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DEPARTMENT OF PUBLIC WORKS

OHIO WATER RESOURCES BOARD

THE WATER RESOURCES OF TUSCARAWAS COUNTY, OHIO

BULLETIN No. 6

MAY 1947

Prepared in cooperation with

U.S. Geological Survey

Bulletin 6

OHIO WATER RESOURCES BOARD

Columbus, Ohio

THE WATER RESOURCES OF TUSCARAWAS COUNTY, OHIO

By

James W. Cummins and Earl E. Sanderson

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Prepared in cooperation with
the U.S. Geological Survey

May, 1947

LETTER OF TRANSMITTAL

Dean Charles E. MacQuigg, Chairman
Ohio Water Resources Board
Columbus, Ohio

Dear Sir:

Herewith is the report "The Water Resources of Tuscarawas County" which I am recommending for publication as Bulletin 6 of the Ohio Water Resources Board.

Many requests for information concerning water supply for industrial sites in the general area of Tuscarawas County made it advisable to prepare a comprehensive report on the available quantity and quality of both surface water and ground water in the county.

The report should be of value to all concerned in developing water supplies for municipal, industrial or agricultural use.

Respectfully submitted

C.V. Youngquist
Chief Engineer

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INTRODUCTION

PURPOSE AND SCOPE OF THE REPORT

This report describes the results of an investigation of the water resources of Tuscarawas County, Ohio. It is one of a series of such reports to be prepared cooperatively by the Ohio Water Resources Board and the U. S. Geological Survey, and is a continuation of the series of reports on the water resources of Ohio, county by county, published by the Ohio Water Supply Board and later by the present Ohio Water Resources Board. It was prepared under the general supervision of C. V. Youngquist and R. J. Bernhagen, Chief Engineer and Chief Geologist, respectively, of the Ohio Water Resources Board, and A. N. Sayre, Chief, Division of Ground Water, U. S. Geological Survey.

The report is intended to serve as a guide for the proper development of farm, public, and industrial water supplies in Tuscarawas County. Agriculturalists interested in proper selection of crops to be grown in the county may also find the report of value insofar as water requirements affect such selection.

The present report is preliminary in scope. Field investigations of the ground-water resources of the county were made in the summer and fall of 1946 to determine the areas in which large ground-water supplies can be expected. No attempt has been made to determine the amounts of water that may be obtained from the more promising areas. Supplemental reports will be prepared for publication when quantitative investigations of these areas are made. Additional data regarding the surface-water supplies of the county will be published as they become available.

ACKNOWLEDGMENTS

Many of the data on which this report is based were obtained from publications of other governmental agencies engaged in related fields of work. A bibliography listing these publications is included at the end of this report for the benefit of those requiring more detailed data than are presented here. The numbered references in the text correspond to the numbered publications listed in the bibliography.

The conduct of the field work and preparation of the ground-water section of this report were done with the advice and assistance of R. J. Bernhagen, Chief Geologist, Ohio Water Resources Board and E. J. Schaefer, Hydraulic Engineer, U. S. Geological Survey. The analyses of precipitation and stream-flow data were done by Professor Don Johnstone, Department of Civil Engineering, Ohio State University. The stream-flow records were furnished by O. H. Jeffers, Acting District Engineer, U. S. Geological Survey.

In addition to the above, the authors acknowledge the assistance of Perry M. Allen, Investigator, Ohio Water Resources Board, in surveying industrial water supplies in the county. R. E. Lamborn, Assistant Geologist, Geological Survey of Ohio, gave valuable assistance in permitting study of unpublished maps and notes from his personal files, concerning the detailed stratigraphy and areal geology in the county. The authors also acknowledge the help given by G. W. White, State Geologist, in making available a great deal of geologic information contained in the files of the Geological Survey of Ohio, and also in reviewing the report.

Many well records were made available by the East Ohio Gas Company, Cleveland; the Ohio Fuel Gas Company, Columbus; the Industrial Gas Company, Newark; the Everett Waltz Drilling Company, Strasburg; the Mont Waltz Drilling Company, Strasburg; and the Ohio Division of Mines, Columbus. Well owners throughout the county also contributed much information regarding ground-water conditions in specific areas.

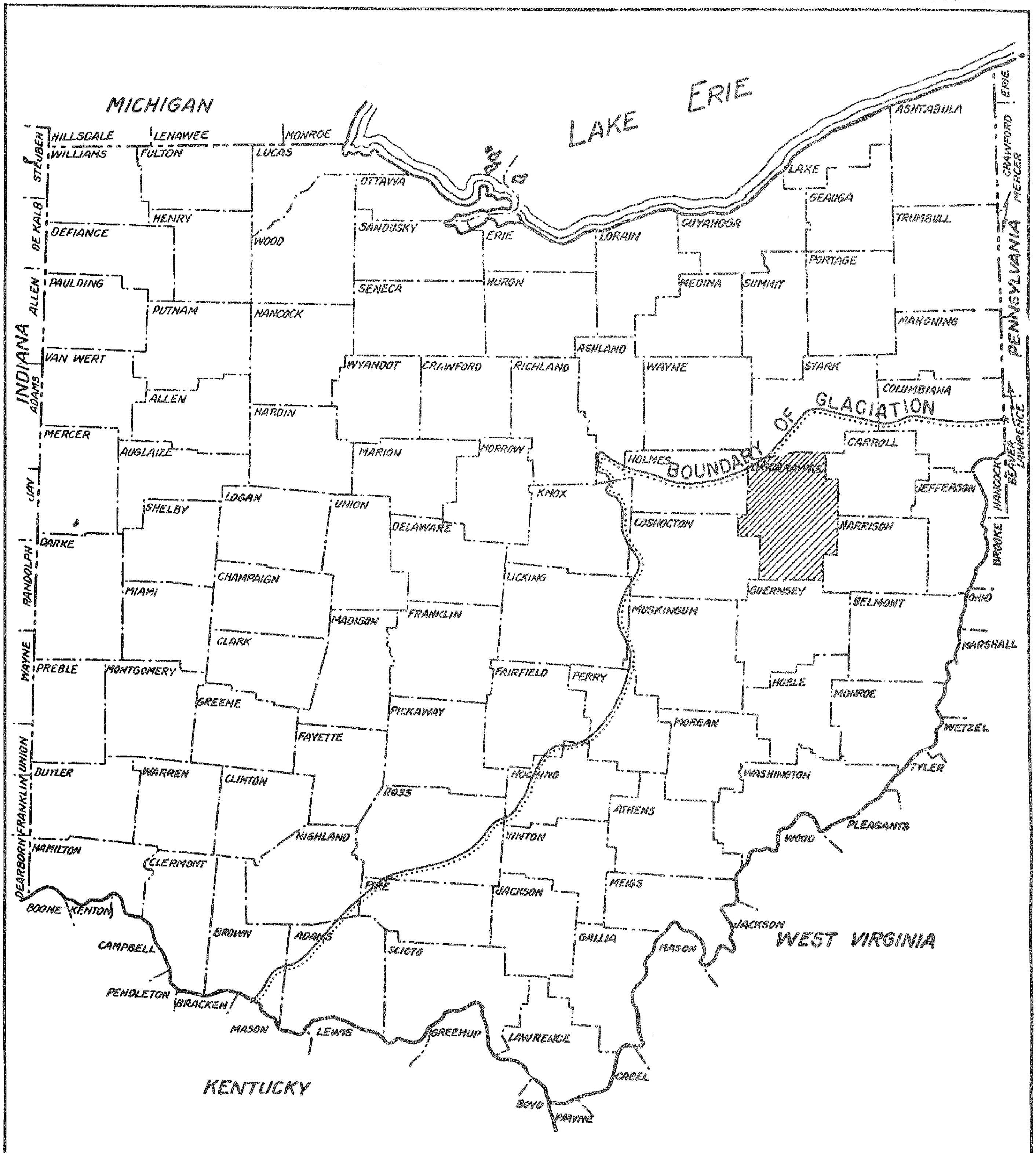


Plate I- Map showing location of the area included in this report and its relation to the Boundary of Glaciation.

GEOGRAPHY

LOCATION AND EXTENT OF THE AREA

Tuscarawas County is located approximately 70 miles south of Lake Erie and 50 miles west of the Ohio River, in the east-central section of Ohio, as shown on the index map on plate 1. It extends about 23 miles east and west and 30 miles north and south and has an area of 571 square miles.

TOPOGRAPHY

Tuscarawas County is located almost entirely outside the glaciated area of Ohio. The boundary of glaciation crossed the extreme northwestern corner of the county, as shown on plate 1. The general topography is that of a plateau, deeply dissected by preglacial, interglacial, and recent stream erosion. The southern and eastern sections of the county consist of sharply crested hills and ridges and V-shaped valleys. In contrast, the hills in the northern and western parts of the county are more gently rounded and the valleys are generally broad and flat. The tops of the hills and ridges throughout the county are about 1,200 feet above sea level. The total relief averages 300 feet in the southern half of the county and 200 feet in the northern half of the county.

DRAINAGE

Tuscarawas County lies entirely within the drainage basin of the Muskingum River. Most of it is drained by the Tuscarawas River and its tributaries. A few square miles along the southern edge of the county are drained by tributaries of Wills Creek, which flows into the Muskingum River near Conesville. The present drainage pattern of streams within the county is shown on the map on plate 2. The characteristics of the streams draining the county are discussed more fully in the surface-water section of this report.

CLIMATE

Tuscarawas County lies along the north boundary of the central climatic section of Ohio. Its climate is near the average for the State (1). The average annual temperature is 50°F. At Dover the 42-year average is 49.8°F. and at Dennison the 36-year average is 51.6°F. The range of daily temperatures averages 33°F. The range of average annual extremes is 106°F., with a maximum annual range of 130°F., which occurred in 1918. The highest temperature of record is 105°F. and the lowest of record is

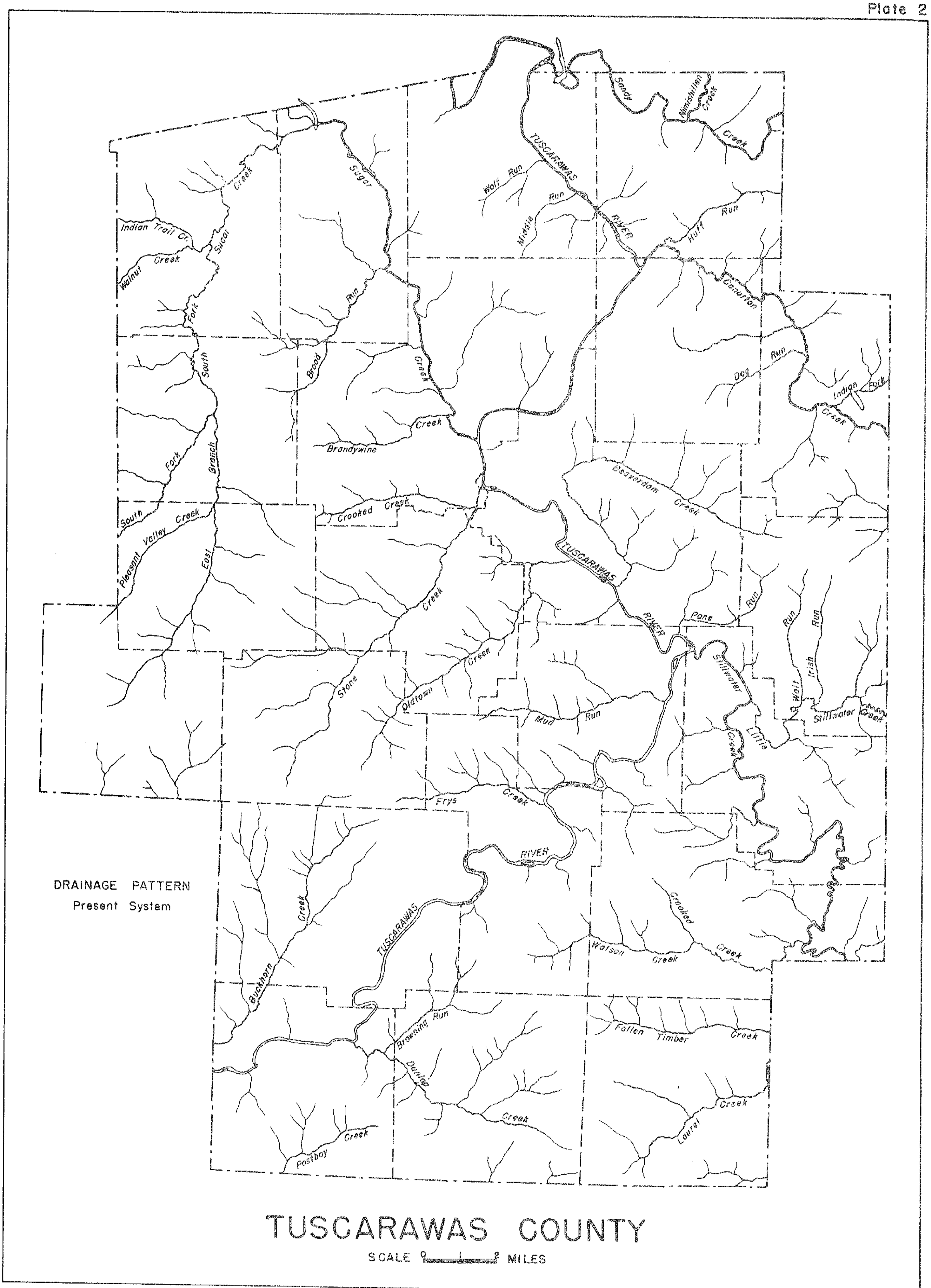


Plate 2 - Drainage pattern, present system.

$-25^{o}F$. It is of interest that both the highest and lowest temperatures recorded occurred in 1918. The average monthly and annual temperatures at Dennison are shown in table 1.

The average length of the growing season is 155 days. The average date of the last killing frost in the spring is May 9, and that of the first killing frost in the fall is September 18. A tabular summary of climatic data pertaining to Tuscarawas County is shown in table 2 (2).

The hydrologic year beginning with October 1 and ending with September 30 is used in the tabulations of temperature, precipitation and other climatic data because it corresponds with the normal annual rainfall and stream-flow cycle in Ohio. October is the month of lowest average stream flow and lowest average total precipitation. Another advantage is that the snowfall season occurs entirely in one year of record and is not divided between two years as would be the case if the calendar year was used. For example, if the calendar year is used, snow that falls in December may not melt until February or March and would appear as stream flow in the records of the following year. The use of the hydrologic year eliminates all such carry-overs from one year of record to another.

Precipitation

The collection of precipitation records in Tuscarawas County was started at Newcomerstown in 1887 by the U. S. Weather Bureau (3). No continuous record at any one location was obtained prior to 1910, when a station for gaging precipitation was established at Dennison. The Dennison gage has been operated continuously since that time. The monthly and annual precipitation at U. S. Weather Bureau stations within the county are shown in table 3, (A-E).

Precipitation gages have been operated throughout Tuscarawas County since 1935 by the U. S. Soil Conservation Service in cooperation with the Muskingum Watershed Conservancy District. The number of stations in operation varies from time to time. The records are tabulated at the Muskingum Climatic Research Center, New Philadelphia, Ohio. The stations were established for the purpose of obtaining data on heavy and intense rainfall within the Muskingum River Basin as a part of the operational studies of the flood-control works of the Muskingum Watershed Conservancy District. The records in general are not continuous at any one locality. Most of the gages have been moved many times and a large percentage of the stations were discontinued during the recent war. The records are published in the Hydrologic Bulletins for the Ohio River District and can be obtained from the U. S. Weather Bureau Office, Chicago, Illinois.

On the average, 56 percent of the annual precipitation falls in the 6 months from April 1 to September 30, and 44 percent falls in the period

TABLE 1

AVERAGE MONTHLY AND ANNUAL TEMPERATURE AT DENNISON, OHIO

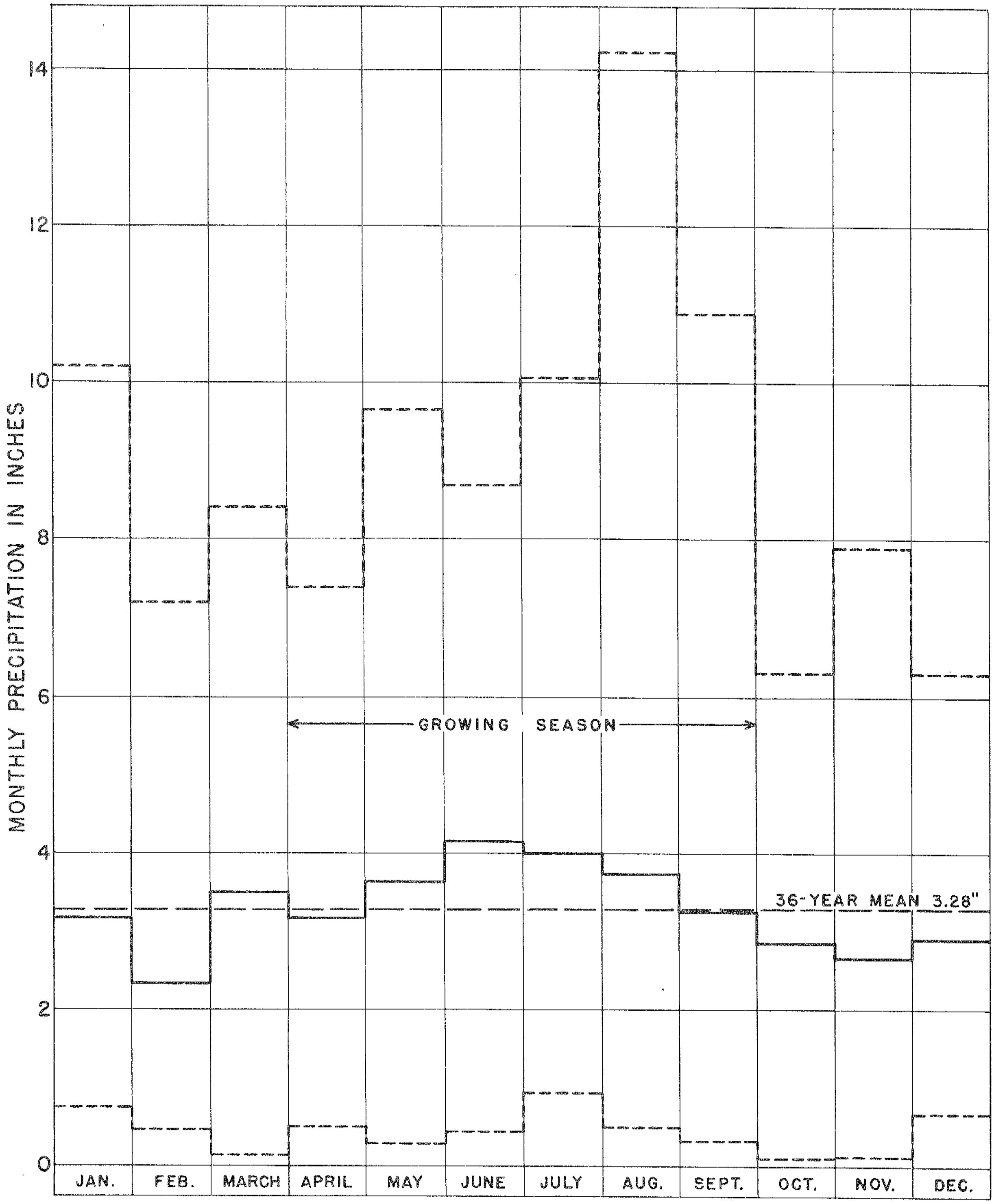
(In Degrees Fahrenheit)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1909-10	49.2	49.0	26.7	28.1	26.4	47.8	52.6	57.2	67.4	74.8	72.4	67.8	51.6
1910-11	58.1	36.4	27.0	34.2	37.2	37.6	49.0	66.5	72.2	74.8	74.2	69.4	53.1
1911-12	52.0	38.6	36.6	19.9	24.6	35.4	53.8	64.0	67.4	75.0	69.8	67.4	50.4
1912-13	54.6	42.0	35.0	37.7	28.3	42.1	51.9	61.4	70.9	73.1	73.8	64.8	53.0
1913-14	54.7	43.3	34.2	33.6	22.8	36.4	51.2	62.2	71.5	73.2	73.2	63.7	51.7
1914-15	57.6	42.4	29.2	28.4	35.7	33.0	54.6	58.8	67.8	71.9	68.8	68.0	51.4
1915-16	55.5	43.8	31.0	33.9	27.6	35.4	48.8	62.9	63.8	76.4	73.8	63.5	51.4
1916-17	52.9	42.3	29.7	28.7	29.3	40.2	49.4	55.0	67.0	72.4	71.6	61.6	50.0
1917-18	47.0	37.4	20.6	15.0	31.8	44.1	50.2	66.3	68.5	70.9	77.0	58.6	49.0
1918-19	57.8	43.0	39.3	33.8	34.2	42.0	50.1	60.2	73.8	74.4	70.4	66.3	53.8
1919-20	61.0	43.0	26.4	23.2	28.6	42.0	47.2	58.0	68.1	69.7	70.8	66.6	50.4
1920-21	57.8	40.5	34.8	33.4	34.4	49.2	55.8	61.0	72.6	76.5	69.2	70.1	54.6
1921-22	52.9	44.0	34.0	27.5	34.5	43.2	52.8	63.6	69.9	72.5	69.3	67.6	52.7
1922-23	55.2	44.4	34.2	32.8	27.0	38.6	48.0	58.6	69.5	71.3	69.6	65.7	51.2
1923-24	51.0	41.3	41.2	27.2	28.4	37.2	49.6	54.4	67.3	69.0	71.2	62.4	50.0
1924-25	54.6	41.4	29.4	28.2	36.0	41.7	53.6	54.2	71.8	70.7	71.0	69.5	51.8
1925-26	46.5	39.6	29.2	29.0	31.5	34.3	43.0	59.4	65.2	71.6	73.6	66.8	49.1
1926-27	52.8	40.6	30.0	29.0	37.0	43.0	50.4	60.4	63.0	71.5	65.2	65.8	49.7
1927-28	56.4	46.8	31.8	29.0	32.0	38.4	46.8	58.0	65.2	72.5	73.2	59.7	50.8
1928-29	42.8	34.0	26.4	26.0	45.2	59.4	67.7	72.0	67.7	72.0	67.0	65.6	51.3
1929-30	51.8	39.7	33.3	30.0	39.1	39.0	53.0	62.8	70.0	74.4	71.0	67.4	52.6
1930-31	50.2	41.8	31.1	32.0	34.2	37.0	49.6	59.8	70.0	77.4	73.4	69.6	52.2
1931-32	56.2	49.3	40.4	41.2	38.4	34.7	48.8	61.8	71.0	72.6	71.2	66.6	54.3
1932-33	55.1	40.2	33.0	38.6	32.8	39.2	52.2	63.6	72.7	73.6	71.8	68.0	53.4
1933-34	52.4	39.4	35.2	33.8	19.6	35.4	49.8	62.7	75.1	76.8	70.2	67.4	51.5
1934-35	52.2	45.8	31.4	31.4	31.6	47.4	48.5	56.8	67.4	76.2	72.8	63.6	52.1
1935-36	52.8	43.4	25.2	23.7	23.3	42.8	45.8	62.6	70.2	74.0	74.2	68.6	50.5
1936-37	54.0	38.7	35.4	38.0	33.2	34.7	49.8	60.0	70.9	73.2	74.6	61.6	52.0
1937-38	51.7	39.9	29.0	30.4	39.0	46.8	52.6	61.0	67.5	73.4	73.9	64.4	52.5
1938-39	54.6	42.8	32.6	33.8	34.2	42.4	49.2	62.9	72.4	71.6	71.0	69.6	53.1
1939-40	54.7	40.0	35.8	15.7	29.6	35.0	47.2	59.1	68.9	71.2	70.6	60.0	49.0
1940-41	51.7	39.8	36.6	29.0	26.4	31.8	55.0	60.5	68.0	71.6	70.0	68.2	50.7
1941-42	58.1	44.2	38.5	29.3	28.0	43.6	55.8	64.4	71.3	73.4	69.8	63.8	53.3
1942-43	55.0	43.6	29.4	31.3	32.8	38.7	45.0	61.4	74.0	73.6	70.8	62.0	51.5
1943-44	51.2	39.2	30.0	32.3	33.4	38.8	49.3	67.3	72.0	73.0	72.2	63.6	51.8
1944-45	52.8	42.6	26.8	22.8	32.4	50.4	54.6	57.0	67.9	72.0	71.5	67.4	51.5
1945-46	51.5	43.6	27.0	32.3	34.0	51.0	50.4	60.0	69.0	71.6	66.0	64.6	51.8
Aver.	53.8	42.1	32.0	29.9	31.2	40.4	50.5	60.7	69.4	73.1	69.5	65.6	51.6
Max.	61.0	49.3	41.2	41.2	39.1	51.0	55.8	67.3	75.1	77.4	77.0	70.1	
Min.	46.5	36.4	20.6	15.0	19.6	31.8	43.0	54.2	63.0	69.0	65.2	59.7	

Maximum hydrologic year 1920-21 = 54.6
Minimum hydrologic year 1939-40 = 49.0

TABLE 2
CLIMATIC DATA - TUSCARAWAS COUNTY

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Temperature at Dennison °F.													
Average	53.9	42.0	31.8	29.0	31.1	40.2	50.8	60.2	68.6	72.8	71.3	65.6	51.3
Average maximum	67.2	52.4	40.8	38.6	41.0	52.7	64.1	74.3	82.4	86.6	85.0	79.5	63.7
Average minimum	40.7	31.6	23.1	19.9	21.1	28.3	37.5	46.2	54.8	58.9	57.6	51.7	39.3
Highest	90	76	70	70	75	85	93	99	101	105	105	97	105
Lowest	15	0	-20	-25	-21	0	5	25	32	38	37	29	-25
Temperature at Dover °F.													
Average	51.8	39.8	30.2	27.2	27.3	38.5	48.4	59.5	67.9	72.4	70.2	63.7	49.8
Average maximum	64.1	48.9	37.6	35.8	36.8	48.8	60.1	71.8	79.9	84.8	82.3	76.2	60.6
Average minimum	40.2	30.7	22.4	18.5	18.5	28.1	36.3	46.7	55.6	60.2	57.7	51.5	38.9
Highest	89	75	68	72	70	85	93	97	100	102	99	98	102
Lowest	12	0	-19	-24	-25	-11	6	25	28	40	39	27	-25
Prevailing wind Direction at Dover	S	S	SW	W	W	W	W	SW	SW	SW	SW	S	SW
Average hourly wind velocity at Coshocton 1939 (miles per hour)	4	5	7	9	9	9	9	5	4	4	4	4	6.1
Average relative humidity (percentage) at Columbus													
8:00 A.M.	81	82	83	83	82	79	74	75	77	77	79	80	79
Noon	60	68	74	72	72	64	61	59	58	53	57	58	63
8:00 P.M.	64	70	76	76	74	68	62	61	63	60	61	63	66
Average snowfall (inches)													
Dennison	.2	2.0	4.2	7.7	6.9	4.0	1.1	T	0	0	0	0	26.1
Dover	.1	1.3	5.1	8.3	6.7	4.4	1.7	T	0	0	0	0	27.6



Notes:

Solid line shows the 36-year mean for each month of the year, at Dennison, Ohio.

