In Cooperation with the Natural Resources Conservation Service

Ground-Water Data and Flow Directions in the Vicinity of Swamp Road, Licking County, Ohio, 2006–07

Open-File Report 2007–1211

U.S. Department of the Interior
U.S. Geological Survey

Cover image: Flowing conditions at well LI-18 on January 17, 2007. (Photograph by Brian Mailot, U.S. Geological Survey.)

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By Denise H. Dumouchelle

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DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
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Conversion Factors, Abbreviations, and Vertical Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.004047	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Elevation, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

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By Denise H. Dumouchelle

Abstract

The Natural Resources Conservation Service (NRCS) is proposing to build a dry dam on the South Fork Licking River to mitigate flood impacts. Concerns have been raised regarding the effects of impounded floodwaters on ground-water conditions in the Swamp Road neighborhood. To obtain a better understanding of existing ground-water conditions, the U.S. Geological Survey, in cooperation with the NRCS, installed three monitoring wells and collected ground-water–quality samples on two occasions from these and four residential wells. In addition, transducers were placed in these seven wells to obtain hourly water-level measurements from August, 2006 to early March, 2007. Intermittent water levels also were measured in another seven residential wells in the area.

Water-quality samples were collected in September 2006 and January 2007. Samples were analyzed for nutrients, inorganic elements, and fecal-indicator bacteria. In general, the ground-water quality was very hard with large iron concentrations of 1,700 µg/L and above.

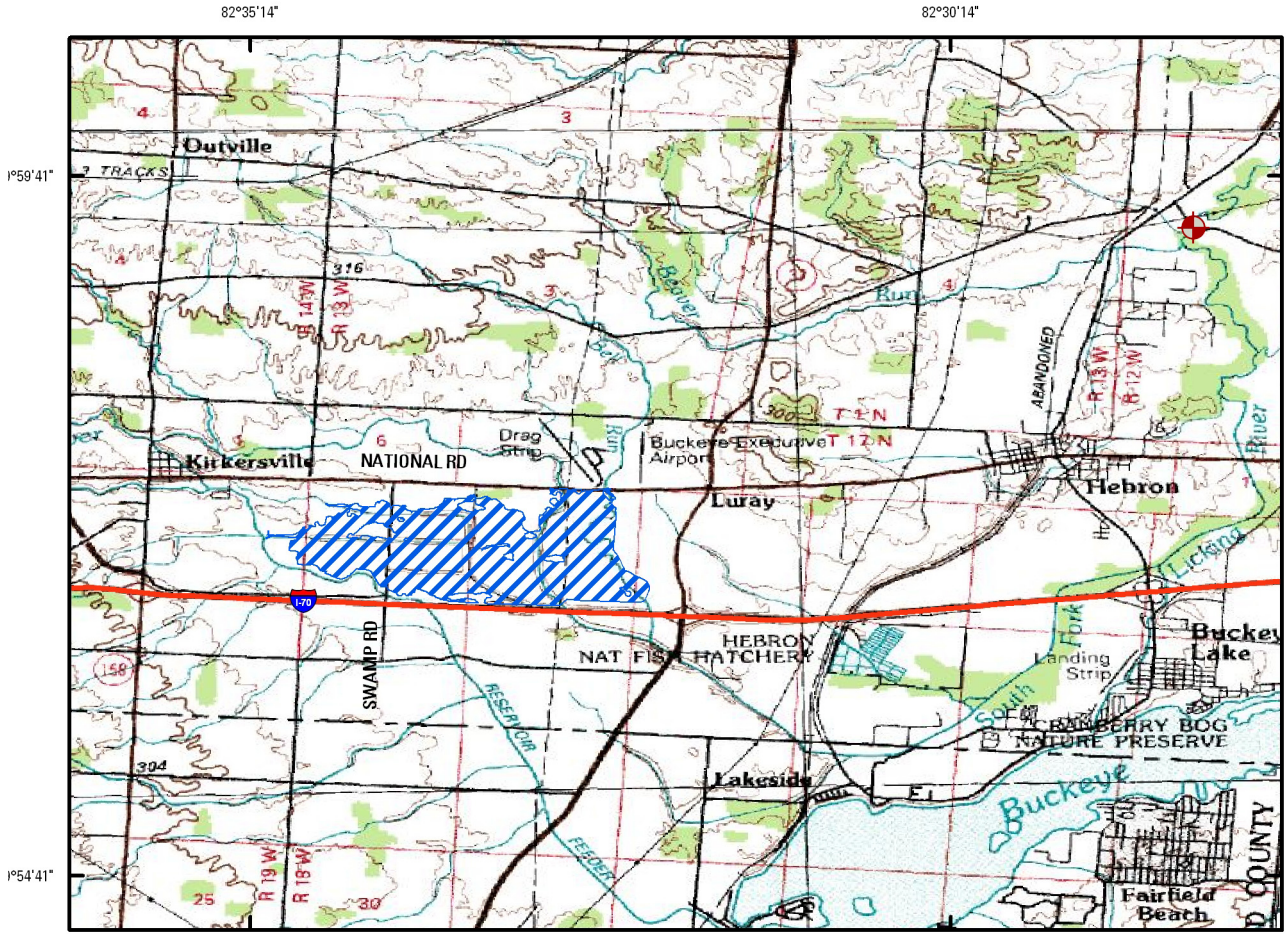
Although the aquifer underlying the Swamp Road area is confined, the continuous water-level records indicate a rapid response to precipitation. Comparison of the well hydrographs with the stage hydrograph for the nearby South Fork Licking River indicates a hydraulic connection between the river and the aquifer. In the vicinity of Swamp Road, the ground-water-flow direction was southeast during the duration of the study. The ground-water-level elevations were above the planned maximum elevation for water impounded by the dam, thus the impounded floodwater should have minimal impact on ground-water conditions along Swamp Road.

Introduction

The Natural Resources Conservation Service (NRCS), a division of the U. S. Department of Agriculture, is proposing to construct a low dam on the South Fork of the Licking River to create a flood detention basin in the Buckeye Lake area (fig. 1) to mitigate flood impacts downstream. The NRCS estimates the inundation area for a 100-year flood would be 907 acres behind the dam, as compared to 763 acres for the 100-year flood with existing conditions (Scott Jerrome, Natural Resources Conservation Service, written commun., 2007). The detention area would store water only during flood conditions. During the planning stages, concerns were raised about the impact of this additional temporary floodwater storage on ground water, residential water wells, and septic systems along Swamp Road (fig. 1), a neighborhood adjacent to the northwestern area of impoundment. A 100-year flood with the dry dam in place would create up to 2.6 ft of additional water column, thus flooding a larger area than what would be flooded without the dam (fig. 2). The NRCS estimates that, in the Swamp Road area, the impounded water would require up to 10 more hours to recede than natural (undammed) floodwaters (Scott Jerrome, oral commun., 2006). To obtain a better understanding of existing ground-water conditions in the area, the U.S. Geological Survey (USGS), in cooperation with the NRCS, collected data to determine the current ground-water-quality characterstics and flow directions.

Purpose and Scope

The purpose of this report is to present data from ground-water samples and water-level measurements collected from selected wells in the vicinity of Swamp Road in Licking County, Ohio. Ground-water flow directions were determined on the basis of the water-level data. During the summer of 2006, three monitoring wells were drilled. Water samples were collected in September 2006 and January 2007 from these wells and from four residential wells, and analyzed for nutrients, inorganic elements, and fecal-indicator bacteria. The water-quality data were collected to provide background data for comparison with any future samples. Transducers for continuous recording of water-levels were installed in the monitoring wells and the four residential wells. Data were collected from late August 2006 until early March 2007. In addition, synoptic water-levels were manually collected in seven additional residential wells in October 2006, January 2007, and March 2007.



