered resistivity stations in the Evansville study area. Base map same as in figure 5.

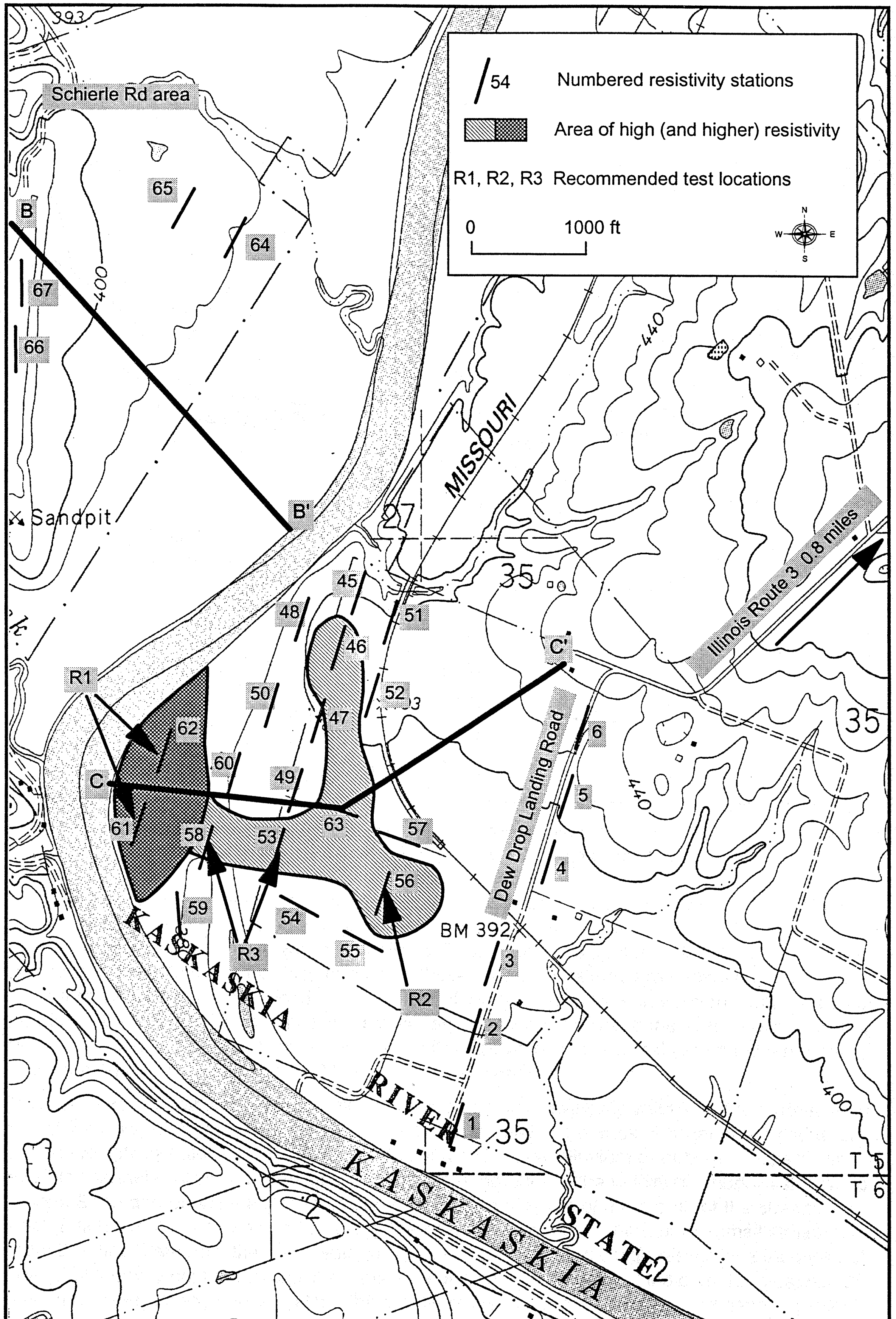

Figure 7 Detailed map of the southern part of the Evansville study area. Map shows areas of high resistivity values, recommended test locations, and approximate locations in figure 8 of lines of cross sections (B–B′ and C–C′) are figure 8. Base map is from the Evansville 7.5–minute topographic quadrangle map. Contour interval is 20 feet.