Dotted lines show the maximum and minimum monthly precipitation of record at any station in the county.

Plate 3 - Average monthly precipitation at Dennison, Ohio, and maximum and minimum monthly precipitation recorded in Tuscarawas County.

TABLE 3A

MONTHLY AND ANNUAL PRECIPITATION IN INCHES AT DOVER, OHIO

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1892-93										3.30	2.75	1.56	
1893-94	3.97	1.71	2.23	2.29	3.65	2.20	3.07	3.36	2.13	1.28	0.50	3.75	30.14
1894-95	1.92	3.85	2.45	5.19	0.79	1.63	1.78	1.62	3.45	3.88	3.64	1.96	32.16
1895-96	1.91	3.46	5.42	1.99	2.74	3.55	3.28	3.25	6.04	10.07	2.85	4.17	48.73
1896-97	1.11	2.21	3.28	2.14	4.25	4.52	4.05	3.81	1.61	6.91	2.69	0.69	37.27
1897-98	0.26	7.88	2.64	4.65	3.22	8.43	2.40	5.62	3.39	4.57	3.79	1.57	48.42
1898-99	4.24	3.00	3.18	3.28	2.18	4.53	2.17	6.84	2.89	3.53	1.28	3.61	40.73
1899-00	1.65	1.90	3.59	2.34	3.12	3.59	2.72	0.84	5.31	7.17	2.99	2.86	38.08
1900-01	1.35	3.82	1.65	2.17	1.58	3.01	4.38	3.12	3.83	2.03	3.71	4.11	34.76
1901-02	0.30	1.42	3.74	1.33	1.18	2.84	2.37	2.03	4.85	6.48	2.02	3.60	32.16
1902-03	1.53	2.09	4.09	2.56	4.99	4.44	3.20	2.99	4.21	2.49	3.02	0.34	35.95
1903-04	2.91	2.20	2.74	4.75	3.31	6.89	4.63	3.90	3.45	5.31	3.31	2.65	46.05
1904-05	1.81	0.58	2.82	2.03	2.54	3.22	2.50	5.80	7.31	4.83	6.96	5.25	45.65
1905-06	3.72	2.04	2.72	2.17	1.26	4.95	2.92	3.04	3.38	4.17	3.64	2.72	36.73
1906-07	3.27	2.41	3.05	5.83	1.20	6.14	3.83	3.40	3.31	4.08	2.25	3.07	41.84
1907-08	1.57	1.44	3.03	1.76	3.18	5.57	3.03	3.45	2.23	4.65	1.99	0.32	32.22
1908-09	1.30	1.45	2.75	3.95	4.87	3.80	4.36	3.62	3.34	4.41	3.33	1.46	38.64
1909-10	2.09	1.82	2.90	5.16	3.80	0.73	2.75	4.21	2.36	4.32	2.11	1.88	34.13
1910-11	3.38	1.17	2.52	3.75	2.04	2.61	4.49	0.96	2.78	1.75	7.27	6.92	39.64
1911-12	4.67	2.87	4.71	1.69	1.60	4.28	5.28	2.72	4.06	5.98	5.17	1.92	44.95
1912-13	2.53	0.59	2.24	6.58	2.53	7.43	3.11	3.00	0.80	6.20	2.70	5.15	42.86
1913-14	3.60	3.00	2.00	2.10	2.80	2.28	3.20	2.52	3.76	2.56	4.86	1.00	33.68
1914-15	3.55	1.50	3.70	4.03	2.06	0.81	1.04	2.41	5.00	7.10	2.35	3.00	36.55
1915-16	1.65	2.70	5.15	4.55	1.80	3.80	3.62	4.35	6.73	2.69	2.79	1.66	41.49
1916-17	2.18	2.99	2.23	4.38	0.89	3.46	2.30	3.04	6.50	2.80	2.63	1.50	34.90
1917-18	5.12	0.12	1.11	1.64	2.21	1.56	2.80	6.54	0.55	2.96	3.81	3.32	31.74
1918-19	2.34	1.61	3.85	1.60	0.82	3.90	2.18	5.94	2.61	7.41	5.45	1.45	39.16
1919-20	5.15	3.86	2.28	1.19	0.61	1.85	6.61	2.63	4.29	4.54	5.36	1.63	40.00
1920-21	1.75	1.80	2.45	2.24	2.11	5.13	3.51	3.57	2.22	2.81	5.39	3.46	36.44
1921-22	1.53	5.71	2.79	1.31	1.60	3.65	3.34	3.73	3.71	4.82	2.16	2.51	36.86
1922-23	1.66	1.55	2.19	1.42	1.70	2.80	2.77	4.70	4.04	1.52	4.92	2.40	31.67
1923-24	1.37	2.42	5.01	4.62	1.93	2.78	2.68	6.41	7.43	3.76	2.52	5.53	46.46
1924-25	0.21	1.56	3.47	1.73	1.87	2.47	1.44	3.17	2.69	4.78	2.76	3.71	29.86
1925-26	3.74	3.53	0.75	2.00	4.77	2.11	3.27	3.23	3.18	2.23	3.04	10.87	42.72
1926-27	4.48	2.47	1.34	4.30	3.12	3.89	3.17	4.18	3.10	5.61	3.10	3.78	43.54
1927-28	1.65	5.82	5.62	2.28	4.72	3.90	3.11	1.30	7.72	4.96	2.47	1.56	45.11
1928-29	2.88	2.60	1.69	3.40	3.15	3.01	5.20	6.03	2.69	6.05	1.81	4.48	42.99
1929-30	3.35	4.48	2.83	3.70	2.95	2.45	1.44	2.57	1.74	1.91	1.64	2.09	31.15
1930-31	0.75	1.60	0.96	1.64	2.07	1.36	4.37	3.14	2.24	4.42	5.22	3.88	31.65
1931-32	2.06	2.60	3.66	7.59	1.82	2.84	2.73	2.11	3.46	4.06	2.48	1.58	36.99
1932-33	3.73	3.34	3.23	1.99	1.72	6.17	4.04	5.06	1.64	2.39	3.84	4.57	41.72
1933-34	1.22	1.51	1.95	1.82	0.72	2.56	2.47	0.55	4.74	1.30	6.10	3.97	28.91
1934-35	0.57	2.67	1.22	2.60	1.13	2.32	1.84	5.09	3.71	6.22	8.40	3.70	39.47
1935-36	2.16	3.15	2.67	2.19	2.82	2.83	2.28	1.57	1.42	6.67	3.04	3.43	34.23
1936-37	4.50	2.56	2.26			1.09							
Ave.	2.37	2.57	2.88	3.02	2.40	3.54	3.15	3.52	3.65	4.36	3.52	3.09	38.12
Max.	5.15	7.88	5.62	7.59	4.99	8.43	6.61	6.84	7.72	10.07	8.40	10.87	48.73
Min.	0.21	0.12	0.75	1.19	0.61	0.73	1.04	0.55	0.55	1.28	0.50	0.32	28.91

Maximum consecutive 12 month period Nov. 1897 to Oct. 1898 = 52.40 inches
Minimum consecutive 12 month period June 1933 to May 1934 = 25.24 inches
Maximum hydrologic year 1895-96 = 48.73 inches
Minimum hydrologic year 1933-34 = 28.91 inches

TABLE 3B

MONTHLY AND ANNUAL PRECIPITATION IN INCHES AT DENNISON, OHIO

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1908-09											4.20	1.80	
1909-10	3.32	2.01	2.80	5.47	5.70	0.15	2.51	4.13	3.42	4.91	2.27	3.99	40.68
1910-11	2.27	1.60	2.38	3.92	2.06	2.87	4.48	1.66	2.91	1.77	5.80	6.77	38.49
1911-12	3.77	2.43	4.32	2.22	1.99	4.46	5.09	1.96	4.03	4.16	3.39	2.13	39.95
1912-13	2.47	0.26	2.48	7.61	1.92	7.20	2.60	2.57	1.10	6.50	2.70	5.19	42.60
1913-14	3.29	3.10	2.14	2.29	3.16	2.66	3.39	3.74	4.42	2.28	4.16	1.45	36.08
1914-15	3.96	1.82	5.96	4.34	2.47	1.59	1.08	3.44	5.18	7.33	2.55	2.48	42.20
1915-16	1.42	2.68	4.82	5.60	1.88	3.83	2.12	3.77	5.39	2.04	2.09	2.08	37.72
1916-17	2.31	2.66	2.76	4.37	1.00	4.07	2.28	2.79	4.28	4.29	3.18	2.32	36.31
1917-18	6.31	0.50	1.35	2.50	2.61	1.33	3.32	6.64	1.09	2.07	5.54	3.44	36.70
1918-19	2.61	2.60	4.30	1.92	1.18	4.31	2.91	3.92	1.81	6.64	5.90	2.06	40.16
1919-20	7.31	3.85	2.82	2.76	1.42	2.30	5.28	1.11	6.26	4.65	4.35	2.70	44.81
1920-21	1.74	2.31	2.82	3.28	2.49	5.86	2.84	2.99	2.53	2.79	4.48	5.61	39.74
1921-22	1.50	5.79	3.54	1.83	1.75	4.60	2.56	4.43	1.85	4.74	3.25	3.69	40.53
1922-23	2.04	1.79	2.30	4.66	2.21	2.99	3.18	4.57	4.86	1.32	5.03	1.84	36.79
1923-24	1.64	3.58	6.29	4.62	2.58	3.86	3.65	4.59	7.93	3.96	1.64	5.30	49.64
1924-25	0.14	1.87	3.02	2.26	2.03	2.65	1.35	3.43	5.56	4.33	2.34	3.11	32.09
1925-26	5.08	4.40	0.82	2.04	3.60	1.53	2.12	2.69	2.08	1.89	4.06	9.14	39.45
1926-27	4.27	2.48	2.35	3.73	2.00	3.94	3.43	4.78	4.97	4.97	1.58	3.45	41.95
1927-28	1.71	5.51	4.84	1.34	3.81	3.74	2.94	1.57	6.37	3.81	3.64	0.67	39.95
1928-29	2.62	2.44	1.16	4.01	2.70	3.08	4.19	5.89	3.74	5.11	1.93	3.78	40.65
1929-30	3.78	4.74	2.96	3.78	2.18	2.33	1.38	2.36	1.89	1.15	2.54	2.75	31.84
1930-31	1.25	1.31	1.25	1.15	2.51	1.95	5.01	3.54	2.67	1.92	6.20	4.83	33.59
1931-32	1.81	3.07	4.00	5.58	1.04	2.90	2.03	1.89	2.62	5.23	3.51	1.21	34.89
1932-33	3.05	3.62	2.19	2.00	1.82	6.38	3.89	4.87	0.45	1.31	4.54	6.07	40.19
1933-34	1.41	1.45	2.64	1.72	1.72	2.75	2.18	0.55	5.87	1.49	5.71	3.68	31.17
1934-35	0.20	2.01	1.67	2.90	2.78	2.65	1.57	4.60	5.54	8.00	6.67	4.12	42.71
1935-36	2.35	2.70	3.01	2.20	2.57	3.92	2.50	1.97	1.27	7.39	4.50	1.85	36.23
1936-37	5.15	2.65	2.72	10.20	1.32	1.79	4.29	5.63	6.11	5.09	3.18	0.87	49.00
1937-38	4.35	1.52	3.53	2.45	2.26	4.47	3.84	6.00	5.36	3.02	3.58	2.79	43.17
1938-39	1.15	3.67	0.97	1.89	4.08	3.31	4.50	0.56	8.53	4.96	0.98	1.07	35.67
1939-40	3.68	0.90	1.96	1.00	2.51	3.23	5.49	4.99	6.26	3.45	5.09	3.57	42.13
1940-41	1.55	4.63	3.97	1.76	0.91	0.96	0.51	4.51	6.66	8.95	5.05	1.35	40.81
1941-42	5.57	2.05	1.91	1.20	3.02	3.83	2.76	5.20	4.28	1.25	2.99	4.13	38.19
1942-43	2.47	2.98	4.88	1.83	1.85	4.50	3.13	4.77	3.76	5.09	3.15	0.52	38.93
1943-44	2.05	1.43	1.10	0.98	1.87	5.15	4.10	4.29	3.98	2.24	5.68	1.42	34.29
1944-45	3.44	1.76	3.39	2.35	3.12	7.89	4.48	4.88	4.35	4.07	1.68	7.61	48.02
1945-46	2.96	4.87	2.37	1.10	4.12	2.61	1.43	7.17	4.19	3.38	2.30	0.90	37.40
1946-47	3.98	2.34											
Ave.	2.84	2.68	2.91	3.10	2.38	3.45	3.12	3.74	4.15	3.99	3.71	3.24	39.32
Max.	7.31	5.79	6.29	10.20	5.70	7.89	5.49	7.17	8.53	8.95	6.67	9.14	49.64
Min.	0.14	0.26	0.82	0.98	0.91	0.51	0.51	0.55	0.45	1.15	0.98	0.52	31.17

Maximum consecutive 12 month period July 1936 to June 1937 = 53.60 inches
Minimum consecutive 12 month period April 1930 to March 1931 = 21.52 inches
Minimum Hydrologic year 1933-34 = 31.17 inches
Maximum Hydrologic year 1923-24 = 49.64 inches

TABLE 3C

MONTHLY AND ANNUAL PRECIPITATION IN INCHES AT GNADENHUTTEN, OHIO

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1922-23				4.00	2.10	2.90	2.90	4.20	5.09	3.98	3.92	2.39	
1923-24	1.41	3.36	5.47	4.50	2.43	3.49	2.62	5.64	6.21	4.90	1.60	6.06	47.69
1924-25	0.12	1.92	3.91	2.42	1.40	2.99	1.40	3.90	4.84	5.47	1.28	2.92	32.57
1925-26	6.15	4.36	0.71	2.09	3.14	1.65	2.80	3.10	2.14	2.04	4.64	9.93	42.75
1926-27	4.82	2.76	2.50	4.02	2.43	4.26	3.49	4.88	5.81	7.48	1.91	3.85	48.21
1927-28	2.09	6.09	5.58	2.11	3.72	3.60	3.21	1.12	7.63	4.04	2.50		

TABLE 3D

MONTHLY AND ANNUAL PRECIPITATION IN INCHES AT NEW PHILADELPHIA, OHIO

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1939-40				1.35	3.49	3.88	4.37	4.55	7.04	5.08	4.42	2.30	
1940-41	1.15	4.62		2.40	0.68	1.55	0.87		6.81	7.02	3.76	1.39	
1941-42	4.92	1.88	1.87	1.56	2.53	3.56	2.28	4.92	3.92	1.35	1.49	3.21	33.49
1942-43	1.99	3.16	4.53	2.12	1.61	4.19	3.97	5.06	3.18	5.22	3.19	0.26	38.48
1943-44	2.15	1.38		1.36	1.66	5.24	3.67	4.55	4.59	2.68	2.78	1.18	
1944-45	2.14	1.41	3.19	1.74	2.69	7.89	5.18	4.65	2.99	4.66	1.60	6.19	44.33
1945-46	2.87	3.75	2.37	0.78	3.62	1.83	1.51	7.12	5.13				

TABLE 3E

MONTHLY AND ANNUAL PRECIPITATION IN INCHES AT NEWCOMERSTOWN, OHIO

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1927-28												0.47	
1928-29	2.53	2.18	1.67	3.73	2.94	2.70	4.91	6.20	3.96	3.84	2.58	3.25	40.49
1929-30	2.50	4.82	2.77	3.69	2.11	3.38	2.58	2.41	1.06	0.94	1.29	1.65	29.20
1930-31	1.05	1.21	1.15	1.26	2.54	1.93	5.12	2.18	2.75	4.14	4.15	4.14	31.62
1931-32	1.57	3.31	4.24	6.71	1.25	3.13	1.96	2.08	3.77	2.83	4.38	0.64	35.87
1932-33	3.26	3.42	3.03	2.12	1.55	6.53	4.01	5.34	1.37	3.00	3.23	4.54	41.40
1933-34	1.48	1.44	2.18	2.00	0.96	3.16	1.88	0.30	4.58	1.56	7.08	3.87	30.49
1934-35	0.80	2.06	1.30	2.81	2.27	2.92	2.01	4.00	5.60	5.77	14.21	2.71	46.46
1935-36	1.91	2.83	3.04	2.24	2.27	3.85	2.77	2.03	1.77	3.74	5.32	2.43	34.20
1936-37	4.66	2.96	2.43	9.68	1.40	1.39	3.91	4.20	8.28	2.79	3.35	0.98	46.03
1937-38	3.58	1.28	3.42	2.49	2.42	5.01	4.13	6.99	4.55	3.05	3.58	3.64	44.14
1938-39	0.79	3.53	1.31	2.17	4.84	3.36	4.29	0.92	7.37	6.62	1.74	1.26	38.20
1939-40	4.07	0.78		2.17	3.55	3.61	6.01	3.98	5.50	5.80	5.42	2.37	
1940-41	1.88	3.34	3.10	2.19	0.47	0.91	0.80	4.31	5.16	7.87	5.98	0.71	36.72
1941-42	5.22	1.73	1.75	1.19	2.81	3.56		3.74	5.57	3.24	3.49	4.25	
1942-43	1.65	3.79		2.26	1.74	4.70	3.48	9.66	1.64	5.01	4.39	0.45	
1943-44	1.67	1.33	0.67	1.09	1.94	5.37	4.22	3.56	4.19	2.00	3.37	1.65	31.06
1944-45	1.70	1.43	2.43	1.98	2.61	8.04	4.34	5.11	4.47	3.42	1.04	8.69	45.26
1945-46	2.72	4.10	1.85	0.89	3.50	1.71	1.29	5.28	4.89	2.33	3.61	1.12	33.29

from October 1 to March 31. The distribution of precipitation is fairly uniform throughout each period. Plate 3 shows graphically the average monthly precipitation for 36 years of record at Dennison, together with the maximum and minimum monthly precipitation which has been recorded in Tuscarawas County.

The average annual precipitation for the 25-year period from October 1920, to September 1945, ranges from 37.5 inches at the northern boundary of the county to 40 inches at the southern boundary. The average annual precipitation for this period is shown on the isohyetal map on plate 4.

The variations in annual precipitation at Dennison and Dover are shown on plate 5. The averages for ten year periods are shown by dashed lines, with the values plotted at the midpoint of the period which they represent. The periods of record are not of sufficient length to indicate definate trends in precipitation. A comparison of the 10-year average curves for the period between 1910 and 1938 indicates that there is not good correlation between the annual average and the moving 10-year average for stations within the county. For example, the 10-year average at Dover in 1920 was below the average annual precipitation for the period of record, whereas at the same time the 10-year average at Dennison was above the average annual precipitation for the period of record at that point.

Summaries of precipitation records for Dover and Dennison are shown in table 4 and table 5, respectively. These tables show the average monthly and annual precipitation that may be equalled or exceeded for indicated percentages of time for the periods of record at Dover and Dennison. A study of the two summaries shows a considerable variation between the two records. A direct comparison cannot be made between the stations because of the difference in the periods of record. It is of interest that the minimum 12-month precipitation at Dover occurred from June 1933 to May 1934, when 25.24 inches of precipitation was recorded; whereas the minimum 12-month precipitation at Dennison occurred from April 1930 to March 1931, when 21.52 inches was recorded. The minimum precipitation for a hydrologic year (October to September) occurred in 1933-34 at both locations, Dover recording 29.91 inches and Dennison 31.17 inches.

The monthly and annual snowfall at Dennison and Dover, as recorded by the U. S. Weather Bureau, are shown in table 2. The monthly and annual snowfall at Dennison for the period from October 1920 to March 1946 are shown in table 6.

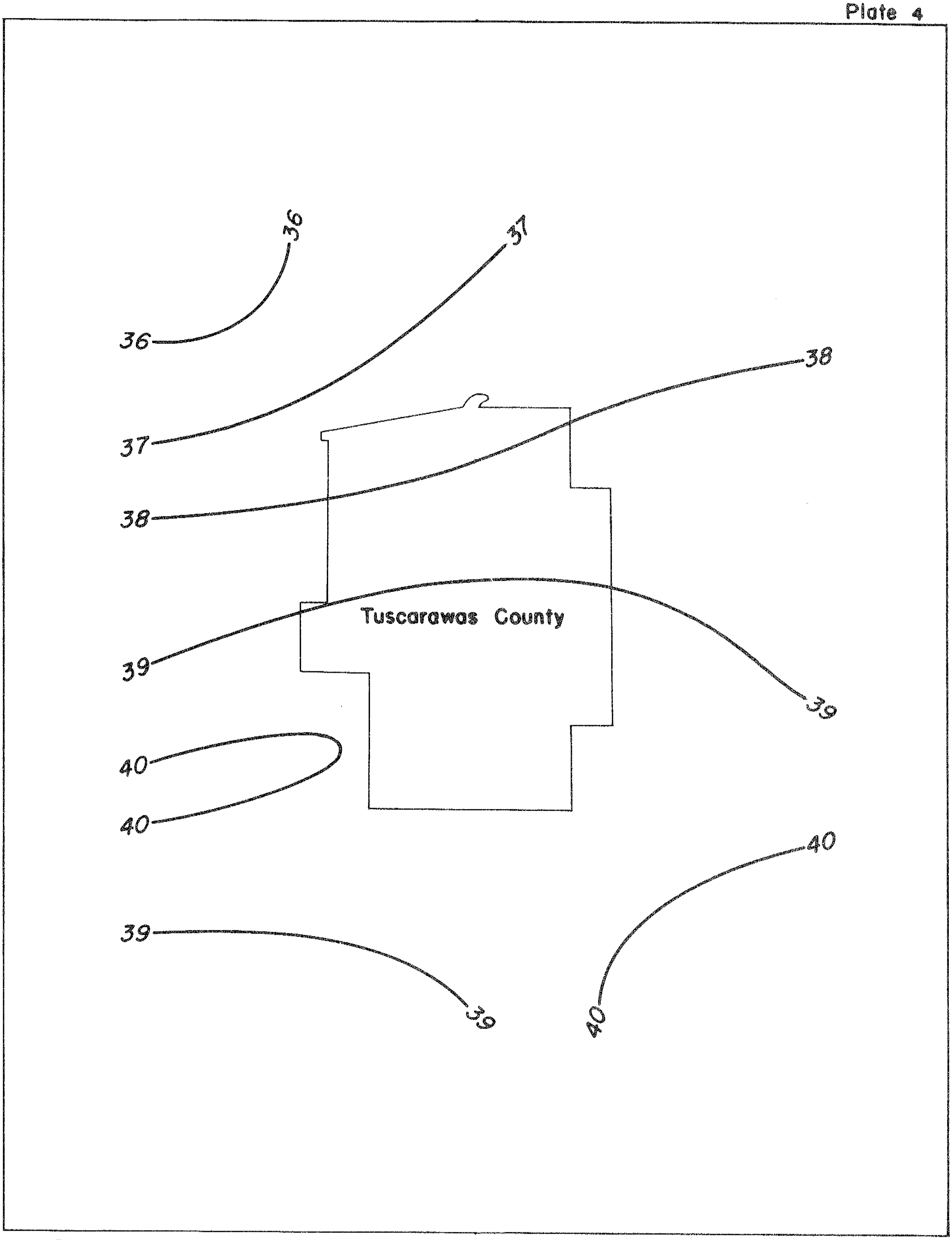


Plate 4 - Isohyetal map showing average annual precipitation in inches in Tuscarawas County for 25 year period from October 1920 to September 1945.

