STATE OF INDIANA

INDIANA DEPARTMENT OF CONSERVATION

DIVISION OF WATER RESOURCES

GROUND-WATER RESOURCES OF THE COLUMBUS AREA, BARTHOLOMEW COUNTY, INDIANA

Prepared in cooperation with

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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Ground-water resources of the Columbus area, Bartholomew County, Indiana

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Introduction

The city of Columbus, Ind. has utilized the Driftwood River as a source of municipal water supply for many years. The surface water treatment facilities are old and require major reconstruction and expansion to meet the increased water demands of the community and of industry. In 1947, the average consumption of water was reported to be about 2.8 million gallons a day, and the present consumption is doubtless much larger. Plans have been made to develop a new municipal supply of water from wells.

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In 1940, five test wells were drilled by the Layne-Northern Company of Indianapolis, to determine suitable locations for the development of a ground-water supply. In 1947, a large diameter gravel-wall well (G18-1-1) was drilled at 25th St. and Haw Creek Avenue. The water from this well has not been used extensively because of its high iron content.

In September 1948, Mayor R. L. Stevenson, of Columbus, in a letter to C. H. Bechert, Director, Division of Water Resources, Indiana Department of Conservation, requested the assistance of the Indiana Department of Conservation and the United States Geological Survey in determining the safe yield of water-bearing formations in the Columbus area or the quantity of water that might be pumped perenially from wells in the area without diminishing the available supply or seriously impairing the chemical quality.

In view of the importance of Columbus as an industrial center of southern Indiana and the need for information on the ground-water resources of the area, it was decided that a preliminary investigation of ground-water conditions should be made in the Columbus area as a part of the State-wide investigation of the ground-water resources of Indiana, now being made by the U. S. Geological Survey, in cooperation with the Indiana Department of Conservation.

A brief field investigation by F. H. Klaer, Jr., T. M. Kingsbury, and others in 1948 indicated that conditions in the Columbus area were favorable for the development of an adequate ground-water supply, although additional information was needed on the coefficients of storage and transmissibility, the natural recharge from Haw Creek, and the natural hydraulic gradients under which ground water was moving, before a precise determination of safe yield could be made.

In September, 1950, Mayor Stevenson, through the firm of H. B. Steeg and Associates, consulting engineers employed by the City of Columbus, requested additional assistance in running a pumping test on a newly-drilled well to provide the additional information needed for the determination of the safe yield of the area. This report describes the results of the preliminary investigation made in 1948 and the results of the pumping test made in September 1950. The results of this work will eventually be included in a report on the ground water resources of the southeast-central area of Indiana, but are being released at the present time because of the immediate demand for the available information.

Acknowledgments

The authors wish to express their thanks to the officials of the City of Columbus, Mayor R. L. Stevenson, D. A. Gunder, City Engineer, and R. Pittman, for their help in collecting information on existing wells in the Columbus area. A number of well records were obtained from C. R. Merrick, of the Layne-Northern Co. and Harry H. Fox, of Shelbyville. The help of H. B. Steeg, and J. E. Loer, of H. B. Steeg and Associates, in the operation of the pumping test, is gratefully acknowledged. Stream flow data were obtained by L. W. Furness and E. R. Buxton, U. S. Geological Survey, Indianapolis.

Location and general description

The City of Columbus is at the junction of the Driftwood River and Flatrock Creek, near the central part of Bartholomew County, about 42 miles south of Indianapolis and about 72 miles north of Louisville, Ky. The estimated population in 1949 was 16,000 and may be somewhat larger at the present time. During the war period the population was even larger than at

present because of the proximity of several Army training camps and air fields. The city is reported to contain about 94 industries, in addition to being the center of a large agricultural region.

Precipitation

The U. S. Weather Bureau has maintained a record of precipitation at Columbus, Ind, since 1884. The average annual precipitation of 39.54 inches is distributed seasonally as follows:

Winter	Precipitation (inches)	Spring	Precipitation (inches)	Summer	Precipitation (inches)	Autumn	Precipitation (inches)
December	2.98	March	3.85	June	3.58	September	3.51
January	3.55	April	3.67	July	2.85	October	2.83
February	2.66	May	3.43	August	3.59	November	3.04
	9.19		10.95		10.02		9.38

The precipitation is well distributed throughout the year, the driest month being February and the wettest month, March. Precipitation is heaviest during the spring months when conditions for recharge of water to the ground-water reservoir are generally most favorable.

Geology

The City of Columbus is situated near the center of a wide valley, bounded on the west by the Knobstone escarpment, which is formed by the resistant Borden group of shales and sandstones of Mississippian age, and the resistant limestones of Devonian and Silurian age to the east. The formation immediately underlying the Columbus area is the black New Albany shale, of Devonian age, which is relatively less resistant to erosion than the adjacent formations. Because of this, a lowland area was formed prior to the advance of the continental glaciers that covered nearly two-thirds of Indiana.

The southern limit of the Illinoian glaciation passes southward through central Brown County about 15 miles west of Columbus, and through the western part of Jackson County, continuing in a southeasterly direction to the Ohio River. The Columbus area was covered by the Illinoian glaciation and the major part of Bartholomew County is covered by a thin mantle of Illinoian glacial till or boulder clay, the thickness of which is generally less than 25 feet.

After the retreat of the Illinoian ice front, the area was exposed to weathering and erosion for a considerable length of time, as indicated by the reports of a buried soil zone in the eastern half of the County. (1) 1/

1/Numbers in parentheses indicate references in bibliography at end of report

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The early Wisconsin ice sheet covered the northeastern half of the County but stopped just north of the City of Columbus. The southern limit of the Wisconsin glaciation crosses the western county line about 1½ miles south of the north county line (Pl. 2) continues eastward to the Driftwood River near Taylorsville, and swings southward parallel to that river to about the northeast corner of section 22, T. 9 N., R. 5 E. The Wisconsin border is then interrupted for nearly 5 miles by the outwash-filled valleys of the Driftwood River, Flatrock Creek, Haw Creek, and Clifty Creek. The border is resumed in the southeast corner of section 32, T. 9 N., R. 6 E., and may be traced southward through Azalia to the southeastern corner of the county.