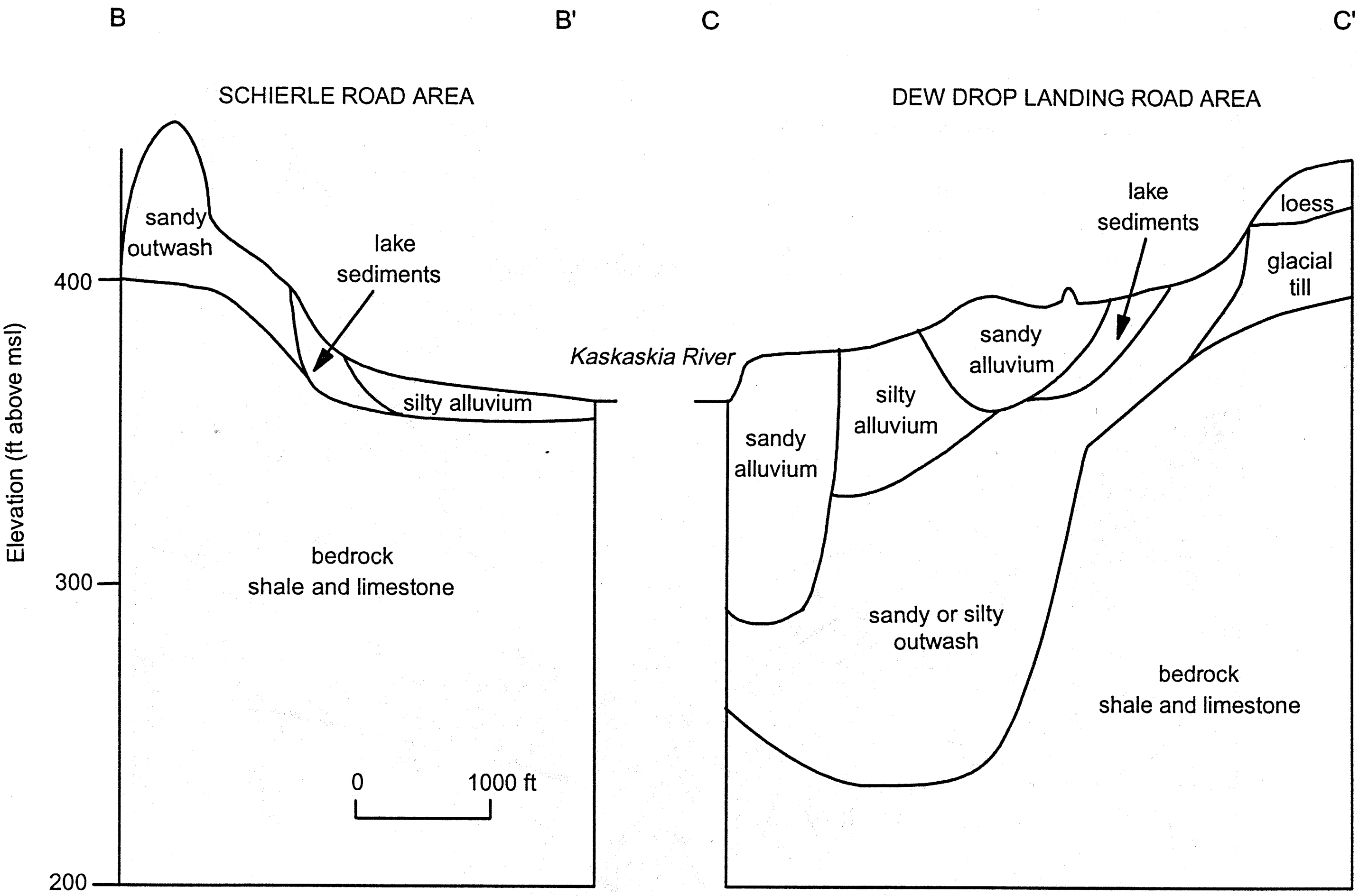

Figure 8 Generalized cross sections in the southern part of the Evansville study area. Locations are indicated by lines B–B′ and C–C′ on figure 7. Interpretations are based on geophysical data, existing well and boring records, and soils maps.

