Ground-Water Resources in the Vicinity Of Cortland, Trumbull County, Ohio

By Gary J. Barton and Peter R. Wright

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
square mile	259.0	hectare
	Volume	
gallon (gal)	3.785	liter
gallon	0.003785	cubic meter
million gallons (Mgal)	3,785	cubic meter
	Precipitation	
inches per year (in/yr)	25.4	millimeter per year
	Flow	
gallon per minute (gal/min)	3.785	liter per minute
foot per day (ft/d)	0.3048	meter per day
million gallons per year (Mgal/d)	0.003785	million cubic meters per year
cubic foot per year	0.02832	cubic meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units used in this report: Chemical concentration is given in milligrams per liter (mg/L). Milligrams per liter is a unit expressing the concentration of the chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. Tritium concentration is expressed in tritium units (TU). One tritium unit is equal to one tritium atom per 10^{18} hydrogen atoms; in terms of radioactivity, it is equivalent to 3.24 picocuries per liter.

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ABSTRACT

The city of Cortland lies on the southeastern shoreline of the 12.3-square-mile Mosquito Creek Lake in Trumbull County, Ohio. Cortland relies upon public wells completed in the Cussewago Sandstone for potable water. The Cussewago Sandstone, the principal aquifer in the study area, is a subcrop of the glaciofluvial sediments in the lake; the unit dips gently towards the southeast. Thickness of the Cussewago Sandstone ranges from less than 20 feet in south-central Bazetta Township to 152 feet in Cortland. The Bedford Shale overlies and confines the Cussewago Sandstone and separates it hydraulically from the Berea Sandstone. The Bedford Shale and Berea Sandstone are not a prolific source of ground water. In places, the Bedford Shale was completely eroded away prior to deposition of the Berea Sandstone. Where the Bedford Shale is absent, such as at the City of Cortland North Well Field, the Berea Sandstone and Cussewago Sandstone are likely in hydraulic connection.

Throughout most of the study area, the Cussewago Sandstone is a confined aquifer. Ground-water flow is to the east and southeast. Pumping at both Cortland well fields has created cones of depression in the potentiometric surface. These cones of depression cause a local reversal in ground-water flow immediately east of both well fields. The absence of detectable concentrations of tritium in water samples from wells completed in the Cussewago Sandstone at Cortland indicates that ground water predates the atmospheric nuclear testing of the 1950's. Ground water requires about 60 to 110 years to flow from the Cussewago Sandstone subcrop of the glaciofluvial sediments in the lake to the Cortland public-supply wells.

A comparison of aquifer storage and pumpage in the study area shows that the Cussewago Sandstone receives adequate recharge to support current withdrawals by Cortland public-supply wells. In the immediate vicinity of Cortland—between Route 305 and the Bazetta-Mecca Township line and between the Mosquito Creek Lake shoreline and the Bazetta-Fowler Township line—approximately 15,000 million gallons of water currently in the Cussewago Sandstone can be gravity drained from the aquifer without considering recharge to the aquifer. The 15,000 million gallons is equivalent to about 75 years of withdrawals by Cortland public-supply wells at current (1990–95) rates.

A numerical flow model rather than an analytical or semianalytical model would be needed to accurately simulate flow and ground-water withdrawals in the Cussewago Sandstone in the vicinity of Cortland. Computer simulations of flow would likely involve conditions where a fully saturated, confined Cussewago Sandstone becomes a partially saturated aquifer.

INTRODUCTION

Cortland, at the southeastern shore of Mosquito Creek Lake in Trumbull County, Ohio, depends on two well fields for a reliable source of potable water. The supply wells in these fields, drilled between 1937 and 1982, are completed in the Cussewago Sandstone (fig. 1). The North Well Field consists of two supply wells and the South Well Field consists of four supply wells (fig. 2). Few domestic supply wells have been drilled in Cortland.

From the late 1930's through 1995, withdrawal of ground water at these well fields has been continuous, and neither excessive drawdown nor declining well yields have been reported (Mark Dunsmoor, city of Cortland, oral commun., 1997). During this period, the concentration of dissolved solids has remained nearly constant, ranging from about 600 to 640 mg/L. From 1991 through 1995, the average daily withdrawal for the North Well Field was 241,700 gal and for South Well Field was 314,800 gal. During this period, the average combined daily withdrawal for the well fields increased by about 7 percent (Mark Dunsmoor, city of Cortland, written commun., 1996).

Before the study described here, the geologic framework of the Cussewago Sandstone aquifer in the vicinity of Cortland had not been mapped at a local scale, and ground-water levels had not been systematically measured. Basic hydrogeologic information is needed as a basis for determining whether sufficient ground-water resources are available to continue to meet the demands of this growing community. To meet this need for information, this investigation of the ground-water resources of the area was done by the U.S. Geological Survey (USGS) in cooperation with the city of Cortland.

Purpose and Scope

This report describes the occurrence and availability of ground water in the vicinity of Cortland and list possible approaches for simulating ground-water flow. The report includes maps that show the hydrogeologic framework of the Cussewago Sandstone aquifer and the water levels and flow directions in the aquifer. Aquifer-test data are analyzed, and the quantity of water in the Cussewago Sandstone aquifer is described. In addition, the area contributing recharge to the well fields in Cortland is characterized. Because all public-supply wells in Cortland are completed in the Cussewago Sandstone, this report focuses on the hydrogeologic setting of that geologic unit.

Hydrogeologic Setting

The study area covers about 115 mi^2 in Trumbull County, Ohio (fig. 1), in a part of the Appalachian Plateaus Physiographic Province that was covered by continental glaciers during the Pleistocene Epoch. The area is characterized by moderate relief, with land-surface altitudes ranging from about 860 to 1,100 ft above sea level. Precipitation averages about 36 in/yr (Owenby and Ezell, 1992).

Glacial drift covers the entire study area except for a few sandstone ledges that crop out on some hillsides. Mosquito Creek and the Mosquito Creek Lake are underlain by an ancient buried valley filled with unconsolidated glaciofluvial sediments (White, 1971). The glacial deposits are underlain by a series of Mississippian sandstone aquifers and shale confining units and a Devonian shale confining unit (table 1). These bedrock strata dip gently towards the southeast (Pepper and others, 1954). The Cussewago Sandstone is the primary aquifer and the Berea Sandstone is a secondary aquifer in the study area. Many domestic supply wells in the study area are open to multiple aquifers, generally the Cuyahoga Formation and the Berea Sandstone and Cussewago Sandstone aquifers.

In and near the Mecca Oil Pool (fig. 1), oil and natural gas naturally occur in the Berea Sandstone (Maslowski, 1988; Orton, 1888) and Cussewago Sandstone (Haiker, 1996). Discharge of oil, gas or brine from an unknown number of abandoned wells that predate oversight by the Ohio Department of Natural Resources (ODNR) may have caused some contamination of the ground water. For example, hundreds of oil wells drilled in the Mecca Oil Pool (fig. 1) and completed in the Berea Sandstone during the late 1800's were reported to have been abandoned without cementing of the annulus of the wells to land surface (Maslowski, 1988, p. 16). Some of these wells are submerged at the bottom of Mosquito Creek Lake (Maslowski, 1988, p. 20) and these wells may pose a threat to water quality in the lake. Currently producing oil and gas wells could be considered a potential source of contamination.

Water-well drillers often report encountering oil in the Berea Sandstone in the study area. When drillers encounter oil in the Berea Sandstone, they often case off the Berea Sandstone and complete the well in the Cussewago Sandstone (Thomas Repphun, TNT Water Company Incorporated, Cortland, Ohio, oral commun., 1996). West and east of the Mosquito Creek Lake, in Bazetta and Mecca Townships, the drillers'