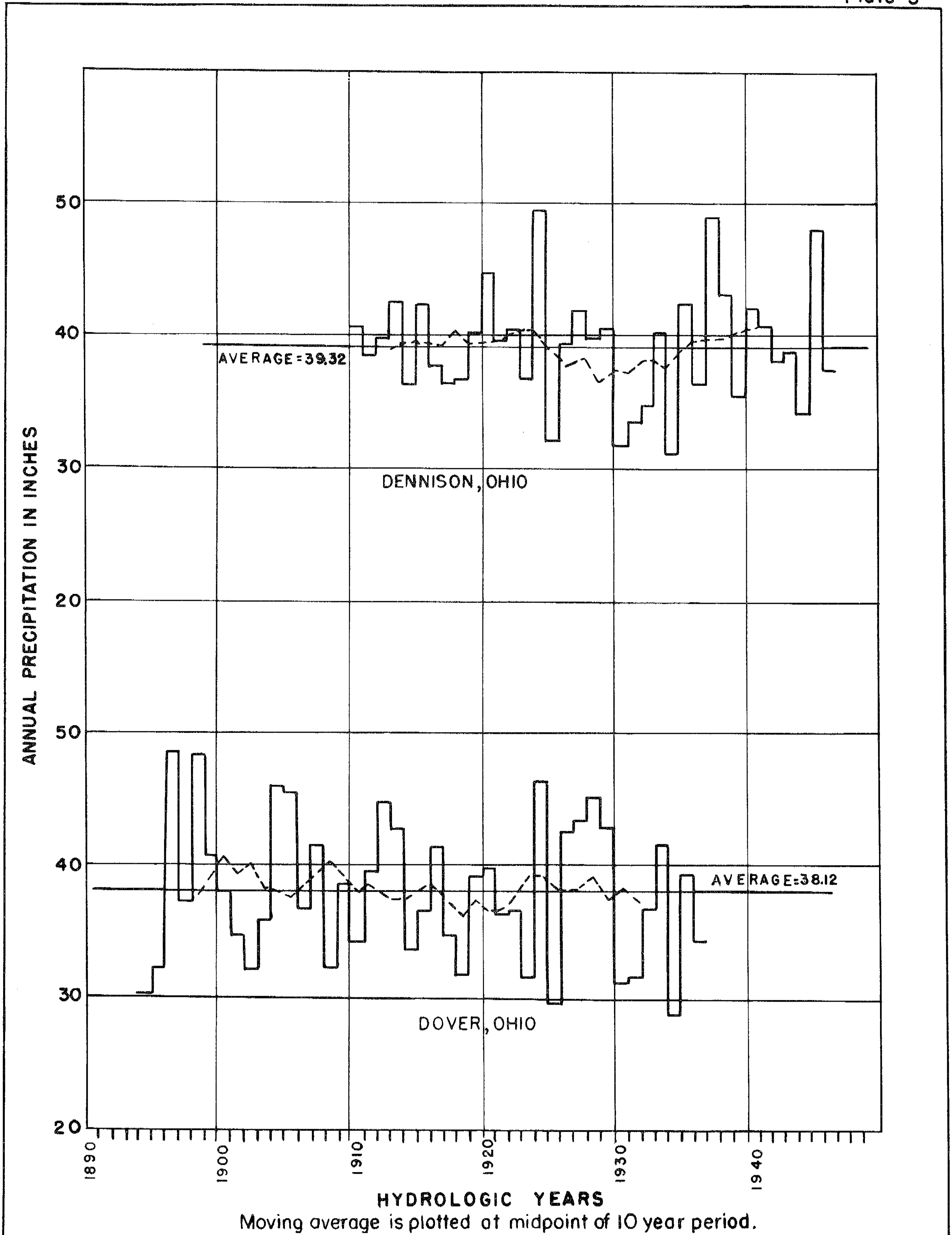


Plate 5 - Annual precipitation and ten-year moving average precipitation at Dover and Dennison, Ohio.

TABLE 4

AVERAGE PRECIPITATION IN INCHES DENNISON, TUSCARAWAS COUNTY, OHIO

Period of Record - Aug. 1908 to Nov. 1946

Month	Average	Maximum Monthly	Minimum Monthly	Average precipitation equalled or exceeded 10% of time	25% of time	50% of time	75% of time	90% of time
Jan	3.10	10.20	.98	5.59	4.25	2.40	1.84	1.19
Feb	2.38	5.70	.91	3.89	2.76	2.23	1.85	1.28
Mar	3.45	7.89	.15	6.02	4.43	3.27	2.62	1.57
Apr	3.12	5.49	.51	5.03	4.16	3.15	2.20	1.42
May	3.74	7.17	.55	5.92	4.84	4.02	2.60	1.61
June	4.15	8.53	.45	6.46	5.55	4.28	2.63	1.65
July	3.99	8.95	1.15	7.35	5.09	4.11	2.11	1.44
Aug	3.71	6.67	.98	5.83	5.04	3.54	2.54	1.84
Sept	3.24	9.14	.52	6.28	4.12	2.95	1.84	1.02
Oct	2.84	7.31	.14	5.28	3.78	2.47	1.71	1.36
Nov	2.68	5.79	.26	4.78	3.61	2.54	1.79	1.37
Dec	2.91	6.29	.82	4.85	3.72	2.78	2.14	1.22
Annual	39.32	10.20	.14	45.77	42.09	39.84	36.44	34.08

*Maximum annual precipitation = 49.64 inches in 1923-24
*Minimum annual precipitation = 31.17 inches in 1933-34
Minimum consecutive 12 month period Apr. 1930 to Mar. 1931 = 21.52 inches
Maximum consecutive 12 month period July 1936 to June 1937 = 53.60 inches

*Hydrologic year - October to September

TABLE 5

AVERAGE PRECIPITATION IN INCHES DOVER, TUSCARAWAS COUNTY, OHIO

Period of Record - July 1893 to Dec. 1936

Month	Average	Maximum Monthly	Minimum Monthly	Average precipitation equalled or exceeded 10% of time	25% of time	50% of time	75% of time	90% of time
Jan	3.02	7.59	1.19	5.18	4.32	2.28	1.95	1.61
Feb	2.40	4.99	.61	4.58	3.16	2.15	1.60	.95
Mar	3.54	8.43	.73	6.16	4.46	3.34	2.46	1.70
Apr	3.15	6.61	1.04	4.59	3.87	3.09	2.45	1.94
May	3.52	6.84	.55	6.00	4.64	3.30	2.61	1.59
June	3.65	7.72	.55	6.66	4.40	3.45	2.55	1.67
July	4.36	10.07	1.28	7.05	6.00	4.41	2.77	1.95
Aug	3.52	8.40	.50	5.91	4.88	3.03	2.48	2.00
Sept	3.09	10.87	.32	5.22	3.90	3.01	1.65	1.45
Oct	2.37	5.15	.21	4.41	3.56	2.07	1.53	.87
Nov	2.57	7.88	.12	4.29	3.20	2.41	1.59	1.43
Dec	2.88	5.62	.75	4.92	3.61	2.77	2.23	1.44
Annual	38.12	10.87	.12	45.93	42.75	37.67	34.02	31.65

*Maximum annual precipitation = 48.73 inches in 1895-96
*Minimum annual precipitation = 28.91 inches in 1933-34
Maximum consecutive 12 month period Nov. 1897 to Oct. 1898 = 52.40 inches
Minimum consecutive 12 month period June 1933 to May 1934 = 25.24 inches

*Hydrologic year - October to September

TABLE 6

MONTHLY AND ANNUAL SNOWFALL IN INCHES AT DENNISON, OHIO

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	ANNUAL
1920-21	0	5.0	2.0	2.2	5.8	0	T	0	15.0
1921-22	0	4.2	6.5	5.2	2.5	4.8	0	0	23.2
1922-23	0	1.0	3.4	2.5	10.0	4.9	0	0.2	22.0
1923-24	0	0	T	4.1	9.0	3.8	3.0	0	19.9
1924-25	0	5.8	4.5	17.8	4.5	0.7	0	0	33.3
1925-26	3.5	T	4.0	16.5	8.0	4.2	1.2	0	37.4
1926-27	T	T	3.3	2.8	8.9	T	T	0	15.0
1927-28	0	T	2.0	1.1	8.5	4.0	1.5	0	17.1
1928-29	0	T	T	5.8	9.5	6.5	T	T	21.8
1929-30	0	T	5.6	5.8	0.7	7.7	0.5	0	20.3
1930-31	T	2.5	0.2	1.2	2.0	1.8	1.0	0	8.7
1931-32	0	3.5	T	T	1.0	2.0	T	0	6.5
1932-33	0	0.2	5.7	T	3.5	0.2	T	0	9.6
1933-34	0	3.0	6.5	0.5	15.3	6.7	T	0	32.0
1934-35	T	1.0	3.1	4.0	9.5	T	T	0	17.6
1935-36	0	T	13.9	15.5	13.5	12.3	0.5	0	55.7
1936-37	0	2.0	7.5	6.0	4.5	2.5	0	0	22.5
1937-38	T	2.5	4.5	5.5	1.2	2.0	T	0	15.7
1938-39	0	4.7	2.5	11.9	5.8	T	2.5	0	27.4
1939-40	T	0	6.0	10.5	14.7	4.5	3.3	0	39.0
1940-41	T	4.0	0.5	10.3	10.2	8.0	0	0	33.0
1941-42	0	T	T	6.5	6.3	7.5	T	0	20.3
1942-43	T	1.2	6.4	7.1	2.9	8.3	2.0	0	27.9
1943-44	0	T	T	T	6.1	8.0	T	0	14.1
1944-45	0	T	17.3	15.3	2.3	T	T	0	34.9
1945-46	0	1.0	8.0	3.0	1.0	T	T	0	13.0
26 Year Average	0.13	1.60	4.36	6.20	6.43	3.86	0.60	T	23.19
Max.	3.5	5.8	17.3	17.8	14.7	12.3	3.3	0.2	
Min.	0	0	T	T	0.7	0	0	0	

Maximum annual - 1935-36 55.7
Minimum annual - 1931-32 6.5

Evaporation

Evaporation records have been obtained at Wooster (4) in Wayne County since July 1916 and at Senecaville Dam in Guernsey County since March 1939. The observations of evaporation have been made with equipment installed in accordance with U. S. Weather Bureau standards. Daily observations are made of evaporation from standard Weather Bureau land pans made of galvanized iron, 48 inches in diameter by 10 inches deep, filled to a depth of approximately 8 inches. The pans are supported so that there is ventilation beneath them. The published records are shown in table 7.

ECONOMIC DEVELOPMENT

Population

According to the 1940 census (5), Tuscarawas County had a population of 68,816. This is a density of population of 121 persons per square mile, as compared to an average density of population of 168 persons per square mile for the entire state. The population of the county is 54.5 percent urban and 45.5 percent rural (6). The county is subdivided into 22 civil townships. The population of each township according to each Federal Census (7) since 1900 is given in table 8.

There are 20 incorporated municipalities and a number of unincorporated communities in Tuscarawas County. The population of these communities is shown in table 9 (7).

TABLE 7

MONTHLY EVAPORATION IN INCHES

WOOSTER, OHIO

Year	Apr.	May	June	July	Aug.	Sept.	Oct.	Total Apr.-Oct.
1916	-	-	-	6.18	6.41	4.72	3.04	--
1917	2.86	4.12	5.04	5.73	5.52	3.60	1.81	28.68
1918	-	5.64	5.63	6.21	6.04	3.01	2.16	--
1919	-	3.45	6.41	7.07	5.22	3.06	2.67	--
1920	-	4.44	5.02	5.81	4.10	3.79	2.24	--
1921	3.49	4.64	6.22	6.65	5.07	3.67	2.20	31.94
1922	3.53	4.21	5.67	6.18	5.41	4.25	2.22	31.47
1923	3.72	4.64	5.24	5.94	4.94	3.20	2.06	29.74
1924	3.11	3.06	5.06	5.77	5.01	2.82	2.12	26.95
1925	-	-	6.26	5.33	4.76	3.67	1.15	--
1926	-	4.25	4.74	4.79	3.94	2.17	1.27	--
1927	-	2.99	3.90	4.74	3.75	3.07	1.97	--
1928	-	3.92	3.20	4.76	4.33	3.12	2.00	--
1929	-	3.53	4.36	5.09	3.82	3.15	1.74	--
1930	-	--	--	--	--	--	--	--
1931	-	--	5.21	6.81	5.53	3.90	2.04	--
1932	3.36	4.74	5.47	6.43	5.40	4.23	2.54	32.17
1933	-	4.35	6.56	6.91	5.61	3.64	2.11	--
1934	-	6.06	7.22	6.39	5.27	4.03	2.43	--
1935	3.16	5.07	4.91	5.90	4.99	3.68	2.58	30.29
1936	3.27	5.06	6.21	7.09	5.09	4.12	2.21	33.05
1937	3.41	4.21	4.52	5.26	4.03	3.74	--	--
1938	-	5.61	5.28	6.25	6.48	3.76	2.45	--
1939	-	5.74	5.24	6.55	7.83	5.39	--	--
1940	-	4.47	5.67	6.92	5.65	3.45	--	--
1941	-	6.67	7.09	6.72	5.75	5.42	--	--
1942	-	--	--	6.11	5.34	--	--	--
1943	-	--	--	--	--	--	--	--
1944	-	--	--	--	--	--	--	--
1945	-	--	4.55	7.33	6.48	--	--	--
1946	-	--	6.71	8.45	7.04	--	--	--

TABLE 7 (Cont'd)

MONTHLY EVAPORATION IN INCHES

SENECAVILLE DAM

Year	Apr.	May	June	July	Aug.	Sept.	Oct.	Total Apr.-Oct.
1939	3.98	6.99	6.18	--	--	--	--	--
1940	4.42	5.27	6.21	7.42	6.15	3.80	2.37	35.64
1941	5.29	6.74	6.48	6.48	6.22	5.34	2.86	39.41
1942	4.69	5.34	5.78	6.15	4.38	3.63	2.50	32.47
1943	3.68	4.91	6.60	6.68	5.58	4.47	2.46	34.38
1944	3.52	5.88	6.99	7.36	6.85	4.01	2.59	37.20
1945	4.21	5.42	5.75	6.54	6.48	5.09	3.14	36.63
1946	4.20	--	6.05	6.32	4.92	--	--	--

TABLE 8

Population of Tuscarawas County by townships, 1900-1940

Township	1900	1910	1920	1930	1940
Auburn	984	790	718	721	714
Bucks	1223	1119	1067	1195	1168
Clay	1415	1346	1197	1550	1686
Dover	7569	8681	10095	12103	12121
Fairfield	1144	1238	1034	1029	890
Franklin	1423	1885	1975	2200	2186
Goshen	9781	11913	14269	16092	16004
Jefferson	928	852	688	764	800
Lawrence	1574	1499	1243	1342	1487
Mill	9894	10347	14238	13257	13180
Oxford	3510	3707	4054	5001	5413
Perry	768	666	500	395	449
Rush	1094	945	879	876	676
Salem	1542	1446	1377	1312	1254
Sandy	2547	2141	1810	1901	1997
Sugar Creek	1747	1650	1827	2407	2389
Union	825	1291	1677	1077	1042
Warren	796	692	604	546	632
Warwick	2044	1944	1868	2066	2201
Washington	781	589	496	484	607
Wayne	1132	1234	1183	976	976
York	1027	1055	839	899	944
Tuscarawas County Total	53751	57035	63578	68193	68816

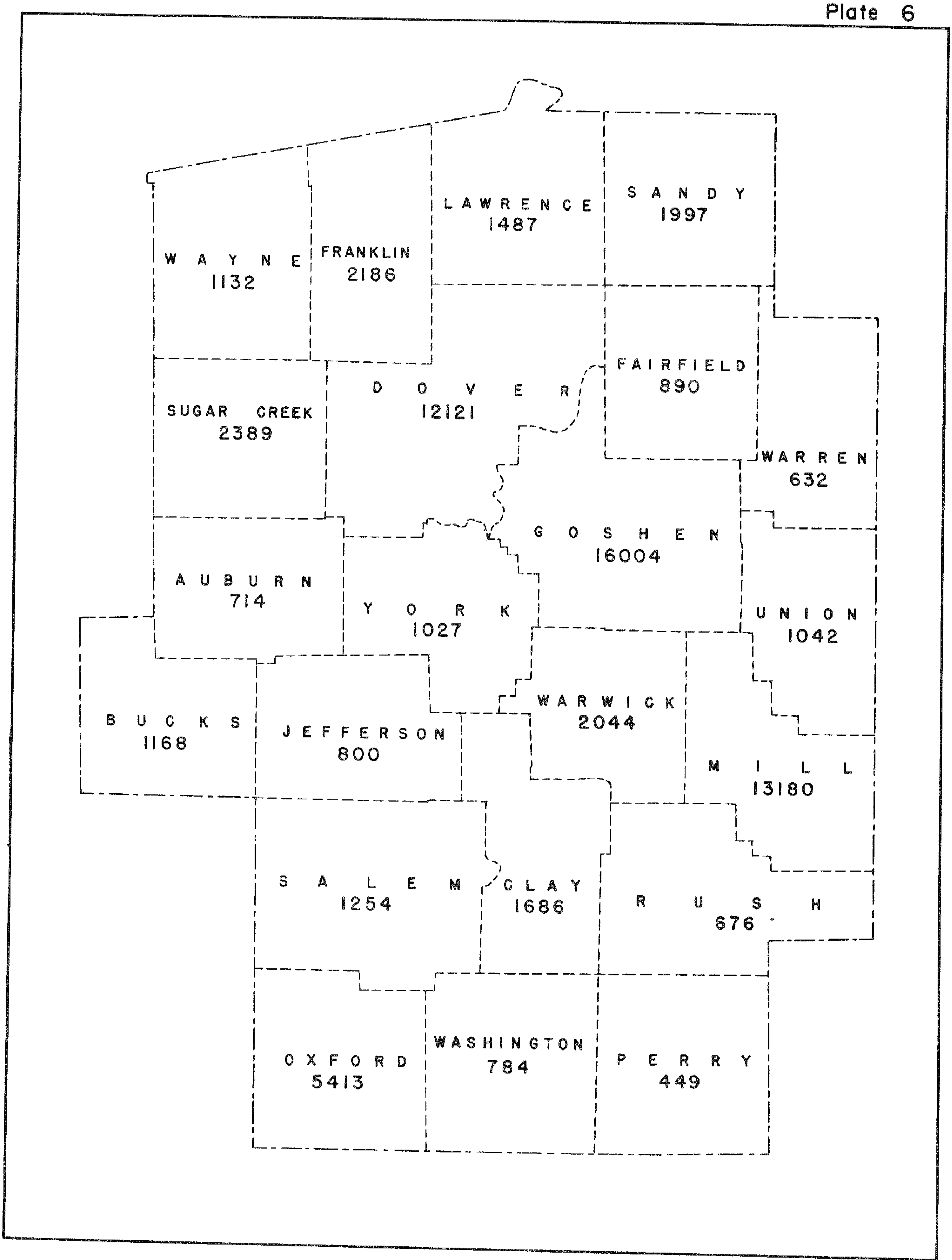


Plate 6 - Population of Tuscarawas County by Townships, 1940.

TABLE 9

Population of incorporated municipalities
in Tuscarawas County, 1900-1940

Municipality	1900	1910	1920	1930	1940
New Philadelphia	6213	8542	10718	12365	12328
Dover	5422	6621	8101	9716	9691
Uhrichsville	4582	4751	6428	6437	6435
Newcomerstown	2659	2943	3389	4265	4564
Dennison	3763	4008	5524	4529	4413
Strasburg	461	835	917	1305	1297
Gnadenhutten	547	560	530	870	876
Sugar Creek	243	389	618	895	836
Mineral City	1220	1032	800	840	820
Midvale	--	--	--	667	670
Tuscarawas	412	471	499	631	663
Bolivar	--	567	519	506	596
Port Washington	424	421	382	499	493
Baltic	--	377	406	545	492
Shanesville	--	334	352	494	453
Barnhill	811	506	513	438	394
Roswell	--	514	420	286	283
Stone Creek	--	144	133	225	214
Zoar	290	182	178	146	208
Parral	--	--	--	205	205

Transportation

Tuscarawas County is served by the Pennsylvania, Baltimore and Ohio, and the Wheeling and Lake Erie Railroads. The broad, flat valleys of the major streams form natural thoroughfares and excellent airport sites in an otherwise rugged region.

Every township in the county is crossed by one or more hard-surfaced state or national highways, and these in turn serve county and township roads which afford ready access to the more remote sections of the upland. The county and township roads are usually surfaced with gravel or slag and are, with a few exceptions, well maintained.

Agriculture

About 27 percent of the area of Tuscarawas County is under cultivation. Large areas in the southern tier of townships are in timber, and many slopes where timber has been removed are too steep for cultivation. A number of rather level tracts which were underlain by seams of coal, fireclay, and shale have been stripped of their soil and surface rock to expose the valuable minerals below, leaving the surface unfit for tillage.

The total area of the county is 364,000 acres. Approximately 97,500 acres were under cultivation in 1945. Table 10 (8) shows the acreage and yield of the principal crops raised.

TABLE 10

Data on agricultural land use in Tuscarawas County

Crop	Acreage	Yield per acre	Total yield
Hay	35,400	1.47 tons	52,000 tons
Corn	25,000	43.00 bu.	1,075,000 bu.
Wheat	20,300	28.00 bu.	568,000 bu.
Oats	11,800	35.60 bu.	420,000 bu.

In addition, a total of 36,000 acres was devoted to livestock and poultry raising and 5,000 acres to miscellaneous crops, including truck crops.

Irrigation projects in the county are few but results show that irrigation is commercially practicable. The level flood plains along the major streams may be easily irrigated with either surface or ground water. Ground water from gravel strata in the valleys has been used to some extent. The more massive sandstones sometimes yield sufficient quantities of water for small irrigation systems, although in some localities the brackish nature of the ground water renders it unfit for this purpose.

Mineral Resources

Tuscarawas County is favored in both variety and distribution of its mineral resources, and it is one of the important mineral-producing counties of the state. Large quantities of sand and gravel are present in the stream beds and valley terraces, and valuable strata of coal, fireclay, shale, limestone, and sandstone compose the valley walls and hillsides. Even the rocks at great depth contribute to the mineral wealth of the county, four horizons yielding appreciable quantities of oil and gas. More than 200 oil and gas wells are now in production in the county. Table 11 lists the amounts of various minerals produced in the county in 1945 and the number of persons employed in their production (9). The number of persons engaged in processing or marketing these minerals or in the manufacture of products made from them is not included in the table.

TABLE 11

Minerals produced in Tuscarawas County in 1945 and number of persons employed in their production

Product	Quantity produced	Persons employed
Coal	1,716,400 tons	892
Clay and shale	466,027 tons	233
Gas	4 billion cubic feet	70
Oil	30,000 barrels	42
Sand and gravel	45,000 tons	20
Sandstone	78,571 tons	18

Industries

The industrial wealth of Tuscarawas County is closely related to its mineral resources. The mining of coal, quarrying of clay and shale, drilling for oil and gas, extraction and washing of sand and gravel, quarrying of sandstone for industrial sand, and the manufacturing of a wide variety of earthenware products constitutes about 85 percent of the industrial activity of the county. Every township in the county contains minable coal and also contains clay or shale in sufficient thickness and of suitable composition for use in the ceramic industry. In 1945 there were 82 producing coal mines, 24 clay and shale quarries, one sandstone quarry, and eight sand and gravel pits in operation.

Every township in the county has been prospected for oil and gas by the drilling of one or more test holes. Encouraging discoveries in several localities have been followed up and further drilling has developed one oil pool and several gas pools. Other industrial activity within the county includes the manufacture of steel, wood, and leather articles and the processing of dairy and other agricultural products.

GEOLOGY

GEOLOGIC HISTORY

In early geologic time the area which is now Ohio was periodically inundated by inland seas. During the times of marine invasion sediments were deposited similar in character and origin to those forming in present day seas. Mud, sand, and calcareous ooze deposited from those ancient seas have been converted by compaction and cementation into shale, sandstone, and limestone. By study of these bedrock strata it is possible to infer the conditions under which they were formed and thus interpret the succession of changes which constitutes the geologic history of the region.