The central part of the county is crossed by a large gravel-filled valley that served as a sluiceway during the glacial period for the water from the melting ice fronts. In the northern part of the county, one branch of the valley lies just east of Driftwood River and extends in a southeasterly direction to join a similar branch of the valley along Flatrock Creek, south of the Union Church. At the junction of the two branches, the valley is nearly 9 miles wide. The valley continues in a southeast direction, passing east of Taylorsville, and through the eastern part of Columbus. The main valley is joined by smaller valleys along Haw Creek and Clifty Creek. In the vicinity of the southern part of Columbus, the valley is about 2 miles wide.

The valley is filled with outwash deposits of sand and gravel that are capable of absorbing and storing large quantities of water. The details of the types and succession of materials in the valley fill are known in only a few places, but it is believed that the materials are such that the valley may be considered as a large underground reservoir.

Water-bearing formations

In order to obtain information on existing industrial and private wells in Columbus, Mr. Robert Pittman, of the City Engineer's office, and Mr. T. M. Kingsbury, of the Indiana Department of Conservation, contacted many well owners and well drillers. Records of about 50 wells in the Columbus area were obtained and are summarized in the well tables at the end of this report. Many of the records are fragmentary and detailed well logs of the formations drilled are scarce. The locations of many of these wells are shown on plate 1.

The bedrock formations of the Columbus area generally yield only small quantitiesof water to wells. The underlying New Albany shale is a dense black shale, ranging in thickness from a few feet to as much as 70 feet. Most wells obtain little or no water from the shale and are drilled into the underlying Devonian limestone to depths of as much as 200 feet. The quantities of water obtained from limestone wells are usually less than 5 gallons a minute and in some localities, the water is highly mineralized and not suitable for most uses. The bedrock formations of the Columbus area provide small quantities of water to domestic and rural wells, but cannot be considered as potential sources of water for municipal and industrial use.

The major aquifers or water-bearing formations of the Columbus area are the deposits of sand and gravel outwash that fill the valley, covering the New Albany shale. The records of existing wells and a detailed study of drainage and soil maps indicate that these deposits in the Columbus area are extensive, particularly north of the city. In the western part of the city, the glacial deposits are relatively thin and are composed mainly of clay. Many of the wells west of Chestnut Street pass through the glacial deposits into the underlying bedrock and obtain only small quantities of water of rather poor quality. Many wells yield highly mineralized or "sulpher" water. The log of a well at the Public Service Co. of Indiana sub-station (well BaF25-2) shows about 9 feet of sand and gravel between depths of 41 and 50 feet, but the formation apparently yielded very little water.

West of Chestnut Street and south of Third Street, the deposit of sand and gravel was encountered from a depth of 5 to 53 feet. A well at the Stadler Packing Co. south and east of Haw Creek, was drilled to a depth

of 95 feet through sand and gravel before hitting bedrock. Wells at the Farmer's Market Association are reported to be 100 feet deep, and although no record of the materials penetrated is available, the yield of at least one of the wells indicated that it obtains water from sand and gravel deposits.

At the Cummins Engine Co. a well (BaG19-7) penetrated gravel to a depth of 85 feet and yielded about 325 gpm. North of this location, wells at the Morgan Canning Co., the Golden Foundry, and the 17th Street and Central Avenue Plants of Noblitt Sparks Industries penetrated deposits of sand and gravel to depths of about 100 feet before hitting bedrock. The yields of several of these wells are reported to be more than 500 gallons per minute. The greatest thickness of sand and gravel in the Columbus area known at the present was found in the new City Well (BaG19-1-1), where 128 feet of sand and gravel was penetrated.

North of Columbus the records of well (BaG5-1-1), at the Camp Atterbury Air Field show that the deposits of sand and gravel are at least 100 feet thick, although the full thickness of the deposits is not known. Other wells further north report similar thicknesses.

The eastern limit of the sand and gravel reservoir is believed to be near the east line of sections 17, 20, and 29, T. 9 N., R. 6 E., although the exact limit is obscured by the valley of Clifty Creek. This would indicate that the sand and gravel reservoir in the Columbus area is perhaps as much as 2 miles wide at Columbus.

It is worthy of note that no clay was reported in the glacial outwash materials in any of the wells east of Chestnut Street, except a small lense of sand and clay in City Well 4, and the sand and gravel

deposits act as a unit in which large quantities of ground water are stored. The water in the ground-water reservoir moves slowly southward as underflow and discharges naturally into the surface streams in places where the ground-water reservoir is full.

Hydrology

Rainfall, falling on the earth's surface, is disposed of in several ways. Part is held in the soil to be returned to the atmosphere by evaporation or transpiration and most of the remainder reaches the stream channels either directly over the surface of the ground or by percolation through underground formations. To classify the disposition of the average rainfall, an analysis of the stream flow characteristics of Driftwood River at Edinburg was made by L. W. Furness, Surface Water Branch, U. S. Geological Survey, Indianapolis. The Driftwood River was chosen because its drainage basin is believed to be similar in geologic, topographic, and climatic character to valleys of Flatrock and Haw Creeks.

Computations by Mr. Furness indicate that the average annual rainfall for the drainage basin was 39.82 inches for the period 1942 through 1946. The average runoff for the same period was 13.01 inches or 32.7 percent of the total rainfall, and the water loss, composed of evapo-transpiration losses, was 26.81 inches or 67.3 percent. The total runoff of 13.01 inches was made up of direct storm runoff of 7.25 inches and base flow or ground-water runoff or 5.76 inches. The latter represents the amount of ground water draining naturally into the stream during dry periods and is about equal to the average annual recharge to the ground-water reservoir. A large part of this "rejected" recharge might be salvaged by pumping from wells if water levels in the water-

bearing formations were lowered to provide additional storage space and to intercept natural discharge into surface streams. The ground-water runoff is equal to about 14.5 percent of the average annual rainfall or about 275,000 gallons per day per square mile. It is believed that the valley of Flatrock Creek and the lower part of the valley of Haw Creek may be somewhat more favorable for ground-water recharge than the basin of Driftwood River as a whole and, therefore, the average annual recharge may actually be somewhat higher.