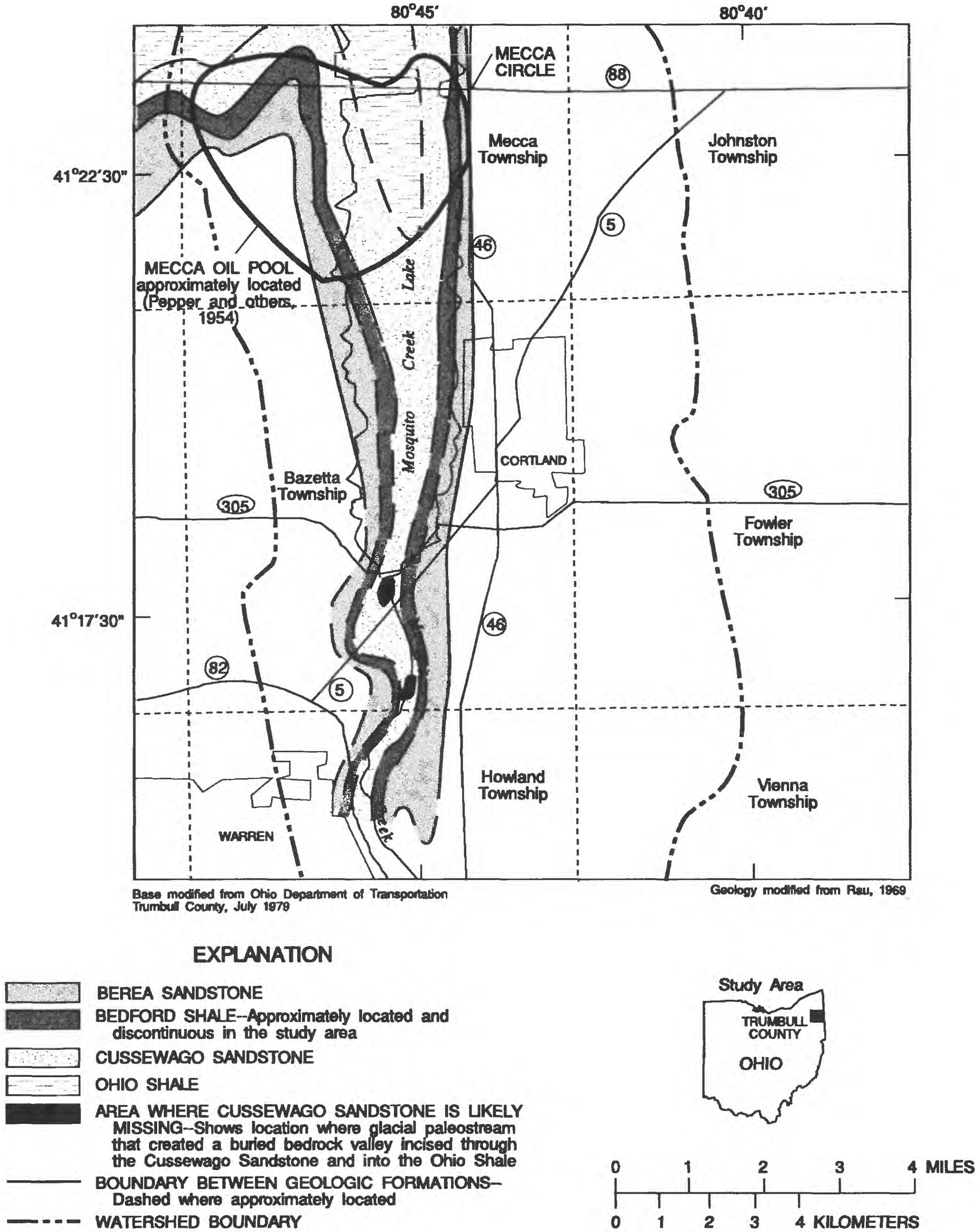


Figure 1. Location of the Berea Sandstone, Bedford Shale, Cussewago Sandstone, and Ohio Shale in the vicinity of Cortland, Ohio.

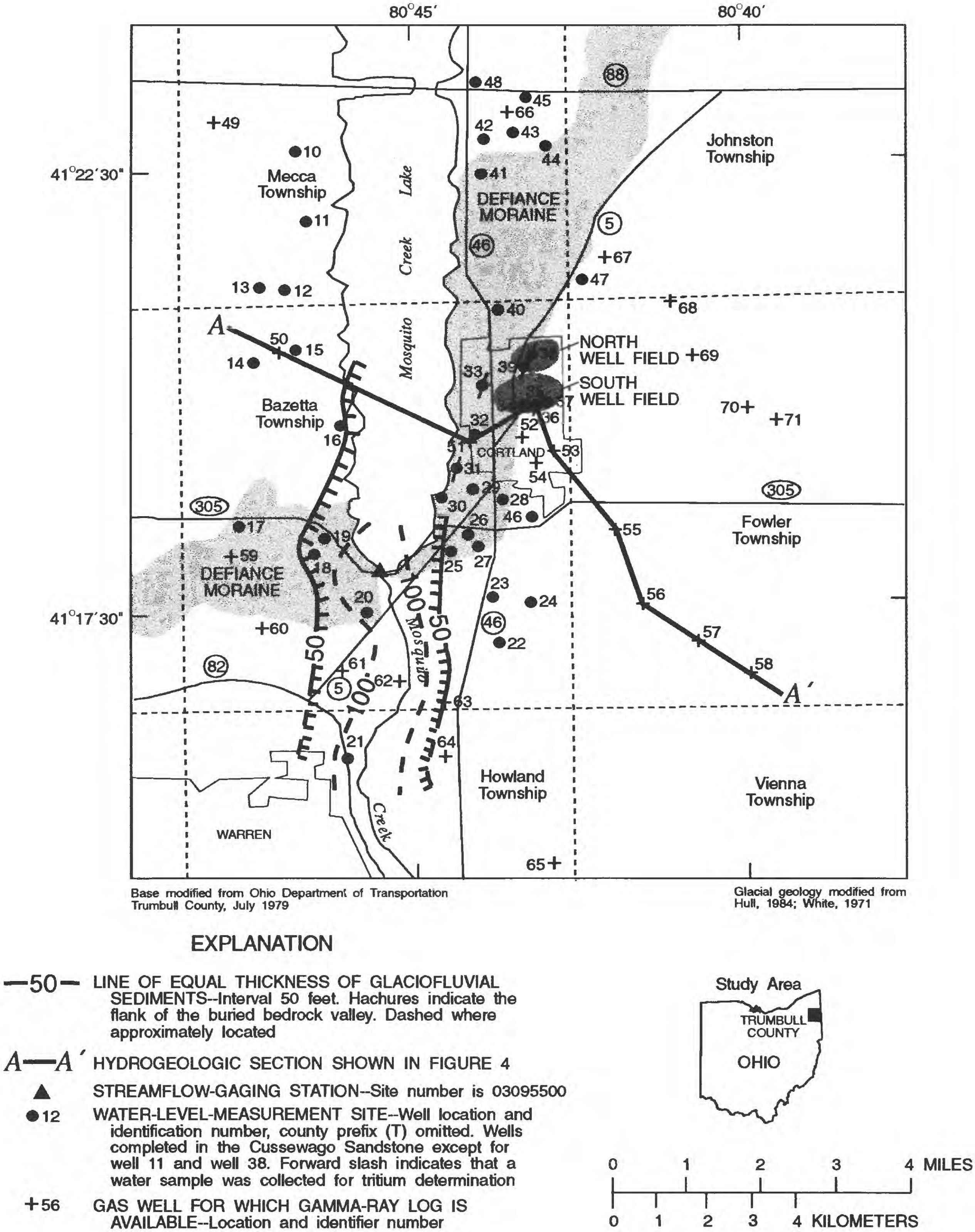


Figure 2. Glacial geology, thickness of glaciofluvial sediments, and location of data-collection sites in the vicinity of Cortland, Ohio.

Table 1. Summary of rock units and associated water-bearing properties in the vicinity of Cortland, Ohio

[Modified from Jagucki and Lesney, 1995. Abbreviations: >, greater than
Thickness of Mississippian geologic units based on water-well drillers' logs and geophysical logs]

System	Geologic unit	Approximate thickness (feet)	Character of deposits	Water-bearing properties
Quaternary (Pleistocene)	Glacial deposits	0 - 140	Clay, silt, sand, and gravel; till and valley fill.	Few domestic wells; wells in coarse gravel may yield 100 gallons per minute.
Pennsylvanian	Pottsville Formation (Sharon member)	0 - >70	Sandstone containing local channels of conglomerate and sandy shale.	Wells commonly yield 10 to 25 gallons per minute or more in the southeast part of the study area.
Mississippian	Cuyahoga Group	0 - 176	Interbedded shales and sandstones, fine-grained.	
	Berea Sandstone	0 - 59	Fine gray sandstone to siltstone, relatively well sorted, with local lenses of shale.	Wells commonly yield 25 to 50 gallons per minute; wells may yield up to 100 gallons per minute.
	Bedford Shale	0 - 29	Interbedded shales and siltstones; discontinuous.	
	Cussewago Sandstone	0 - 152	White quartz sandstone; relatively well sorted, poorly cemented.	Wells commonly yield 50 to 100 gallons per minute; sustainable yields of greater than 100 gallons per minute not uncommon.
Devonian	Ohio Shale	>100	Shales.	Not a source of water to wells.

logs of Cussewago Sandstone water wells often report cloudy water during a well-acceptance test. Cloudy water can be an indicator of gas in solution, including natural gas, as well as suspended fine-grained sediment.

An earthen dam at the southern end of Mosquito Creek Lake was constructed by the U.S. Army Corps of Engineers in the 1940's for flood control. The lake covers an area of approximately 12.3 mi^2 and has 13.9 mi of shoreline. The maximum storage in the lake occurs at a pool elevation of 904 ft above sea level and is about 33,900 Mgal (U.S. Army Corps of Engineers, 1992, p. I-30). During September 1996, the pool elevation was 899.1 ft above sea level and storage was about 21,200 Mgal. During 1943–91, the mean annual stream discharge at USGS streamflow-gaging station 03095500, at the outlet of the lake, was 89 ft^3/s. Several periods of no flow at the outlet have been reported at streamflow-gaging station 03095500. The maximum daily streamflow at the outlet was 1,280 ft^3/s on June 5, 1947. On average, about one lake volume of water passes through the lake outlet during a 1-year period. The city of Warren, about 5 mi southwest of Cortland (fig. 1), relies on the Mosquito Creek Lake as a sole source of potable water. During 1991–95, approximately 22 percent of the average discharge at the lake dam was diverted to the city of Warren for water supply. During this time, the concentration of dissolved solids in the raw water supply ranged from 145 to 161 mg/L (James Sherwood, City of Warren Department of Water Utility, written commun., 1996).