Base from U.S. Geological Survey, 2000; scale 1:24,000; Topographic contour is 10 feet.

0 1 2 Miles

0 1 2 Kilometers

EXPLANATION

Stream -gaging station 03145000

Land surface area covered by 100-year flood waters with dry dam, elevation 899.5 ft. Data from Natural Resource Conservation Service

Figure 1. Location of the study area in central Ohio.

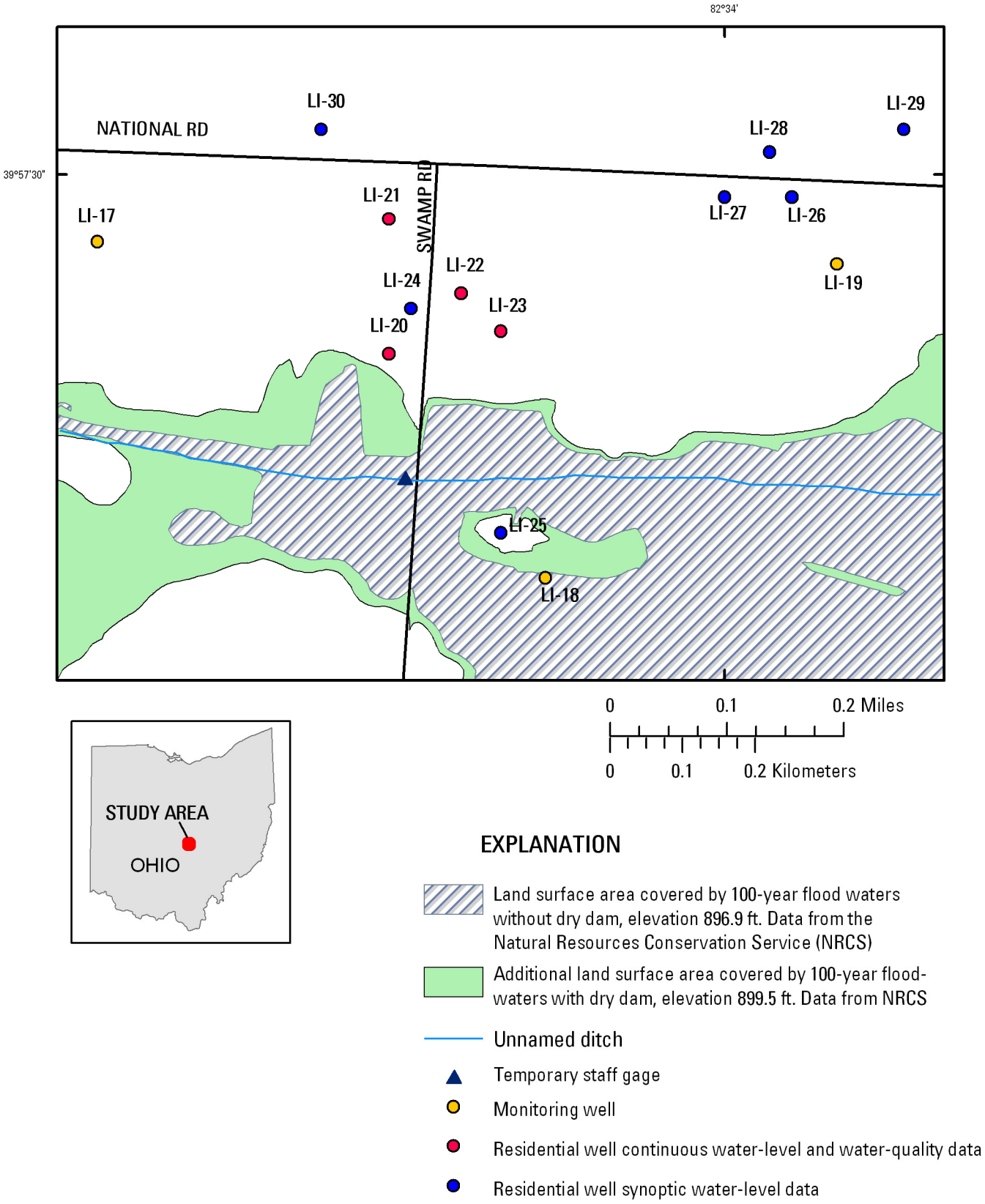


Figure 2. Areas of 100-year flood inundation with and without dry dam and location of wells at the study site.

Description of the Study Area

The study area is in the vicinity of the intersection of Swamp Road and National Road in south-central Licking County (figs. 1 and 2) between Kirkersville and Hebron. The South Fork Licking River, to the north and east of the study site, flows east-southeast. The land use in the Kirkersville-Swamp Road region is mostly agricultural with some rural-residential. Homes are served by residential water wells and leach-line septic systems. Residential wells in the Kirkersville-Swamp Road region are generally from 30 to 60 ft deep although one well is 107 ft deep. The region is underlain by glacial deposits consisting of clay till interspersed with sand and gravel. Residential wells in the region are completed in sand and gravel and the overlying clay generally ranges from about 15 to 50 ft thick.

Methods of Data Collection and Analysis

Three monitoring wells (LI-17, 18, and 19) (fig. 2) were installed with a hollow-stem auger rig by the USGS. The 2-in. diameter PVC-cased monitoring wells have 10-ft long screens. The annular space around the screens was packed with sand and the remaining annular space was sealed with bentonite chips. The wells were completed with a steel, lockable, protective casing set in concrete. Logs for the wells are available from the USGS Ohio Water Science Center upon request.

Drillers' logs for residential wells (Ohio Department of Natural Resources, 2006) were reviewed for geologic information. Four residential wells along Swamp Road were selected for continuous water-level monitoring with pressure transducers (table 1). Seven additional residential wells along Swamp and National Roads were selected for intermittent water-level measurements by hand. The residential wells were selected based on location and access.

The pressure transducers were installed above the residential water-supply pumps and secured to prevent shifting over time. Water levels were recorded hourly and were accurate to 0.04 ft. Synoptic and transducer-calibration water-levels measured manually were made using either a calibrated electric tape or chalked-steel tape. Measurements were accurate to 0.01 ft. Water-level equipment was cleaned by a dilute chlorine-bleach rinse between measurements. The top of each well casing was used as the measuring point. The elevations of the top of the well casings for the 14 wells were surveyed by the NRCS and were reported to .05 ft.

Monitoring well LI-18 periodically would overflow, thus requiring the use of a nonvented transducer to collect water-level data. The water-level data had to be corrected to account for changes in barometric pressure. Barometric-pressure data from the Port Columbus International Airport station (WBAN 14821) were obtained from the National Oceanic & Atmospheric Administration (2007). As a result of the flowing conditions and barometric corrections, the accuracy of the continuous water-level data from this well is less than that of the other transducers. The accuracy is estimated to be between .05 and .1 ft.

A staff gage was temporarily installed at Swamp Road in the ditch (fig. 2). The gage elevation was surveyed by NRCS and was reported to 0.01 ft. The water level in the ditch was periodically recorded. The staff gage was removed at the end of the study.