Paleozoic Era

The Paleozoic era was a period of alternating deposition and erosion, the deposition occurring during times of inundation and the erosion taking place during the intervals of emergence. This cycle of deposition and erosion was repeated many times during the Paleozoic era and was accompanied by numerous changes in the character of the materials brought into the region and in the conditions under which they were deposited.

Subdivisions of the Paleozoic era are made on the basis of classification of the changing marine faunas rather than on the basis of lithological characteristics.

Early Paleozoic seas were somewhat roily and generally quiet, but as the era progressed toward the Silurian period the seas became clear. This condition continued into the early part of the Devonian period, but in Middle Devonian time the waters became filled with silt and plant material. With the beginning of Mississippian period the seas became progressively smaller, and during the Pennsylvanian period the area now occupied by Tuscarawas County was apparently very near the shore. It is not known whether deposition occurred in Tuscarawas County during the Permian period, the last of the Paleozoic era.

The Peleozoic era was brought to a close by widespread uplift. This initiated a long period of erosion and denudation, which continued until the advance of the continental ice sheet in the Pleistocene epoch.

Cenozoic Era - Pleistocene Epoch

Continental glaciation during the Pleistocene occurred in Ohio on three or more occasions. Two distinct advances of the glacier have left glacial materials in moraines, outwash plains, valley trains, and lake deposits. A third and earlier glaciation is inferred from drainage modifications (10).

The glacial stages will be referred to in this report as a pre-Illinoian stage and the Illinoian and Wisconsin stages.

The erosional stages will be called the Teays erosional stage, (pre-glacial) the pre-Illinoian and post Illinoian erosional stages (inter-glacial) and the post-Wisconsin (present) erosional stage.

STRATIGRAPHY §

The bedrock of Tuscarawas County is of sedimentary origin. The surface rocks are all Pennsylvanian in age but drilling has penetrated rocks of all ages from Ordovician to Pennsylvanian. Overlying the bedrock are local unconsolidated deposits of Quaternary age, including both Pleistocene and Recent sediments. Although only the Pennsylvanian bedrock formations are exposed at the surface, the underlying rocks have been penetrated by drilling and their characteristics thus determined. A generalized geologic section of the rocks underlying Tuscarawas County is shown in table 12.

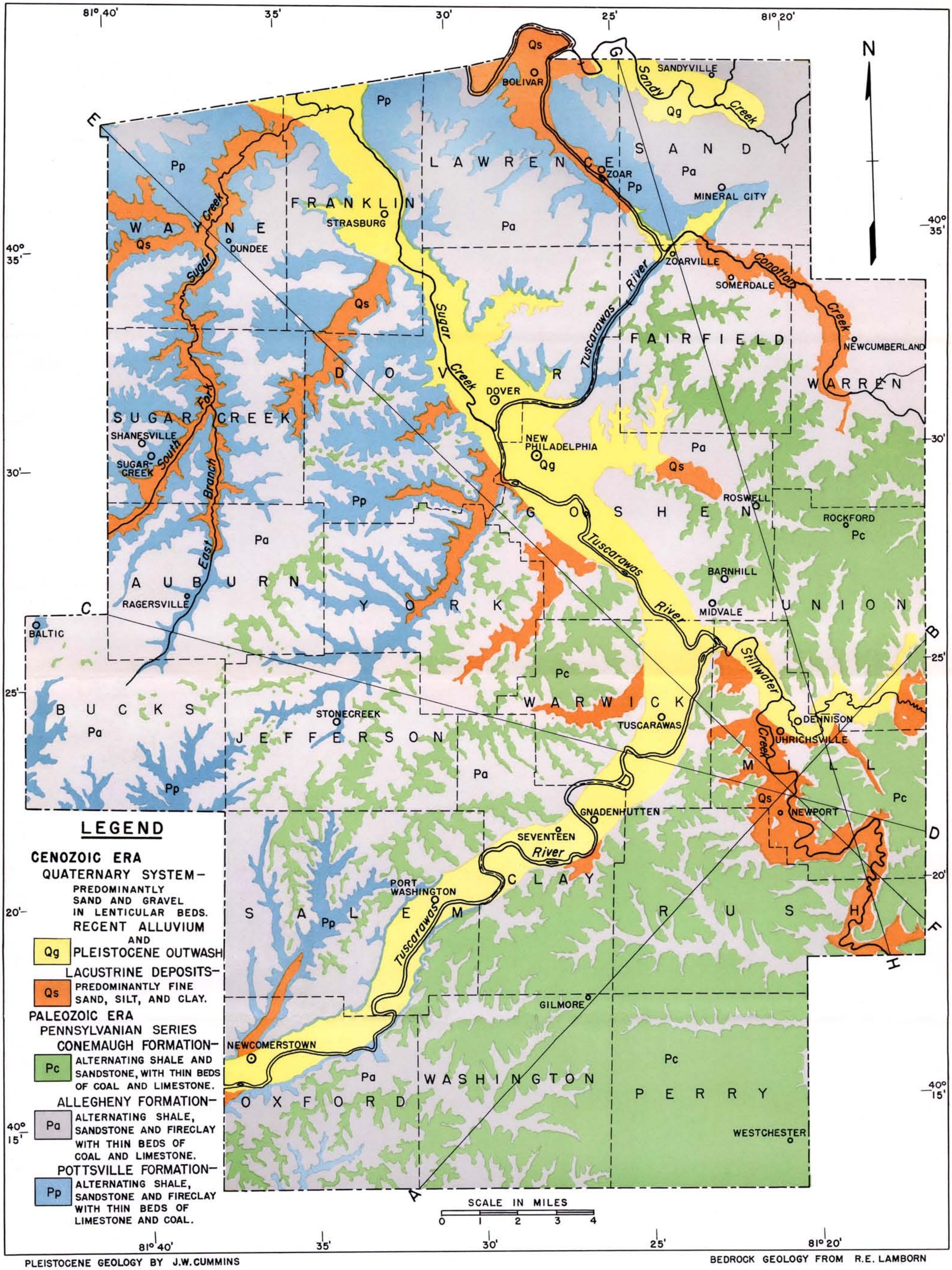
It is beyond the scope of this report to discuss the stratigraphic details of the older, unexposed formations. However, some of the members of the Pennsylvanian formation are water-bearing, and it is appropriate to describe these strata. A detailed description of the more important water-bearing members is given in this report in the section on water-bearing properties of the rock formations.

Pennsylvanian System

All the bedrock strata exposed at the surface in Tuscarawas County belong to the Pennsylvanian system (the Pennsylvanian series of the Carboniferous system of the U.S. Geological Survey). This great system of rocks, commonly referred to as "Coal Measures", is represented in Tuscarawas County by the Pottsville, Allegheny, and Conemaugh formations. The lower third of the Pottsville formation is below the surface in Tuscarawas County, and the upper third of the Conemaugh has been removed by erosion.

The areas of outcrop of the various formations are given in table 13. The areal distribution of these formations is shown on plate 7.

§ The stratigraphic nomenclature follows the usage of the Geological Survey of Ohio.



PLEISTOCENE GEOLOGY BY J.W.CUMMINS

BEDROCK GEOLOGY FROM R.E. LAMBORN

Plate 7.— Geologic map of Tuscarawas County, Ohio.

TABLE 12

Generalized stratigraphic section in Tuscarawas County, Ohio showing water-bearing properties of major subdivisions

			Group or formation thickness in feet	Character of materials	Ground-water conditions
ROCKS EXPOSED AT THE SURFACE	QUATERNARY	RECENT	Alluvium 0 - 20	Flood plain deposits Alluvial fans Silt, sand, and gravel	Moderate water supplies from dug wells
ROCKS EXPOSED AT THE SURFACE	QUATERNARY	PLEISTOCENE	Deposits of Wisconsin stage Till confined to 1 square mile in the northwest corner of the county 0 - 50 Outwash confined to valley trains and terraces 0 - 225	Interbedded and stratified deposits of silt, sand, and gravel in the main valleys. Clay and silt deposits in tributary valleys. Till is composed of clay and boulders, unstratified	Excellent supplies of water in the main valleys. Poor supplies of water in tributary valleys. Very meager supplies of water in the till.
ROCKS EXPOSED AT THE SURFACE	PENNSYLVANIAN		Conemaugh 0 - 300	Variable sequence of sandstone, shale, clay, coal, and limestone.	Sandstones and sandy shales supply sufficient water for domestic and farm purposes. Other strata contain no water.
ROCKS EXPOSED AT THE SURFACE	PENNSYLVANIAN		Allegheny 0 - 250	Variable sequence of sandstone, shale, clay, coal, and limestone. Sandstones are generally thin-bedded or shaly.	Upper and Lower Freeport sandstones supply moderate quantities of water. Other strata are barren.
ROCKS EXPOSED AT THE SURFACE	PENNSYLVANIAN		Pottsville 0 - 150	Variable sequence of sandstone, shale, clay, coal, and limestone.	Homewood sandstone contains fair supplies of water where the sandy phase is developed adjacent to deposits of gravel in the buried valleys. Massillon sandstone is a good source of water at shallow depths but under deep cover the water is generally brackish or saline.
ROCKS ENCOUNTERED IN DRILLING	MISSISSIPPIAN		Cuyahoga and Logan 250	Sandstone and sandy shale	Large supply of fresh water in Black Hand Sandstone at moderate depth. Saline or brackish water encountered under deep cover.
ROCKS ENCOUNTERED IN DRILLING	MISSISSIPPIAN		Sunbury 45	Black shale	No water
ROCKS ENCOUNTERED IN DRILLING	MISSISSIPPIAN		Berea 10 - 60	Gray sandstone	Generally saline water
ROCKS ENCOUNTERED IN DRILLING	MISSISSIPPIAN		Bedford 20	Black shale	No water
ROCKS ENCOUNTERED IN DRILLING	DEVONIAN		Ohio 2200	Black shale with occasional thin lenses of sandstone, the most prominent being the "Gordon" horizon	Small quantities of sulfur water in the sandstone lenses
ROCKS ENCOUNTERED IN DRILLING	DEVONIAN		Olentangy 15	Blue shale	No water
ROCKS ENCOUNTERED IN DRILLING	DEVONIAN		Delaware, Columbus and Detroit River group 1500	Limestone and dolomite. Formations not differentiated in drill cuttings.	No water
ROCKS ENCOUNTERED IN DRILLING	DEVONIAN		Oriskany 20	White or gray sandstone	Water strongly saline
ROCKS ENCOUNTERED IN DRILLING	SILURIAN		Bass Island, and Niagara Group 1500	Dolomite. Formations not differentiated in drill cuttings.	Water when present is strongly saline
ROCKS ENCOUNTERED IN DRILLING	SILURIAN		Clinton 80	Shale and limestone	No water
ROCKS ENCOUNTERED IN DRILLING	ORDOVICIAN		Medina 200	Shale and limestone	Usually dry. Water when present is saline
ROCKS ENCOUNTERED IN DRILLING	ORDOVICIAN		Formations below the Medina have not been penetrated by drilling		

TABLE 13

Area of surface exposure of formations of different geologic ages

(square miles)

Township	Pennsylvanian			Pleistocene	
	Pottsville formation	Allegheny formation	Conemaugh formation	Clay	Gravel
Auburn	3.88	16.72	1.76	0.93	
Bucks	4.14	18.02	.44		
Clay		9.72	9.20	.29	4.26
Dover	11.40	18.38	.59	2.78	7.73
Fairfield	.62	13.21	5.73	2.06	.56
Franklin	7.02	7.17		1.57	7.35
Goshen	.44	5.80	17.00	1.95	10.62
Jefferson	1.94	16.47	4.25		
Lawrence	9.43	11.43		4.48	.26
Mill		5.50	11.45	8.78	3.27
Oxford	2.03	13.62	4.38	.48	4.17
Perry		1.72	24.18		
Rush		8.67	17.63	2.34	
Salem	4.32	16.85	6.63	.22	5.30
Sandy	2.98	16.36	.07	.08	4.77
Sugar Creek	9.27	9.70		3.26	
Union		5.42	13.10	.90	1.97
Warren		13.88	6.04	2.28	
Warwick		13.10	5.46	.90	6.73
Washington		9.75	16.00		
Wayne	10.14	11.14		4.95	.15
York	4.47	14.10	2.57	1.32	
Totals	72.08	256.73	145.48	39.57	57.14

Pottsville Formation

The Pottsville is the basal formation of the Pennsylvanian system and is of importance as a source of water. Its areal distribution is shown on the map on plate 7. It underlies the entire county. It ranges in thickness from 50 to 150 feet, part of this variation being caused by the unconformable contact of this formation with the eroded surface of the Mississippian rocks beneath, part by the thinning or local absence of some of the members, and part by the erosion of the upper part of the formation in some localities. The members of the Pottsville formation which occur above the drainage level in Tuscarawas County are shown in table 14 (13).

TABLE 14

Generalized succession of the members of the Pottsville formation in Tuscarawas County

Material	Geologic name of member	Thickness Ft.	In.
Clay, gray, plastic	BROOKVILLE	5	0
Clay, gray, arenaceous	TIONESTA	4	0
Shale, bluish-gray, sandy, and shaly sandstone	HOMEWOOD	39	0
Limestone, black, flinty	UPPER MERCER	0	6
Coal and black shale	BEDFORD	0	9
Clay, bluish-gray		3	0
Shale and sandstone		12	4
Coal, local	UPPER MERCER #3A	1	0
Clay, bluish-gray		1	0
Limestone, bluish-gray, fossiliferous	LOWER MERCER	2	6
Coal, shaly, local	MIDDLE MERCER	0	4
Clay, bluish-gray		4	9
Coal, shaly, local	FLINT RIDGE	0	4
Clay, bluish-gray		7	2
Shale, gray, arenaceous		25	0
Sandstone, heavy-bedded	MASSILLON	40	0
	Total thickness	146	8

The Massillon and Homewood members of the Pottsville formation are water-bearing. The shales and shaly sandstones also contain water, generally along the joints and bedding planes, but in quantities too small to be of much use. The coal beds in some places contain meager supplies of water which is generally sulfurous and non-potable. The clays and limestones are practically dry.

Allegheny Formation

The Allegheny formation is by far the most widely distributed formation in Tuscarawas County. It occurs at the surface in some locality in every township. The zone of outcrop occupies almost one-half of the total area of the county. The members of the formation form the steep valley walls along both sides of the Tuscarawas River and many of its tributaries. It ranges in thickness from 175 to 250 feet and averages about 200 feet. A generalized section of the Allegheny formation is shown in table 15 (14).

TABLE 15

Generalized succession of the members of the Allegheny formation in Tuscarawas County

Material	Geologic name of member	Thickness Ft.	In.
Coal	UPPER FREEPORT #7	2 -	2
Clay, bluish-gray		6 -	0
Shale, bluish-gray		4 -	0
Clay, light bluish-gray	BOLIVAR	7 -	6
Sandstone, local, shaly	UPPER FREEPORT	21 -	6
Coal, shaly	LOWER FREEPORT #6A	1 -	3
Limestone, local	LOWER FREEPORT	0 -	6
Clay, bluish-gray calcareous		2 -	8
Sandstone and sandy shale	LOWER FREEPORT	63 -	7
Shale, black		0 -	6
Coal	MIDDLE KITTANNING #6	3 -	2
Shale, bluish-gray arenaceous		15 -	0
Coal, local	STRASBURG	0 -	10
Clay, shaly, impure	OAK HILL	3 -	0
Shale, soft, dark, with iron nodules		15 -	7
Coal	LOWER KITTANNING #5	2 -	6
Clay, bluish-gray, flint and plastic		8 -	2
Shale, bluish-gray		14 -	6
Limestone, bluish-gray, fossiliferous, local	VANPORT	3 -	0
Shale, bluish-gray		27 -	11
Limestone, light bluish-gray, dense, fossiliferous	PUTMAN HILL	1 -	0
Shale, dark, carbonaceous		0 -	5
Coal, often shaly	BROOKVILLE #4	1 -	7
	Total thickness	212 -	2

Because of its thick and persistent beds of coal and clay, the Allegheny formation is of considerable importance to the mineral industry of the county. Its importance as an aquifer is negligible. The few sandstone horizons in the Allegheny formation are only locally developed and grade laterally into shales. The most important of these are the Lower Freeport and Upper Freeport sandstone members. These sandstones supply water locally for domestic use. The shales, clays, coals, and limestones contain little or no water.

Conemaugh Formation

The Conemaugh formation is the third and uppermost division of the Pennsylvanian system in Tuscarawas County. Its outcrop occurs in the upper part of the hills through the central part of the county, but east of the Tuscarawas River it is more widespread and occupies most of that area. The areal distribution of its outcrop is shown on the map on plate 7 (14). It ranges in thickness from 0 to 300 feet, this variation being due to erosion.

Whereas the Conemaugh formation is predominantly shale elsewhere in Ohio, in Tuscarawas County much of this shale grades laterally into sandstone. Four horizons of sandstone or sandy shale are water-bearing, two of which produce water for farm and domestic supplies. As may be expected, the shales, clays, coals, and limestones contain little or no water.

TABLE 16 (14)

Generalized succession of the members of the Conemaugh formation in Tuscarawas County

Material	Geologic name of member	Thickness Ft. In.
Sandstone and sandy shale	MORGANTOWN	100 - 0
Limestone, greenish-gray, fossiliferous, unsteady	AMES	1 - 6
Shale, bluish-gray, olive, or red		46 - 0
Coal, shaly, local	BARTON	1 - 0
Clay, calcareous, with limestone nodules	EWING	8 - 0
Shale, bluish-gray, arenaceous		35 - 10
Coal, shaly	ANDERSON	0 - 6
Clay, yellowish-gray		4 - 0
Shale, variegated		19 - 4
Limestone, nodular, ferruginous, fossiliferous, discontinuous	CAMBRIDGE	0 - 5
Shale, dark bluish-gray		5 - 0
Coal, shaly, local	WILGUS	0 - 6
Clay, dark bluish-gray, calcareous		5 - 2
Sandstone, massive, local; arenaceous shale	BU FFALO	23 - 0
Shale, dark, arenaceous, carbonaceous	BRUSH CREEK	4 - 0
Coal, generally missing	BRUSH CREEK	
Clay, dark bluish-gray, local		2 - 6
Shale, bluish-gray		13 - 2
Coal, local; carbonaceous shale	MASON	1 - 0
Clay, bluish-gray, variegated		5 - 6
Sandstone, local; sandy shale	UPPER MAHONING	32 - 0
Coal, discontinuous	MAHONING	1 - 9
Clay, bluish-gray, calcareous		5 - 8
Sandstone, thin-bedded to massive	LOWER MAHONING	1 - 9
Shale, carbonaceous, with iron nodules		5 - 0
	Total thickness	316 - 8

The rocks of the Conemaugh formation have been described in detail in 1912 by Condit (15), who has compiled a generalized stratigraphic succession of the members of this formation. More recently R. E. Lamborn, of the Geological Survey of Ohio, has measured and studied the Conemaugh formation in Tuscarawas County. Table 16 shows the succession of members as described by him, and the thickness given therein for each member is the average of all his measurements of that member.

Quaternary System

The Quaternary system includes all the unconsolidated sediments overlying the bedrock surface. The sediments consist of valley train deposits, valley inwash, and till, all of Pleistocene age, and of Recent alluvial materials.

Valley train and valley inwash deposits occupy valleys which existed in pre-Pleistocene time or which were eroded by melt-water from the front of the glacier. A pre-Pleistocene valley extended from the southeast corner of the county northwestward to the present site of Beach City. This valley, which is now occupied by Stillwater Creek, Tuscarawas River, and the lower part of Sugar Creek, was joined by tributary valleys which are now occupied by part of the Tuscarawas River and Conotton Creek, by Sandy Creek, and by the upper part of Sugar Creek.

During the erosional phases of glaciation the main valley and some of its tributaries were deepened and an outlet for the river system was eroded past the present sites of Port Washington and Newcomerstown.

During the depositional phases of glaciation these deepened valleys were partially filled with glacial deposits. The valleys which conducted the melt-water away from the glacial front received the materials that make up the valley train, and those tributaries which were out of the direct line of flow were partially filled with inwash materials.

The valley train is composed of stratified sand and gravel interbedded with lenses of clay. Many of the gravel horizons are laterally continuous over extensive areas.

The inwash deposits in the tributary valley are composed of fine sand and clay, intermingled with a variety of clastic materials derived from the adjacent uplands.

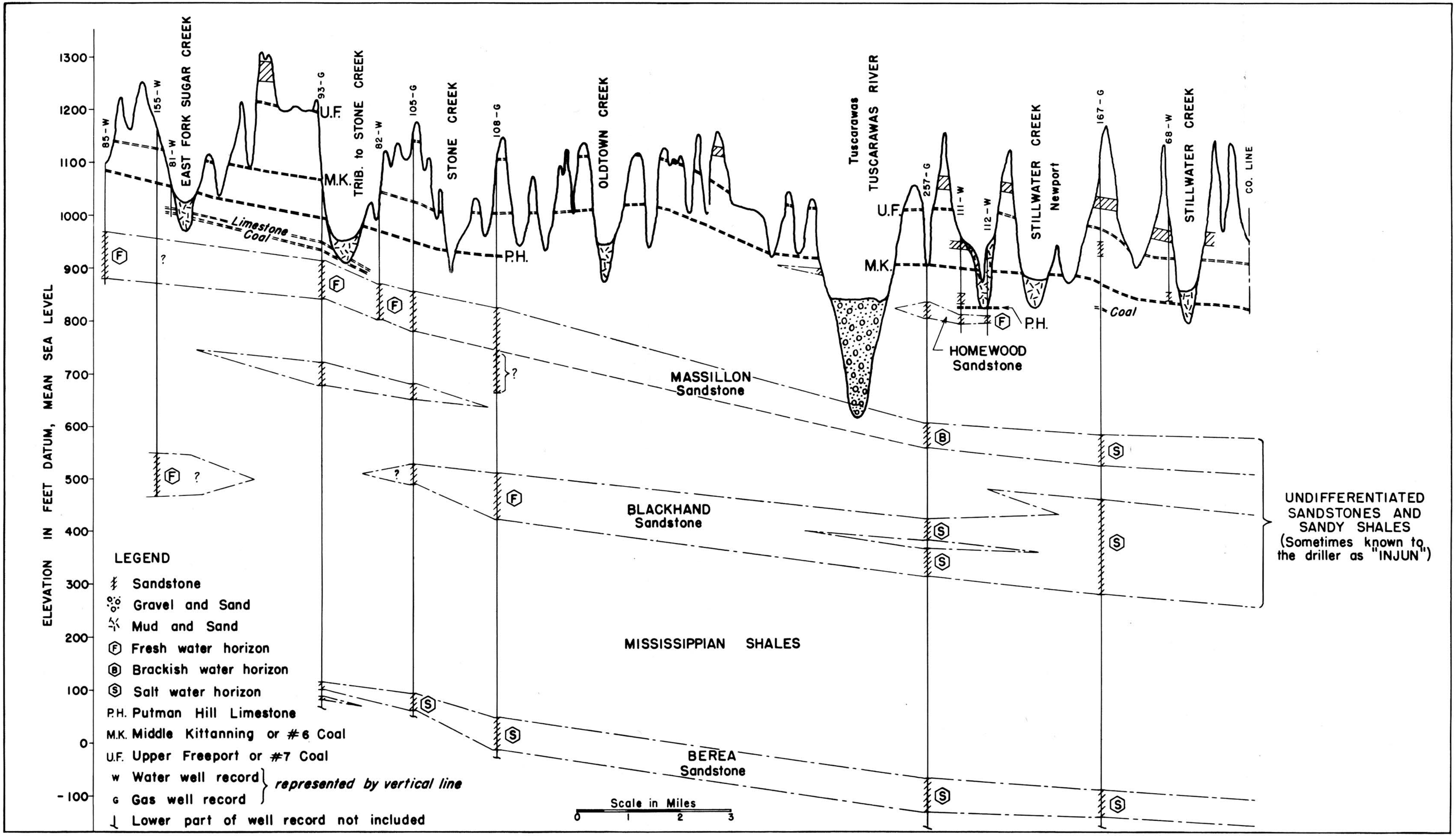
The till, representing material deposited directly by the ice, occupies about one square mile in the northwest corner of the county. Its thickness is less than 50 feet. The material is morainal and is composed of unstratified clay containing intermixed sand and gravel.

It is unimportant as a source of water. It is a part of the terminal moraine of the Wisconsin glacier.