Study Methods

The descriptions of the geology of aquifers and confining units in the study area given in the following sections of this report are based on the regional geologic maps prepared by Pepper and others (1954), Rau (1969), and White (1971). During this investigation, the Cussewago Sandstone (fig. 1) was mapped by examining gamma-ray logs from oil and gas wells and water-well drillers' logs, and the buried bedrock valley was delineated on the basis of drillers' logs (fig. 2 and tables 2 and 3). The depth of geologic units penetrated by each water well examined in this study has been input into the USGS Ground-Water Site Inventory data base.

Table 2. Records of selected gas wells for which gamma-ray logs are available in the vicinity of Cortland, Ohio

USGS[1] identifier	ODNR[2] permit number	Altitude of land surface (feet above sea level)
49	1794	929
50	2194	941
51	3382	965
52	2777	1,042
53	3313	1,061
54	2927	1,055
55	919	1,068
56	1503	1,088
57	1505	1,153
58	1399	1,191
59	3571	980
60	2916	958
61	3517	890
62	3314	870
63	414	902
64	2528	905
65	3306	1,070
66	1468	977
67	1465	1,055
68	1970	1,129
69	1125	1,153
70	1102	1,145
71	1207	1,147

[1] U.S. Geological Survey identifier number (see location in figure 2).
[2] Ohio Department of Natural Resources permit number.

During September 17–20, 1996, water levels were measured in 36 domestic, industrial, and public-supply wells open to the Cussewago Sandstone (fig. 2; table 2). These measurements were used to construct a map showing the water level and flow direction in the Cussewago Sandstone. Described below are wells 17, 19, 38, 39, and 41, which are also open to a much lesser extent to an adjoining geologic unit. At wells 38 and 39 in the North Well Field and at 11 domestic wells, the Bedford Shale is believed to be absent and

Table 3. Records of selected water wells in the vicinity of Cortland, Ohio

[Depth of geologic units penetrated by water well as recorded in the U.S. Geological Survey Ground-Water Site Inventory data base; ---, no data available]

USGS [1]identifier	ODNR[2] number	USGS site[3] identifier	Land surface	Open interval		Water level	Date of water-level measurement
				Top	Bottom		
			Elevation (feet above sea level)				
T-10	804549	412238080463501	934	829	809	907	9/17/96
T-11	748382	412151080463501	931	904	781	907	9/17/96
T-12*	724727	412058080465101	942	862	830	901	9/17/96
T-13	743794	412101080472001	951	900	826	904	9/17/96
T-14	410999	412011080473201	953	857	828	904	9/18/96
T-15*	793864	412020080464801	940	845	815	903	9/17/96
T-16*	391742	411925080460301	910	857.5	843	900	9/17/96
T-17	620787	411828080474001	962	910	822	903	9/18/96
T-18	748606	411809080462501	925	825	778	902	9/18/96
T-19	663331	411812080461701	920	845	805	903	9/18/96
T-20[4]	N/A	411736080454701	900	753	735	884	9/18/96
T-21[5]	340868	411552080455301	872	760	752	876	9/17/96
T-22**	767056	411705080435801	983	823	778	885	9/18/96
T-23	804531	411744080440001	985	785	735	885	9/18/96
T-24*,**	804523	411740080432001	1,051	836	775	881	9/18/96
T-25	762248	411812080443501	914	801	764	883	9/18/96
T-26	804556	411828080442101	935	820	791	883	9/18/96
T-27**	767011	411825080440801	960	830	792	883	9/18/96
T-28	679780	411852080435101	1,015	853.2	745	883	9/18/96
T-29*,**	N/A	411902080441401	955	835	805	892	9/18/96
T-30**	793854	411857080443701	982	842	817	896	9/17/96
T-31	N/A	411923080442601	920	845	806	893	9/19/96
T-32*	N/A	411934080435801	980	880	840	887	9/17/96
T-33*	N/A	411951080440201	980	880	840	888	9/17/96
T-34	N/A	411946080431601	1,035.5	855.5	740.5	---	---
T-35	N/A	411946080431101	1,039.7	---	---	851	9/18/96
T-36	258808	411943080430801	1,039	855	725	839	9/18/96
T-37	379495	411945080430301	1,043	848	725	838	9/18/96
T-38*	N/A	412015080432001	1,034.4	830.4	730.4	852	9/18/96
T-39*	N/A	412012080432101	1,040	835	723	875	9/18/96
T-40*	793854	412039080435401	928	836	821	887	9/17/96
T-41*	N/A	412215080441201	942	793	613	901	9/17/96

Table 3. Records of selected water wells in the vicinity of Cortland, Ohio—Continued

[Depth of geologic units penetrated by water well as recorded in the U.S. Geological Survey Ground-Water Site Inventory data base; ---, no data available]

USGS [1]identifier	ODNR[2] number	USGS site[3] identifier	Land surface	Open interval		Water level	Date of water-level measurement
				Top	Bottom		
			Elevation (feet above sea level)				
T-41*	N/A	412215080441201	942	793	613	901	9/17/96
T-42	747727	412244080440801	940	860	835	903	9/17/96
T-43	694843	412249080434501	970	870	855	902	9/17/96
T-44*	767020	412238080431701	1,013	853	823	901	9/17/96
T-45*	838462	412310080432401	990	860	825	897	9/17/96
T-46	N/A	411831080430801	1,055	790	727	881	9/20/96
T-47[6]	700631	412115080423701	1,048	1,000	938	1,042	9/20/96
T-48	635854	412323080441101	933	853	813	898	9/17/96

[1] U.S. Geological Survey identifier. Prefix 'T' indicates well is in Trumbull County (see location in figure 2).

[2] Ohio Department of Natural Resources number.

[3] First 13 digits represents the latitude and longitude of the well.

[4] Well completed in the Ohio Shale.

[5] Flowing well.

[6] Well completed in the Cuyahoga Group.

* Drillers' log indicates that the Bedford Shale is missing; the Berea Sandstone and Cussewago Sandstone may be hydraulic connection.

** Tritium sample collected from this well. A composite sample was collected from wells 29 and 30.

the Berea Sandstone and Cussewago Sandstone are to some extent hydraulically connected. Water levels measured in these wells are a composite that predominantly reflects water levels within the Cussewago Sandstone, but to a limited extent may also reflect the water level in the Berea Sandstone. Bottom of casing in wells 17 and 19 is in the shale confining unit that overlies the Cussewago Sandstone. Well 41 is open to the Cussewago Sandstone and the underlying Ohio Shale confining unit. Wells 17, 19, and 41 are pumped daily. Water levels in these wells are believed to be representative of water levels in the Cussewago Sandstone. In addition, water levels were measured in well 20, which is completed in the Ohio Shale, and in well 47, which is completed in the Cuyahoga Group. The altitude of land surface at most wells was determined from USGS 7.5-minute topographic maps, which have a 10-ft topographic contours and whose depicted altitudes are considered accurate to ± 5 ft. The land-surface altitude at five of the Cortland public-supply wells were surveyed to an accuracy of ± 0.1 ft.

Water levels in domestic and industrial wells were measured by use of steel tape or an electric tape. The depth to water was measured from the top of the steel casing; accuracy is ± 0.01 ft. Depth to water in public-supply wells was measured by use of either an airline with a pressure gage, accuracy of ± 2 ft, or an electric tape. Water levels in public-supply wells were measured during pumping and approximately 10 minutes after pumping ceased. The latter measurement provides a reasonable approximation of the water level in the aquifer near the well bore, because drawdown caused by well inefficiency dissipates rapidly after pumping is halted.

During September 8–9, 1996, water samples were collected from wells 22, 24, and 27, and a composite sample was collected from wells 29 and 30; all samples were analyzed for tritium (table 3). Three casing volumes of water were removed from the well before a water sample was collected. Samples were collected from the spigot closest to the wellhead and ahead of where water entered a pressure holding tank or treatment tank. Samples were analyzed for enriched tritium at the Environmental Isotope Laboratory at the University of Waterloo, Ontario, Canada.

GROUND-WATER RESOURCES

Glacial Deposits

In the study area, glacial drift is generally 3 to 25 ft thick (White, 1971). The drift is composed of till—a mixture of clay, silt, gravel, cobbles, and boulders. The drift is not a significant source of ground water principally because the deposits are clay rich and too thin.

The Defiance Moraine, which trends southwest-northeast across the study area and overlies the western and northern half of Cortland, is made up of at least three separate tills (White, 1971). Water-well drillers' logs from the study area indicate that this moraine is generally less than 40 ft thick. Areas overlain by this moraine are generally less permeable than off-moraine areas.