Water samples from four residential wells and the three monitoring wells were collected for the analysis of nutrients, inorganic elements, and fecal-indicator bacteria. Homeowners of the selected wells gave permission for water-quality sampling and identified exterior household spigots from which untreated water could be drawn. All of the samples from the residential wells were collected from these spigots, as supplied by the existing plumbing and well pumps. Sterile tubing and fittings were connected to the spigots for well and supply line purging and sample collection. For the monitoring wells, the transducers were removed and a portable submersible pump was used for purging and sample collection. Sterile tubing was used for sample collection. The pump was cleaned with soap and deionized water between wells. Monitoring wells were purged of at least three borehole volumes; residential wells, which are in daily use, were purged of one to more than three borehole volumes. During purging, field measurements of pH, specific conductance, dissolved oxygen concentration, and temperature were monitored. Water samples were collected after the field measurements had stabilized. Because LI-18 was flowing at the time of the January sample collection, no purging was necessary; the sample was collected using a peristaltic pump with the sterile tubing placed a few feet down into the casing. Sample collection protocols for the USGS are documented in the National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, 2007).

Water samples were analyzed for nutrient and inorganic elements by the USGS National Water Quality Laboratory in Denver, Colo. The water samples were analyzed for the nutrients ammonia, nitrite, nitrite plus nitrate, total nitrogen, and orthophosphate concentrations. The water samples were analyzed for the inorganic elements calcium, chloride, fluoride, iron, magnesium, manganese, potassium, silica, sodium, and sulfate. The water samples to be analyzed for fecal-indicator bacteria were collected with sterile tubing and bottles. Analyses for bacteria were done at the USGS Ohio Water Microbiology Laboratory, in Columbus, Ohio. Samples were analyzed for total coliforms and *Escherichia coli* (*E. coli*) by use of the membrane-filtration method (U.S. Environmental Protection Agency, 2002).

A duplicate sample and a blank sample were collected for quality-control purposes. These samples were collected to verify that contaminants were not being introduced during sample collection or laboratory methods. The results of the duplicate sample were compared qualitatively with the results

of the field sample; the two samples were comparable (table 2). No analytes were detected in the blank sample (table 2). Procedures for the microbiology quality-assurance/quality-control laboratory procedures are described in Francy and others (2006). Because the portable submersible pump used for the monitoring could not be sterilized, the pump was rinsed thoroughly with sterile water, and then extra blank samples for bacterial analyses were collected to ensure that there was no cross-contamination between well samples. None of the pump blanks yielded any total coliform or *E. coli* bacteria.

Ground-Water-Quality Data

Data for the wells used in this study are listed in table 1; well locations are shown on figure 2. The three monitoring wells, LI-17, 18 and 19, were 37.4, 37.1 and 28.2 ft deep, respectively; the residential wells in the study ranged from 32 to 87 ft deep (table 1). Water samples were collected from the wells LI-17-23 in September 2006 and January 2007.

Water samples from the wells were analyzed for major ions, nutrients, and bacteria. Data from field measurements of pH, specific conductance, and dissolved oxygen concentrations are presented in table 2 with the results of the laboratory analyses. In general, the water sampled was very hard and had high iron concentrations. Water with a hardness of 180 mg/L (of $CaCO_3$) or more is considered very hard (Hem, 1989); all of the samples from wells in this study had hardnesses greater than 300 mg/L, except for the January sample from LI-22, which was less than 1 mg/L. Iron concentrations in samples from the wells in this study ranged from 1,700 to 2,700 µg/L, except for the January sample from LI-22, which had a concentration of 7 µg/L. The secondary maximum contaminant level for iron is 300 µg/L; at concentrations exceeding that level, iron contributes to staining of fixtures and laundry, and water can have a metallic taste (U.S. Environmental Protection Agency, 2007). The significant differences in concentrations of hardness, ammonia, calcium, magnesium, manganese, sodium, and iron in the two samples at LI-22 are due to water treatment. The January sample was unintentionally collected from an exterior spigot that received softened water from the household treatment system.

Table 1. Well data from wells in the vicinity of Swamp Road, Licking County, Ohio.

[Measuring point was the top of the well casing; elevation datum is the North American Vertical Datum of 1988; bls, below land surface; M, monitoring well; T, continuous water-level data; R, residential well; S, synoptic water-level data; --, unknown; na, not applicable]

Well number	Measuring point elevation (feet)	Depth (feet, bls)	Approximate thickness of clay layer[1] (feet)	Type	Transducer installed
LI-17	922.22	37.4	28	M-T-S	08-21-06
LI-18	900.35	37.1	32	M-T-S	09-20-06
LI-19	914.60	28.2	20	M-T-S	08-22-06
LI-20	909.69	47	37	R-T-S	08-28-06
LI-21	915.43	47	35	R-T-S	08-22-06
LI-22	919.09	50	28	R-T-S	08-25-06
LI-23	916.03	60	29	R-T-S	08-25-06
LI-24	914.20	55	-- [2]	R-S	na
LI-25	901.30	54	45	R-S	na
LI-26	914.10	32	28	R-S	na
LI-27	914.91	31.5	28.5	R-S	na
LI-28	915.40	--	--	R-S	na
LI-29	911.56	87	75	R-S	na
LI-30	917.70	51	30	R-S	na

[1] Based on drillers' logs, this layer is the first unit recorded on the log and may contain silt, sand, or gravel, but is predominantly clay.

[2] The driller's log records 13 feet of topsoil, followed by gritty gravel, then sand and gravel.

Table 2. Results of the analyses of water samples from wells in the vicinity of Swamp Road, Licking County, Ohio, for water-quality characteristics.

[NTU, nephelometric turbidity units; mg/L, milligrams per liter; deg C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; evap, evaporation; N, nitrogen; P, phosphorus; -- no data; E. coli, *Escherichia coli*; col/100 mL, colonies per 100 milliliters; E, estimated; <, less than; bolded text indicates analyses were from treated (softened) water]

Well number	Date	Turbidity field (NTU)	Dis-solved oxygen (mg/L)	pH, field	Specif. conduc-tance, lab (µS/cm 25 deg C)	Hardness (mg/L as $CaCO_3$)	Calcium (mg/L)	Magnes-ium (mg/L)	Potas-sium (mg/L)	Sodium (mg/L)	Alkalinity, field (mg/L as $CaCO_3$)	Bicar-bonate, field (mg/L)
LI-17	09-12-06	3.5	0.3	7.2	674	340	85	32	1.4	9.0	255	311
	01-17-07	.8	.3	7.5	675	340	85	31	1.3	9.6	262	319
LI-18	09-12-06	30	.2	7.4	671	320	76	32	2.0	16	266	324
	01-17-07	.1	.2	7.5	678	330	80	32	1.9	17	296	360
LI-19	09-13-06	.6	.2	7.3	902	430	110	39	1.6	17	280	341
	01-17-07	1.9	.4	7.5	886	420	110	38	1.5	18	284	345
LI-20	09-11-06	.2	.6	7.3	727	360	88	33	1.6	12	262	319
	01-18-07	.6	.2	7.4	737	370	90	34	1.7	12	278	338
LI-21	09-11-06	.7	.4	7.4	738	380	94	36	1.4	8.4	316	384
	01-18-07	.4	.2	7.4	757	380	95	35	1.4	8.7	312	380
LI-22	09-13-06	.4	.2	7.4	719	350	87	33	1.5	11	272	331
	01-18-07	**.1**	**.2**	**7.5**	**769**	**0.650**	**.16**	**.06**	**.18**	**180**	**289**	**351**
Duplicate	01-18-07	**.1**	**.2**	**7.5**	**766**	**--**	**.15**	**.06**	**.15**	**180**	**280**	**340**
LI-23	09-11-06	14	3.7	7.4	721	350	85	35	1.8	17	267	325
	01-18-07	3.5	.7	7.4	722	340	83	32	1.7	17	286	348
Blank	09-12-06	--	--	--	3	--	E.01	<.01	<.16	<.20	--	--

Table 2. Results of the analyses of water samples from wells in the vicinity of Swamp Road, Licking County, Ohio, for water-quality characteristics—Continued.