The computation given for ground-water runoff and equivalent recharge to the ground-water reservoir is an average yearly figure. It should be realized that the recharge may vary within wide limits. During the winter and spring months, conditions for recharge are generally favorable and the recharge is generally high. During the summer, when losses by evaporation and transpiration are at a maximum, recharge of water to the ground-water reservoir is low.

A study of the geologic aspects of the Flatrock Valley suggest that the width of the permeable sands and gravels becomes reduced from about 5 miles near Taylorsville to about 2 miles in the vicinity of Columbus, and the thickness apparently remains about the same. Assuming this to be true, the quantity of ground water that could flow through the 5-mile width of valley must be considerably greater than that which could pass through the 2-mile width, assuming that the permeabilities, thicknesses, and natural hydraulic gradients remain about the same. Records of wells in the valley north of Columbus suggest that the thickness and permeabilities of the materials are about the same, and water levels in wells in Columbus indicate little steepening in the hydraulic gradients. The water that moves southward as

underflow must enter the surface streams in the vicinity of Columbus.

In order to check the validity of the above assumption, several measurements of stream flow in Flatrock Creek and Haw Creek were made by L. W. Furness and E. R. Buxton of the U. S. Geological Survey, Indianapolis. The results of these measurements are shown in Table 1.

According to these computations, the drainage area of Flatrock Creek above point C is 546 square miles and that of Haw Creek above point F is 49.5 square miles (pl. 2). The total drainage area of the two basins above Columbus is, therefore, about 595 square miles.

The discharge in second feet per square mile was computed for the several sections of the drainage basins as a basis for comparison. In the Flatrock basin, the additional discharge picked up by the stream in the area between St. Paul and point A is slightly lower than the average for the basin above St. Paul. This may indicate that some water from the creek is draining underground. In the basin between points B and C the discharge per square mile is considerably greater than the average for the basin, indicating that part of the water that is flowing underground north of point A drains from the ground into the stream and passes southward as surface-stream flow. The area between points B and C is in the area where the width of the valleys of Flatrock and Haw Creeks, and the width of the section through which the underflow must pass is greatly decreased.

The decrease in runoff per square mile between points D and E in the Haw Creek valley indicated that water is being lost to the ground-water reservoir. As in the lower part of the Flatrock basin, the runoff per square mile between points E and F in the Haw Creek basin is also considerably above the average for the basin, indicating drainage from the ground-water reservoir to the stream.

The discharge measurements were made on October 15, 1948, after a period of 3 days during which no precipitation was reported at Columbus, Franklin, Shelbyville, Rushville or Greenfield. It is believed that any direct runoff due to precipitation had already passed down the streams and that the major part of the measured flow was base flow or ground-water runoff. Assuming this is true, the total flow of 37.9 second-feet from Flatrock Creek and Haw Creek represents a ground-water runoff of 17,000 gallons a minute or about 24.5 million gallons a day. Although this flow is not necessarily the minimum flow during the year or during the period of record, it does represent conditions during a relatively dry period.

Table 1- Summary of discharge measurements made on October 15, 1948 by L. W. Furness and E. R. Buxton, Columbus Area, Ind.

Point of Measurement	Drainage area (sq. mi.)	Total Discharge (cu. ft. per sec.)	Drainage per sq. mi. of drainage area (c.f.s./sq. mi.)
Flatrock Creek			
Flatrock Creek at St. Paul	303	15 ±	0.049
A. SE¼NW¼ sec. 30 T. 10 N., R. 6 E about 4.4 miles north of Columbus	521	22	0.042
1. Drainage area between St. Paul and point A	218	+7	0.032
B. Center, south line sec. 36 T 10 N., R. 5 E about 2.6 miles north of Columbus	541	31.2	0.058
2. Drainage area between points A and B	20	+9.2	0.460
C. Center, West½sec.12, T. 9 N., R. 5 E.,about 1.1 miles north of Columbus	546	36.9	0.068
3. Drainage area between points B and C	5	+5.7	1.14
Haw Creek			
D. NE cor. SE¼ sec. 33 T. 10 n., R. 6 E. about 3.6 miles northeast of Columbus	44.2	0.75	0.017
E. SE cor. SW¼SE¼sec. 5,T.9 N., R. 6 E., about 1.6mi. northeast of Columbus	48.2	0.02	+0.0004
4. Drainage area between points D and E	3.0	-0.73	-0.243
F. NW¼NW¼sec. 17, T. 9 N., R. 10 E., 25 Street and Haw Creek, Columbus	49.5	1.03	+0.021
5. Drainage area between points E and F	1.3	+1.01	+.777

Quality of Water

The chemical quality of the ground water in the Columbus area is shown in a general way by an analysis of water from test well 1, near the golf course, made by the Indiana State Board of Health in June 1940; an analysis of water from permanent well 1, made by F. C. Atkinson, Inc., in October 1947; and an analysis of water from a well at the Cummins Engine Co. made by the Pittsburg Laboratories, Inc. in January 1946. Copies of these analyses are attached.

The ground water from the deposits of sand and gravel in the Columbus area is moderately hard and generally contains enough iron to be objectionable for some uses without treatment. The chemical quality of the ground water is reported to be better than that of the surface supply for most uses. In the new municipal water system, facilities are provided for iron removal.

Pumping tests

Several attempts were made to run a pumping test using City well 1 at the northeast corner of the proposed well field. These attempts had been unsuccessful because of inadequate means of disposal of the waste water and insufficient length of the pumping period. In August, 1950, a second well, City well 4, was drilled by the Diehl Pump and Supply Co. of Louisville Ky., on the south line of 23rd street, extended, about 150 feet west of the west bank of Haw Creek. The well was equipped with an electric deep-well turbine pump. The water was pumped through a 6-inch discharge line equipped with a 6 by 4½-inch orifice and piezometer tube, and the water was wasted into Haw Creek. Two observation wells were also drilled to depths of about 40 feet, well T-7 being 65 feet east of the pumped well, and well T-8 being

130 feet west of thepumped well on the line of 23rd street, extended.

