Sandstone Aquifers in Eastern Sullivan County, Indiana

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Abstract

Surface water is poor in quality and small in quantity in the Busseron Creek watershed, eastern Sullivan County, Indiana. Shallow wells in unconsolidated deposits and in Pennsylvanian sandstones supply most of the rural domestic water needs, but most individual wells produce less than 10 gallons per minute.

At least 6 potential sandstone aquifers of Pennsylvanian age are present at depths ranging from 10 to 600 feet and having individual thickness ranging from 1 to 104 feet. Although these sandstone bodies are considered as sheet sands they are lenticular and are mostly confined by shale above and below them. Thus, there is minimum recharge of the aquifers except in areas where the sandstone body intersects the bedrock surface and is recharged by ground water moving downward through the unconsolidated materials. These sandstones are fine grained and well cemented. Porosity, as calculated from electrical logs of oil and gas test holes, ranges from 11 to 50 per cent. The coefficient of permeability is extremely low, about 0.04 gallons per day per square foot. Recorded well production from sandstone averages less than 4 gallons per minute. Thus, the sandstones are poor aquifers and cannot furnish enough water for a small municipality, but may be used successfully by individual households. Deeper sandstones should be investigated.

Introduction

The surface-water resources of the Busseron Creek watershed, an area of 237 square miles in Sullivan County (Fig. 1), were studied as part of an investigation of the effects of surface mining for coal by Corbett and Agnew (1). The groundwater resources of this area have been examined in a reconnaissance fashion by Watkins and Jordan (4) and a considerable body of water well data is available in their inventory report.

Surficial Deposits

Unconsolidated deposits at and near the surface of the Busseron Creek watershed area include glacial drift, weathered alluvial material, and soil. These glacial deposits in the upland area constitute a relatively thin veneer of till beneath the soil of the area, and belong to the Illinoian Stage of the Pleistocene. The till is mostly unsorted but locally it contains thin lenses of sand. The valleys of Busseron Creek and its major tributaries contain stream deposits and lake deposits of material washed in from the uplands during the past 100,000 years. Terraces are now present along the main valley of Busseron Creek where later erosion has dissected lake beds that were deposited during Wisconsinan time. All of these deposits except Recent alluvium are overlain by a thin layer of loess deposited by winds in late Winconsinan time and now mostly incorporated in the soil. Neither the till nor lake deposits are uniformly permeable and thus are not able to supply large quantities of water to wells. Nevertheless, the unconsolidated material may provide the opportunity for recharge to bedrock aquifers below, by slow leakage downward.

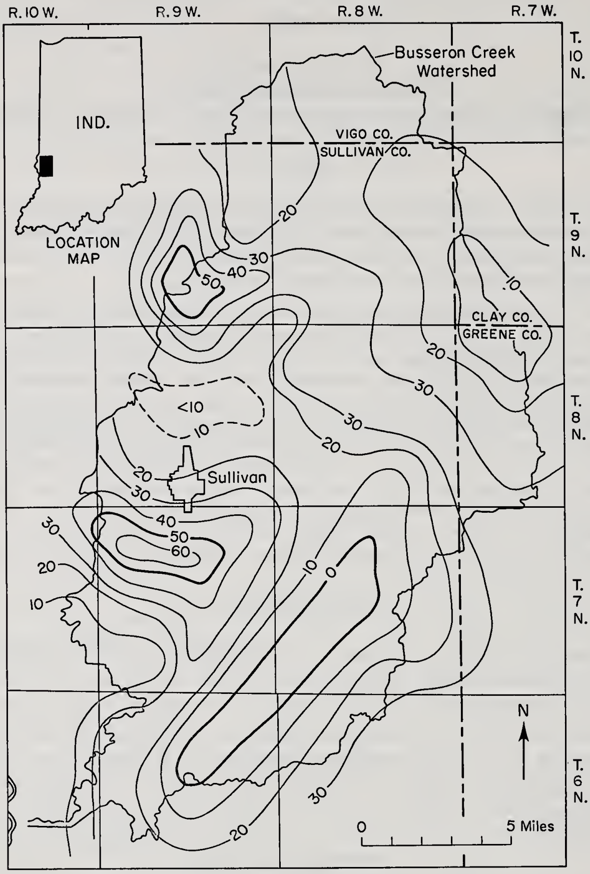

FIGURE 1. *Map of Busseron Creek watershed showing thickness of Coxville Sandstone Member. Modified from Glore (2).*

In the Wabash River Valley, to the west of the Busseron, thick and permeable deposits of outwash sand and gravel occur. These materials, laid down by meltwaters from both the Illinoian and Wisconsinan ice, can supply large quantities of water. These deposits also occur in the Busseron Creek watershed, but only in the lower 3 miles of Busseron Creek valley (southwest corner) where it merges with the Wabash River Valley (Fig. 1).