[NTU, nephelometric turbidity units; mg/L, milligrams per liter; deg C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; evap, evaporation; N, nitrogen; P, phosphorus; -- no data; E. coli, *Escherichia coli*; col/100 mL, colonies per 100 milliliters; E, estimated; <, less than; bolded text indicates analyses were from treated (softened) water]

Well number	Date	Carbonate, field (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Sulfate (mg/L)	Residue on evap at 180 deg C (mg/L)	Ammonia as N (mg/L)	Nitrite plus nitrate as N (mg/L)	Nitrite as N (mg/L)	Total nitrogen (mg/L)
LI-17	09-12-06	0.0	15	0.68	15	82	421	0.26	E0.03	<0.002	0.29
	01-17-07	.6	17	.73	15	82	425	.26	<.06	<.002	.30
LI-18	09-12-06	.0	12	1.2	15	74	410	.42	<.06	<.002	.46
	01-17-07	.7	13	1.2	16	75	421	.41	<.06	<.002	.47
LI-19	09-13-06	.0	74	.56	16	83	541	.25	E.03	<.002	.28
	01-17-07	.7	71	.61	16	84	527	.24	<.06	<.002	.30
LI-20	09-11-06	.0	27	.62	15	83	447	.32	<.06	<.002	.33
	01-18-07	.4	28	.64	16	86	467	.31	<.06	E.001	.37
LI-21	09-11-06	.0	18	.78	15	83	466	.29	<.06	<.002	.31
	01-18-07	.7	20	.82	15	84	465	.28	<.06	<.002	.35
LI-22	09-13-06	.0	19	.70	15	88	434	.31	<.06	<.002	.35
	01-18-07	**.6**	**18**	**.74**	**15**	**87**	**464**	**E.01**	**<.06**	**<.002**	**E.04**
Duplicate	01-18-07	**.6**	**18**	**.76**	**15**	**87**	**463**	**E.01**	**<.06**	**<.002**	**.07**
LI-23	09-11-06	.0	18	.66	16	87	461	.40	<.06	<.002	.40
	01-18-07	.5	18	.71	15	88	468	.37	<.06	<.002	.44
Blank	09-12-06	--	--	<.20	<.10	<.04	<.18	<10	<.010	<.06	<.002

Table 2. Results of the analyses of water samples from wells in the vicinity of Swamp Road, Licking County, Ohio, for water-quality characteristics—Continued.

[NTU, nephelometric turbidity units; mg/L, milligrams per liter; deg C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; evap, evaporation; N, nitrogen; P, phosphorus; -- no data; E. coli, *Escherichia coli*; col/100 mL, colonies per 100 milliliters; E, estimated; <, less than; bolded text indicates analyses were from treated (softened) water]

Well number	Date	Orthophos-Phate. as P, (mg/L)	E. coli (col/100 mL)	Total coliform (col/100 mL)	Iron (µg /L)	Manganese (µg /L)
LI-17	09-12-06	E0.006	<1	>80	2,400	19
	01-17-07	.008	<1	E5	2,300	16
LI-18	09-12-06	E.006	E1	34	2,200	20
	01-17-07	.006	<1	<1	2,200	15
LI-19	09-13-06	.009	<1	E2	2,700	26
	01-17-07	.007	<1	E2	2,500	20
LI-20	09-11-06	.007	<1	E11	2,400	15
	01-18-07	.007	<1	<1	2,500	15
LI-21	09-11-06	E.006	<1	E1	2,400	18
	01-18-07	E.006	<1	<1	2,400	19
LI-22	09-13-06	.007	<1	<1	2,200	15
	01-18-07	**.007**	**<1**	**<1**	**7**	**<.2**
Duplicate	01-18-07	**E.010**	**<1**	**<1**	**6**	**<.2**
LI-23	09-11-06	E.005	<1	<1	2,200	19
	01-18-07	.006	<1	<1	1,700	19
Blank	09-12-06	<.006	--	--	E4	<.6

Ground-Water-Level Data

Transducers were installed during August 2006, with the exception of well LI-18. Because of periodic flowing conditions, a nonvented transducer was needed at LI-18; it was installed on September 20. Water-levels were recorded hourly. The transducers were removed on March 8, 2007.

Hydrographs of the continuous water-level data from the transducers are shown in figure 3. The hydrographs are similar to each other. The water levels in the monitoring wells, LI-17, 18, and 19, are less variable than those of the residential wells, LI-20, 21, 22, and 23, because the monitoring wells are not pumped for water supply. The periodic pumping from the residential wells is evident on the graphs as vertical lines that indicate rapid drops in the water level. The water levels quickly recover from any pumping, as shown by the immediate return to the initial water level. The similarity of the hydrographs for wells LI-17 and LI-19 to those of the residential wells shows that long-term monitoring of water levels in either of these monitoring wells would adequately represent water levels in the residential wells along Swamp Road.

The peaks on the hydrograph for well LI-18 are subdued with respect to those for the other wells (fig. 3). Water in well LI-18 occasionally overflows the top of the well casing, which is 3.53 ft above the land surface (see front cover photo). The water level measured in the well actually is recorded by the transducer as the pressure head, which is the weight of the water plus atmospheric pressure, above the device; when the well overflows, the pressure is reduced (i.e., the water column is shorter than it would be if the well did not overflow) as the water is released, thus resulting in the subdued peaks of the hydrograph. Due to ice in the well, data collected after February 7, 2007, were unusable; the stainless-steel wire thread holding the transducer was snapped by ice sometime after this date.