On September 7, 1950, a pumping test was started at 9:30 a.m. under the supervision of J. E. Loer, of H. B. Steeg and Associates, and G. E. Davis, of the U. S. Geological Survey. City well 4 was pumped at a rate of 1,000 gallons a minute continuously, with one short interruption because of power trouble, until 10:30 a. m. on September 8, a period of 25 hours, Measurements of water levels were made in wells T-7, by a water-stage recorder, T-8, T-1, and T-2. Measurements in the latter three wells were made by steel tape. After the pumped well was shut off on September 8, measurements of water levels in all observation wells were continued for a period of 24 hours.

Pumping-Test Results

The abilities of a formation to store and to transmit water are determined by the coefficients of storage and transmissibility. The coefficient of storage, which under water-table conditions is usually referred to as specific yield, is defined as the cubic feet of water discharged from each vertical column of the aquifer with a base 1 foot square as the hydrostatic head is lowered 1 foot, and is often expressed as a percentage of the total volume of material drained. The coefficient of transmissibility is defined as the quantity of water in gallons a day that will pass through a vertical strip of the formation 1 foot wide extending the full saturated thickness of the formation under a hydraulic gradient of 1 foot per foot. The coefficients are determined in the field by pumping tests. A detailed discussion of pumping tests and their analyses is beyond the scope of this report and the interested reader is referred to the published works of Ferris, (2,3) Meinzer,(4) Theis,(5) and Wenzel, (6).

The results of the test indicate that the specific yield of the water-bearing deposits of sand and gravel in the Columbus area is about 12 percent and the coefficient of transmissibility is about 300,000 gallons per day per foot. If the water table were lowered 1 foot uniformly over an area of 1 square mile, in material having a specific yield of 12 percent, about 25 million gallons of water would be released from ground-water storage. In Columbus area it would probably be possible to pump large quantities of water from ground-water storage during periods when the daily pumpage was greater than the daily recharge. During the winter and spring months, the depletion in ground-water storage would probably be replenished by increased natural recharge.

The pumping tests showed no positive evidence of direct recharge from Haw Creek during the period of the test within a reasonable distance of the pumped well. This may be due to the fact that pumping did not continue long enough to induce recharge at a locality where a free hydraulic connection exists between the stream and the deposits of sand and gravel or to the presence of a relatively local lense of clayey sand, found in test well T-2 and in City well 4, apparently extending along the west side of Haw Creek in this locality. The fact that the base flow of Haw Creek increases an unusual amount in the stretch above 25th Street would suggest that a free hydraulic connection exists somewhere north of 25th Street.

The drawdown in water level in the pumped well after pumping 1,000 gallons a minute for a period of 25 hours was about 11 feet, and in observation wells at a distance of 65 feet was 1.78 feet, at a distance of 130 feet was 1.33 feet, and at a distance of about 548 feet was 0.22 feet.

Estimate of safe yield of the Columbus area

The quantity of water that can be pumped perenially from wells in the Columbus area depends on the areal extent and thickness of the deposits of sand and gravel in the valley of the Driftwood River, Flatrock Creek, Haw Creek, and Clifty Creek, the quantity of natural recharge or replenishment of the ground water supply from precipitation and stream flow, the natural gradients under which ground water moves, and the specific yield and coefficient of transmissibility of the water-bearing beds.

The horizontal movement of water through the deposits of sand and gravel is slow and generally the rate is in the order of a few tens or hundreds of feet per year, depending on the permeability or transmissibility of the water-bearing beds and hydraulic gradient. The direction is generally southward except near the streams where ground water drains into the streams by the shortest path.

The quantity of water moving southward through the deposits of sand and gravel in the valley at Columbus can be computed by Darcy's Law:

1. $$Q=TIW$$

Where Q= Discharge, in gallons per day
T= Coefficient of transmissibility, in gallons per day per foot
I= Hydraulic gradient, in feet per foot
W= Width of the cross-section through which water is moving, in feet.

The natural hydraulic gradient is estimated to be about 10 feet per mile, based on the records in wells T-1, T-2, T-6, and T-7 prior to the start of pumping. This figure closely approximates the gradients of the surface streams and of the land surface in the broad valley area north of Columbus. In order to measure the underflow in a unit width of valley, say 1 mile, W is assumed to be 5,280 feet.

Therefore:

$$2.\ Q = 300{,}000 \times \frac{10}{5{,}280} \times 5{,}280$$

Q=3,000,000 gallons per day per mile width of valley.

The underflow through each mile of width of the valley is about 3 million gallons a day. The regional cone of depression, developed by pumping, will continue to expand until the quantity of water crossing its outer limits plus recharge occurring within its outer limits equals the quantity of water being pumped. The regional cone of depression could extend across the full 3-mile width of valley in the vicinity of the north end of Columbus and might intercept as much as 9 million gallons a day of underflow.

Although recharge from the streams may not occur south of 25th Street, because of a relatively local lense of impermeable material along Haw Creek, it is believed that recharge from Haw Creek and from Flatrock Creek can occur either directly or indirectly in the area north of 25th Street. As the cone of depression develops, it will eventually reach the area where recharge can be induced from the streams. The amount of induced recharge will be dependent on the location and operation of wells causing the necessary lowering of water levels.

The storage capacity of the ground-water reservoir in the Columbus area is sufficiently large that ground water can be pumped from storage over a long period of time during droughts or periods of little or no recharge. The lowering of water levels by pumping from storage will provide additional storage space for recharge during the winter and spring months.

At the present time, a large quantity of ground water is draining naturally into the streams because the ground-water reservoir is already full.

The full development of a regional cone of depression will increase the hydraulic gradients through the 3-mile cross section of the valley at the north end of Columbus and therefore will greatly increase the available underflow.