Sandstone Bodies

Bedrock underlying the Busseron Creek watershed dips gently to the southwest into the Illinois Basin. These rocks consist of alternating beds of shale, sandstone, limestone, coal and clay (3, 5) and belong to the Pennsylvanian System. More than 90 per cent of the beds are interbedded sandstone and shale. Locally, sandstone beds may be quite thick and be a potential aquifer.

Thicknesses of these sandstone bodies are extremely variable (Table 1). If one thinks of the clastic rocks between two coal beds as being predominantly shale then sandstone bodies become the disruptive units. Because of the different amount of compaction of sand, *versus* mud, where sand bodies are present the interval between the coal below and above is thicker than normal.

TABLE 1. *Thickness, porosity, and water production determinations for each sandstone body.*

Sandstone	Thickness (ft.)			Porosity (%)			Water Prod. (gpm)		
	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.
Busseron Sandstone Mbr.	18	32	50	12	21	31	0.1	2.5	15
In upper Dugger Fm.	8	16	32	14	22	50	0.3	3.6	25
In upper Petersburg Fm.	15	43	104	12	25	44	0.8	2.5	10
In upper Linton Fm.	12	29	60	11	34	44	3.0	—	39
Coxville Sandstone Mbr.	5	17	37	13	32	35	8.0	—	56
In upper Staunton Fm.	12	38	90	11	23	40	2.0	—	3

Preliminary investigations indicated that there are six shallow sandstone bodies that might be satisfactory aquifers in some localities. They are listed in sequence from top to bottom under the appropriate formation in which they occur:

Shelburn Formation
1) Busseron Sandstone Member overlying Coal VII

Dugger Formation
2) Unnamed sandstone between Coals VI and VII in upper part of formation

Petersburg Formation
3) Unnamed sandstone between Coals IVa and V in upper part of formation

Linton Formation
4) Unnamed sandstone between Coals IIIa and IV in upper part of formation
5) Coxville Sandstone Member overlying Coal III

Staunton Formation
6) Unnamed sandstone below Coal III in upper part of formation

In general, all six sandstones are fine grained and poorly sorted. Commonly, clay fills a large part of the area between grains. Although such sandstone bodies have been classified as being either a channel-fill or a sheet sandstone, they are irregularly lenticular in shape (Fig. 1). Water recharge is minimized by the presence of impermeable shale surrounding the sandstone lenses. These sandstone beds range in depth from a few to 600 feet. The Busseron sandstone and the sandstone in the upper part of the Dugger Formation crop out in the east half of the area. The other sandstone beds are deeper and crop out even farther to the east.

Thickness and Porosity

Thickness of the shallow sandstone bodies may be obtained, in some areas, from coal test and water well records. However, only electrical logs of oil and gas tests uniformly provide information that is deep enough to include all six sandstone bodies.

About 450 holes were drilled for oil and gas in the area studied. Electrical logs are available for nearly 100 of them. Utilizing the self-potential and resistivity curves the depth to, thickness of, and porosity of each of the six sandstone bodies were interpreted (Table 1). Sandstone bodies show high resistivity on both the short normal and long normal resistivity curves, and where the sandstone is more than 10 feet thick its depth and thickness are easily measured (Fig. 2). The stratigraphic position of the sandstone is identified by its relationship to coal beds.