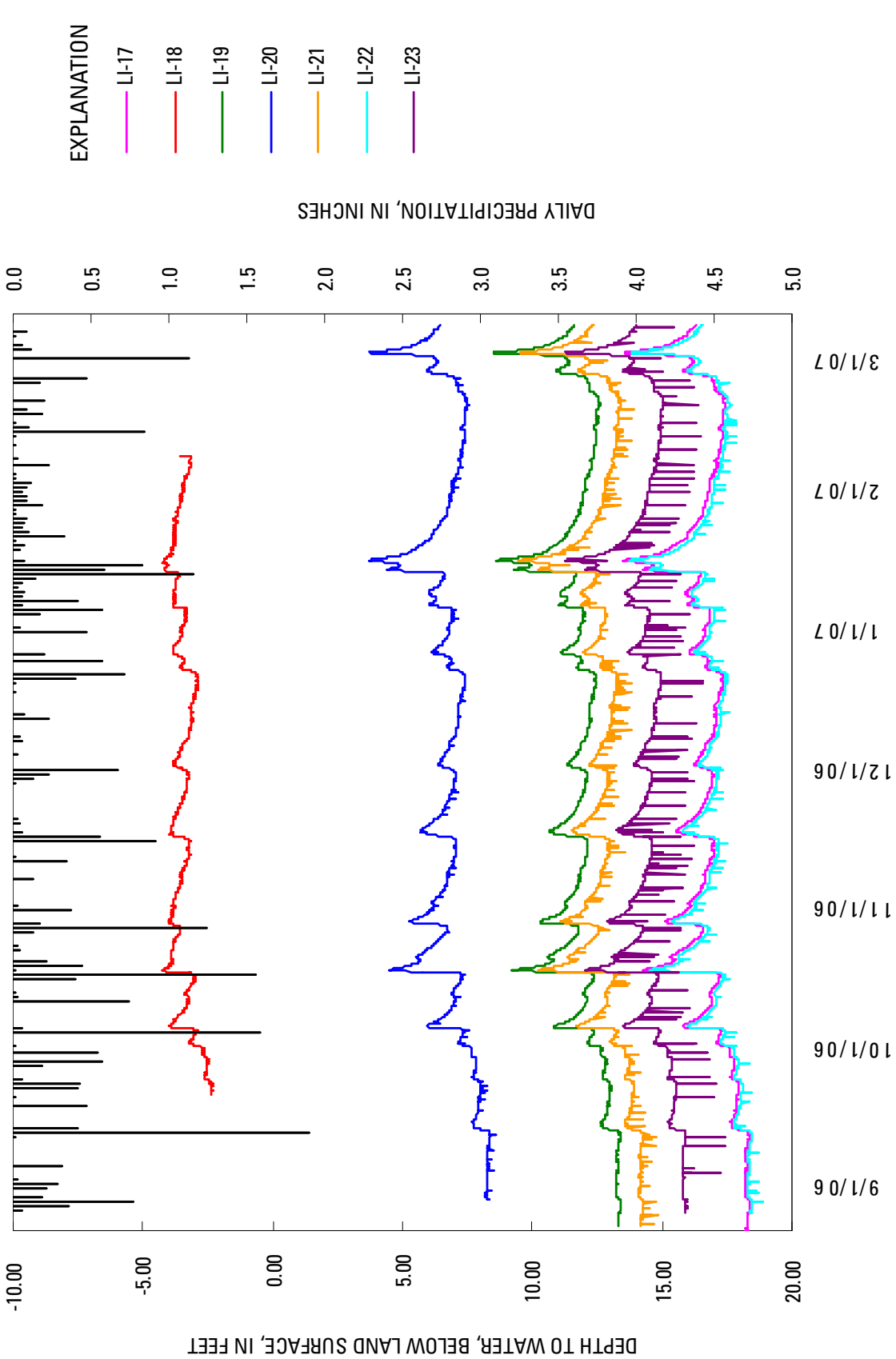


Figure 3. Hydrographs of continuous water levels in wells and precipitation in the study area. [Precipitation data from the Port Columbus International Airport station (WBAN 14821) National Oceanic & Atmospheric Administration (2007)]

The hydrographs show that the water levels in these wells rise quickly in response to precipitation events (fig. 3). This quick response is unexpected given that these wells are completed in a confined aquifer. A confined aquifer, also known as artesian, is one in which the ground water is confined under pressure greater than the atmosphere by an overlying layer of low permeability sediments (Todd, 1980); water levels in wells penetrating a confined aquifer will rise above the bottom of the confining layer and, in some cases, above land surface, and they are called "flowing artesian wells". The low-permeability confining layer can delay the response in wells to precipitation events, but this is apparently not the case at this study site. The location of the site within a bend of the South Fork Licking River (fig. 1) suggests the potential for local surface-water influence on ground water. There is a USGS streamgaging station on the South Fork Licking River near Hebron (03219743). The similarity of the fluctuations in river stage at this station with fluctuations in the ground-water levels strongly indicates a hydraulic connection between the river and the confined aquifer in the area (fig. 4). Drillers' logs for some wells in and around Kirkersville and a map of surficial sediments (fig. 5) indicate the potential for more permeable surficial sediments such as sandy clay or sand and gravel overlain by less than 10 ft of clay, thus supporting the probability of a connection between the river and the confined aquifer.

Data from the three synoptic water-level measurements are shown in table 3. The synoptic data were collected from 14 wells (fig. 3): the 7 wells with transducers and an additional 7 residential wells. All of the wells show a rise from 0.65 to 1.10 ft in water level between the October and January measurements; most of the wells have the same rise in water level, 0.8 ft. Between the January and March measurements, the wells have a rise in water level from 0.02 to 0.07 ft. Two wells, LI-18 and LI-25, had water levels above land surface during the January and March measurements.

Direction of Ground-Water Flow

Ground water flows in the direction of decreasing hydraulic head; contours on a ground-water-level map represent lines of equal hydraulic head. Figures 6, 7, and 8 show the water levels and water-level contours for October 3, 2006, January 24, 2007, and March 8, 2007. Although the data are limited to a small area around Swamp Road, the water levels are coherent and hydrologically reasonable. The ground-water-flow direction is southeasterly.

If the aquifer underlying the pool of the proposed dam is confined, then the impounded water would not appreciably affect ground water in the vicinity of Swamp Road. Although data from this study indicate that the aquifer is confined along Swamp Road, the rapid response of water levels to precipitation and changes in river stage suggest that there are nearby connections between the surface and the aquifer. The ground-water elevations measured in this study were higher than the dam pool (fig. 9) and these elevations were measured during conditions that were dryer than what would occur should the dam retain floodwater. Thus, the effect on the ground water around Swamp Road would be similar to backwater conditions on a stream during high flows—the ground-water flow direction would not change, although flow would likely slow, and perhaps stall for a brief period, before resuming natural conditions as the floodwater drained. Any rise in ground-water levels due to the impounded water, probably only a few inches, would be due mainly to the pressure effect from the weight of the impounded water. In other words, because the temporary flood pool from the dam has an elevation lower than the current ground-water levels along Swamp Road, the natural ground-water flow conditions will dominate flow directions in the event of 100-year flood event, notwithstanding the presence of the dam.

Table 3. Synoptic water-level elevations from wells in the vicinity of Swamp Road, Licking County, Ohio.

[Elevations are in feet above the North American Vertical Datum of 1988; na, not available]

Well number	Oct. 3, 2006	Jan. 24, 2007	Mar. 8, 2007
LI-17	902.01	902.85	902.92
LI-18	899.84	900.56[1]	900.60[1]
LI-19	899.26	899.93	899.95
LI-20	900.80	901.58	901.62
LI-21	901.02	901.80	901.83
LI-22	900.63	901.40	901.45
LI-23	900.49	901.24	901.29
LI-24	900.77	901.52	901.56
LI-25	900.24	900.99[2]	901.04[2]
LI-26	899.54	900.22	900.26
LI-27	899.72	900.40	900.45
LI-28	899.48[3]	900.58	900.61
LI-29	899.68	900.33	900.37
LI-30	901.13	901.89	901.95
Ditch gage	na	891.18	890.85

[1]. Flowing artesian conditions, measurement was an estimate of the water level above the casing.

[2]. Water level was above land surface, but not above well casing.

[3]. Water level was not static at the time of measurement.