The safe yield of the ground-water reservoir in the Columbus area is made up of the underflow across the 3-mile section at the north end of Columbus plus additional recharge that can be induced from the streams north and perhaps south of 25th Street, plus additional underflow that may be obtained by increasing the hydraulic gradients. The safe yield is believed to be in excess of 15 million gallons a day and might be considerably more, if ground-water levels were lowered by pumping properly located wells. The available recharge appears to be greatly in excess of 15 million gallons a day in the valley area tributary to the Columbus area.

Summary and Conclusions:

The deposits of sand and gravel in the Columbus area are large underground reservoirs in which large quantities of water are stored. It is estimated that about 25 million gallons of water are stored in each square mile of the outwash deposits for each foot thickness of material. The storage capacity of the reservoir is sufficient to allow pumping water from storage during periods of extended drought. The specific yield of these deposits is about 12 percent as determined from pumping tests.

Although the pumping tests showed no evidence of direct recharge from Haw Creek in the immediate vicinity of the well, the unusual increase in stream flow in Flatrock River and Haw Creek in the area north of Columbus suggests the existence of a hydraulic connection between the streams and the ground-water reservoirs.

The lack of recharge in the immediate vicinity of the well field may be due primarily to a relatively local lense of clayey sand, found in test well T-2 between depths of 3 and 18 feet and in City Well 4 between depths of 4 and 12 feet. It was not reported in wells T-1 or T-3 and probably extends as a narrow strip along Haw Creek at about creek-level. It is believed therefore that induced recharge can occur when the cone of depression around the proposed well field extends beyond the limits of the clay lense.

The coefficient of transmissibility of the deposits of sand and gravel was determined to be about 300,000 gallons per day per foot. The underflow moving southward toward the Columbus area, under the existing hydraulic gradients is about 3 million gallons a day per mile width of valley. As pumping in the Columbus area is increased, a regional cone of depression will be developed, which will continue to expand until the quantity of water crossing its outer limits plus recharge occurring within its limits is equal to the quantity of water being pumped. When the cone of depression has expanded across the full 3-mile width of the valley, it may be impossible to intercept about 9 million gallons a day under the existing hydraulic gradients.

It is believed that ground-water conditions in the Columbus area are favorable for the development of municipal and industrial ground-water supplies up to 15 million gallons a day. Observation wells, however, should be established and maintained and measurements of water level should be made to determine long time trends in ground-water levels. Such records will provide the well-owners in the Columbus area with a fore-warning of continued decline in water levels and possible overdevelopment.

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Appendix A.

Records of wells in the Columbus Area Bartholomew County, Indiana

Well-numbering system

In order to facilitate reference to the individual well, each well isassigned a number that indicates its geographic position within one square mile. The numbers of all wells in Bartholomew County are preceded by the prefix Ba, indicating the county in which they are located. Each township or part of a township as established by the Public Lands Survey is given a letter starting with A in the northwestern part of the County and following consecutively across the northern tier of townships. The letter takes the place of the township and range designation.

The third part of the well number indicates the section within the township and the fourth part indicates the well or well field. A fifth part, when used, indicates the number of the well used by the owner. Test wells are indicated by the letter T.

Well number	B aB21-1	G-BaD15-1	BaF23-1	BaF24-1-1	BaF24-1-2
Location	SE¼SE¼ sec. 21 T.10 N. R. 5 E.,at Valley Mills	NE¼NE¼ sec. 15, T. 10 N., R. 7 E.	NE¼SE¼sec. 23, T. 9 N., R. 5 E., at Sandy Point Cabin	NE¼NW¼ sec. 24 14th and Washington Streets	NE¼NW¼ sec. 24 14th and Washington Streets
Owner	Valley Mills	Frank Fishel #1	City of Columbus	Reliance Mfg. Co.	Reliance Mfg. Co.
Driller	C. C. Anderson	Haw Creek Oil and Gas Co.	Layne-Northern Co.	H. H. Fox	Bannister
Date drilled	___	August 1940	June 1940	_____	___
Altitude above sea level (feet)	___	___	611±	622±	622±
Depth (feet)	82	1476	35	1100	96
Diameter (inches	___	8-6 5/8	6	___	5
Water level below land surface(feet) Date	___	___	___	___	3
Yield and use	___	Oil or gas test	Test well #2	Mineral Water	Not in use
Remarks	___	Dry hole	___	___	Low in mineral content. Well water preferable to city water for boiler use.
Log	Earth 0-10 Black shale 10-80 Lime stone 80-82	Clay 0-16 Lime16-84 Shale 84-86 Lime and stone 86-275 Shale 275-880 Trenton 880-1100 Lime 1100-1460 St. Peter sandstone 1460-1476	Soil andsand 0-8 Gravel 8-27 Clay 27-35 Clay		

Well number	B aF24 -5	BaF24-6	BaF24-7	BaF24-8	BaF24-9
Location	SE¼SW¼ sec. 24 northwest corner of 5th and Washington Streets	SE¼SW¼ sec. 24 southwest corner of 5th and Washington Streets	SW¼SE¼ sec. 24 317 Washington Street	NE¼SW¼ sec. 24 816 Jackson Street	SE¼SW¼ sec. 24 522 Jackson Street
Owner	W. W. Mooney and Sons	Irwin-Union Bank	Mode Theater	Butler-Kist Bottling Co.	Dunlap and Co.
Driller	H. H. Fox	H. H. Fox	H. H. Fox	Elliott Brøs	—
Date drilled	—	—	—	1930	1900
Altitude above sea level (feet)	625±	625±	630±	625±	625±
Depth (feet)	—	200+	200	122	300-400
Diameter (inches)	—	6	10	5 5/8	4
Water level below land surface (feet) Date	—	—	—	6	—
Yield and use	—	20gpm	25 gpm Cooling	—	Domestic
Remarks	"Well no good"	—	Water probably from bedrock abandoned.	Water from bedrock "sulphur water"	Water from bedrock
Log	—	Black slate 0-30 Limestone 30-200+	—	—	—