Buried Bedrock Valley and Glaciofluvial Deposits

Structure contours on the top of the Cussewago Sandstone (fig. 3) show a buried bedrock valley that was carved out by a south-flowing glacial paleostream and later filled in by glaciofluvial sediments. The depth of this buried bedrock valley, especially beneath the Mosquito Creek Lake, is poorly defined because of a lack of well logs. The buried bedrock valley generally extends to about 100 ft below land surface and locally extends to more than 140 ft below land surface south of the lake (fig. 2). Several water-well drillers' logs and soil-boring records (U.S. Army Corps of Engineers, Pittsburgh, Pa., archived records) show that the unconsolidated glaciofluvial sediments in the valley are typically fine grained and dominated by clay-rich till layers, with discontinuous layers of sand and gravel. Coffee and others (1916, p. 13 and 48) reported that the Holly clay loam occurs along the Mosquito Creek valley bottom and underlies much of Mosquito Creek Lake. This heavy soil impedes recharge to the underlying glaciofluvial sediments. Hull (1984) reported that the flank of the valley is predominantly till and that coarse outwash deposits are along the center of the valley. A small percentage of domestic supply wells in the study area are completed in sand and gravel lenses in these glaciofluvial sediments.

Pottsville Formation

The Sharon Member of the Pennsylvanian Pottsville Formation is the uppermost bedrock unit in the study area (table 1; Sedam, 1973, sheet 1). It is found in eastern Fowler Township and eastern Vienna Township. The Sharon Member is composed of sandstone interbedded with layers of conglomerate. Some wells completed in the Sharon Member have moderate to good yields (Sedam, 1973, sheet 2; Winslow and White, 1966, p. 11).

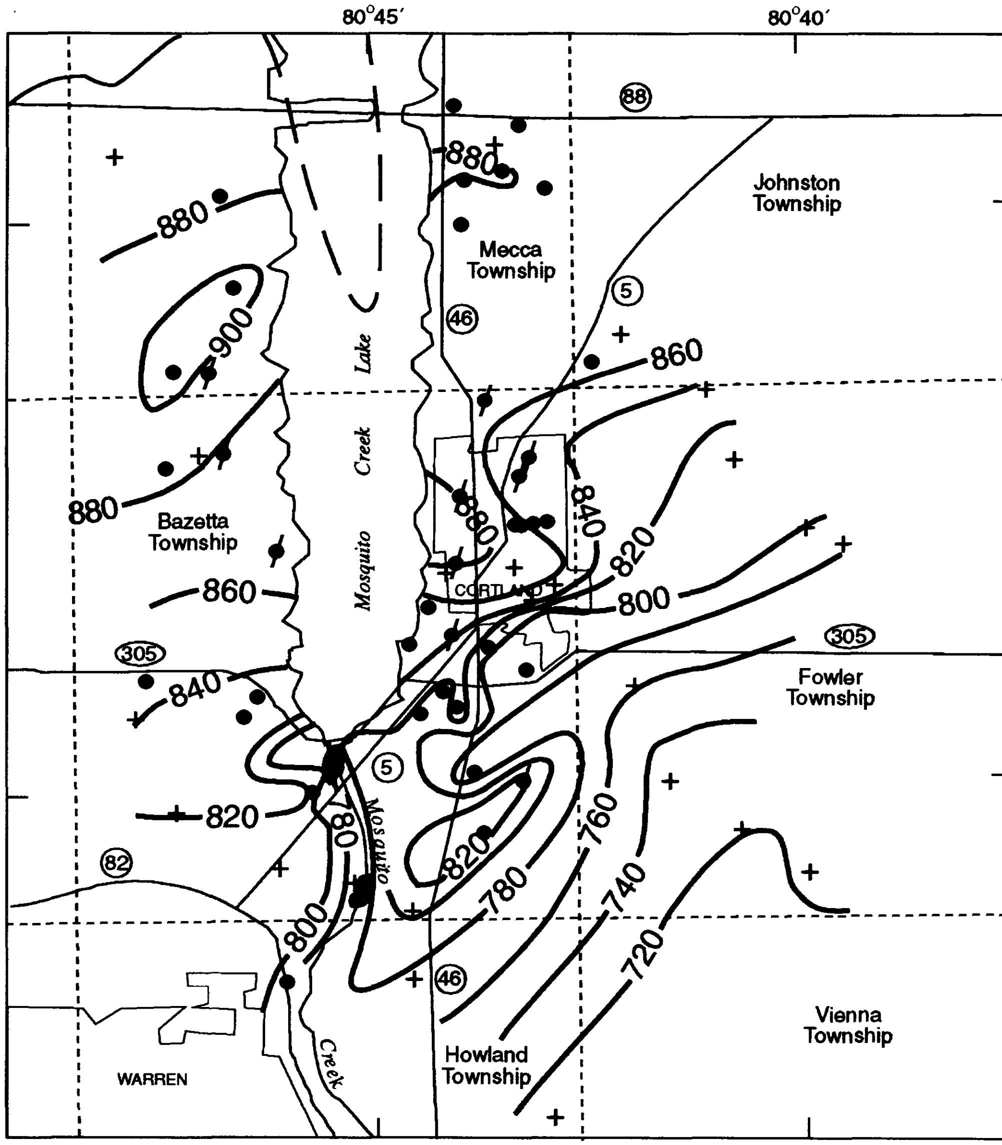
Cuyahoga Group

Mississippian rocks of the Cuyahoga Group crop out in the southern and eastern parts of the study area. In the study area, the Cuyahoga Group ranges in thickness from 0 to greater than 176 ft. The Cuyahoga Group is principally composed of shale, with thin interbedded, fine-grained sandstones, and it generally functions as a confining layer. Most domestic supply wells completed in the Cuyahoga Group are in the eastern and southeastern part of the study area, and their yields are generally low.

Berea Sandstone

As mapped by Rau (1969, sheet 1), the Berea Sandstone crops out beneath and along the eastern and western shoreline of the Mosquito Creek Lake, south of the lake, and west of the lake in Mecca Township (fig. 1). The Berea Sandstone is unconformably overlain by the Cuyahoga Group. In the study area, the thickness of Berea Sandstone ranges from 0 to 59 ft, but thickness generally is less than 30 ft. The Berea Sandstone consists of a dirty gray, silty sandstone and intercalated beds of shale. Berea Sandstone is eroded away beneath parts of the buried valley where a glacial paleostream incised through it. The Berea Sandstone is difficult to identify on gamma-ray logs because the unit is thin and silty. On section A-A′ (fig. 4), the Berea Sandstone correlates with a negative deflection (decreasing natural gamma radiation) on the gamma-ray log for well 50 and shows as a zone of low natural-gamma radioactivity from 898 to 915 ft above sea level.

In Mecca, Bazetta, and Howland Townships, domestic supply wells are commonly completed in the Berea Sandstone, and they are also usually open to the overlying Cuyahoga Formation or the underlying Cussewago Sandstone. Rau (1969) reported an average horizontal hydraulic conductivity of 8 ft/d for the Berea



Base modified from Ohio Department of Transportation
Trumbull County, July 1979

EXPLANATION

■ AREA WHERE CUSSEWAGO SANDSTONE IS LIKELY MISSING--Shows location where glacial paleostream that created a buried bedrock valley incised through the Cussewago Sandstone and into the Ohio Shale

——— NORTHERN EXTENT OF CUSSEWAGO SANDSTONE--Dashed where approximately located

-840- STRUCTURE CONTOUR--Shows altitude of the top of the Cussewago Sandstone. Interval 20 feet. Dashed where approximately located. Datum is sea level

● WATER WELL--Shows location of well used to map the geologic framework (driller's log available). Identifier number is given in figure 2. Forward slash indicates that drillers' logs show the Bedford Shale as missing; the Berea Sandstone and cussewago Sandstone may be in hydraulic connection

+ GAS WELL--Shows location of well used to map the geologic framework (gamma-ray log available). Identifier number is given in figure 2