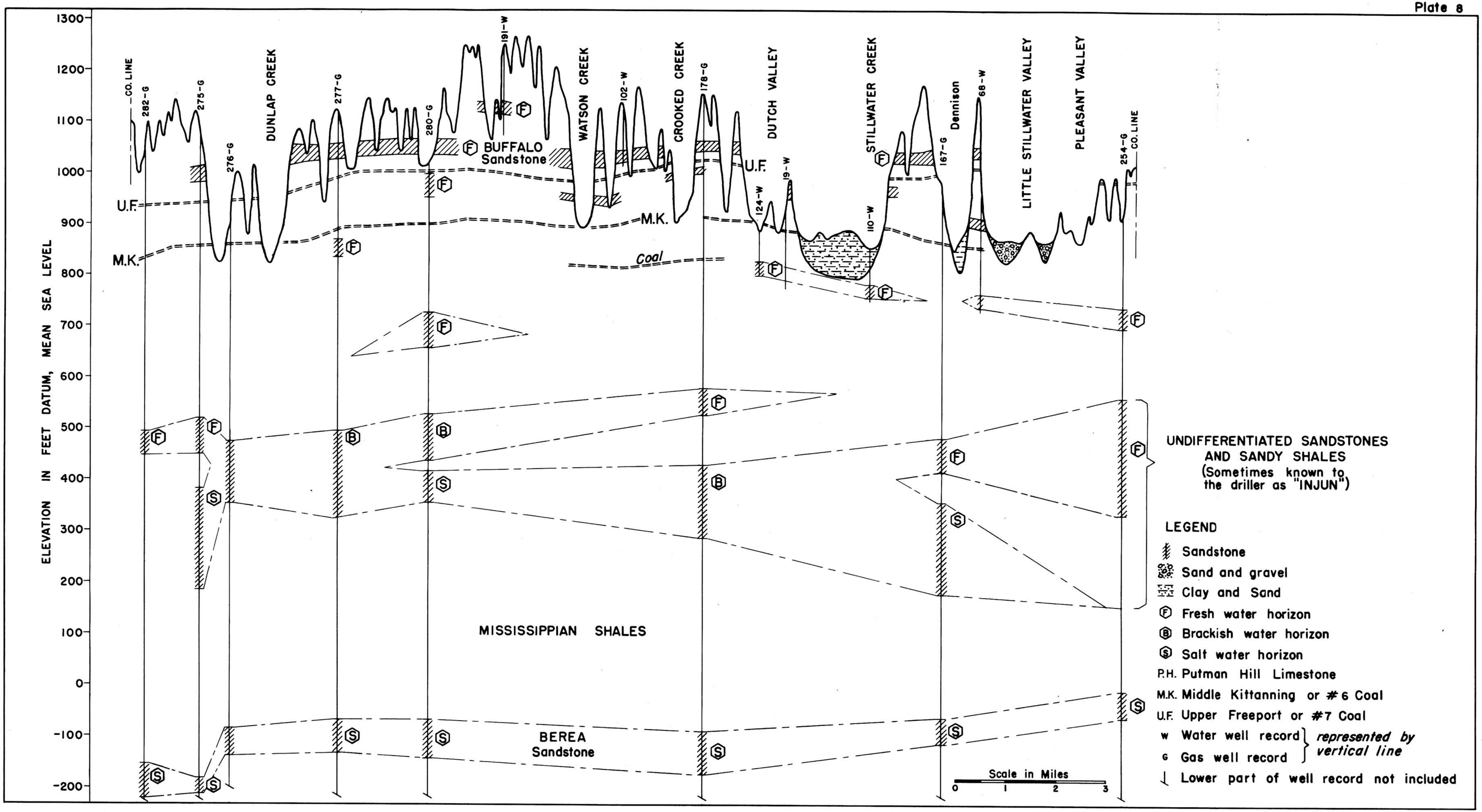
The Recent alluvial deposits are confined to flood plains and alluvial fans. They are chiefly sand and silt. Gravel beds, where present, are usually reworked Pleistocene deposits. Alluvial sand and gravel, where of adequate thickness, and in contact with flowing stream water, yield large water supplies. Small alluvial fans in some of the valleys provide small water supplies for farm use.

GEOLOGIC STRUCTURE

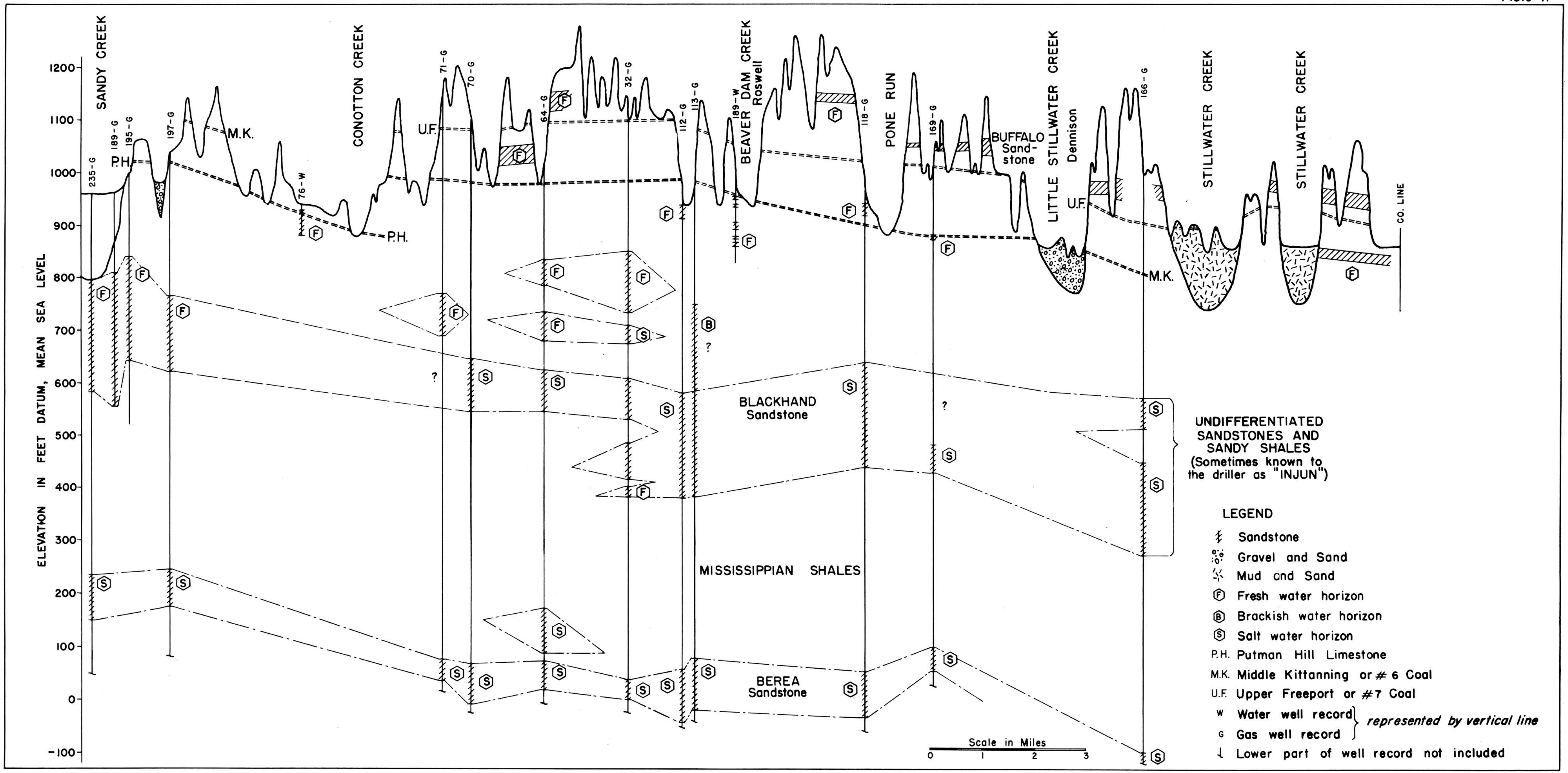
Structurally the area lies on the western flank of the Appalachian geosyncline. With local exceptions, the strata dip in a southeasterly direction at a rate of 30 feet per mile. Formations found at the surface in the western part of the county occur at considerable depth to the east. Owing to eastward thickening of some of the subsurface formations, the lower strata dip more steeply than those at the surface. The general attitude of the beds is shown in the several geologic cross-sections in plates 8, 9, 10, and 11.



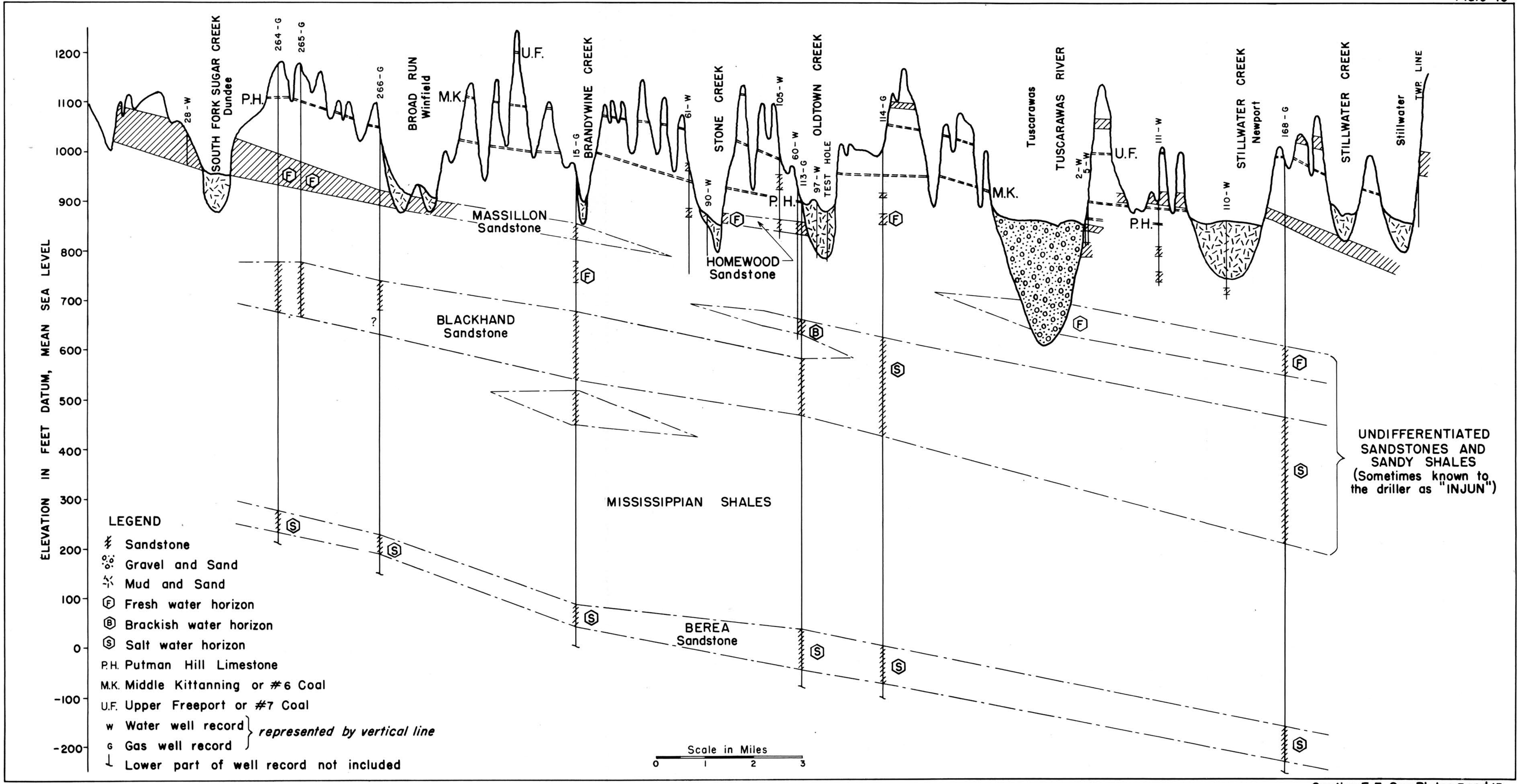
Section C-D. See Plates 7 and 13.



Section A-B. See Plates 7 and 13.



Section G-H. See Plates 7 and 13.



Section E-F. See Plates 7 and 13.

UTILIZATION OF WATER

METHODS OF RECOVERY

Both surface and ground water are used in Tuscarawas County. The surface-water developments, with one exception, use the flow of streams without storage or impoundment. The exception is the municipal water system of Dennison and Uhrichsville, which makes use of a small impounding reservoir on Stillwater Creek.

Ground water is recovered from springs, dug wells, drilled wells, and driven wells. Springs are numerous in Tuscarawas County, occurring principally along the outcrops of the sandstone beds. Many of the springs are high on the valley walls and supply sufficient water of good quality and under good pressure to homes in the valleys. A large number of homes in the southeastern two-thirds of the county derive their water supplies from this source. In addition, water from springs is widely used for watering stock. The yields of springs in Tuscarawas County range from a minute trickle of water which is soon lost by evaporation to flows of more than 20 gallons a minute.

It is estimated that more than 250 dug wells supply water for domestic and farm use in the county. In many places these are located at the ends of tributary valleys where alluvial material has been deposited in a fan-shaped body on top of the flood plain materials of the main valley. Some dug wells in the upland areas are dug to depths of 50 feet or more, through thick layers of shale and fireclay into water-bearing sandstone horizons. As a rule, water is pumped from dug wells by means of hand-operated suction pumps or by deep well cylinder-type pumps. The yields of dug wells usually do not exceed 1 or 2 gallons a minute.

Driven wells are used to supply water to homes in many small communities and in rural areas of the broad, flat valley of the Tuscarawas River, where many suburbanites have settled. These home water supplies usually include an electric pump and a pressure tank, and sometimes a water softener. The yield of small-diameter driven wells is usually sufficient for household needs.

Some contractors drive 6 or 8 inch pipe in areas where experience has shown the smaller diameters to be unsuitable. Driven wells are sunk only far enough below the water table to accommodate the drawdown produced by pumping and to allow for the normal seasonal fluctuations of the water table.

By far the greatest number of drilled wells in the county penetrate the bedrock strata, either the sandstone or the sandy shale horizons. Most of these wells are used to supply water for farm and domestic purposes. They are generally 4, 5, or 6 inches in diameter and range from 15 to 350 feet in depth. They yield from 2 to 50 gallons a minute.

Few domestic wells are drilled into sand and gravel, but many industrial and municipal wells, ranging in diameter from 8 to 30 inches, are drilled into productive sand and gravel. A well, 30 inches in diameter at the New Philadelphia waterworks yields 1,560 gallons a minute with only 5 feet of drawdown. However, the yields of most of the municipal and industrial wells penetrating sand and gravel in the county average about 500 gallons a minute.

CONSUMPTION OF WATER

A survey of the use of water in Tuscarawas County was made in October 1946, the results of which show that the total daily consumption of ground and surface water averages 18,741,000 gallons. Of this amount 8,410,000 gallons is obtained from surface streams and 10,331,000 gallons is derived from ground-water sources. Table 17 shows the source and amounts of water used by the three major groups of consumers.

TABLE 17

Water consumption in Tuscarawas County, in gallons a day

Type of consumer	Surface water	Ground water	Total
Industrial	6,010,000	7,013,000	13,023,000
Municipal	1,800,000	2,918,000	4,718,000
Rural	600,000	400,000	1,000,000
Total	8,410,000	10,331,000	18,741,000

Municipal consumption

About 43,000 persons, or 62 percent of the population of the county, obtain their water from municipal water systems. The remainder depend upon private sources such as wells and springs. There are 12 municipal water-supply systems in the county (16), which supply an average demand of 4,718,000 gallons a day, or an average per capita consumption of about 70 gallons daily. Table 18 shows the location, population served, average daily total pumpage, and average daily per capita consumption for each of these municipal water systems.

TABLE 18

Data on municipal utilization of water in Tuscarawas County

Municipality	Population	Source	Average pumpage, G.P.D.	Per cap. consump., G.P.D.
Baltic	492	Rock well	20,000	41
Bolivar	596	Gravel well	30,000	50
Dennison and Uhrichsville	10,848	Surface water	1,800,000	170
Dover	9,691	Gravel wells	1,150,000	119
Gnadenhutten	876	Gravel wells	45,000	51
Mineral City	820	Gravel wells and spring	50,000	61
Newcomerstown	4,564	Gravel wells	400,000	88
New Philadelphia	12,328	Gravel wells	1,080,000	88
Shanesville	453	Rock well	5,000	11
Sugar Creek	836	Rock wells	60,000	73
Strasburg	1,297	Gravel wells	60,000	46
Tuscarawas	663	Gravel well	18,000	27
Total pop. served	43,464	Total use	4,718,000	

Baltic

The village of Baltic has two municipal wells from which 325 customers are supplied. The wells are 192 feet deep and 8 inches in diameter. The water is derived from the Massillon sandstone and is used without treatment. The schoolhouse is the largest consumer.

Bolivar

The village of Bolivar furnishes water to 110 customers, the schoolhouse using the largest amount. The water is drawn from a stratum of medium-sized gravel at a depth of 98 feet. The original static level was 53 feet, and the well has a capacity of 25 gallons a minute per foot of drawdown. The well is 10 inches in diameter and is equipped with a deep well turbine pump. The water is used without treatment.

Dover

The city of Dover furnishes water to many industries in addition to its domestic consumers. The water is pumped from four

12-inch wells about 100 feet deep. The wells penetrate a stratum of well-washed gravel which probably extends laterally across most of the width of the valley. The wells are equipped with suction pumps and are operated at the total rate of about 2,000 gallons of water a minute. The static level is 10 feet below the surface.

Gnadenhutten

The village of Gnadenhutten pumps its water supply by means of a deep well turbine pump from one 10-inch well 84 feet deep, drilled into coarse, clean gravel. The static level is 30 feet below the surface and the well is capable of producing 40 gallons a minute per foot of drawdown.

Mineral City

The village of Mineral City obtains its water from one spring and two wells. The wells are close together in the valley of Sandy Creek and are drilled about 80 feet into a stratum of coarse, clean gravel. The water is supplied without treatment to about 300 customers.

Newcomerstown

The village of Newcomerstown requires about 400,000 gallons of water a day. This supply is pumped by suction from 12 wells, 8 inches in diameter and 50 feet deep. These wells are spaced 50 feet apart along the north bank of the Tuscarawas River, near the east end of the village. The water is derived from a gravel stratum which extends beneath the river. The temperature of the well water varies with the temperature of the river, indicating that some recharge is derived from river infiltration. The wells yield about 900 gallons a minute and the water is stored and used without treatment.

New Philadelphia

New Philadelphia obtains its water from five wells drilled 110 feet into a gravel stratum along the Tuscarawas River in the southern part of the city. Two of these wells are 30 inches in diameter and are equipped with turbine pumps, and produce a total of 3,000 gallons a minute. The other three wells, two of which are 12 inches and the third 24 inches in diameter, are equipped with suction pumps, and produce a total of 1,130 gallons a minute. For the present requirements of the city it is necessary to operate these pumps only 8 to 16 hours a day. Table 19 gives the yield and drawdown of some of the wells pumped by the city.

TABLE 19

Municipal well data, New Philadelphia

Well	Diameter inches	Present pumping rate	Max. drawdown Feet	Inches
No. 1	24	690 G.P.M.	27	10
No. 2	12	440 G.P.M.	10	5
No. 4	30	1380 G.P.M.	12	0
No. 5	30	1560 G.P.M.	5	0

The water is treated with a zeolite or base-exchange softener, then with sodium carbonate to raise the pH, and finally with chlorine. The wells are about 125 feet apart and 150 feet from the river. At present the water from these wells does not contain a high concentration of chloride, probably because the present rate of pumping is not high enough to cause infiltration of river water, which is high in chloride.

Shanesville

The village of Shanesville depends for its water supply upon one well 6 inches in diameter, drilled into the Black Hand Sandstone at a depth of 460 feet. The water is furnished without treatment to 115 customers. The per capita use is the smallest in the county, as it averages only 11 gallons a day per person. The well is pumped 12 hours each day and 12 hours three nights each week. A second well, 8 inches in diameter and 420 feet deep, is available for use when a pump can be obtained.

Sugar Creek

The village of Sugar Creek owns two 10-inch wells, drilled into the Black Hand Sandstone at a depth of 295 feet. The water is furnished without treatment, and both quality and quantity are reported to be satisfactory.

Strasburg

The village of Strasburg obtains its water from two wells, 8 inches in diameter, 25 feet apart, and 72 feet deep. The water is derived from a stratum of clean gravel in which the static level is 10 feet below the surface of the ground. The water is used without treatment.

Tuscarawas

The village of Tuscarawas pumps one municipally owned well 10 inches in diameter and 85 feet deep. The static level is 55 feet below the surface and the amount of drawdown is unknown. The well is located three-quarters of a mile from the river and the material from which the water is derived is reported to consist of a thick stratum of pea-sized gravel, overlain by 10 feet of heavy clay. The water is used without treatment.

Dennison and Uhrichsville

The villages of Dennison and Uhrichsville, with a combined population of 10,848, have developed a combined water supply by impounding the flow of Stillwater Creek and treating the water for municipal use. About 3,000 customers, of whom the Pennsylvania Railroad is the largest, require a daily average of approximately 1,800,000 gallons of water, or about 170 gallons a day per capita. The raw water is treated with alum, copper sulfate, and chlorine, and is filtered through activated carbon.

Industrial consumption

The development of the ceramic industry has been a controlling influence in the civic and cultural progress of Tuscarawas County. Municipalities were located near the clay mines, and other associated industries have been established in these towns. The industrial activity of the county is consequently centered in the municipalities.

In many places the municipal water supply was an important factor in attracting an industry. Conversely, lack of an adequate municipal water supply had a tendency to discourage industrial expansion. Occasionally, as a result of plant expansion and the influx of new business with its corresponding increase in population, the demand for water outgrew the amount that the municipality could supply. It then became necessary for industries to develop their own independent water-supply systems.

At present a total of more than 13 million gallons of water is pumped daily by industrial water-supply systems. This amount is about evenly divided between surface water and ground water. However, the number of industries using ground water is far in excess of those which use surface water. Although slightly more than 6,000,000 gallons of water a day is removed from surface streams for industrial use, most of it is returned to the streams.

Table 20 shows the municipalities in or near which private industrial water supplies have been developed, and the approximate amount of water used daily in these localities.

TABLE 20

Amounts of water pumped by water-supply systems owned by industries in Tuscarawas County, Ohio

Locality	Ground water G.P.D.	Surface water G.P.D.
Baltic	23,600	
Bolivar	48,000	
Columbia	11,500	
Dennison	102,000	
Dover	3,590,000	6,000,000
Goshen	24,000	
Midvale	4,800	10,000
Mineral City	4,800	
Newcomerstown	1,814,400	
New Philadelphia	821,000	
Newport	9,600	
Parral	28,800	
Port Washington	15,000	
Seventeen	14,400	
Shanesville	134,400	
Sugar Creek	160,800	
Stone Creek	29,400	
Strasburg	48,000	
Tuscarawas	3,000	
Uhrichsville	115,800	
Zoar	4,800	
Zoarville	4,800	
Totals	7,013,300	6,010,000

Of the 7 million gallons a day of water pumped out of the ground by industries, slightly more than 1 million gallons a day is used by industries engaged in producing and processing foods, including cheese and other dairy products. About 4 million gallons of water a day is used by the steel industry in the manufacture of a number of finished products, including tools, dies, molds, etc., for the use of other industries.

Ice manufacturing and air conditioning plants use almost 500,000 gallons a day, and a similar amount is used by the electric power companies. Twenty privately owned water systems have been developed by the ceramic industry, but a total of only 453,000 gallons daily is pumped for this purpose. Other smaller amounts of water are pumped by soft drink manufacturers, breweries, greenhouses, lumber companies, chemical plants, and other miscellaneous industries.

Rural consumption

In the course of the survey upon which this report is based an inventory of farm water supplies was made by a house-to-house check in certain selected areas. It is realized that this type of survey is neither complete nor accurate; nevertheless, it affords some basis for estimating water consumption in rural areas.

On the basis of this survey it is estimated that the rural consumption of ground water amounts to 400,000 gallons a day, about half of which is used for household purposes and half for watering stock.

In addition to water derived from wells, about 600,000 gallons a day is taken from cisterns, springs, and streams. Of this amount, which is divided about evenly between household use and stock use, about 350,000 gallons a day is taken from springs and cisterns, the remainder being stream water. Table 21 shows a tabulation of the source and utilization of water in rural areas.

TABLE 21

Source and utilization of water in rural areas in Tuscarawas County, Ohio

Type of utilization	Average daily amount in gallons		
	Wells	Cisterns and springs	Streams
Household	200,000	250,000	-
Stock	200,000	100,000	250,000
Total	400,000	350,000	250,000

GROUND WATER

STORAGE, SOURCE, AND MOVEMENT

Many of the rocks forming the outer crust of the earth, both consolidated and unconsolidated, contain numerous openings called voids or interstices, which may contain water, oil, natural gas, or air. There are many kinds of rocks and the interstices in them differ greatly in number, size, shape, and arrangement. The occurrence and movement of ground water in any region is therefore determined by the geology.