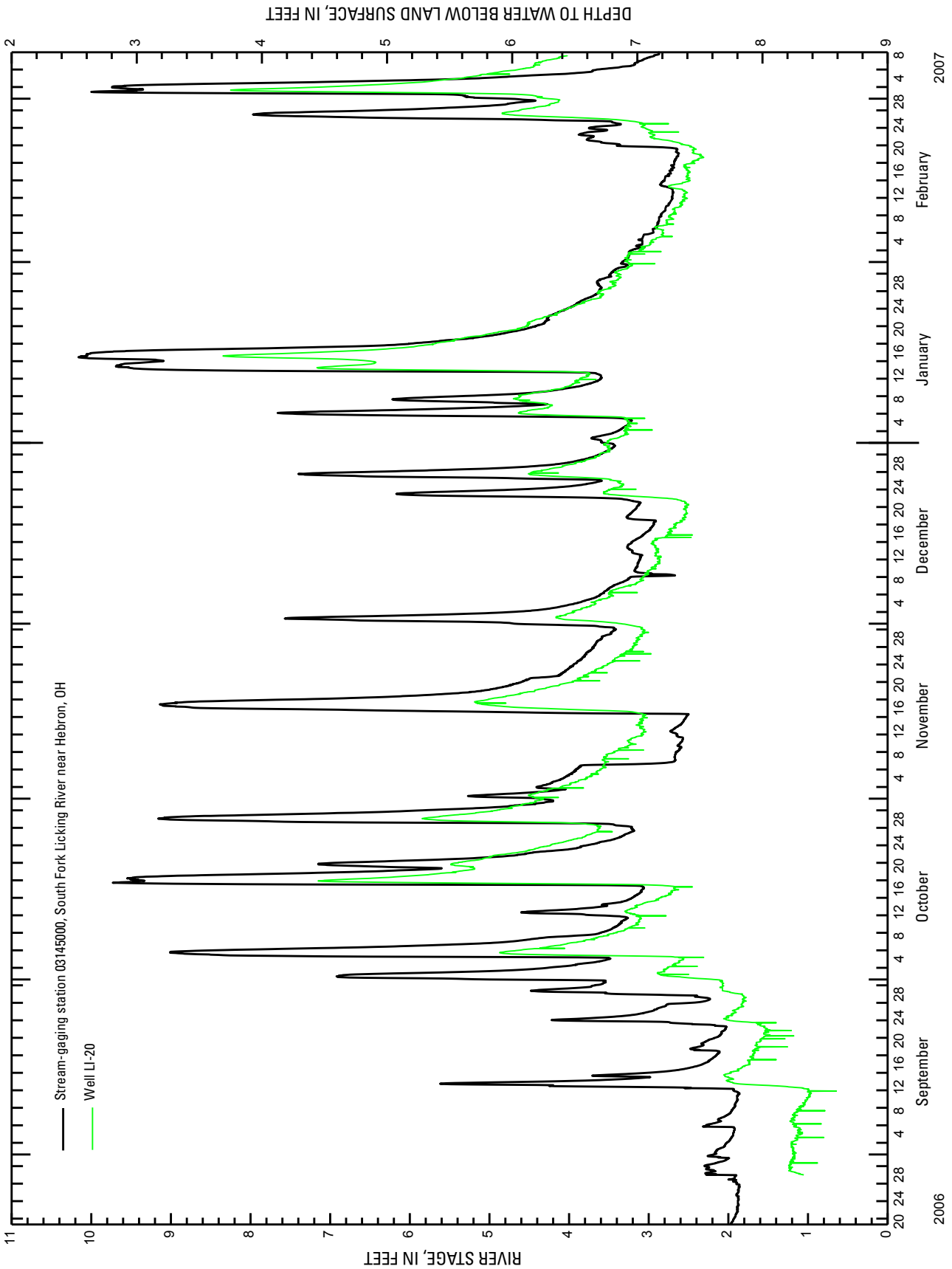


Figure 4. Hydrographs of continuous water levels in LI-20 and river stage at South Fork Licking River near Hebron.

EXPLANATION

Sand and gravel deposits of variable thickness yield 100 to 200 gallons per minute. Long-term yields are limited by lack of immediate recharge and clay or silt layers separating sand and gravel zones.

Relatively thin but well sorted sand and gravel deposits yield as much as 100 gallons per minute to properly developed, screened wells. Overlying or interbedded clay layers limit recharge and long-term yields. Well depths average less than 150 feet but may be over 250 in some areas.

Sand and gravel interbedded with clay may produce 25 to 50 gallons per minute. Sand and gravel lenses are generally less than ten feet thick and should be screened to develop maximum yields. Small diameter domestic wells may produce only 15 to 25 gallons per minute.

Sand and gravel interbedded with thick layers of clay and silt may produce as much as 15 gallons per minute. Fine sand and thin water producing zones necessitate the use of screens in domestic wells.

The western portion of the county may have as much as 400 feet of unconsolidated material in pre-glacial valleys. Wells not encountering sand and gravel can be expected to produce less than two gallons per minute from the bedrock at these great depths.

Sandy shale bedrock overlain by less than 100 feet of glacial material, mostly clay, yields generally less than five gallons per minute. Additional storage may be necessary to meet peak daily demands for domestic wells.

Figure 5. Hydrogeologic characterization of Swamp Road and vicinity (extracted and modified from Hartzell,1992).