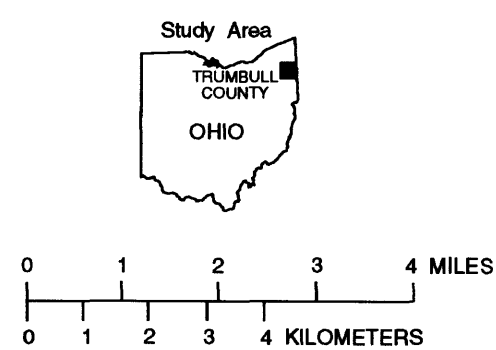
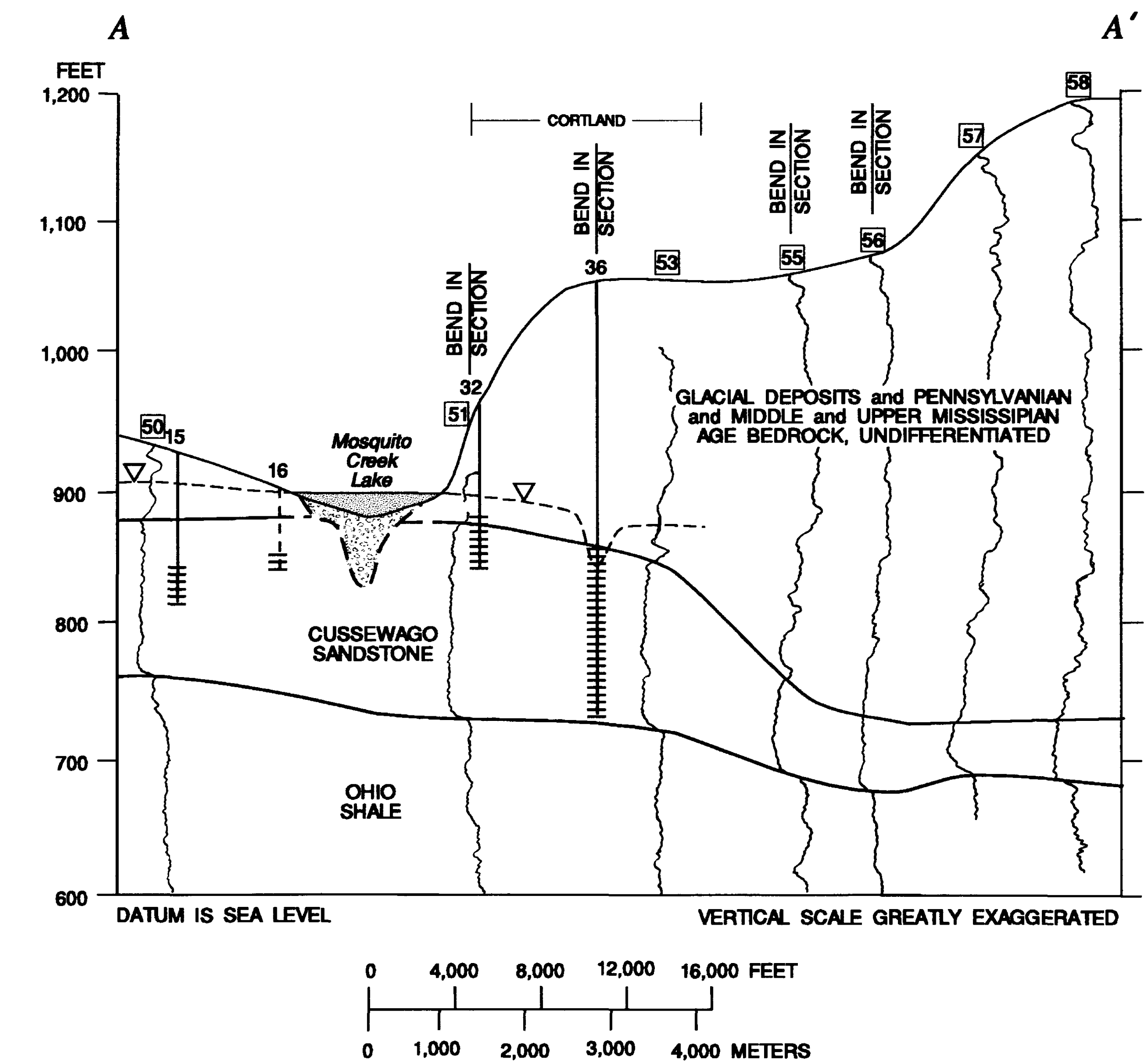


Figure 3. Structure on top of the Cussewago Sandstone in the vicinity of Cortland, Ohio.



EXPLANATION

GLACIOFLUVIAL SEDIMENTS--Deposited over bedrock valley

POTENTIOMETRIC SURFACE--Shows altitude at which water level would rise in tightly cased wells, September 1996

BOUNDARY BETWEEN GEOLOGIC FORMATIONS--Dashed where inferred

15 WATER WELL--Number is identifier with county prefix omitted. Dashed well has been projected onto section line

INTERVAL OF WATER WELL THAT IS OPEN TO AQUIFER

50 GAS WELL AND IDENTIFIER NUMBER

radiation increasing → GAMMA-RAY-LOG--Measure of the natural radioactivity of rocks near the borehole of a well. Shale is more radioactive than sandstone

Figure 4. Hydrogeologic section *A-A′* through Corland, Ohio. (Line of section shown in fig. 2.)

Sandstone aquifer in northeastern Ohio. The sandstone yields more water at shallow depth than where it is deeply buried, because weathering has enlarged joints within the formation near the land surface. Locally, the Berea Sandstone is thin and not a prolific source of ground water.

Bedford Shale

The Bedford Shale unconformably underlies the Berea Sandstone and is composed largely of silty gray shale; hard, silty, gray mudstone; and thin, platy, gray siltstone. The Bedford Shale functions as a confining layer between the Berea Sandstone and Cussewago Sandstone aquifers. The Bedford Shale ranges from 0 to 29 ft in thickness at the water wells in the study area. The upper contact of the Bedford Shale is extremely irregular, because the overlying Berea sandstone was deposited in channels that were scoured into the Bedford Shale prior to deposition of the Berea. In places, the Bedford Shale was completely eroded away prior to deposition of the Berea Sandstone. Where the Bedford Shale is absent (table 3, figs. 3 and 5), the Berea Sandstone and Cussewago Sandstone are likely in hydraulic connection. In addition, the Bedford Shale is missing beneath parts of the buried valley where a glacial paleostream incised through the confining unit.

The Bedford Shale correlates with a positive deflection (increasing natural-gamma radiation) on the gamma-ray log for well 50 and shows as a zone of high natural gamma radioactivity from 881 to 898 ft above sea level. Discontinuities in the Bedford Shale confining unit are reflected at the Cortland well fields. The drillers' logs for wells 36 and 37 in the South Well Field (fig. 2) show that the Bedford Shale is approximately 30 ft thick. However, geologic logs for wells 38 and 39 in the North Well Field do not report any clay or shale between the Berea Sandstone and Cussewago Sandstone.

Cussewago Sandstone

The Cussewago Sandstone was deposited by the delta fans of a system of rivers that flowed into Trumbull County from the east and southeast (Rau, 1969, sheet 1; Warner, 1978) during the Early Mississippian Epoch. The Cussewago Sandstone is a subcrop below the glaciofluvial sediments in the Mosquito Creek Lake, and it crops out west of the lake in Mecca Township (fig. 1). The Cussewago Sandstone is predominantly a white quartz sandstone that is usually free of silt, well sorted, and poorly cemented. The Cussewago Sandstone has a distinctive signature of low natural radioactivity on gamma-ray logs (fig. 4).

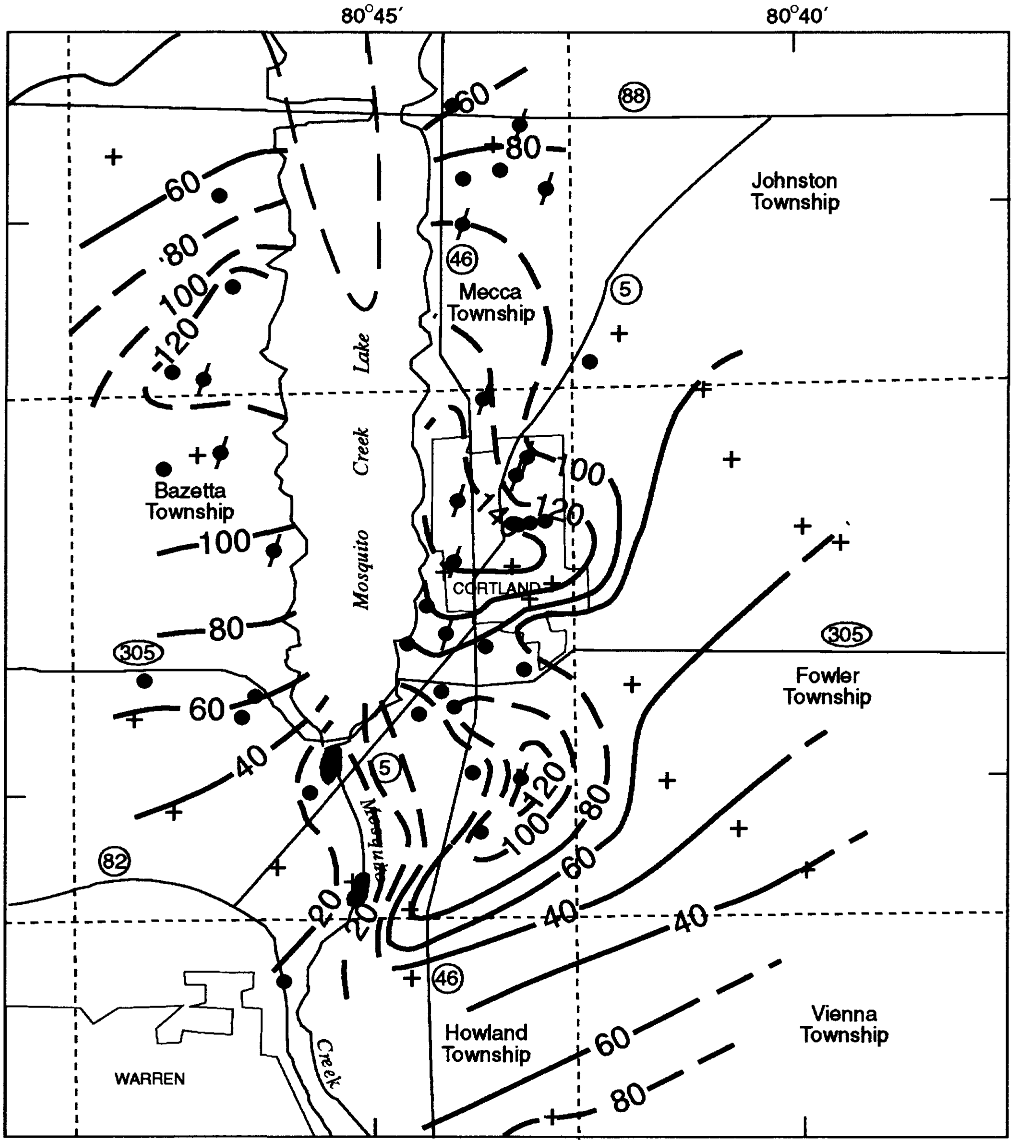
The upper surface of the Cussewago Sandstone in the study area ranges from 715 to 906 ft above sea level, and its altitude generally decreases toward the southeast (fig. 3). Beneath the Mosquito Creek flood plain, the upper surface of the Cussewago Sandstone is eroded to form a buried bedrock valley (figs. 2, 3, and 4). The glacial paleostream that created the bedrock valley incised into the Cussewago Sandstone, and further downward, incised through the Cussewago Sandstone and into the underlying Ohio Shale. The Cussewago Sandstone is missing at well 20 (figs. 1 and 2) and possibly missing at the Mosquito Creek Lake dam (U.S. Army Corps of Engineers, Pittsburgh, Pa., archived records). Results of this investigation show that the location of the Cussewago Sandstone subcrop south of the lake (fig. 1) is considerably different than previously mapped by Rau (1969, sheet 1).