Well number	BaF24-10	BaF25-1-1	BaF25-1-2	BaF25-1-3	BaF25-1-4
Location	SE¼SE¼ sec. 24	NW¼NW¼ sec. 25 300 feet west of river	NW¼NW¼ sec. 25 150 feet ± W. of river	NW¼NW¼ sec. 25 West bank of river	NW¼NW¼ sec. 25 East bank of river
Owner	Farmer's Market Association	—	—	—	—
Driller	—	Ind St.Hwy. Comm	Ind. St. Hwy. Comm	Ind. St. Hwy. Comm	Ind. St. Hwy. Comm
Date drilled	—	1947	1947	1947	1947
Altitude above sea level (feet)	630 ±	606.5	604.7	605.5	607.4
Depth (feet)	100	12	10	12	12
Diameter (inches)	6	—	—	—	—
Water level below land surface (feet)	9.03 m	—	—	—	—
Date	October 14, 1948				
Yield and use	Abandoned	Test pit	Test pit	Test pit	Test pit
Remarks	Has not been used in about 20 years	—	—	—	—
Log	—	Clay 0-3 Sand 3-6 Probably sand 6-12	Probably sand 0-6 Probably sandy clay 6-10	Probably sand 0-12	Sandy clay 0-5 Unknown 5-6 Sandy blue clay 6-9 Probably sand 9-12

Well number	BaF25-2	BaF25-3-1	BaF25-3-2	BaF25-4	BaF25-5
Location	NW¼NE¼ sec. 25 429 First Street	NW¼NE¼ sec. 25 542 Third Street	NE¼NE¼ sec. 25 542 Third Street	NE¼NE¼ sec. 25 155 yds. east from south end of Lafayette Street	NE¼SW¼ sec. 25 ½mi. south and ¼ mi. east of river bridge on U.S. 31
Owner	Public Service Co. of Indiana	Serv-Ice and Coal Co.	Serv.-Ice and Coal Co.	City of Columbus	City of Columbus
Driller	H. R. Lamb	—	H. H. Fox	Layne-Northern Co.	Layne-Northern Co
Date drilled	August 1936	1915	1945	June 1940	June 1940
Altitude above sea level (feet)	620 ±	620 ±	620±	610 ±	611±
Depth (feet)	205	50	47	66	69
Diameter (inches)	8	16	16	6	6
Water level below land surface(feet)	—	35	—	6	8
Date	—	1936	—	June 2, 1940	June 10, 1940
Yield and use	50 gpm Cooling	150-75gpm Cooling	250 gpm Cooling	—	—
Remarks	—	Well abandoned	—	Test well 4	Test well 3
Log	Soil and clay 0-6 Hardpan 6-18 Sand, gravel 18-19 Blue clay 19-41 Sand, gravel 41-50 Shale 50-102 Gray limestone 102-135 Dark brown stone 135-205 Water at 44,160 T75	—	—	Soil, clay 0-5 Gravel 5-53 Clay and gravel 53-66 Shale	Soil, sand 0-8 Gravel 8-37 Clay 37-60 Coarse sand 60-64 Clay 64-69 Shale

Well number	BaF25-6	BaG5-1-1	BaG5-1-2	BaG7-1-T6	BaG17-1-T 3
Location	NE¼NE¼ sec. 25 100 ft. south of Franklin Street	SW¼SW¼ sec. 25 182 ft. east of main camp road and 200' south of T Street.	SW¼SW¼ sec. 25 400 ft. north well BaG5-1-1	SE¼SW¼ sec. 7 on Locust Dr. 100± ' west of Spruce St.	NE¼SW¼ sec. 17 45' south of 25th St. 47 feet west of east side of Midway St.
Owner	Columbus Dog Pound	Camp Atterbury	Camp Atterbury	City of Columbus	City of Columbus
Driller	Mr. B arrows	H. H. Fox	H. H. Fox	Layne-Northern Co.	Layne-Northern Co.
Date Drilled	1948	1942(?)	1942 (?)	January 1950	December 1949
Altitude above sea level (feet)	615±	650±	650±	—	—
Depth (feet)	41	103-90	77	119	628.6
Diameter (inches)	6	6	6	6	6
Water level below land surface(feet)	18	18	9	12.5	9
Date	1948	1942	1948	January, 1950	January, 1950
Yield and Use	Stock	200 gpm Camp supply	200 gpm Camp supply	Test	Test
Remarks	Driven by hand	20 ft. screen 70-94 ft.	20 ft. screen 57-77 ft.	Top soil 0-3 Sandy clay 3-11 Sand, gravel 11-49 Sand, gravel clay balls 49-52 Sand-gravel 52-86 Clay 86-98 Sand,gravel 98-114 Clay strips 114-116 Limestone 116-119	Pilot point set at 84 feet Top soil 0-5 Gravel and sand 5-52 Gravel 52-98 Limestone 98+

Well number	BaG18-1-1	BaG18-1-2	BaG18-1-T1	BaG18-1-T2	BaG18-1-T4
Location	NE¼SE¼ sec. 18 Haw Creek Ave. and 25th St.	NW¼SE¼ sec. 18 Haw Creek Ave. and 25th St.	NE¼SE¼ sec. 18 50'S of 25th St. 370' E. of Haw Creek Ave.	NE¼SE¼ Sec. 18 50' S. of 25th St. 200' W of Park Road	SE¼SE¼ sec. 18 220' E. of Haw Creek Ave. and 75' S. of 20th St
Owner	City of Columbus	City of Columbus	City of Columbus	City of Columbus	City of Columbus
Driller	Layne-Northern Co.	Layne-Northern Co.	Layne-Northern Co.	Layne-Northern Co.	Layne-Northern Co.
Date Drilled	October 1947	November 1947	December 1949	December 1949	December 1949
Altitude above sea level (feet)	630±	630±	638.6	636.2	628.9
Depth (feet)	132	128	125	121	120
Diameter (inches)	6	38-18	6	6	6
Water level below land surface feet Date	20 October 1947	18 November 1947	18 December, 1949	18 December, 1949	12 December, 1949
Yield and Use	Test well 5	1500 gpm Public [illegible] Supply	Test	Test	Test
Remarks	Top soil 0-5 Sand,gravel 5-45 Med. gravel 45-50 Med. sand 50-65 Coarse gravel,sand 65-128 Sandy clay 128-132 Limestone	Same as log of BaG18-1-1	Sandy clay 0-5 Sand,gravel 5-46 Clay,gravel 46-47 Coarse gravel 47-52 Clay strips 52-53 Coarse gravel,sand 53-114 Muddy gravel,sand 114-125 Limestone 125+	Top soil 0-3 Yellow clay 3-8 Gravel,clay 8-18 Gravel,sand 18-35 Coarse sand 35-50 Gravel sand 50-108 Gravel,sand,muddy 108-118 Sand,gravel 118-120½ Limestone 120½-121+	Top soil 0-2 Sandy clay 2-5 Gravel,sand 5-25 Muddy sand,gravel 25-30 Sand, gravel 30-120 Limestone-120+