On the east side of the river, 23 stations were located in the bottomland west of Beagle Lane (fig. 9). Several local residents indicated that bedrock had been exposed in the river bed during times of low river stage before the river was channelized. During the investigation, we collected data from five isolated seismic refraction lines to confirm these reports (locations are shown on fig. 5). We found that the bedrock was indeed within 15 feet of the ground surface in the very northern part of the Beagle Lane area where the river flows westward. Farther south where the river flows southward, the tests indicated that the bedrock is 60 to 100 ft deep, which is comparable to depths reported in test borings drilled for the Route 3 bridge south of Evansville.

Several resistivity stations in the Beagle Lane area had high resistivity values. In the northeastern part of the area, high resistivity values are attributed to shallow bedrock. Farther south and west, the high resistivity values more likely indicate sand and gravel alluvium or outwash. In particular, a possible channel containing coarse grained deposits is indicated in the vicinity of a northwest–flowing stream. Sand and gravel are also indicated both north and south of the mouth of the stream. An area of high resistivity extends south along the river bank from the mouth of the small stream for about 0.5 mile. Data from the 1941 resistivity survey indicate that this high resistivity area does not extend all the way south to Evansville. This area of high resistivity could indicate the presence of sand and gravel alluvial deposits along the margin of the modern river valley. The general geologic conditions in the northern area are shown in a pair of west–east cross sections (fig. 10).