The interstices in rock formations range in size from minute openings such as those between individual grains in sand or sandstone to large cracks and caverns in limestone. In Tuscarawas County the principal aquifers are the sandstone beds and the sand and gravel deposits of glacial and alluvial origin, bordering streams. The ability of these formations to store water is dependent upon their porosity. It must be remembered, however, that porosity alone determines only how much water a given rock can hold, and not how much it may yield to wells. A bed of clay may have a porosity as high as that of a bed of coarse sand, but because of the small size of the interstices in the clay, the application of great pressure might be needed to cause a movement of water.

The ability of a formation to transmit water is called its permeability, and this property largely determines the yield of a well tapping a particular formation. The aquifers of Tuscarawas County differ greatly in both porosity and permeability. Generally it may be stated that the sandstones have relatively low porosity and permeability when compared with the sand and gravel beds. The yield per foot of drawdown (called the specific capacity) of wells drilled in sand and gravel aquifers is therefore usually much greater than that of wells drilled in sandstone aquifers. In Tuscarawas County all fresh water in the ground is derived by infiltration of water from the surface. This occurs from precipitation or stream flow, either within the county or to the west of the county wherever good intake facilities exist for recharge to the water-bearing formations.

The source of the deep brines has not been determined but they are thought to be residual waters remaining from the time of deposition of the formations in which they are contained.

Movement of ground water in a water-bearing formation is caused by differences in hydraulic head in different parts of the formation. The differences in hydraulic pressure in artesian formations where ground water is confined in the formation between beds of silt, clay, shale, or other impermeable materials are caused by differences in hydraulic head between the areas of recharge and discharge. The areas of natural discharge are usually along streams. However, pumped or flowing wells also discharge water from an aquifer and may alter the direction of ground-water flow. Intake of water into an artesian formation occurs in its outcrop area, or in areas where the formation is overlain by permeable materials.

In water-table aquifers, where the ground water is not confined between impermeable beds, the surface of the water body, called the water table, follows roughly the surface topography. The movement of ground water in such formations is usually from the upland areas to the valleys, the discharge of the ground water being into the streams. In such areas the low flow of streams is derived from ground water discharge. As in artesian formations, the direction of ground-water flow may be altered by pumping wells, which constitute new points of discharge.

The movement of ground-water in the consolidated formations in Tuscarawas County is generally from west to east. The areas of recharge are west of the areas of discharge because of the eastward dip of the bedrock strata. Some of the deeper bedrock aquifers receive recharge in areas outside of Tuscarawas County, many miles to the west. Discharge from these aquifers is into the gravel strata in the buried valley beneath the Tuscarawas River and Sugar Creek. East of the Tuscarawas River these strata have no area of natural discharge and the water is highly mineralized.

Where water-table conditions exist in the unconsolidated deposits of sand and gravel filling buried valleys bordering streams, the ground water flows both downstream and toward the stream, so that the flow is obliquely toward the stream from both sides. Thus, no particle of water moves downvalley very far before it discharges into the stream.

Two ground-water bodies may exist in some buried valleys bordering streams, the upper under water-table conditions and the lower under artesian conditions, separated by a layer of silt or clay. The flow in the lower stratum is usually in the direction of the flow of the stream. Recharge occurs from the upper stratum to the lower stratum where the separating layer is absent, or from the bedrock in which the buried valley is cut.

FLUCTUATIONS OF GROUND-WATER LEVELS

Ground-water levels seldom remain stationary, being influenced by a number of factors including recharge and natural discharge, changes in barometric pressure, and the effects of pumping. Long dry periods often cause large declines in ground-water levels. At such times many farm wells go dry and the impression is created that ground-water levels are dropping continuously. Unless an area is overpumped, however, ground-water levels return to more or less normal stages, particularly when precipitation occurs in the spring months when vegetation is dormant, the ground is not frozen, and evaporation losses are low.

Plate 12 shows the records of water levels obtain from 1943 to 1945, inclusive, in six wells in Tuscarawas County. Data regarding these wells are given in table 22. All these wells are pumped to supply water for domestic and farm use. The fluctuations of water levels in these wells are therefore influenced by pumping and the natural fluctuations may be somewhat obscured.

TABLE 22

Data on observation wells in Tuscarawas County

Well number	Depth of well in feet	Observer	Type of well
1	25	Orrin J. Steiner	Dug
3	19.5	J. Harry Deitz	Driven
7	100	Jasper Johnson	Drilled
22	50	C.F. Dessly	Drilled
29	17	Carl Fenton	Dug
30	11	Scot B. Murphy	Dug

The records for wells 1, 3, 22, 29, and 30 show large changes in water levels in response to changing rates of recharge and discharge. The largest rises occur in the winter and spring months when vegetation is dormant. The fluctuations in well 7, which is an artesian well, may be caused principally by fluctuations in the rate of pumping.

Significantly, none of the records show a continuing downward trend in water levels, although the range in fluctuation is large in all the wells except well 7. The total range of fluctuations in well 1, for example, has amounted to about 16 feet.

Plate 12

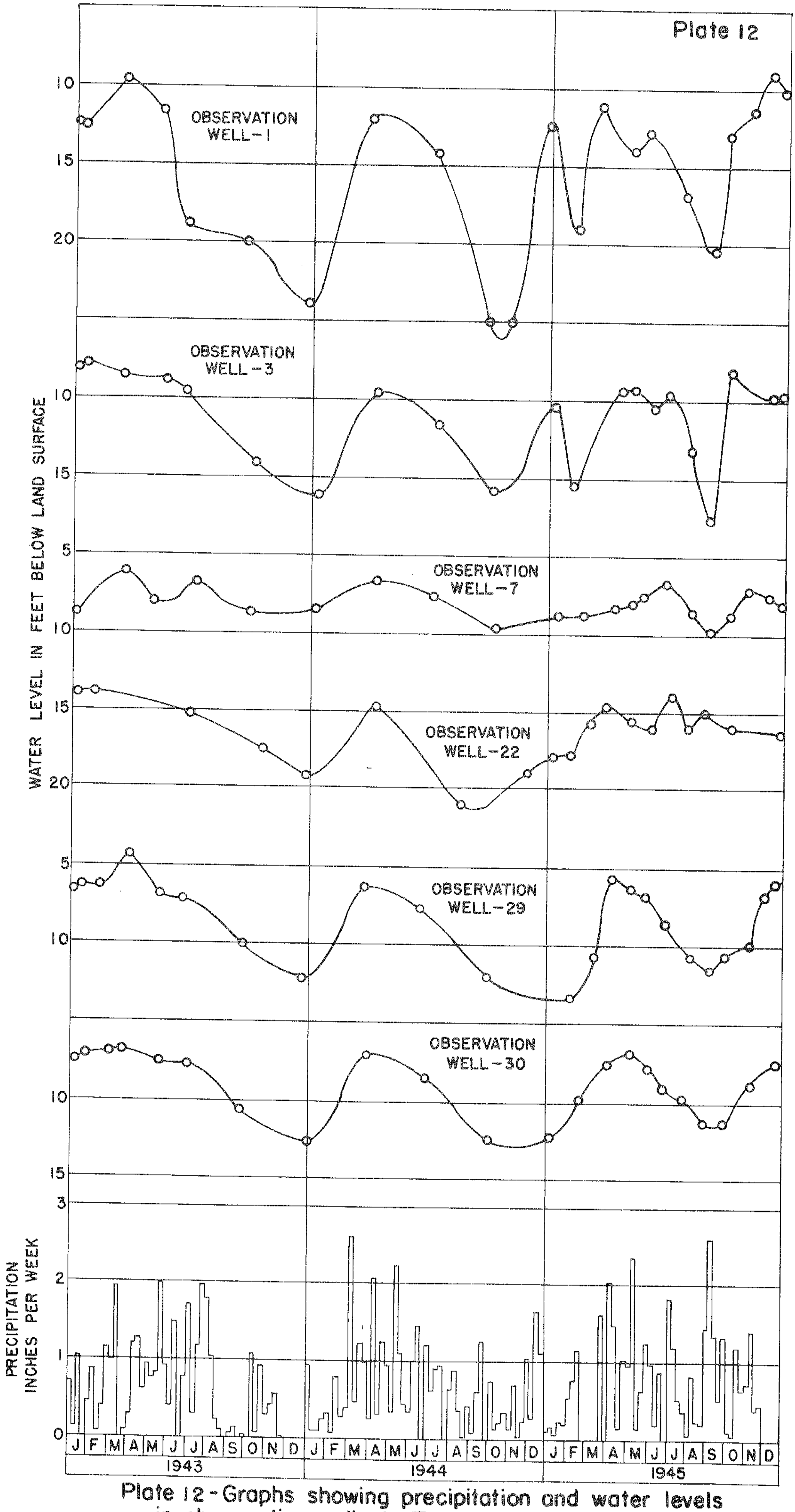


Plate 12 - Graphs showing precipitation and water levels in observation wells in Tuscarawas County, Ohio.

WATER-BEARING PROPERTIES OF SELECTED GEOLOGIC STRATA

The geologic strata underlying Tuscarawas County differ widely in their composition, texture, and structure, and as a result the quality and quantity of the ground water contained in the various strata also differ widely. A certain amount of water is present in all strata, but if a stratum is to be considered a potential source of ground water it must be so constituted as to yield its water to wells at a usable rate. In Tuscarawas County the sandstone units of the bedrock succession and the unconsolidated glacial outwash gravels are the most important sources of ground water. The shales, clays, coals, and silts can afford only meager supplies of water.

Several strata yield water to wells in appreciable quantities, but the water is so high in salt or sulfur content as to be unfit for either human or animal consumption. Several of the deeper strata yield salt water wherever penetrated. All water-bearing formations below and including the Berea sandstone of Mississippian age contain brine. Some aquifers above the Berea contain both salt and fresh water, the salt water being down the dip in the eastern part of the county, and the fresh water being up the dip, above the salt water. Within a given formation there is usually a gradational zone of brackish water separating the fresh water from the brine.

The stratigraphic relationship of these aquifers has been determined by study of the outcrops and by analysis of the logs of approximately 400 wells. Plate 13 shows a map of the county on which are located the wells for which data are available. It also shows four lines which indicate the locations of the four geologic cross-sections shown on plates 8 to 11, inclusive.

Only the more important aquifers are considered in the following detailed discussion. These formations offer the most dependable sources of permanent and potable ground-water supplies.

Bedrock Aquifers

Black Hand Sandstone

The Black Hand sandstone is a member of the Cuyahoga formation of Mississippian age. It does not occur at the surface in Tuscarawas County. Knowledge of its characteristics in this area is therefore derived from well records. It appears to be a firmly cemented but rather porous sandstone. It is sufficiently permeable to supply water for domestic purposes throughout most of its extent. Many wells produce 15 gallons a minute or more from this formation, and yields of as much as

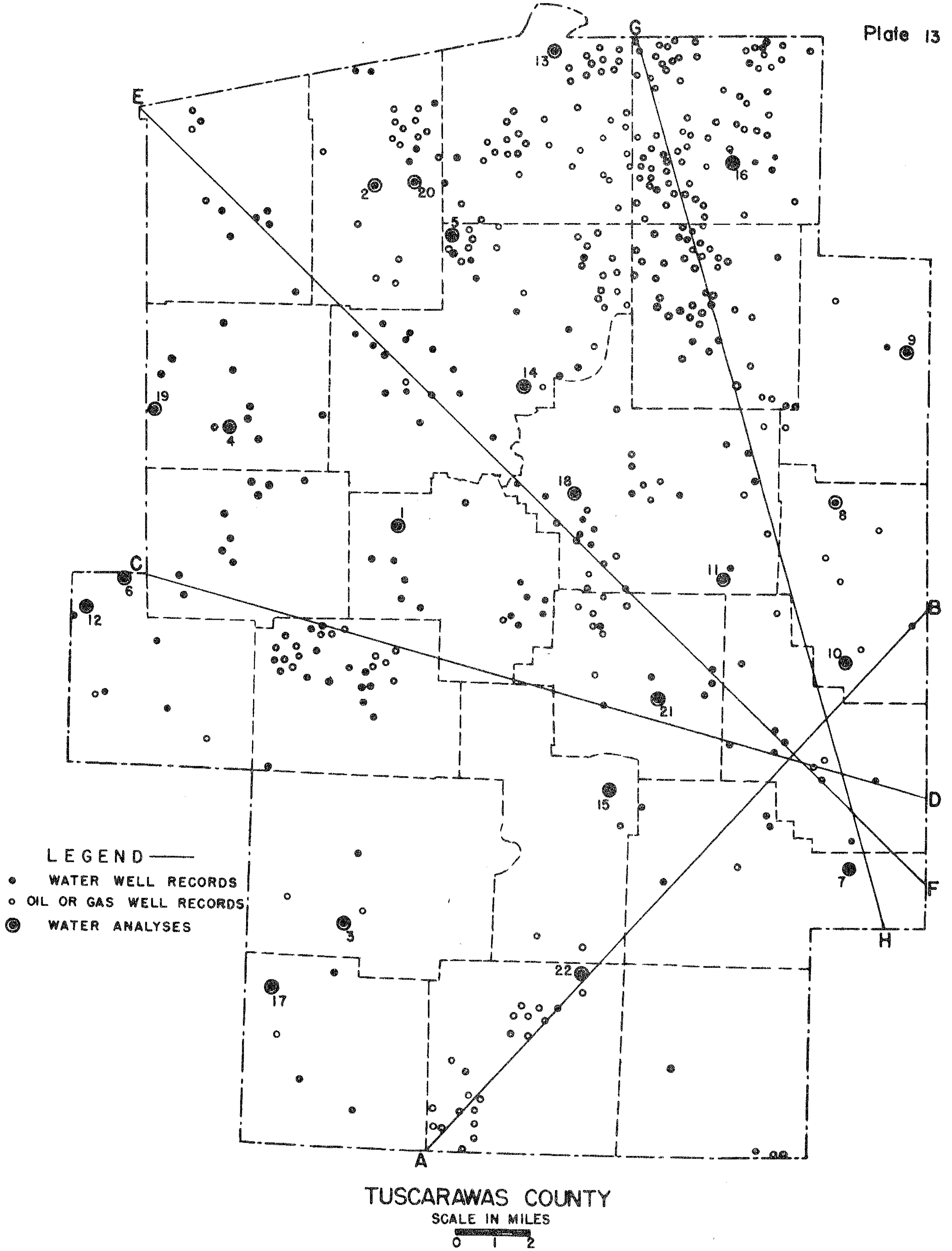


Plate 13 - Locations of wells for which drill records are available and locations of geologic cross sections.

50 gallons a minute have been reported. On the other hand, several dry holes also have been recorded, and many wells which were of sufficient capacity when pumped by hand have proved inadequate when electrically driven pumps have been installed. The apparent lack of uniformity of production is partially the result of varying degrees of cementation, of the nature and extent of fracturing within the formation, and of the extremely variable thickness of the permeable horizons.

The outcrop of this formation is in Holmes and Coshocton Counties, several miles west of Tuscarawas County. It seems probable that recharge occurs in the outcrop area, where the elevation is greater than in Tuscarawas County. This would account for the high hydrostatic head in this formation in Tuscarawas County, particularly in the area of flowing wells in the northwestern part of the county.

The water in the Black Hand sandstone, where fresh, is relatively soft, but it grades laterally to the southeast through brackish water into brine. The level marking the boundary between fresh and salt water has not been clearly defined. In some wells the water has been fresh at first but has gradually become brackish and then saline. The water from one well in the southern part of Salem Township is alternately fresh and brackish.

The Black Hand sandstone is about 50 feet thick in the western part of the county and dips to the southeast at a rate of about 18 feet per mile, although steeper dips have been noted in some places. In the vicinity of Dennison and elsewhere in the eastern part of the county as much as 180 feet of sandstone has been reported in this horizon. This thickness may include alternating beds of shale and sandstone lying above the Black Hand and not properly a part of it.

In contrast, many wells have been drilled in which this sandstone was not reported. It is uncertain in many of these cases whether the sandstone was actually missing or simply was of no interest to the driller and consequently was not recorded. However, it is known from other studies that the Black Hand sandstone is discontinuous or lenticular in many places, and grades laterally into sandy shale and shale.

Table 23 shows the elevation in various localities in the county at which the top of the Black Hand sandstone has been encountered in the drilling of oil, gas, and water wells.

TABLE 23

Elevations of the top of the Black Hand sandstone

Locality	Elevation, feet above sea level	Locality	Elevation, feet above sea level
Baltic	800	Gnadenhutten	430
Dennison	450	Shanesville	810
Dover	600	Stillwater	500
Dundee	820	Stone Creek	665

Massillon sandstone

The Massillon sandstone member of the Pottsville formation is a massive, coarse-grained, in places pebbly sandstone, which is cross-bedded, open-textured, and laterally continuous. It ranges in thickness from 40 to 80 feet but is absent or unreported in many wells, as shown in sections E-F and G-H on plates 10 and 11.

The Massillon sandstone is not a prolific source of water, as wells seldom produce more than 30 gallons a minute from this formation. Many wells have been reported which have failed to supply sufficient water for domestic purposes. As a general rule the water in the Massillon is fresh in localities west of the Tuscarawas River and brackish or saline east of the river. A few wells, notably in the vicinity of Stone Creek, have encountered brackish water in this formation west of the Tuscarawas River. The brackish and saline character of the water in the deeper parts of the formation east of the river has caused it to be misnamed the "Salt Sand" by many drillers. It is not a source of potable water where it is encountered at elevations less than 800 feet above sea level.

This formation crops out in the northwestern part of Tuscarawas County, particularly in Wayne Township. It also lies just beneath the surface throughout several square miles of Wayne Township, overlain by only a few feet of mantle rock or sandy shale. This area is a major recharge zone of this aquifer for the county, although the sandstone may receive considerable recharge at some places where it crops out in the walls of deep buried valleys.

The maximum exposed thickness of the Massillon is about 50 feet, but records of wells near the outcrop, in the vicinity of Dundee, indicate the presence of 80 to 85 feet of sandstone. It dips to the southeast at a rate of about 33 feet per mile, thinning rapidly down the dip, as shown by well records near Dover. This feature is shown on section E-F in plate 10.

The Massillon sandstone is not reported as a separate unit in many of the well records southeast of Dover, but it is generally included in the series of sandstones and sandy shales known to the driller as "Injun Sand". At the southeastern border of the county the "Injun Sand" is reported to be 250 feet thick and more than 400 feet below the surface. Table 24 shows the elevation of the top of the Massillon at several localities.

TABLE 24

Elevations of the top of the Massillon sandstone

Locality	Elevation, feet above sea level	Locality	Elevation, feet above sea level
Baltic	980	Newcomerstown	
Dennison	700	New Cumberland	
Dover	710	Shanesville	1000
Dundee	1030	Stillwater	580
Gnadenhutt en	720	Stone Creek	830
Mineral City		Westchester	570

Homewood sandstone

About 15 feet below the Brookville number 4 coal horizon, which marks the contact between the Pottsville and Allegheny formations, there is a sandy shale horizon called the Homewood sandstone member of the Pottsville. The character of this horizon is not persistent laterally, and the sandy shale grades either into shale or into rather pure and firmly cemented sandstone within short distances. The formation ranges in thickness from 10 to 40 feet, but the pure sandstone facies seldom exceeds 20 feet.

In localities where the sandstone facies is well developed, dependable supplies of ground water can be obtained for domestic use. At its best it is known to yield 10 gallons a minute, as evidenced by wells in the vicinity of Newport and Barnhill and in the area south of Dennison along the Stillwater River. Although misnamed the "Salt Sand" in several well records, it has been found to contain fresh water wherever penetrated within the county.

Freeport sandstones

The Lower and Upper Freeport sandstones occupy about 40 feet of the interval between the Middle Kittanning and Upper Freeport coals. At the outcrop these sandstones are generally thin-bedded, in places interbedded with shale, and tend to break up into small, blocky fragments. In spite of the interbedded shale layers, these members permit infiltration of rain water and lateral percolation of ground water. In the central and eastern parts of the county they are good sources of water for domestic purposes where encountered, but their presence cannot be relied upon. Wells in these sandstones seldom produce more than 5 gallons a minute. The Freeport sandstones cannot be positively identified in well records and are frequently called by local names, loosely applied.

Buffalo sandstone

Condit states (15) "By far the most conspicuous stratum of the Conemaugh beds throughout this region is the massive sandstone lying 60 to 80 feet above the Upper Freeport coal.

"Ordinarily the Buffalo sandstone is a coarse-grained, massive, cliff-forming ledge, over 40 feet thick, but occasionally it is less coarse, less massive, and may even be shaly. Its resistance to erosion has developed a rather rugged, bold topography, especially in the southeast part of the county, where cavernous, overhanging cliffs are common in the hill-side ravines."

This sandstone is an important source of small supplies of water in the southeastern part of the county, both from shallow wells and hillside springs.

Unconsolidated deposits

The unconsolidated deposits in Tuscarawas County include gravel, sand, silt, and clay which are derived largely from glacial detritus released by melting ice along the front of the glacier during the Pleistocene epoch. Some small deposits of sand and silt, the result of recent alluvial erosion and deposition, occupy the stream beds and valley flood plains, and large quantities of the glacial materials have been reworked by recent alluvial action.

The map on plate 7 shows the general relationship between the coarse and fine materials, but the complex interbedding and frequently limited lateral distribution of the beds do not permit more specific representation. Likewise, the sections shown on plates 8 to 11 indicate only the general conditions in the valleys.

The clay and silt deposits which fill the valleys of the northward flowing streams contain only small quantities of water and are unimportant and unreliable sources of supply. In many places the sands and gravels which fill the buried valleys are poorly sorted and are interbedded with lenses of clay. In places large gravel masses are imbedded in layers of mud, and even when free from mud and silt the gravel beds may be of limited lateral extent. Only where a laterally extensive and rather thick bed of relatively clean gravel exists in a buried glacial valley may large supplies of water be obtained. Wells penetrating these deeply buried gravels may yield 350 to 500 gallons of water a minute.

Where present streams flow directly upon glacial outwash gravel these beds are reliable sources of ground water but can be made still more reliable if infiltration of river water can be induced by the proper location, construction, and operation of wells. This condition has been found to exist along the Tuscarawas River from Newcomerstown to Dover and near Bolivar. Conditions are also favorable along Sugar Creek from Dover to Beach City and along Sandy Creek near Sandyville. These localities deserve further intensive study and should be thoroughly explored by test drilling and pumping tests to determine how much water is available for development.

The depth and thickness of the sand and gravel beds are not known in all places, and the variety of size and amount of sorting of the gravels can be determined only by drilling. In localities where wells have been drilled, the thickness of the deposits ranges from 40 to 150 feet. The material ranges in texture from fine sand to gravel with pebbles 4 inches in diameter. Almost any degree of sorting may be expected.

Excellent gravels exist in the vicinity of Newcomerstown, both up and down stream. The municipal wells at Newcomerstown are drilled into the shallow gravels along the river bank. At many places nearby the river is cutting its channel through banks of well-sorted gravel. At Port Washington a well is reported to have penetrated 110 feet of "large-sized gravel". At Gnadenhutten "a good thickness of washed gravel" was estimated by the driller to be more than 60 feet. The pebbles were the size of walnuts but free from clay. At Dover the gravels are reported to be smaller but very well washed and sorted.

South of New Philadelphia, in the gravel pit of Clarence Hansel, gravels have been taken from a depth of 30 feet and a well drilled 43 feet into this material yields 450 gallons of water a minute with a drawdown of 10 feet from a static level of 18 feet.

The municipal wells of Tuscarawas, Port Washington, Gnadenhutten, New Philadelphia, Dover, Strasburg, Mineral City, and Bolivar all derive their water supply from reworked glacial gravels at relatively shallow depths.

Any plan to utilize water from these shallow gravels along the major streams must recognize that lowering of the water level in the gravel to a point below the level of the stream may induce infiltration from the river. In view of the present high chloride content of the Tuscarawas River, such developments along that stream would probably yield undesirable water. This is more fully discussed in the section on quality of ground water. The Strasburg-Beach City area, being on Sugar Creek, would not be thus affected, and would probably be the best area for further detailed investigation of river-infiltration possibilities.

QUALITY OF GROUND WATER

Chemical analyses

A number of water samples were collected from wells in known formations in order that the chemical character of the water from these formations could be determined. Chemical analyses were made of water from wells in the glacial gravels, and the Black Hand, Massillon, Homewood, Buffalo, and Freeport sandstones. Analyses of 22 samples are presented in table 25. Results are shown in parts per million (ppm). Of these samples, 12 were from privately owned wells and 10 were from public water-supply wells (17). All analyses were made at the laboratory of the Ohio Department of Health. The locations of the wells from which samples were obtained are shown on the map on plate 13.

The analyses show a wide range of variation in chemical content of the waters, even in samples obtained from one formation. Total hardness ranges from a minimum of 2.0 ppm to a maximum of 338 ppm.

Iron content ranges from 0 to 7.0 ppm, seven samples showing more than 1.0 ppm. In general, the iron content is found to be excessive in the sandstone aquifers. Water containing more than 1 ppm of iron is usually unsatisfactory for municipal and industrial water supplies unless provision is made for its removal.