In the study area, the thickness of the Cussewago Sandstone is varied, ranging from less than 20 ft in south-central Bazetta Township to 152 ft at well 32 in Cortland (fig. 5). At well 38 in the Cortland North Well Field, the Cussewago Sandstone is 105 ft thick. At well 36 in the Cortland South Well Field, it is 137 ft thick. About 4 mi southeast of the South Well Field, the Cussewago Sandstone thins to less than 30 ft. The Cussewago Sandstone is directly overlain by the Berea Sandstone where the Bedford Shale is absent at 13 water wells (figs. 3 and 5 and table 3).

In general, the Cussewago Sandstone is a prolific source of ground water. Wells commonly yield 50 to 100 gal/min. The aquifer can sustain well yields of greater than 100 gal/min in most areas east of the lake. The production rates of the Cortland public-supply wells range from 70 to 250 gal/min. Well yields are less in areas west of the lake.

Aquifer Hydraulic Properties

Hydraulic conductivity and storage coefficient are two measures used to describe hydraulic properties of an aquifer. Hydraulic conductivity, a measure of how readily water is transmitted through an aquifer, indicates the volume of water that can be moved horizontally or vertically through a unit area of an aquifer per given unit of time; in this report, storage coefficient (storativity) represents the volume of water that



Base modified from Ohio Department of Transportation
Trumbull County, July 1979

EXPLANATION

- AREA WHERE CUSSEWAGO SANDSTONE IS LIKELY MISSING–Shows location where glacial paleostream that created a buried bedrock valley incised through the Cussewago Sandstone and into the Ohio Shale
- NORTHERN EXTENT OF CUSSEWAGO SANDSTONE–Dashed where approximately located
- —40— STRUCTURE CONTOUR--Shows altitude of the top of the Cussewago Sandstone. Interval 20 feet. Dashed where approximately located. Datum is sea level
- ● WATER WELL--Shows location of well used to map the geologic framework (driller's log available). Identifier number is given in figure 2. Forward slash indicates that drillers' logs show the Bedford Shale as missing; the Berea Sandstone and cussewago Sandstone may be in hydraulic connection
- + GAS WELL--Shows location of well used to map the geologic framework (gamma-ray log available). Identifier number is given in figure 2

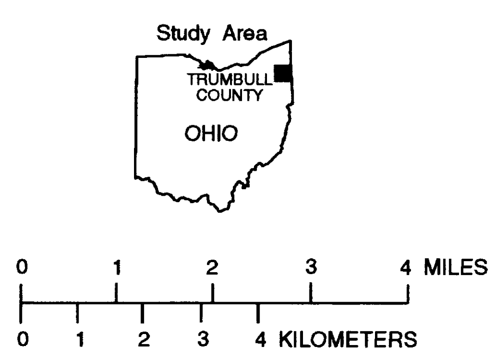


Figure 5. Thickness of the Cussewago Sandstone aquifer in the vicinity of Cortland, Ohio.

can be released from storage per unit area of aquifer per unit change in water level (head), expressed as a dimensionless number. Aquifer tests are one of a few techniques available for quantifying hydraulic properties.

Results from only one aquifer test, conducted on May 3–4, 1979 (Simpson, Moody and Associates, Inc., written commun., 1996), are available for the Cussewago Sandstone in the vicinity of Cortland. This aquifer test was a modified step test: during the first 100 minutes, well 38 (fig. 2; local identifier is well 5) in the Cortland North Well Field was pumped at 100, 200, and 300 gal/min, and during the next 1,400 minutes well 38 was pumped at 270 gal/min. Drawdown was measured in the pumped well. The Jacob semilog-analytical method (Cooper and Jacob, 1946) was used to interpret this aquifer test. In this method, the aquifer is assumed to be confined and of uniform thickness over the area influenced by the test, and the well is assumed to fully penetrate the aquifer and receives water by horizontal flow. The Jacob semilog-analytical method also requires constant discharge, a condition not met during the test. Because not all assumptions of the Jacob semilog-analytical method were met, and considering that one field test cannot be representative of an aquifer that covers many square miles, the results of this aquifer test are useful merely as an indicator of how readily the aquifer transmits water in the vicinity of the well. The reported horizontal hydraulic conductivity for the Cussewago Sandstone at well 38 is approximately 8 ft/d, which is within the range of hydraulic conductivity reported for a quartz sandstone aquifer of the Mississippian Period (Norman Grannemann, U.S. Geological Survey, oral commun., 1996; Freeze and Cherry, 1979, table 2.2 and 2.3).

Aquifer Confinement

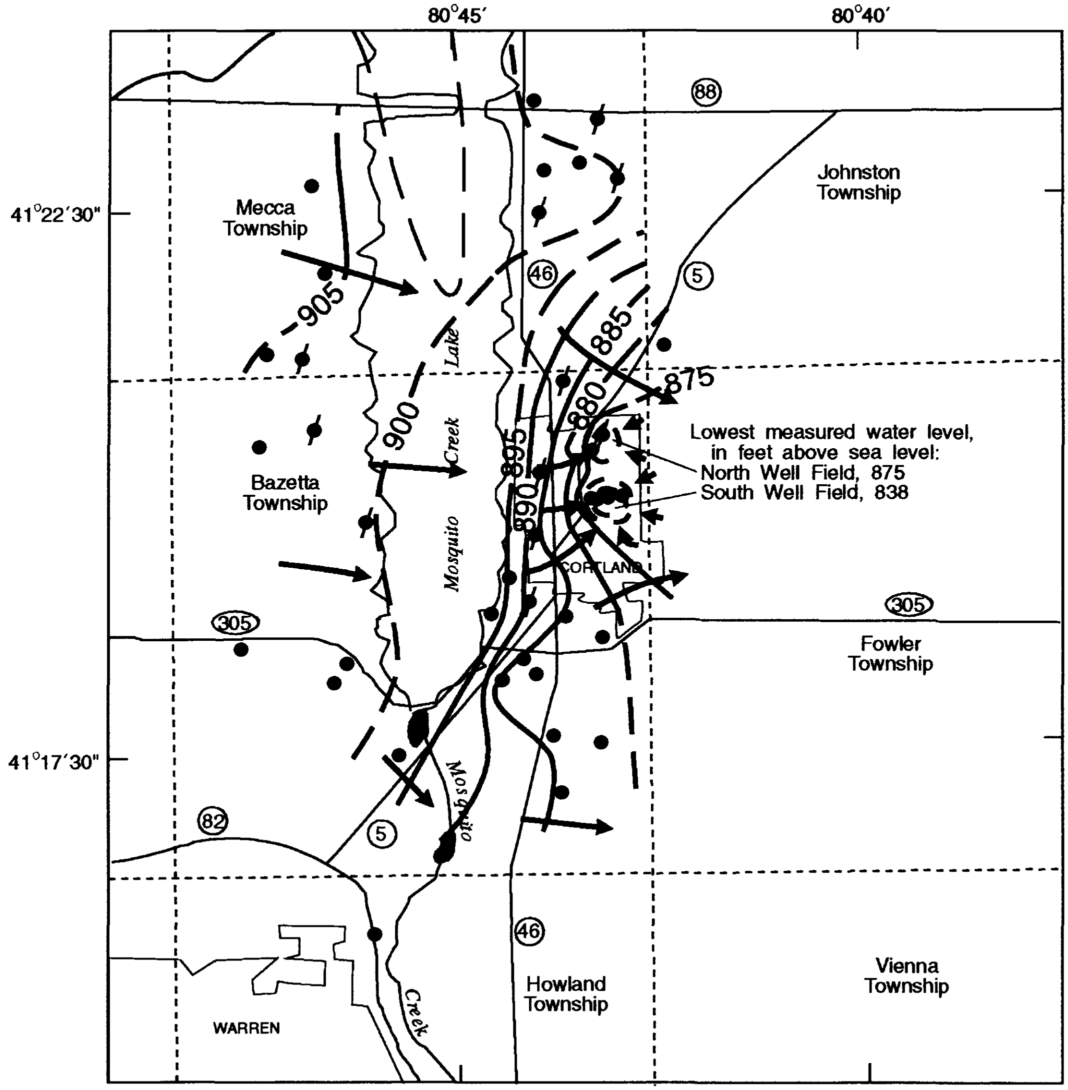
The Cussewago Sandstone is confined throughout most of the study area. This confinement helps protect the water in the aquifer from contamination associated with a surface spill. Impervious clay-rich till and shale overlies the Cussewago Sandstone throughout most of the study area. Water levels in the Cussewago Sandstone wells rise above the top of the aquifer. Aquifer confinement is best illustrated at well 21 (fig. 2), which naturally discharges water at about 1 gal/min. The well is located in the buried-bedrock valley south of Mosquito Creek Lake (fig. 1); here, the fine-grained glaciofluvial sediments overlying the Cussewago Sandstone function as a confining layer. West of the lake, where the Cussewago Sandstone crops out (fig. 2), the aquifer is near land surface; thus, it is likely to be unconfined and function as a water-table aquifer.