Well number	BaG18-1-T5	BaG18-3	BaG18-4	BaG18-5	BaG18-6
Location	NE¼SE¼ sec. 18 700 ft. east of Haw Creek Ave., on center of 21st st. extended	SE¼SW¼ sec. 18 Orinoco Plant	NE¼SW¼ 1804 22nd st.	SE¼SE¼ sec. 18 17th and Meridian St.	NE¼SE¼ sec. 18 25th and Brookside
Owner	City of Columbus	Noblitt-Sparks Co.	V. E. Sprouse	Bartholomew Co. Hospital	City of Columbus
Driller	Layne-Northern Co.	H. H. Fox			
Date Drilled	December 1949	1941-1942	1925		
Altitude above sea level (feet)	626.6	635±	—	635±	625±
Depth (feet)	105	71 m	52 m	25	—
Diameter (inches)	6	6	6	1¼	1½
Water level below land surface (feet)	8½	25.43	17.40	—	—
Date	December 1949	Oct. 14, 1948	Oct. 14, 1948	—	—
Yield and Use	Test	Abandoned	Abandoned	Not in use	Abandoned
Remarks					
Log	Top soil 0-3 Gritty clay 3-9 Muddy sand, gravel 9-25 Rusty sand, gravel 26-30 Sand, gravel 30-97 Muddy sand 97-103 Sandy clay 103-104 Limestone 104-105				

Well number	BaG19-1	BaG19-1-4	BaG19-1-T7	BaG19-1-T8
Location	SE¼NE¼ sec. 19 13th and Brookside	NW¼SW¼ sec. 19 On south line of 23rd st. extended 150± west of Haw Creek	NW¼SW¼ sec. 19 On south line of 23rd st. extended, 280' west of Haw Creek	NW¼SW¼ sec. 19 On south line of 23rd St. extended 280' west of Haw Creek
Owner	City of Columbus	City of Columbus	City of Columbus	City of Columbus
Driller	Layne-Northern Co.	Diehl Pump and Supply Co.	Diehl Pump and Supply Co.	Diehl Pump and Supply Co.
Date Drilled	June, 1940	August 1950	September, 1940	September, 1950
Altitude above sea level (feet)	625±	635	632.2	633
Depth (feet)	86	98	36	43
Diameter	6	12	6	6-1¼
Water level below land surface(feet)	7	17	11.7	12.1
Date	June, 1940	September,1950	September, 1950	September, 1950
Yield and Use	Test well 1	Supply well	Test	Test
Remarks	Soil, dirt 0-15 Fine gravel 15-50 Med. gravel 50-67 Fine gravel 67-77 Med. gravel 77-84 Hard clay 84-86	Top soil 0-4 Sand and clay 4-12 Sand and gravel 12-43 Sand 43-51 Gravel and sand 51-98 Rock 98+		

Well number	BaG19-2-1	BaG19-2-2	BaG19-2-3	BaG19-3-1	BaG19-3-2
Location	NW¼NE¼ sec. 19 Central Ave. Plant 17th and Central	NW¼NE¼ sec. 19 17th St. Plant 17th and Central	SE¼NW¼ sec. 19 13th St. Plant 1531 13th St.	SW¼NW¼ sec. 19 13th and Michigan Streets	SW¼NE¼ sec. 19 13th and Michigan Streets
Owner	Noblitt-Sparks Co	Noblitt-Sparks Co.	Noblitt-Sparks Co.	Morgan Packing Co.	Morgan Packing Co.
Driller	H. H. Fox	H. H. Fox	H. H. Fox	H. H. Fox	H. H. Fox
Date Drilled	1940-1945	1941-1942	1943	1936	—
Altitude above sea level (feet)	631±	630±	632±	632±	632±
Depth (feet)	108	—	—	80	60-109
Diameter (inches)	10	12	8	10-6	6-10
Water level below land surface(feet) Date	—	—	—	—	—
Yield and use	500 gpm Ind.	—Ind.	—Ind.	930-1000 gpm, Ind. and cooling	500-1000 gpm, Ind. and cooling
Remarks	—	—	—	Used only about 6 weeks per year	Used only about 6 weeks per year
Log	—	—	—	Gravel	Gravel

Well number	BaG19 -4-1	BaG19-4-2	BaG19-5	BaG19-6	BaG19-7
Location	SE¼NW¼ sec. 19 13th and Cottage Avenue	SE¼NW¼ sec. 19 13th and Cottage Avenue	SW¼NW¼ sec. 19 1428 10th Street	NW¼SW¼ sec. 19 1225 7th Street	SW¼SW¼ sec. 19 1138 5th Street
Owner	Golden Foundry	Golden Foundry	Lewellen Mfg. Co.	Reeves Pulley Co.	Cummins Engine Co
Driller	H. H. Fox	H. H. Fox	—	—	H. H. Fox
Date Drilled	—	—	—	—	1946
Altitude above sea level (feet)	632±	632±	632±	628±	630±
Depth (feet)	100	100–90	20	20	85
Diameter(inches)	6	8	1½	2	6
Water level below land surface (feet) Date	—	—	—	—	$ April 1946
Yield and use	—Ind.	—Ind.	5 gpm (?) Ind.	25 gpm, Ind.	325 gpm, Ind.
Remarks	—	—	Driven well	Driven well	Total hardness 343 ppm Iron and aluminum. oxides 5.5 ppm SiO_2 11.5 ppm.
Log	Gravel 0-100	Gravel 0-100	—	—	Cinderfill 0-3 Yellow gravel 3-44 Fine gray sand 44-50 Coarse gravel 50-65 Med. gravel 65-85 Shale