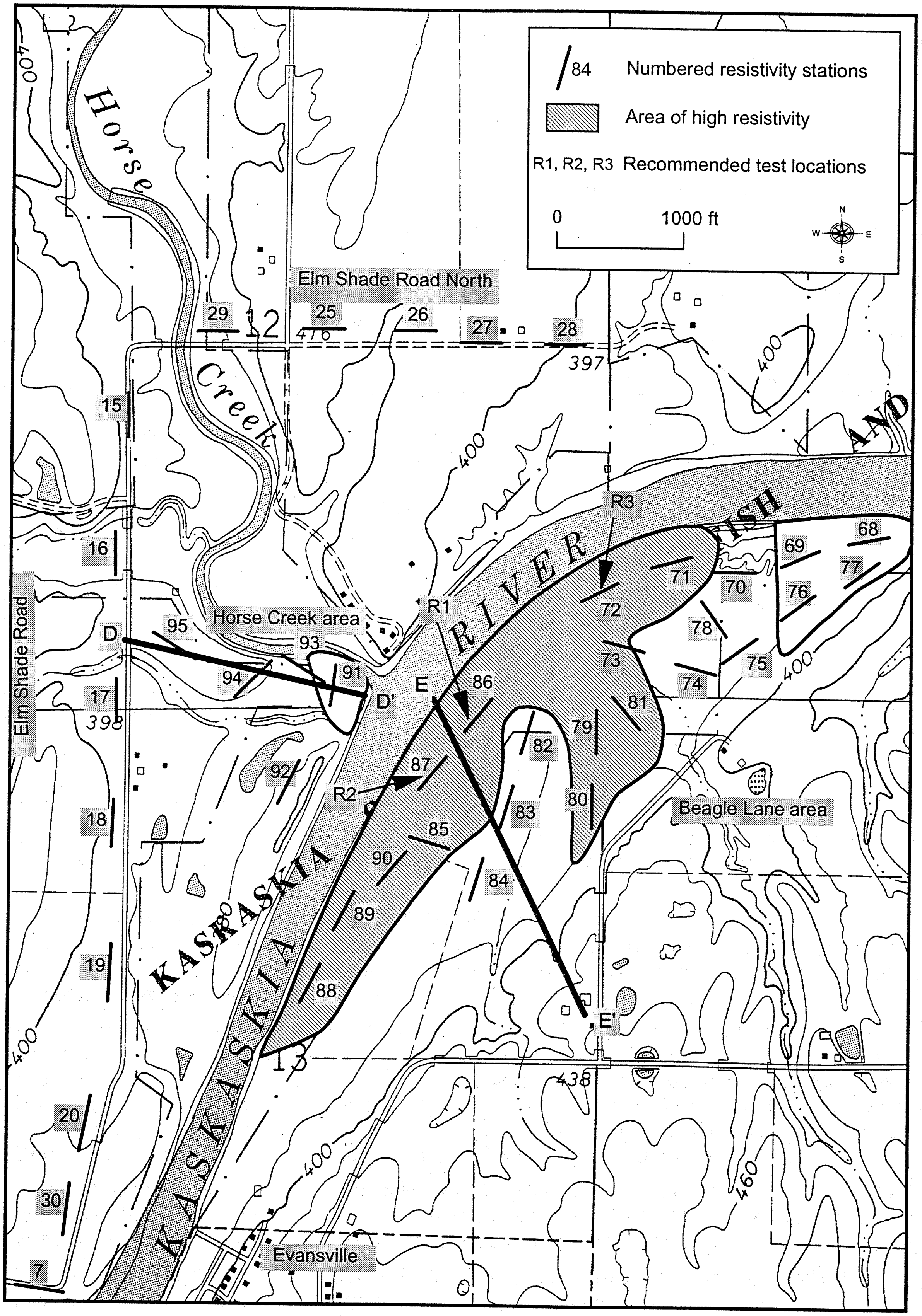

Figure 9 Detailed map of the northern part of the Evansville study area. Map shows areas of high resistivity values, recommended test locations, and approximate locations of lines of cross sections (D–D′ and E–E′) in figure 10. Base map is from the Evansville 7.5–minute topographic quadrangle map. Contour is 20 feet.