The Cussewago Sandstone aquifer at Cortland is confined. The concentrations of tritium in water samples collected from wells 31, 33, and 36, and in the composite sample from wells 38 and 39 (fig. 2) in Cortland were less than 0.8 TU. This near absence of detectable tritium in the water samples indicates that water in the Cussewago Sandstone at Cortland predates the atmospheric testing of nuclear weapons of the 1950's. Thus, shale confining layers overlying the Cussewago Sandstone at Cortland have virtually prevented any post-1953 tritium-enriched precipitation from infiltrating the Cussewago Sandstone aquifer.

Ground-Water Levels

The height of the potentiometric surface—the level to which water rises in a tightly cased well—is as much as 115 ft above the top of the Cussewago Sandstone in eastern Bazetta Township and is generally greatest in the southeastern part of the study area (fig. 4 and 6; table 2). Ground-water levels are above the top of the Cussewago Sandstone at all domestic supply wells. West of Mosquito Creek Lake in southwestern Mecca Township, however, the potentiometric surface is for the most part only a few feet above the top of the Cussewago Sandstone.

In the northern part of Cortland, water levels are about 10 to 25 ft above the top of the Cussewago Sandstone. South of Cortland's South Well Field, water levels are as much as 90 ft above the top of the Cussewago Sandstone. At the Cortland public-supply wells, airline water-level measurements ranged from about 10 ft above the top of the Cussewago Sandstone in well 39 in the North Well Field to about 20 ft below the top of the Cussewago Sandstone in well 35 and well 36 in the South Well Field. Water levels fluctuate daily in the public-supply wells in response to the volume of water withdrawn on a given day. For example, on December 3, 1996, electric tape water-level measurements in wells 35 and 36 showed water levels to be 7 and 13 ft above the top of the Cussewago Sandstone, respectively. In the North Well Field and in the South Well Field, water levels are at times below the top of the Cussewago Sandstone. During such times, a free-water surface develops in the Cussewago Sandstone; hence, the aquifer is not fully saturated and is unconfined. This is a local condition, and the free-water surface probably extends no more than a few hundred feet from a public-supply well.



Base modified from Ohio Department of Transportation Trumbull County, July 1979

EXPLANATION

AREA WHERE CUSSEWAGO SANDSTONE IS LIKELY MISSING--Shows location where glacial paleostream that created a buried bedrock valley incised through the Cussewago Sandstone and into the Ohio Shale

NORTHERN EXTENT OF CUSSEWAGO SANDSTONE--Dashed where approximately located

–905– STRUCTURE CONTOUR--Shows altitude of the top of the Cussewago Sandstone. Interval 20 feet. Dashed where approximately located. Datum is sea level

GENERALIZED DIRECTION OF GROUND-WATER FLOW

● WATER WELL--Shows location of well used to map the geologic framework (driller's log available). Identifier number is given in figure 2. Forward slash indicates that drillers' logs show the Bedford Shale as missing; the Berea Sandstone and cussewago Sandstone may be in hydraulic connection

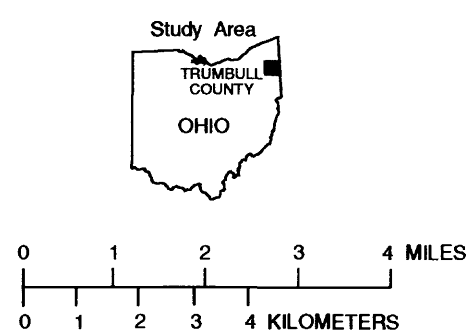


Figure 6. Water levels in the Cussewago Sandstone aquifer in the vicinity of Cortland, Ohio, September 1996.

During September 16–20, 1996, the direction of ground-water flow was to the east and southeast throughout most of the study area (fig. 6). West of Mosquito Creek Lake, the altitude of the potentiometric surface ranges from 900 to 907 ft above sea level and is higher than the lake pool elevation of 899.1 ft above sea level, indicating an easterly ground-water flow and a possibility that some ground water from this area discharges into the lake. East and south of the lake in Bazetta Township, the potentiometric surface ranges from 896 to 838 ft above sea level and is consistently lower than the lake pool elevation, indicating an easterly flow and potential for water to flow from the lake and recharge the Cussewago Sandstone. Ground-water withdrawals at both Cortland well fields have created cones of depression in the potentiometric surface (fig. 6). These cones of depression cause a local reversal in regional ground-water flow immediately east of both well fields.

Relation of Storage and Recharge to Pumpage

Preliminary computations of hydrologic-budget components are presented here to summarize the few broad generalizations that can be made about recharge to the Cussewago Sandstone in relation to aquifer storage and pumpage from the Cortland public-supply wells. For these computations, the area referred to as "in the immediate vicinity of Cortland" is the area between Route 305 and the Bazetta-Mecca Township line and east of Mosquito Creek Lake to the Bazetta-Fowler Township line.

Although average pumping rates are known and the amount of water in the aquifer can be computed, information needed to compute recharge rates is unavailable:

- Recharge by infiltration of rain and melting snow is added to the Cussewago Sandstone where the aquifer crops out west of lake; however, the aquifer recharge rate cannot be determined from base-flow separation of the streamflow data for USGS station 03095500 (fig. 1) because this station was installed during the impoundment of Mosquito Creek.

- The rate at which water flows from the lake and recharges the Cussewago Sandstone is not known. As previously indicated, recharge to the Cussewago Sandstone almost certainly occurs where this aquifer is a subcrop of the glaciofluvial sediments in lake, but flow from the lake to the Cussewago Sandstone must be impeded to some extent by the poorly permeable Holly clay loam soil and glaciofluvial bed sediments. Since impoundment of the lake, fine-grained silt and clay has been continuously deposited on the bottom, thus reducing the permeability of the bottom sediments.

- Although the Cussewago Sandstone aquifer is confined, the Berea Sandstone and the Bedford Shale probably provide recharge to the aquifer. The downward hydraulic gradient believed to exist over much of the study area (see section on "Vertical Hydraulic Gradient") induce some flow of water from the Berea Sandstone through the Bedford Shale and into the Cussewago Sandstone. The vertical hydraulic gradient between the two aquifers was not measured during this investigation, so recharge rates cannot be determined; however, the rate of recharge must be low because water in the aquifer does not contain any substantial concentrations of tritium.

The amount of water that the Cussewago Sandstone aquifer holds is vast. In the immediate vicinity of Cortland, approximately 15,000 Mgal of water currently in the Cussewago Sandstone could be gravity drained from the aquifer without considering recharge to the aquifer. This volume of water was computed by use of the following equation:

$$V_g = 7.481(10^{-6})AbS_y,$$

where

V_g is volume of water drained by gravity (Mgal),
A is surface area of the aquifer (ft^2),
b is estimated average saturated aquifer thickness (ft), and
S_y is specific yield (dimensionless).

This computation is based on a specific yield of 15 percent (Lohman, 1979, p. 8) and on an average saturated aquifer thickness of 115 ft. The 15,000 Mgal is equivalent to about 75 years of withdrawals at current (1990–95) rates. The Cussewago Sandstone in Mecca Township east of Mosquito Creek Lake contains approximately 13,000 Mgal of water. This estimate also is based on a specific yield of 15 percent and on an average saturated aquifer thickness of 95 ft.

A more pertinent computation, however, is the volume of water in storage that could be withdrawn without considering recharge to the aquifer and without lowering water levels below the top of the aquifer. (Water that is released from or taken into storage in a confined aquifer can be attributed only to the compressibility of the confined artesian aquifer and of the water.) In the immediate vicinity of Cortland, this volume is estimated to be about 2 Mgal, a volume equivalent to only 1 percent of the average annual 1990–95 pumping rate of the Cortland well fields. The volume of water in storage was computed by use of the following equation (Lohman, 1979):

$$V_s = 7.481(10^{-6})ASh_z,$$

where

V_s is volume of water in storage (Mgal),
A is surface area of the aquifer (ft^2),
S is estimated storage coefficient (dimensionless), and
h_z is average water level above the top of the Cussewago Sandstone (ft).

This computation is based on an estimated storage coefficient of 0.0001 (Lohman, 1979, p. 8) and an average water level extending about 25 ft above the top of the Cussewago Sandstone (fig. 6). Although the volume of water that could be withdrawn from storage in the aquifer is not large enough to support current ground-water withdrawals without causing significant water-level drawdown, no widespread declines in ground-water levels have been reported for the Cussewago Sandstone aquifer. Therefore, the Cussewago Sandstone must receive adequate recharge to support current withdrawals by Cortland public-supply wells.