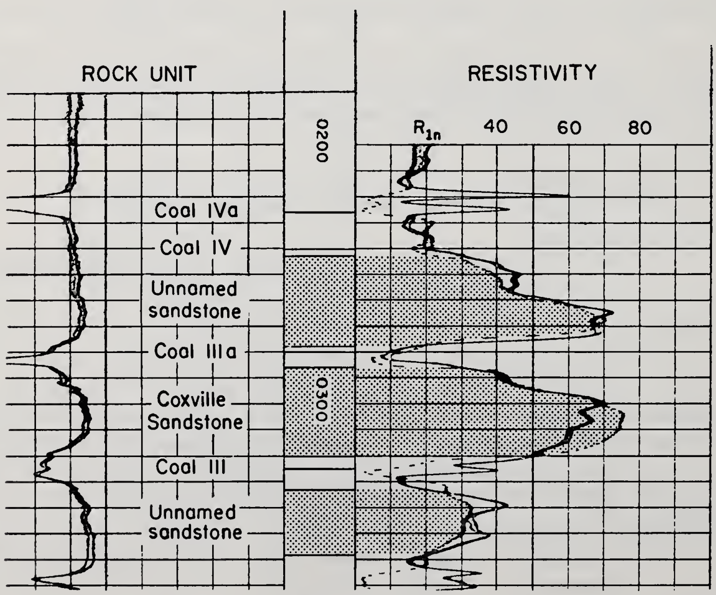

FIGURE 2. *Part of electrical log of C&EI RR #1 well, SE¼NE¼NE¼ Sec. 6, T8N, R8W, showing position of three sandstone bodies (in stippled pattern) in relation to coal beds and showing resistivity values for the long normal curve.*

Thick sandstone bodies are commonly considered as a potential source of water. In order to evaluate their potential as an aquifer the areal distribution, thickness, porosity and permeability must be known.

Approximate porosity but not permeability can readily be determined from electrical logs. The relationship of the characteristics of a rock unit is shown by the formula:

$$\frac{R_{ln}}{R_f} = \frac{a}{\phi^m}$$

in which R_{ln} is resisitivity of the rock unit as shown on the long normal curve, R_f is resistivity of the drilling fluid, "a" is an emperically-determined rock unit factor that can be obtained from the Schlumberger Log Interpretation Charts, ϕ is porosity, and "m" is cementation factor of the rock. For the Illinois Basin "a" is about 0.81 and "m" is 2. A usable formula is $\phi^2 = \frac{0.81R_f}{R_{ln}}$.

Resisitivity of the drilling fluid is given in the data (upper) part of the electrical log and resistivity of the long normal curve is read from the right side of the log (in ohms m^2/m) for each sandstone (Fig. 2). Most sandstones are in the 30 to 70 range.

Porosity of the Pennsylvanian sandstones is surprisingly high, 11 to 50% (Table 1). The larger the grain size, the greater angularity of grains and the less amount of clay matrix, the higher is porosity.

Permeability

In order to produce significant quantities of water from a sandstone aquifer, the sandstone must have good permeability. Selected samples from cores were run for permeability in a permeameter that measured the amount of water that flows through the rock sample. The highest permeability constant determined was 0.1 gal/day/ft^2 for the sandstone between Coals IV and IIIa. Others ranged from 0 to 0.044. A good aquifer should produce more than 10 gal/day/ft^2. Thus all eight samples tested are classified as impervious or as poor aquifers.

Water Production

Production of water from wells in this area was listed by Watkins and Jordan (4). By using their depths to aquifers and collating these with depths (or elevations) determined from coal tests or from electrical log data, the stratigraphic position of the producing sandstone was identified in the wells. Water production from the three upper sandstones, as recorded in about 50 wells, was extremely low (Table 1). It averaged less than 4 gallons per minute (gpm). Only four wells recorded production from the sandstone in the upper Linton Formation, and two each from the lower two. One well in the Coxville listed the maximum production noted—56 gpm. The small production for most wells confirmed the findings of low permeability.

Production from unconsolidated material in the upland area (Table 2) was only slightly better than that from sandstones, but production from the sand and gravel in the Wabash River valley (to the west of the area) averaged 780 gpm.

TABLE 2. *Water production from unconsolidated sediments.*

Material	Water Production (gpm)		
	Min.	Ave.	Max.
Upland: till, clay, sand, and gravel	0.5	11	50
Wabash River valley: sand and gravel	325	780	2100

Conclusions

Although numerous areas were mapped by Glore (2) where one or more of the six sandstone bodies were thick and had high porosity, all sandstones generally have low permeability. Thus water production is usually small. More information should be obtained on permeability, especially on samples of the Coxville sandstone and the sandstone in the upper part of the Linton Formation. Wells in these two sandstone bodies show the greatest production, a fact that must indicate areas of higher permeability within the sandstone bodies.

The small municipalities in the watershed area are abandoning their local water wells and are running waterlines from wells that are 10 to 20 miles to the west in the Wabash River valley. However, sandstone bodies in the Brazil and Mansfield Formations that are deeper than the six discussed herein should be tested and evaluated as a potential source of water.

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