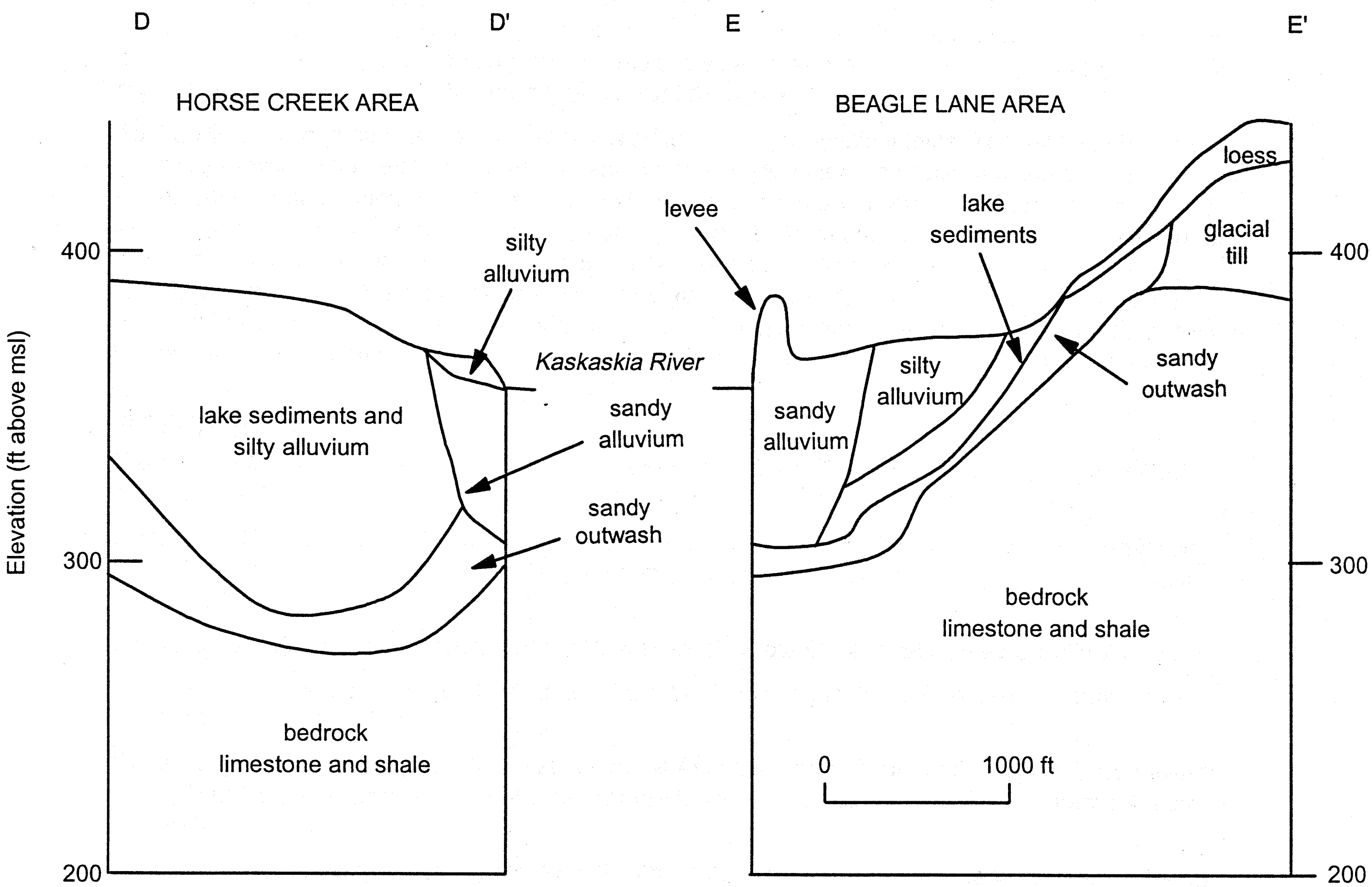

Figure 10 Generalized cross sections in the northern part of the Evansville study area. Locations are indicated by lines D–D′ and E–E′ on figure 9. Interpretations are based on geophysical data, existing well and boring records, and soils maps.

CONCLUSIONS AND RECOMMENDATIONS

In summary, no extensive areas of high resistivity values that would indicate sand and gravel deposits were found west of the Kaskaskia River. If present, coarse grained alluvium or outwash do not form extensive deposits.

East of the Kaskaskia River, localized areas of high resistivity that can be attributed to sandy deposits are present both north and south of Evansville. The most favorable location for coarse grained deposits is south of Evansville in a 20- to 25-acre area on the inside bend of the Kaskaskia River (fig. 7). Although not as extensive as other areas, it has much higher resistivity and because of its proximity to the river, has a high likelihood of favorable well yield. Other locations in the Dew Drop Landing Road area have resistivity values sufficiently high to warrant test drilling.

North of Evansville (fig. 9), a long but narrow zone along the river has high resistivity values similar to those in the well field near Baldwin. The narrow width of this area could limit the yield of any wells drilled, but the relatively high resistivity values suggest that test drilling is warranted.

In total, the areas within the study area with elevated resistivity values are small and restrict the potential for obtaining a 2- to 3-mgd groundwater supply. None of the recommended areas is larger than the Baldwin–Red Bud fields, which together yield approximately 0.5 mgd. The Beagle Lane area is almost as large as the Baldwin fields; and if testing proves that the materials are comparable to those upstream near Baldwin, then 0.5 mgd is probably an upper limit for that area's yield. The most favorable part of the Dew Drop Landing Road area is about half the size of the Baldwin fields; but because the resistivity values are much higher, this area might support a somewhat higher capacity well. The rest of the area underlain by elevated resistivity values in the Dew Drop Landing Road area is approximately the size of the Baldwin fields. By comparison, 0.5 mgd is likely to be an upper limit for the yield from this area.

Test drilling is recommended to confirm the results of the geophysical tests. Test drilling should be continued through the unlithified material and into bedrock. Recommended test sites are identified by resistivity station numbers. Three recommended test sites are in the Dew Drop Landing Road area: at either station 61 or 62 at the far west end of the area, at station 56, and at either station 58 or 53 (fig. 7). Bedrock is estimated to be 80 to 120 feet deep in this area. The most favorable area for test drilling in the Beagle Lane area is from station 87 north to station 72, near the mouth of the small stream entering the Kaskaskia River (fig. 9). Test drilling sites should be within 500 feet of the river bank in the Beagle Lane area, where bedrock is estimated to be 75 to 85 feet deep.

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