Although recharge rates for the Cussewago Sandstone aquifer have not been determined, estimates can be made to broadly characterize the relation between aquifer recharge and the diversion of ground water by the Cortland public-supply wells. Recharge over 1 mi^2 of the Cussewago Sandstone subcrop beneath the glaciofluvial sediments in Mosquito Creek Lake (fig. 1 and 2) appears to provide sufficient water to the aquifer to replenish the ground water diverted by the Cortland public-supply wells. This estimate is based on an average pumping rate of 203 Mgal/yr for 1990–95 and an assumed aquifer recharge rate of 6 in/yr (Pettyjohn and Henning, 1979; Eberts and others, 1990, p. 19). The 1-mi^2 recharge area represents less than 50 percent of the Cussewago Sandstone subcrop beneath the lake. As a caveat to this calculation, the following should be considered: (1) The area of the Cussewago Sandstone subcrop beneath the lake is based on geologic mapping (Pepper and others, 1954; Rau, 1969, sheet 1) done on a regional scale, and (2) currently, no geologic data are available for mapping the Cussewago Sandstone beneath the lake. In addition to recharge from the lake, a small amount of downward leakage from overlying rock units could potentially be counted as recharge. An assumed 1 in. of leakage per year from the Berea Sandstone and Bedford Shale overlying the Cussewago Sandstone in the immediate vicinity of Cortland would amount to approximately 70 Mgal/yr of recharge to the aquifer; this recharge is equivalent to about 35 percent of the average 1990–95 annual withdrawal rate.

Area Contributing Recharge to Cortland Public-Supply Wells

The closest contributing recharge area for the North Well Field and South Well Field is the Cussewago Sandstone subcrop below the glaciofluvial sediments in Mosquito Creek Lake (fig. 1 and 2). The estimated traveltimes along ground-water flow paths from the Cussewago Sandstone subcrop beneath Mosquito Creek Lake to the Cortland well fields range from about 60 to 110 years. Traveltimes are computed by use of the Darcy equation for ground-water flow. These traveltimes are based on a hydraulic gradient that ranges from 0.003 to 0.007, hydraulic conductivity of 8 ft/d, and an estimated effective porosity of 15 percent (Driscoll, 1989, table 5.1). Based on these traveltime estimates, the age of the ground water at the well fields predates the detonation of nuclear weapons in the atmosphere during the 1950's and is consistent with the absence of substantial concentrations of tritium in the water samples collected from wells 29, 31, and 36 and the composite sample from wells 38 and 39.

Vertical Hydraulic Gradient

The general decrease in water-level altitude with depth, from aquifer to aquifer, throughout much of the study area, indicates a prevalent downward hydraulic gradient. Local water-well drillers report that the water level in an open borehole declines when a cable-tool drill bit advances through the Cuyahoga Group and into the Berea Sandstone, and the water level declines again when the bit advances into the Cussewago Sandstone (Thomas Repphun, TNT Water Company Incorporated, Cortland, Ohio, oral commun., 1996). Data collected on September 18 and 20, 1996, support the drillers' statements. Well 47, located about 1 mi northeast of Cortland and completed in the Cuyahoga Group, had a water level of 1,042 ft above sea level. This water level is estimated to be about 180 ft higher than the water levels of the Cussewago Sandstone at the same location, indicating a downward hydraulic gradient towards the Cussewago Sandstone aquifer. Well 20, located south of the Mosquito Creek Lake and completed in the Ohio Shale, had a water level of 884 ft above sea level. This water level is approximately 16 ft below the mapped potentiometric surface in the Cussewago Sandstone at that same location (fig. 6), indicating a downward hydraulic gradient between the Cussewago Sandstone and the underlying Ohio Shale confining unit.

As previously mentioned, there is a strong downward vertical hydraulic gradient between the Berea Sandstone and Cussewago Sandstone east and southeast of Mosquito Creek Lake. Thus, in domestic supply wells that are open to both the Berea Sandstone and Cussewago Sandstone aquifers, water in the Berea Sandstone can enter the well, flow down the open borehole, and exit from the borehole into the Cussewago Sandstone. In effect, a well completed in both aquifers functions as a pipeline that hydraulically connects both aquifers. The long-term effect that this mixing of water between the two aquifers has on water quality is unknown.

Possibilities For Simulation of the Effects of Ground-Water Withdrawals

Computer simulation of the effects of long-term ground-water withdrawals on water levels, the optimization of ground-water withdrawals, and the delineation of contributing recharge areas to pumped wells require the use of a numerical flow model. Analytical and semianalytical models, although less time-consuming than numerical models, require certain simplifying assumptions that are not met in the case of the Cussewago Sandstone and Berea Sandstone. The hydraulic gradient in the study area is not uniform; thus, the analytical and semianalytical model approach would not be valid (Ohio Environmental Protection Agency, 1992, p. 32).

The most important reason for using a numerical flow model to simulate ground-water withdrawals is that such models are designed to simulate fully saturated confined aquifers that become partially saturated during simulations of the withdrawals. Computer simulations to study the optimization of ground-water withdrawals at Cortland would likely involved pumping alternative whereby a fully saturated, confined Cussewago Sandstone becomes partially saturated. Important benefits of using a numerical flow model in the study area include investigating (1) the rate of infiltration of water from the Mosquito Creek Lake to the underlying Cussewago Sandstone and (2) the vertical leakage of water from the Berea Sandstone and Bedford Shale to the Cussewago Sandstone.

SUMMARY AND CONCLUSIONS

The city of Cortland, on the southeastern shoreline of the 12.3-mi^2 Mosquito Creek Lake, relies on wells for potable water. These wells are completed in the Cussewago Sandstone, the principal aquifer in the vicinity of Cortland.

The Cussewago Sandstone aquifer is a subcrop of the glaciofluvial sediments in the Mosquito Creek Lake, and the unit dips gently towards the southeast. The thickness of the Cussewago Sandstone is varied and ranges from less than 20 ft to about 152 ft. The regional ground-water flow pattern is generally west to east in the study area. East and south of the lake, the potentiometric surface of the aquifer is lower than the pool elevation in the lake. Water flows from the lake and recharges the Cussewago Sandstone; however, flow is impeded to some extent by low-permeability bed sediments in the lake. The confined nature of the aquifer is evident from measured water levels showing that the potentiometric surface is above the top of the Cussewago Sandstone. The absence of detectable concentrations of tritium in water samples from Cussewago Sandstone wells at Cortland indicates that the ground water predates the atmospheric nuclear testing of the 1950's. Ground water requires about 60 to 110 years to flow from the aquifer subcrop of the glaciofluvial sediments in the lake to the Cortland well fields.

The Berea Sandstone is above the Cussewago Sandstone in the study area; however, is not a prolific source of ground water. The Bedford Shale functions as a confining layer between the Berea Sandstone and Cussewago Sandstone. In places, the Bedford Shale was completely eroded away prior to deposition of the Berea Sandstone. Where the Bedford Shale is absent, such as the City of Cortland North Well Field, the Berea Sandstone and Cussewago Sandstone are likely in hydraulic connection.

East and southeast of Mosquito Creek Lake, there is a strong downward vertical hydraulic gradient between the Berea Sandstone and Cussewago Sandstone. Thus, in domestic supply wells that are open to both the Berea Sandstone and Cussewago Sandstone aquifers, water in the Berea Sandstone can enter the well, flow down the open borehole, and exit from the borehole into the Cussewago Sandstone. In effect, a well completed in both aquifers functions as a pipeline that hydraulically connects both aquifers. The long-term effect that this mixing of water between the two aquifers has on water quality is not known. In addition, south of the lake, there is a downward vertical hydraulic gradient between the Cussewago Sandstone and the Ohio Shale.

In the immediate vicinity of Cortland—between Route 305 and the Bazetta-Mecca Township line and east of Mosquito Creek Lake to the Bazetta-Fowler Township line—about 2 Mgal of water currently in storage in the Cussewago Sandstone could be withdrawn from the aquifer without considering recharge to the aquifer and without lowering water levels below the top of the aquifer. This volume of water, however, is equivalent to only 1 percent of the average annual 1990–95 pumping rate of the Cortland well fields. The volume of water in storage in the aquifer is not large enough to support ground-water withdrawals by the Cortland public-supply wells, yet no widespread declines in ground-water levels have been reported for the Cussewago Sandstone aquifer. Thus, recharge to the Cussewago Sandstone (sources are Mosquito Creek Lake and the downward leakage of water from the overlying Berea Sandstone and Bedford Shale) must replenish the water that is diverted from the aquifer by pumped supply wells. This recharge is adequate to support current withdrawals by Cortland public-supply wells.

A numerical flow model rather than an analytical or semianalytical model would be needed to accurately simulate flow and ground-water withdrawals in the Cussewago Sandstone in Cortland. The most important reason for using a numerical flow model to simulate ground-water withdrawals is that such a model can simulate fully saturated confined aquifers that may become partially saturated during simulations of future withdrawal. Computer simulations of flow would likely involve alternatives whereby a fully saturated, confined Cussewago Sandstone becomes a partially saturated aquifer.

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