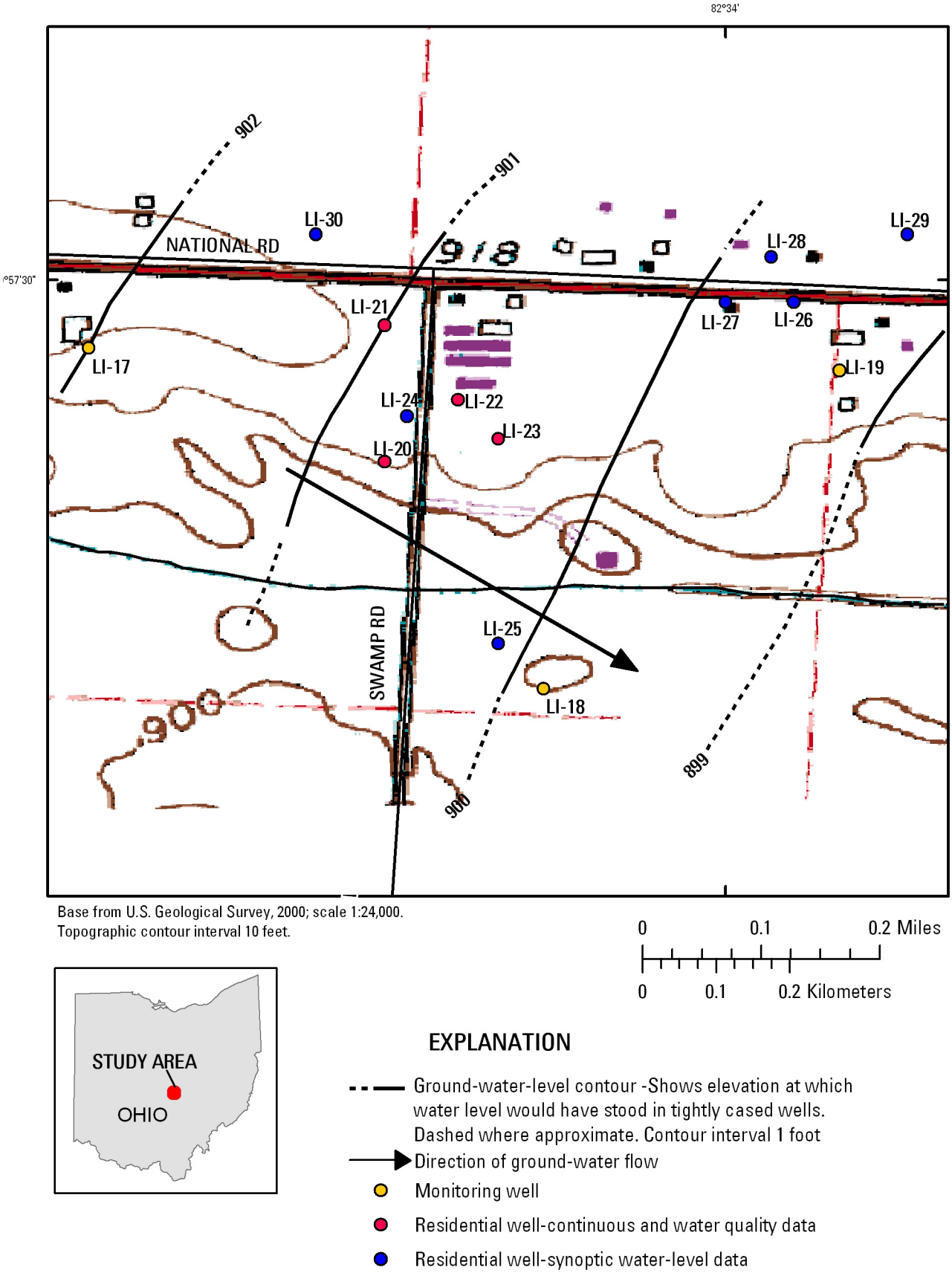


Figure 6. Ground-water-level contours for October 3, 2006.

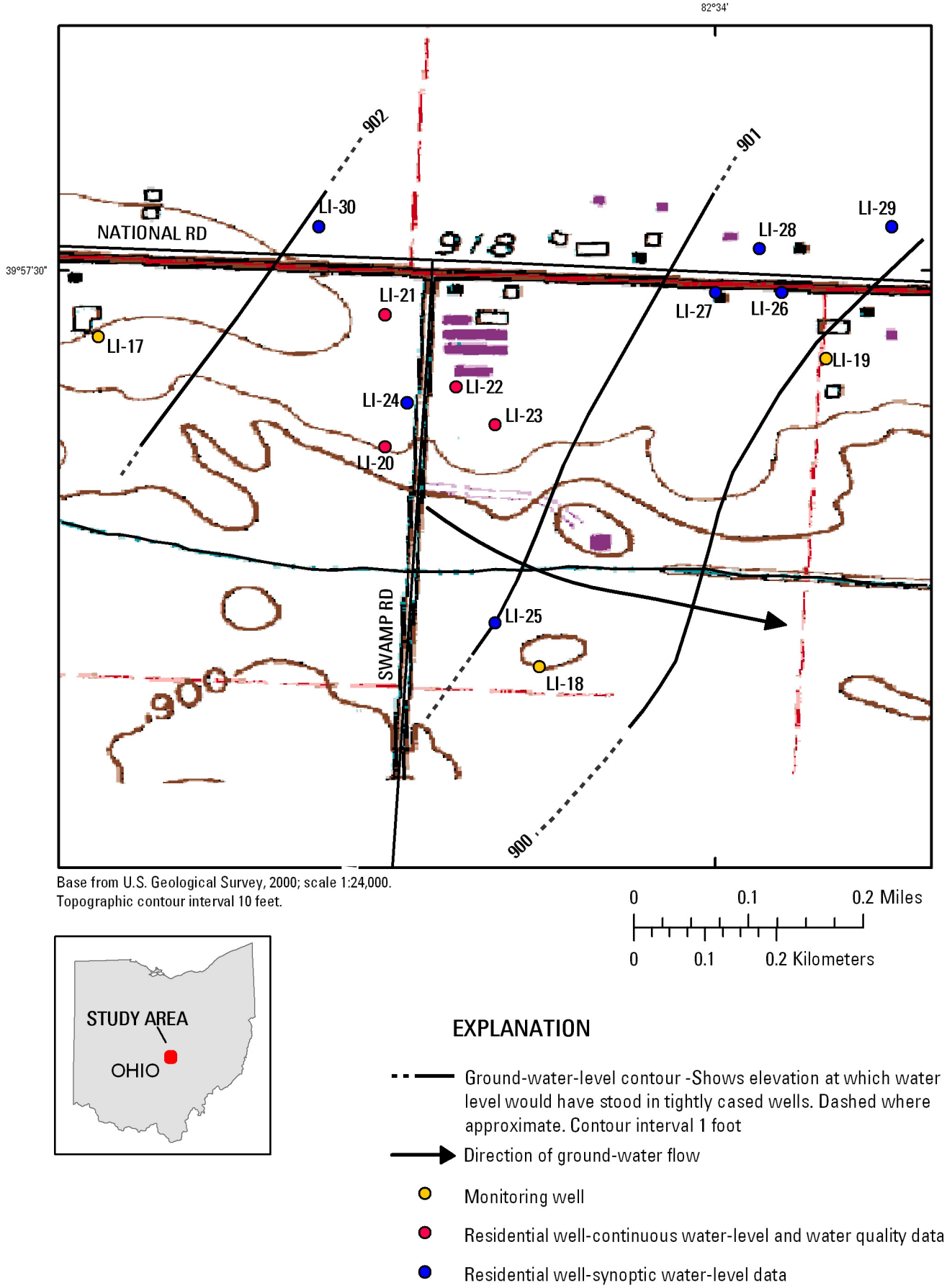


Figure 7. Ground-water-level contours for January 24, 2007.