Chloride is present in all the waters analyzed but usually in small amounts. Three samples, numbered 3, 4, and 19, show excessive amounts of chloride; all are derived from the Black Hand sandstone. Generally chloride in excess of 250-300 ppm can be detected by taste, but is not too distasteful for domestic use when in the range of 300 to 500 ppm.

The amounts of fluoride in the samples analyzed range from 0.1 to 1.4 ppm. Contents higher than 1.0 to 1.5 ppm may cause mottled

Table 25

CHEMICAL ANALYSES OF GROUND WATER IN TUSCARAWAS COUNTY
Analyses by Ohio Department of Health
(Parts per million)

Well No.	Township	Date of collection	Aquifer	Total Solids	Alkalinity			Alkali Bicarbonates	Hardness		Free CO_2	pH	pH after $CaCO_3$	Corrosion Index	$CaCO_3$		Iron Total	Manganese	Chloride	Fluoride	Silica	Calcium	Magnesium
					Total	Phenol	Caustic		Non-Carb.	Total					Excess	Deficiency							
1	York	12/19/46	Massillon ss	395	275	0	0	213	0	62	22	7.4	7.55	.15	0	16	.4	.1	11	.8	10	18	4
2	Clinton	12/19/46	Massillon ss	388	302	0	0	300	0	2	8	7.9	8.1	.2	0	14	1.65	0	5	.7	10	-	-
3	Salem	12/19/46	Black Hand ss	1480	574	0	0	425	0	149	34	7.55	7.7	.15	0	24	.4	0	540	1.4	8	58	1
4	Sugar Creek	12/19/46	Black Hand ss	1051	349	0	0	310	0	39	17	7.6	7.65	.05	0	13	.6	0	410	.9	7	9	4
5	Dover	12/19/46	Massillon ss	290	213	0	0	5	0	208	10	7.6	7.5	.1	1	0	.6	.2	19	.1	12	59	15
6	Bucks	12/19/46	Black Hand ss	305	255	0	0	170	0	85	20	7.4	7.5	.1	0	7	2.05	0	10	.2	8	23	7
7	Rush	1/27/47	Freeport ss	259	229	0	0	20	0	209	10	7.7	7.7	0	3	0	2.7	.08	1	.4	6	55	17
8	Union	1/27/47	Freeport ss	120	52	0	0	0	25	77	8	7.1	7.5	.4	0	10	7.0	.08	9	.1	8	24	4
9	Warren	1/27/47	Freeport ss	283	226	0	0	13	0	213	38	7.1	7.3	.2	0	3	3.9	.35	7	.6	12	60	16
10	Union	1/28/47	Homewood ss	1137	310	0	0	208	0	102	13	7.9	7.7	.2	6	0	1.6	.1	63	1.2	6	28	8
11	Goshen	1/27/47	Homewood ss	253	220	0	0	45	0	175	9	7.7	7.7	0	6	0	2.2	.08	12	.4	9	49	13
12	Bucks	1/26/44	Black Hand ss	298	268	0	-	159	0	109	10	7.75	7.7	.05	-	-	.1	.01	4	.4	12	-	-
13	Lawrence	11/28/43	Gravel	406	205	0	-	0	80	285	10	7.6	7.4	.2	-	-	.15	.06	40	.1	12	-	-
14	Dover	12/23/43	Gravel	278	149	0	-	0	66	215	5	7.7	7.6	.1	-	-	.03	.08	8	.1	10	-	-
15	Clay	12/22/42	Gravel	380	146	0	-	0	92	238	11	7.4	7.3	.1	-	-	.4	.2	32	.1	10	-	-
16	Sandy	3/10/43	Gravel	132	9	0	-	0	38	47	4	6.6	7.8	.2	-	-	.02	.05	4	.1	9	-	-
17	Oxford	2/24/43	Gravel	498	145	0	-	0	125	270	8	7.5	7.4	.1	-	-	0	.02	79	.3	9	-	-
18	Goshen	2/16/43	Gravel	560	210	0	-	0	171	381	17	7.4	7.4	0	-	-	.05	.53	27	.1	10	-	-
19	Sugar Creek	11/17/42	Black Hand ss	1504	485	15	-	466	0	19	0	8.4	8.4	0	-	-	.1	0	580	.6	7	-	-
20	Franklin	11/ 4/43	Gravel	294	145	0	-	0	71	216	5	7.7	7.5	.2	-	-	.05	.03	8	.1	8	-	-
21	Warwick	12/18/42	Gravel	534	188	0	-	0	150	338	14	7.4	7.2	.2	-	-	.4	.45	8	.1	11	-	-
22	Washington	1/28/47	Buffalo ss	242	57	0	0	0	68	125	6	7.3	7.7	.4	0	10	.6	.02	14	.1	10	37	8

Well	Owner	Well	Owner	Well	Owner	Well	Owner
1	Elmer Stuki	7	Louis Marstrell	12	Baltic Waterworks	18	New Philadelphia Waterworks
2	Earl Flickenger	8	Roxford M. E. Church	13	Bolivar Waterworks	19	Shanesville Waterworks
3	Richard Lyons	9	Atwood Dam, Ranger's House	14	Dover Waterworks	20	Strasburg Waterworks
4	Nelson Miller	10	Mary Orino	15	Gnadenhutten Waterworks	21	Tuscarawas Waterworks
5	Columbia Fire Brick Co.	11	Ray Postel	16	Mineral City Waterworks	22	Gilmore School
6	General Clay Products Co.			17	Newcomerstown Waterworks		

teeth when the water is used continuously by young children. Two samples, numbers 3 and 10 contained slightly more than 1.0 ppm. A small amount of fluoride in water, not more than 1 part per million, is considered to be a preventative of dental decay.

In the examination of ground water for industrial utilization the corrosion index is significant because it shows the degree to which the water will either cause corrosion or form scale. It is determined by the relationship of the hydrogen ion concentration (pH) of the water before and after the addition of $CaCO_3$. If the pH increases with this addition the water is corrosive; if it decreases the water is scale-forming. The values of the index given in the table are increases unless otherwise shown by means of a minus sign (decrease) or zero (no change). Nine of the samples show a decrease in pH value, nine show an increase, and four are neutral. A more detailed discussion of the significance of the chemical constituents of natural waters is included in the surface-water section of this report.

Salt-water contamination of the gravel deposits

Because of the highly corrosive nature of waters containing excessive amounts of chloride salts, industries necessarily require water relatively free of these salts. Likewise, water from municipal systems must be relatively free of chloride because of the taste.

In many places in the valley of the Tuscarawas River the water-bearing gravels are in contact with the stream and then under certain conditions receive recharge from the stream. This is especially true in areas where there is a considerable amount of pumpage from the gravel. When the cone of depression created by pumping spreads to the river, infiltration of river water into the aquifer is induced. The chemical nature of the water then changes, representing a blending of the ground water with some river water.

The section of this report on quality of surface water shows that at times the chloride content of the water in the Tuscarawas River reaches 12,000 ppm. In areas of heavy pumping that are adjacent to the river, chloride is present in the water pumped from the gravel. The seriousness of this condition is clearly shown by the situation at Coshocton in Coshocton County. The City of Coshocton in the past year has been forced to find a new source of ground water because of the salt-water contamination of the city well field.

The gravel deposits of the Tuscarawas Valley offer possibilities for the development of large ground-water supplies, but because of the high chloride content that may be induced by heavy pumping the ground water may be unsuitable for certain industrial and municipal uses.

SURFACE WATER

Tuscarawas County is roughly bisected from north to south by the Tuscarawas River. Within the county three principal tributaries - Sandy Creek, Conotton Creek, and Stillwater Creek - enter from the east, and one - Sugar Creek - enters from the west. The stream flow from practically the entire county reaches the main stream within the county borders either directly or by way of one of these tributaries. Exceptions are a narrow strip along the south boundary, which drains southward to Wills Creek; and the south half of Bucks Township, which drains into the Tuscarawas River in Coshocton County. The drainage pattern of the Tuscarawas River and its principal tributaries is shown on the map on plate 14.

STREAM-FLOW RECORDS

Collection of stream-flow data in Tuscarawas County began in 1921 when a gaging station was installed on the Tuscarawas River at Newcomerstown. A continuous record has been obtained at this station up to the present. Other gaging stations within the county with records of 20 years or more are located on Stillwater Creek at Uhrichsville, Sandy Creek at Sandyville, and Tuscarawas River at Dover. Stream-flow records on Sugar Creek have been obtained at or near Strasburg since 1931, except for several months in 1933 and 1934. Gaging stations have been installed downstream from each of the flood-control dams constructed by the Muskingum Watershed Conservancy District, and all these stations have continuous records to date. The schematic location and an index of published stream-flow records for the streams contributing to flow in Tuscarawas County are shown on plate 15, the geographic locations of the stations are shown on plate 14, and a summary of the discharge records is given in table 26.

ANALYSIS OF DATA

The data for the various stations shown in table 26 are not directly comparable, owing to the differences in length of the records and the modification of flow characteristics on many of the streams by the operation of flood-control reservoirs of the Muskingum Watershed Conservancy District, shown on plate 14.

The maximum stream flow usually occurs from January through April and the minimum between July and October. The average flow is above the annual mean for 4 months and below the annual mean for 8 months of the year. Periods of high flow may occur at any season. Extreme low flow usually occurs during the growing season. The highest monthly discharge of the year for Stillwater and Sandy Creeks has

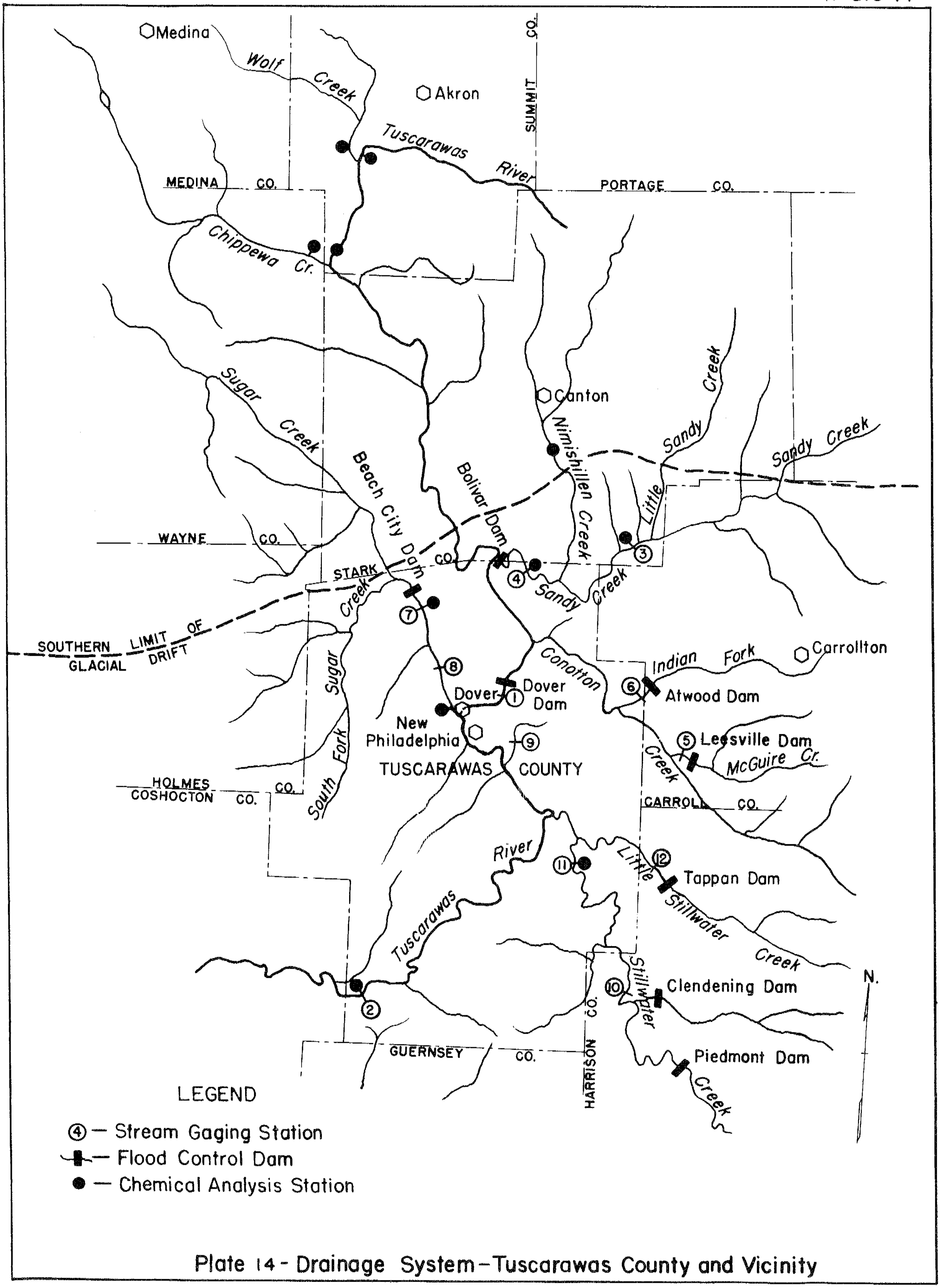
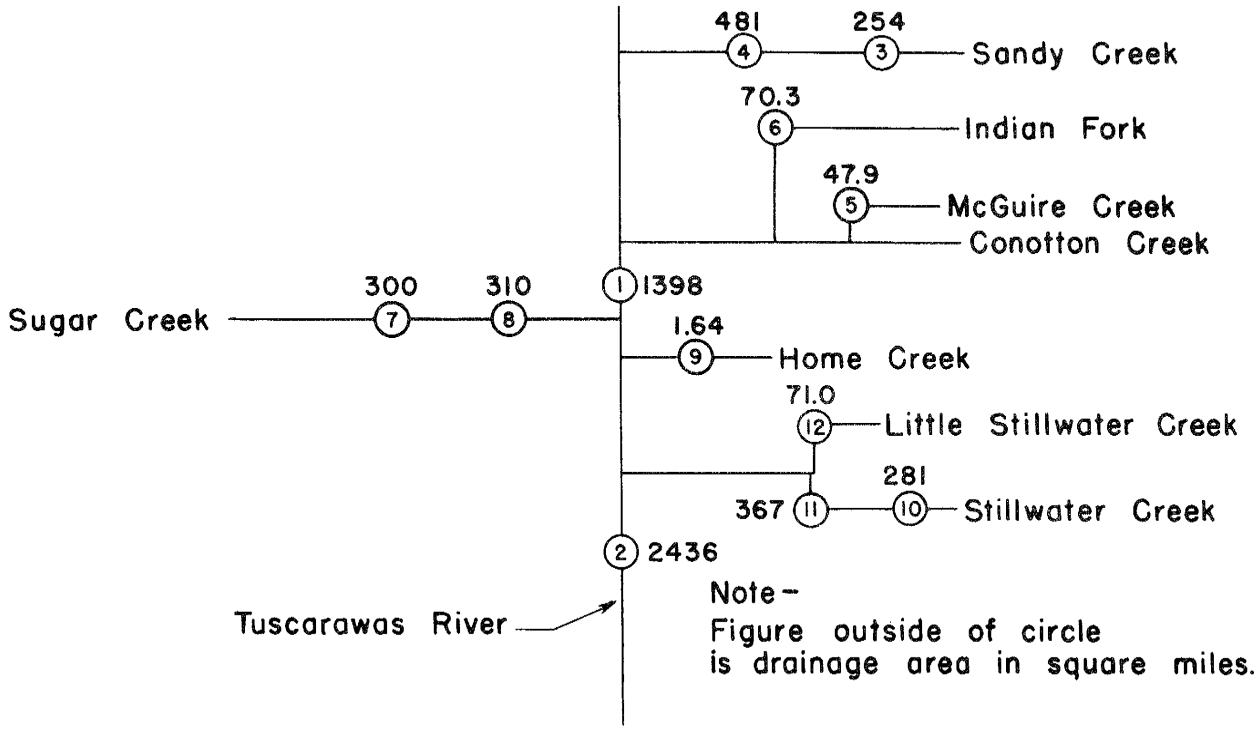
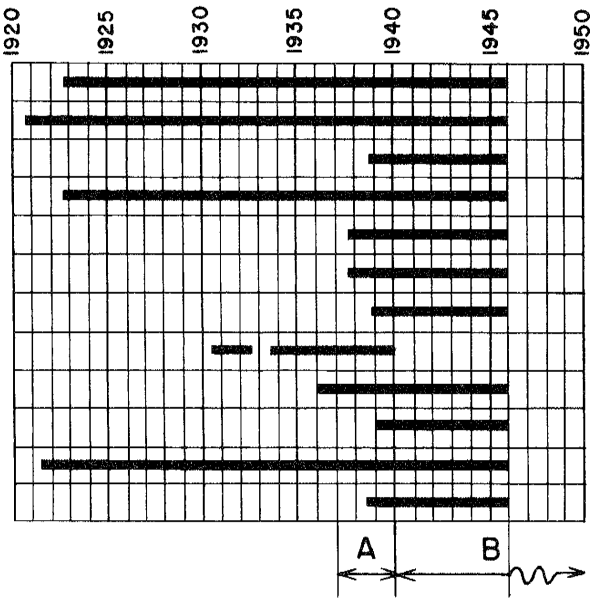


Plate 14 - Drainage System - Tuscarawas County and Vicinity



LOCATION OF GAGING STATIONS

Sta.
No.
1 Tuscarawas River at Dover
2 Tuscarawas River at Newcomerstown
3 Sandy Creek at Waynesburg
4 Sandy Creek at Sandyville
5 McGuire Creek near Leesville
6 Indian Fork near New Cumberland
7 Sugar Creek near Beach City
8 Sugar Creek at Strasburg
9 Home Creek near New Philadelphia
10 Stillwater Creek at Tippicanoe
11 Stillwater Creek at Uhrichsville
12 Little Stillwater Creek below Tappan Dam



INDEX CHART OF STREAM FLOW RECORDS

A = Flood control reservoirs of Muskingum Watershed Conservancy District in partial operation in this period affecting Stations No. 1, 2, 5, 6, 7, 8, 10, 11 & 12.
B = Flood control reservoirs in full operation affecting Stations No. 1, 2, 5, 6, 7, 10, 11 & 12.

Plate 15 - Schematic diagram of gaging station locations and index chart of record periods.

STA. NO.	STATION AND LOCATION (DRAINAGE AREA)	PERIOD OF RECORD	MAXIMUM MOMENTARY DISCHARGE CFS	MEAN DISCHARGE - Cubic feet per second.							MINIMUM MOMENTARY DISCHARGE CFS
				HIGHEST DAY	HIGHEST MONTH	HIGHEST WATER YEAR	PERIOD OF RECORD	LOWEST YEAR	LOWEST MONTH	LOWEST DAY	
1	Tuscarawas River near Dover (1398 Sq. Mi.) (a.)	Oct. 1923 to Sept. 1944	26,400 (Jan. 26, 1937)	24,900 (Jan. 26, 1937)	8,694 (Jan. 1937)	1,990 (1927)	1,347 (1923-1939)	598 (1931)	181 (Feb. 1934)	68 (Aug. 5, 1930)	—
2	Tuscarawas River at Newcomerstown (2436 Sq. Mi.) (a.)	Oct. 1, 1921 to Sept. 30, 1944	46,800 (Jan. 26, 1937)	45,000 (Jan. 26, 1937)	16,130 (Jan. 1937)	3,790 (1937)	2,396 (1921-1939)	967 (1931)	227 (Oct. 1931)	170 (Aug. 6, 1930)	120 (Aug. 7, 1930)
3	Sandy Creek at Waynesburg (254 Sq. Mi.)	Dec. 1938 to Sept. 1944	6,300 (Mar. 4, 1940)	5,460 (Mar. 4, 1940)	880 (Feb. 1939)	314 (1934)	235	162 (1944)	21.5 (Sept. 1939)	16 (Oct. 10, 1940)	16 (Oct. 10, 11, 1940)
4	Sandy Creek at Sandyville (481 Sq. Mi.)	Oct. 1923 to Sept. 1939	14,200 (Jan. 25, 1937)	12,200 (Jan. 25, 1937)	3,122 (Jan. 1937)	734 (1937)	492	233 (1934)	76.3 (Sept. 1932)	43 (July 25, 1934)	26 (Sept. 22, 1932)
5	McGuire Creek near Leesville (47.9 Sq. Mi.) (b)	Oct. 1938 to Sept. 1944	740 (Mar. 4, 1940)	697 (Mar. 4, 1940)	202 (Feb. 1939)	55.6 (1940)	46.45	31.3 (1942)	0 (Sept. & Oct. 1940)	No flow at frequent intervals thru	out record
6	Indian Fork near New Cumberland (70.3 Sq. Mi.) (b.)	Oct. 1938 to Sept. 1944	1430 (Mar. 4, 1939)	1400 (Mar. 4, 1939)	319 (Feb. 1939)	88.4 (1943)	65.5	47.8 (1944)	1.09 (Sept. 1932) (c.)	0.10 (Several days in 1939, 1942, 1943)	0.10 (Sept. 4, 1939 June 19, 1944)
7	Sugar Creek near Beach City (300 Sq. Mi.) (a.)	Oct. 1938 to Sept. 1944	7,500 (Mar. 13, 1939)	7,000 (Mar. 13, 1939)	914 (Mar. 1939)	310 (1943)	227	148 (1944)	12.2 (Sept. 1939)	5.2 (Sept. 25, 1939)	4.9 (Sept. 25, 1939)
8	Sugar Creek at Strasburg (310 Sq. Mi.)	July 1931 to Mar. 1933 Dec. 1934 to July 1939	19,700 (Aug. 7, 1935)	10,200 (Aug. 7, 1935)	2,025 (Jan. 1937)	446 (1937)	332	275 (1936)	16.3 (Sept. 1932)	8.0 (Sept. 18, 1932)	7.2 (Sept. 18, 1932)
9	Home Creek near New Philadelphia (1.64 Sq. Mi.)	Dec. 1936 to Sept. 1944	208 (May 27, 1937 & June 18, 1940)	40 (June 21, 1937)	11.8 (Jan. 1937)	1.69 (1937-1938)	1.26 (Oct. 1937-Sept. 1944)	0.764 (1944)	0 (Sept. 1939)	No flow at frequent intervals thru	out record
10	Stillwater Creek at Tippecanoe (281.0 Sq. Mi.) (b)(d)	Jan. 1939 to Sept. 1944	3790 (Apr. 20, 1940)	3240 (Apr. 20, 1940)	1074 (Apr. 1937)	445 (1943)	131.3	238 (1942)	2.96 (Sept. 1939)	1.1 (Oct. 4, 1939)	1.0 (Oct. 3, 4, 1940)
11	Stillwater Creek at Uhrichsville (367 Sq. Mi.) (b.)	July 1922 to Sept. 1944	7,650 (Aug. 8-9, 1935)	7,380 (Aug. 9, 1935)	2,917 (Jan. 1937)	704 (1937)	437	188 (1934)	No flow July 31 to Nov. 17, 1930 (d.)	No flow at times 1939,	in 1932, 1936, 1940. (d.)
12	Little Stillwater Creek below Tappan Dam (71.0 Sq. Mi.) (b.)	Oct. 1938 to Sept. 1944	1050 (Mar. 1939)	623 (Mar. 13, 1939)	243 (Feb. 1939)	92.7 (1943)	73.2	56.3 (1944)	0.25 (Sept. 1939)	No flow Sept. 12-15, 18-19, 21-29, and	Oct. 13-21, 1939.

a- Flow affected by flood-control reservoirs after 1937.
b- Flow controlled by flood-control reservoir.
c[Mean discharge for 16 days in Apr., 1940 = 0.2 cfs.
  Mean dischrage for 29 days in Aug., 1940 = 0.2 cfs.
d[Water diverted for municipal supply of Dennison and Uhrichsville.
  Mean diversion July 1922 to Sept. 1944, approximately 2.5 cfs.

Table 26 - Summary of stream flow records - Tusarawas River and Tributaries.

Records furnished by U.S. Geological Survey.

occurred in every month from December through May and once in August. The lowest monthly discharge of the year has twice occurred as early as June. The 16-year hydrograph of monthly stream flow in Stillwater Creek at Uhrichsville, shown on plate 16, illustrates the general seasonal pattern of stream flow and the frequency and magnitude of departures from the normal pattern. The distribution of stream flow throughout the year is similar for all streams in the county.

The various streams in Tuscarawas County exhibit considerable individuality in sustained daily flow during dry periods. The flow sustained in dry periods is closely related to the geology of the drainage basin. Sandy Creek, which traverses an area containing a high percentage of permeable glacial gravels capable of storing and transmitting large quantities of water, has higher sustained flow than either Sugar Creek or Stillwater Creek, as may be seen by inspection of the graphs on plate 17. Sugar Creek traverses an area consisting largely of glacial till and has a higher sustained flow than Stillwater Creek, which traverses an area predominantly underlain by hard rocks. Sustained flow in Sugar Creek generally ranges from 50 to 20 second-feet even in protracted drought periods, whereas Stillwater Creek has several periods of no flow. (See table 26.)