Well number	BaG19-8-1	BaG19-8-2	BaG30-1-1	BaG30-1-2	BaG30-1-3
Location	NE¼NW¼ sec. 19 1603 Cottage Ave.	NE¼NW¼ sec. 19 1603 Cottage Ave.	NW¼NW¼ sec. 30 East Columbus 660 Belmont	NW¼NW¼ sec. 30 660 Belmont	NW¼NW¼ sec. 30 660 Belmont
Owner	Hamilton Mfg. Co.	Hamilton Mfg. Co.	Stadler Packing Co.	Stadler Packing Co.	Stadler Packing Co.
Driller	Charles Critzer	—	H. H. Fox	H. H. Fox	H. H. Fox
Date Drilled	1946	—	—	1940	1946
Altitude above sea level (feet)	635±	635±	620±	620±	620±
Depth (feet)	90	30	50	55	80
Diameter (inches)	6	1¼	8	8	12
Water level below land surface (feet) Date	—	—	—	—	—
Yield and use	400 gpm, Ind.	—Ind.	—Ind.	350-375 gpm, Ind.	500 gpm, Ind.
Remarks	—	There are 3 driven wells equipped with small pumps	—	Water high in iron, Total hardness 240 ppm.	
Log	—	—	—	—	Sand and gravel 0-95 Stone and sulphur water at 95 ft.

Well number	BaG30-1-4	BaG30-2-1	BaG30-2-2	BaK13-1	BaK15-1
Location	NW¼NW¼ sec. 30 660 Belmont	NW¼NW¼ sec. 30 1136 2nd Street	NW¼NW¼ sec. 30 1136 2nd Street	SW¼SW¼ sec. 13 T. 8 N., R. 6 E., Elizabethtown	SE¼SE¼ sec. 15, T. 8N., R. 6 E., near Elizabethtown
Owner	Stadler Packing Co	Farmer's Market Assoc.	Farmer's Market Assoc.	Town of Elizabeth-town	H. H. Trent
Driller	H. H. Fox	H. H. Fox	Charles Bay	Harry Anderson	Harry Anderson
Date Drilled	1946	1947	1933	1898	1905
Altitude above sea level (feet)	620±	622±	622±	646	—
Depth (feet)	40	100	100	105	65
Diameter (inches)	6	12	6	5 5/8 to 4 1/4	5 5/8
Water level below landsurface(feet)	—	15	—	40	—
Date		1947		1898	
Yield and use	Ind.	300 gpm., Ind.	Ind.	Public supply	50 gpm, Domestic
Remarks	—	High in iron	Low in iron, high in sulphur	Probably high in iron	—
Log	—	—	—	Clay 0–60 Gravel 60–65 Limestone	Clay and sand 0–25 Quicksand 25–30 Hardpan 30–38 Blue clay 38–45 Black shale 45–60 White limestone 60–62 Dark limestone 62–65 Water at 65

INDIANA

STATE BOARD OF HEALTH

BUREAU OF SANITARY ENGINEERING

201 State House Annex
Indianapolis, Indiana June 17, 1940

REPORT OF THE SANITARY EXAMINATION OF WATER

C. R. Merrick
c/o Layne-Northern Company
3712 Brill Street
Indianapolis, Indiana

Description of sample

Lab. No. C 448

#1 Test Well-Golf Course, Columbus, Indiana

Date Collected 6-8-40

PHYSICAL AND CHEMICAL DATA

Color	15
Sediment	Slight
Turbidity	15.
Nitrite	.001
Nitrate	0.0
Iron	1.6
Chloride	1
Alkalinity	260
Total Hardness	291
pH	7.4

All results in parts per million, except pH.

Analysis of water from 6-inch well, 85 feet deep, at Cummins Engine Co. plant, 1138 5th Street, Columbus, Indiana made by Pittsburg Testing Laboratories, Inc., January 21, 1946.

Total Hardness as $CaCO_3$	343 ppm.
Carbonate ion	nil
Bicarbonate ion	316 ppm.
Silica	12 ppm.
Aluminum and Iron Oxides	5.5 ppm.
Calcium as $CaCO_3$	207 ppm.
Magnesium as $CaCO_3$	115 ppm.

FREDERICK C. ATKINSON, INC.

Chemical Engineers and Technologists

213 East South Street

INDIANAPOLIS

October 25th
1947

Refer: Water from Test
Well No. 5,
Columbus, Ind.
Depth 128 feet.
October 2nd, 1947

Layne-Northern Company
227 West Edwards
Indianapolis 44, Indiana

Gentlemen:

Your sample of WELL WATER identified as above shown has been analyzed and we report our findings, as follows:

pH Value	7.6	
Dissolved Carbon Dioxide	5	Parts per million
Dissolved Oxygen	1.8	"
Iron	0.7	"
Alkalinity as Calcium Carbonate (MO)	245	"
Silica	14.8	"
Alumina	19.2	"
Calcium Oxide	95.0	"
Magnesium Oxide	45.8	"
Alkalis, as Sodium Oxide	6.7	"
Chlorides, as Cl	7.7	"
Sulphates, as SO_3	22.8	"
Carbonates, as CO_2	104.3	"

Hypothetical Combinations, in grains per gallon:

Silica		0.863 gr/gal
Oxide of Iron and Alumina		1.178 "
Calcium Bicarbonate	15.70	"
Equivalent to $CaCO_3$		9.698 "
Magnesium Bicarbonate	6.360	"
Equivalent to $MgCO_3$		3.674 "
Magnesium Sulphate		2.408 "
Sodium Chloride		0.741 "
Total Solids		18.562 "
Total Hardness, as $CaCO_3$		16.073 "

Very truly yours,

FREDERICK C. ATKINSON, INC.

FCA/12
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