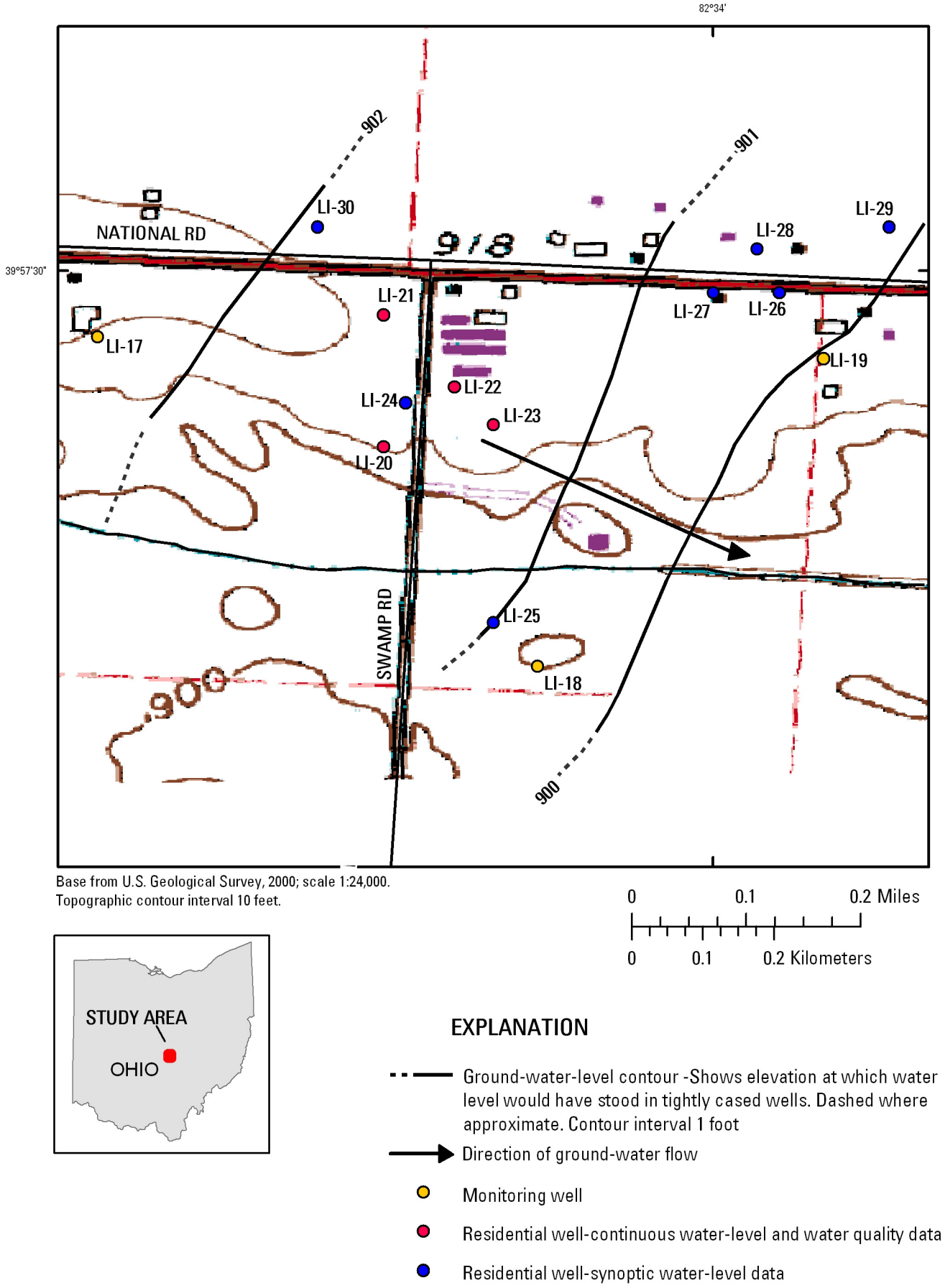


Figure 8. Ground-water-level contours for March 8, 2007.

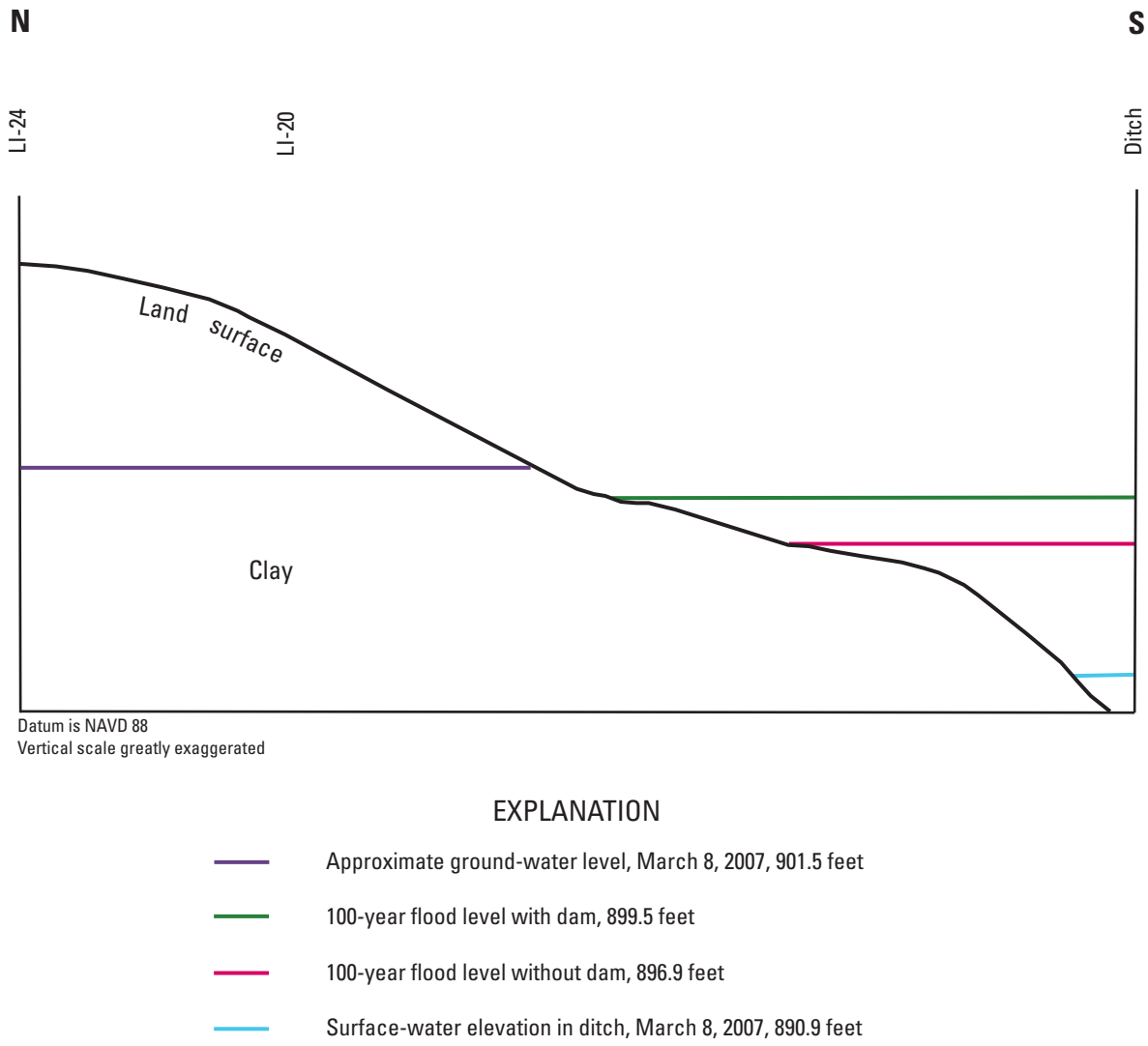


Figure 9. Schematic hydrologic section from north to south along Swamp Road.

Summary

The Natural Resources Conservation Service (NRCS) is proposing to build a dry dam on the South Fork Licking River to mitigate flood impacts. Concerns have been raised regarding the effects of impounded floodwaters on ground-water conditions in the nearby Swamp Road neighborhood. To obtain a better understanding of existing ground-water conditions, the U.S. Geological Survey, in cooperation with the NRCS, installed three monitoring wells and collected ground-water quality samples on two occasions from these and four residential wells. Transducers were placed in these seven wells to obtain hourly water-level measurements from August 2006 to early March 2007. Water levels also were measured intermittently in another seven residential wells.

Water samples were collected from seven wells in September 2006 and January 2007. Samples were analyzed for nutrients, inorganic elements, and fecal-indicator bacterial. In general, the ground water was very hard with high iron concentrations. With the exception of one sample of treated water, hardness values ranged from 320 to 430 mg/L as $CaCO_3$, and iron concentrations ranged from 1,700 to 2,700 µg/L.

Well logs and water-level data indicate that the aquifer underlying the vicinity of Swamp Road is confined. However, the continuous water-level records indicate a rapid response to precipitation. A review of well logs from the Kirkersville area,

about 1 mile west of Swamp Road, indicates the potential for more permeable surficial deposits. A comparison of the well hydrographs with the hydrograph of the stage (water level) of nearby South Fork Licking River indicates that at some location a hydraulic connection exists between the river and the aquifer.

In the vicinity of Swamp Road, the ground-water-flow direction was southeasterly during the duration of the study. The ground-water-level elevations were above the maximum planned (100-year flood) elevation for water impoundment by the dam, thus the impounded floodwater should have minimal impact on ground-water conditions along Swamp Road.

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