The effects of the Muskingum Watershed Conservancy District reservoirs on stream regimen in Tuscarawas County may be summarized as follows:

Effect of reservoirs on flood flows

Crest stages and peak flows will be reduced, and periods of near-bank-full stages following floods will be lengthened. The reservoirs are operated as a system for optimum benefits to both Muskingum Valley and Ohio River communities. The effect on the Tuscarawas River depends on the plan of operation of upstream reservoirs, which may be varied depending on the storm pattern, and other factors. However, the system is designed "for such operation that all the reservoirs will be filled to spillway level, but not beyond, in case of a storm with a magnitude equal to the official plan storm," and the latter is defined as "A storm about 36 percent greater than the 1913 storm above Zanesville," or "a total of 10 inches of rainfall in 5 days, assumed to yield 90 percent or 9 inches of runoff." The quotations are from the official plan for the Muskingum Watershed Conservancy District as revised June 5, 1935.

Effect of reservoirs on total stream flow for the year

As the operating plan contemplates drawing the reservoirs down to conservation pool levels as soon as possible after a flood period, it is likely that the end of each water year will find all reservoirs at or near those levels. Hence the system should not change the total stream flow

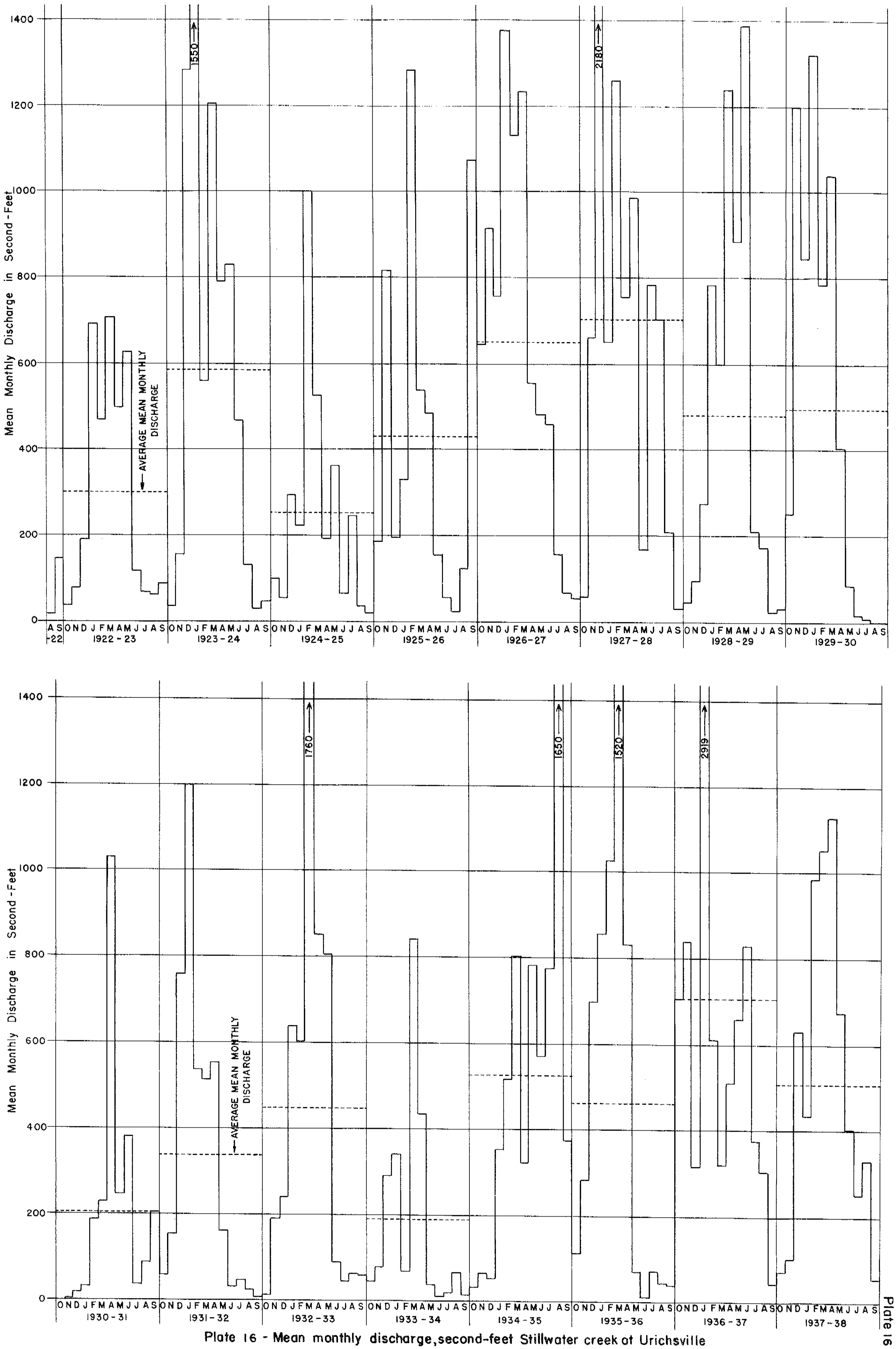


Plate 16 - Mean monthly discharge, second-feet Stillwater creek at Urichsville

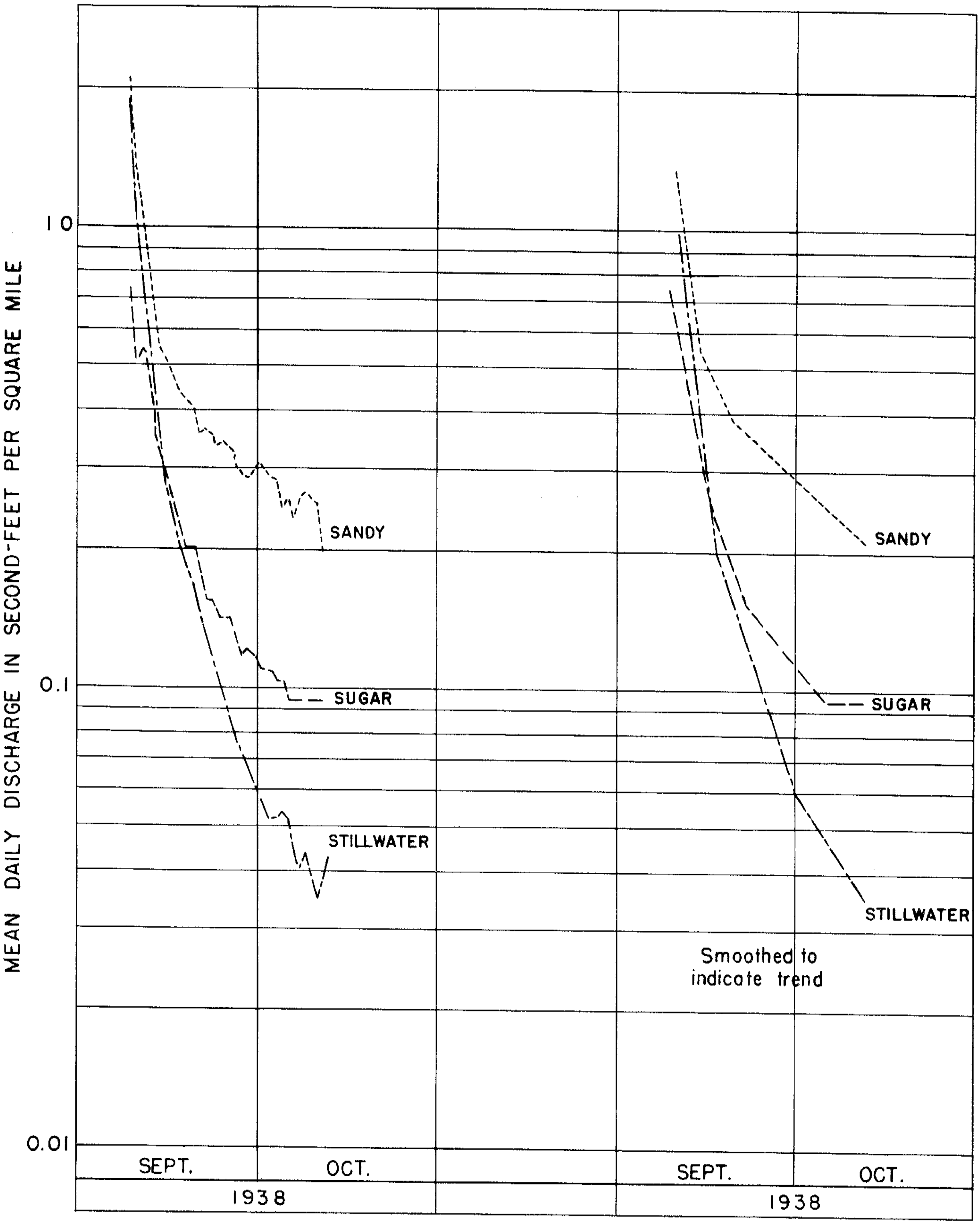


Plate 17 - Mean daily discharge in Sandy, Sugar, and Stillwater creeks - Sept., Oct. 1938

in any given year. (Some reductions took place, of course, in the first 3 or 4 years of operation, while the reservoirs were filling; in 1942, for example, 2 1/2 percent of the total natural flow for the year at Newcomerstown was held back in upstream storage.) Theoretically, a slight reduction in the total stream flow may be expected by evaporation as a result of the increase in the amount of free water surface area in the drainage basins. Any quantitative estimate of such a reduction is highly conjectural, but the following assumptions are at least of the right order of magnitude:

Annual loss from free water surfaces	36 inches
Annual loss from land surfaces	24 inches
Net increase in loss from areas now occupied by conservation pools	12 inches

Thus, considering the reservoirs to be at conservation pool levels throughout the year, the annual net loss from free water surface evaporation on the various basins would be:

Sandy Creek	0
Conotton Creek	2540 acre-feet
Stillwater Creek (above Little Stillwater)	4070 acre-feet
Little Stillwater Creek	2350 acre-feet
Sugar Creek	420 acre-feet
Tuscarawas River and tributaries	9730 acre-feet

The minimum yearly flow of record for the Tuscarawas River at Newcomerstown is in excess of 700,000 acre-feet; thus the maximum effect of evaporation in conservation pools is only a little more than 1 percent of of the minimum yearly flow. The minimum annual flow of record of Stillwater Creek was about 137,000 acre-feet in 1933-34. Had the conservation pools been in existence at that time the total annual flow might have been reduced by 3 percent. The percentage reductions in the flow in other years would obviously be less.

Effect of reservoirs on minimum flows

Theoretically, at least, the conservation storage may be used to augment low flows. Conservation storage is provided in the reservoirs on Conotton Creek, Stillwater Creek, Little Stillwater Creek, and Sugar Creek. Recreational interests would be adversely affected by large drawdowns in conservation pools and it would appear unlikely that such drawdowns would be made except in extreme drought emergencies. In general, then, the reservoir system as operated will not augment minimum flows. During prolonged drought periods present operation may reduce natural minimums unless some releases are made. The most critical possibility appears to be Stillwater Creek. In 1930, 1932, 1934, and 1936 the mean discharge of Stillwater Creek during the 4-month period June through September averaged 20 second-feet or less at

Uhrichsville, where the drainage area is 367 square miles. The 154 square miles of drainage area above the present Clendening and Piedmont Dams contributed about 40 percent of this flow or a total of 1,900 acre-feet in the 4 months. But it is likely that more than 1,900 acre-feet would have been required to hold the pools at the design level through 4 warm months; hence existence of the pools would have greatly reduced minimum flows unless releases had been made.

RELATION OF STREAM FLOW TO PRECIPITATION

The amount of water that appears as stream flow from a drainage area is always less than the amount that falls on the area as precipitation. The difference between stream flow and precipitation is represented by the water lost by transpiration and evaporation from the ground surface, free water surfaces, and the water table. In some instances some loss may be attributed to water which either has reached the water table and returned to the stream below the gage, or has been removed by pumping. Accretions to ground-water storage may affect the apparent annual water loss, either positively or negatively, but over a period of several years the variations due to storage will tend to average out.

In general, the annual water losses over large areas vary less from one drainage basin to another than does the annual stream flow and precipitation. Water losses from drainage basins are affected by soil, topography, geology, land use, and other factors. Factors that tend to produce relatively low water losses include:

(1) Permeable surface soils, which permit rapid percolation to a water table that lies relatively deep below the surface so that storage space is available for water which later returns to the streams through springs, seeps, and wells.

(2) Steep barren slopes that promote rapid run-off and thus decrease the opportunity for evaporation from the surface.

Factors that tend to produce relatively high losses include:

(1) Ground-water levels within capillary range of the ground surface.

(2) Flat slopes or other factors producing poor drainage, which increase the opportunity for evaporation from surface pondage.

(3) Underground flow that by-passes the stream gage.

(4) Dense plant growth and ground cover which absorbs large amounts of water and permits it to be returned to the atmosphere by evaporation and transpiration by plants.

The relation of annual stream flow to annual precipitation for different drainage areas in the Tuscarawas River basin is shown in table 27, which gives the average annual precipitation in inches and the annual stream flow expressed as inches of depth over the drainage area.

The partially glaciated drainage basin of Sugar Creek, with its flat slopes and relatively impermeable till areas, retains a greater amount of precipitation in surface storage and as soil moisture which is subsequently lost to evaporation and transpiration, than does the more rugged basin of Stillwater Creek, where surface run-off is rapid, or the basin of Sandy Creek, where the soil is relatively loose and more rainfall appears to infiltrate to the water table and then percolate into stream channels.

QUALITY OF SURFACE WATER

Chemical character

Comprehensive data relating to the chemical character and temperature of the surface waters of Tuscarawas County, which will determine the suitability of water for industrial purposes or the methods for its treatment, are being collected as part of the Statewide program initiated by the Ohio Water Resources Board in 1946. The sampling is being done by the U. S. Geological Survey in cooperation with the Ohio Water Resources Board. The analyses of samples of water during periods of low flow in May, July, and September 1946 are shown in table 28 (18).

The analyses of miscellaneous samples collected during periods of low flow by the Ohio Water Resources Board and analyzed by the Ohio Department of Health are shown in table 29.

Samples of natural waters collected during periods of low flow range from slightly acid to slightly alkaline and contain moderate amounts of silica, iron, calcium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, and nitrate. The natural waters in general are moderately hard.

Samples collected during periods of low flow in the upper tributaries and reaches of the Tuscarawas River are high in noncarbonate hardness, chloride, and dissolved solids. The total hardness and the concentrations of chloride and dissolved solids become smaller in the downstream reaches of the river. The chloride content at Newcomerstown varies greatly. The analyses of daily samples taken during the months of July, August, and September 1946 at Newcomerstown are shown on plate 18.

TABLE 27

RELATION BETWEEN PRECIPITATION AND STREAM FLOW - TUSCARAWAS RIVER AND TRIBUTARIES
- Depth in inches over drainage area -

Water Year	Stillwater Cr. at Uhrichsville			Sugar Creek near Beach City			Sandy Creek at Sandyville			Tuscarawas River at Massillon			Tuscarawas River at Dover			Tuscarawas River at Newcomerstown		
	P	SF	Diff.	P	SF	Diff.	P	SF	Diff.	P	SF	Diff.	P	SF	Diff.	P	SF	Diff.
1922																39.01	14.12	24.89
1923	35.91	11.04	24.87	33.36												34.27	9.37	24.90
1924	47.05	21.87	25.18	44.05			47.29	20.20	27.09				46.31	18.66	27.65	46.55	18.39	28.16
1925	31.21	9.28	21.93	26.28			29.72	8.66	21.06				28.97	9.19	19.78	29.70	8.71	20.99
1926	42.76	15.78	26.98	39.90			39.67	13.24	26.43				40.28	13.71	26.57	41.45	12.86	28.59
1927	44.10	23.89	20.21	40.88			41.02	19.59	21.43				39.68	19.32	20.36	41.05	19.88	21.17
1928	45.16	26.03	19.13	39.70			45.72	18.87	26.85				42.27	18.12	24.15	43.01	18.48	24.53
1929	39.53	17.76	21.77	40.63			43.78	16.56	27.22				41.75	15.67	26.08	41.10	15.62	25.48
1930	32.37	18.25	14.12	31.88			34.97	16.70	18.27				33.11	15.39	17.72	32.85	15.23	17.62
1931	35.23	7.53	27.70	31.93			33.94	6.75	27.19				32.51	5.80	26.71	33.29	5.42	27.87
1932	35.45	12.57	22.88	35.68	10.69	24.99	33.50	12.78	20.72				33.56	11.24	22.32	34.26	12.17	22.09
1933	43.02	16.52	26.50	38.20			36.59	12.74	23.85				36.70	12.23	24.47	38.22	12.58	25.64
1934	33.09	7.01	26.08	31.03			33.85	6.58	27.27				30.99	6.39	24.60	31.67	6.21	25.46
1935	44.88	19.56	25.32	42.05			37.63	12.58	25.05				39.65	11.92	27.73	40.79	13.24	27.55
1936	36.27	17.19	19.08	35.83	12.09	23.74	33.74	14.60	19.14				35.94	13.06	22.88	35.53	14.21	21.32
1937	47.34	25.91	21.43	42.13	19.53	22.60	43.07	20.70	22.37				42.58	18.69	23.89	43.81	21.14	22.67
1938	42.14	18.78	23.36	41.44	14.87	26.57	43.92	16.89	27.03				41.03	15.11	25.92	41.84	15.93	25.91
1939	37.63	14.06	23.57	35.83	11.74	24.09	33.98	14.11	19.87	32.97	9.64	23.33	35.45	12.41	23.04	35.95	13.13	22.82
1940	43.51	17.51	26.00	38.70	12.27	26.43	37.14	13.26	23.88	36.88	11.99	24.89	39.10	13.54	25.56	40.05	14.40	25.65
1941	37.86	13.34	24.52	31.41	8.01	23.40	34.68	10.35	24.33	31.90	7.22	24.68	34.23	9.79	24.44	34.86	10.85	24.01
1942	38.33	13.11	25.22	34.83	9.13	25.70	35.56	11.43	24.13	35.34	8.25	27.09	36.12	10.54	25.58	36.85	10.99	25.86
1943	41.89	20.49	21.40	38.44	14.02	24.42	38.85	16.57	22.28	40.95	13.68	27.27	40.61	15.75	24.86	41.24	16.31	24.93
1944	34.89	11.98	22.91	32.47	6.72	25.75	29.21	8.77	20.44	28.71	6.99	21.72	31.45	8.39	23.06	32.19	9.19	23.00
1945	47.78			40.91			39.00			38.45			41.93			43.11		
1946	34.91			35.12			34.73			36.39			35.79			35.42		

Summary of Records

10 Year Average - 1932; 1936-39; 1940-44	39.53	16.50	23.03	36.67	11.90	24.77	36.37	13.95	22.42				37.00	12.85	24.15	37.66	13.83	23.83
21 Year Average - 1924-44	39.71	16.61	23.10				37.51	13.90	23.61				36.77	13.09	23.68	37.91	13.57	24.34
5 Year Average - 1940-44	39.30	15.28	24.02	35.17	10.03	25.14	35.09	12.07	23.02	34.76	9.63	25.13	36.31	11.61	24.70	37.04	12.35	24.69
5 Year Average - 1932; 1936-39	39.77	17.70	22.07	38.18	13.78	24.40	37.64	15.82	21.82				37.71	14.10	23.61	38.28	15.32	22.96

Table-28 Temperature and chemical analyses of surface waters of Tuscarawas County and vicinity, May-September, 1946.
(Samples analyzed by Quality of Water Division, U.S. Geological Survey, Washington D.C.)

Date of collection	Discharge (second-feet)	Temperature (°F.)	Color	pH	Specific conductance (K x 10^5 at 25° C.)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Non-carbonate
TUSCARAWAS RIVER AT CLINTON																			
									Parts per million										
May 9	110	60	20	7.2	546	3.2	0.07	0.05	663	14	405	152	80	1,690	0.0	1.0	3,060	1,710	1,590
Sept. 10	58	81	—	—	2,960	—	—		—	—	—	—	—	12,200	—	—	—	—	—
									Equivalents per million										
May 9	—	—	—	—	—	—	—	—	33.084	1.151	17.601	2.491	1.666	47.663	.000	.016	—	—	—
Sept. 10	—	—	—	—	—	—	—	—	—	—	—	—	—	344.079	—	—	—	—	—
TUSCARAWAS RIVER AT NAVARRE																			
									Parts per million										
June 26	—	78	7	7.0	210	8.8	.16	—	205	21	180	118	129	525	—	11	1,320	598	—
TUSCARAWAS RIVER AT PORT WASHINGTON																			
									Parts per million										
June 26	—	76	5	7.2	62.1	10	.03	—	71	15	30	85	126	70	.3	4.7	391	239	—
TUSCARAWAS RIVER AT NEWCOMERSTOWN																			
									Parts per million										
May 7	1,250	57	15	7.3	262	5.4	0.05	0.02	271	18	247	100	167	730	0.5	1.9	1,540	750	668
July 1-10	1,130	73	3	7.3	545	9.2	.03	.00	93	18	58	101	150	125	.5	5.1	545	306	223
Sept. 1-10	374	66	7	7.6	456	6.0	.08	.30	482	24	440	120	217	1,350	.8	4.5	2,820	1,300	1,200
									Equivalents per million										
May 7	—	—	—	—	—	—	—	—	13.523	1.480	10.758	1.639	3.477	20.588	.026	.031	—	—	—
July 1-10	—	—	—	—	—	—	—	—	4.641	1.480	2.537	1.655	3.123	3.525	.026	.082	—	—	—
Sept. 1-10	—	—	—	—	—	—	—	—	24.052	1.974	19.130	1.967	4.518	38.074	.042	.073	—	—	—
SANDY CREEK AT WAYNESBURG																			
									Parts per million										
May 7	120	54	35	7.2	40.5	5.2	0.29	0.00	52	13	7.3	88	113	6.0	0.2	0.3	262	183	111
Sept. 10	33	67	6	7.4	48.4	7.6	.10	—	69	14	11	153	114	6.0	.1	.7	312	230	104
									Equivalents per million										
May 7	—	—	—	—	—	—	—	—	2.595	1.069	.316	1.442	2.353	.169	.011	.005	—	—	—
Sept. 10	—	—	—	—	—	—	—	—	3.443	1.151	.472	2.507	2.374	.169	.005	.011	—	—	—
SUGAR CREEK AT BEACH CITY																			
									Parts per million										
May 7	96	55	25	7.5	39.3	1.8	0.08	0.00	47	14	10	130	76	7.1	0.2	0.6	240	175	68
Sept. 20	8.54	76	6	6.8	29.0	—	—	—	—	—	—	70	81	6.0	—	3.5	—	126	69
									Equivalents per million										
May 7	—	—	—	—	—	—	—	—	2.345	1.151	.438	2.131	1.582	.200	.011	.010	—	—	—
Sept. 20	—	—	—	—	—	—	—	—	—	—	—	1.147	1.686	.169	—	.056	—	—	—
STILLWATER CREEK AT UHRICHSVILLE																			
									Parts per million										
May 8	493	56	38	7.2	24.1	4.8	0.44	0.00	30	6.8	6.3	80	44	2.9	0.2	0.5	149	103	37
Sept. 13	4.5	65	4	7.0	53.7	6.0	.03	—	64	18	16	83	177	11	.2	1.1	364	234	166
									Equivalents per million										
May 8	—	—	—	—	—	—	—	—	1.497	.559	.272	1.311	.916	.082	.011	.008	—	—	—
Sept. 13	—	—	—	—	—	—	—	—	3.194	1.480	.710	1.360	3.685	.310	.011	.018	—	—	—

TABLE 29 A

CHEMICAL ANALYSES OF MISCELLANEOUS WATER SAMPLES COLLECTED FROM TRIBUTARIES OF TUSCARAWAS RIVER IN 1946

(Dissolved Constituents in Parts Per Million)

Source of Sample	* Conotton Creek at Zoarville	* Sugar Creek at Dover	* Stillwater Creek at Midvale	* Sandy Creek at Sandyville	** Nimishellen Creek at North Industry	**
Date of Collection	Oct. 28	Oct. 28	Oct. 28	Oct. 28	May 7	Sept. 10
Discharge, Second Feet	--	--	--	--	176	55
Sediment	High	Moderate	High	Moderate	--	--
Turbidity	18	13	16	14	--	--
Color	25	5	0	12	30	8
Dissolved Solids	322	394	432	457	448	763
Total Alkalinity	39	40	73	78	--	--
Alkali Bicarbonates	0	0	0	0	--	--
Hardness, Non-Carbonate	68	148	98	140	225	367
Hardness, Total	107	188	171	218	278	514
Free CO_2	15	5	18	8	--	--
pH	6.7	7.2	6.9	7.3	6.5	7.0
Corrosion Index	0.9	0.5	0.7	0.2	--	--
$CaCO_3$ Excess	0	0	0	0	--	--
$CaCO_3$ Deficiency	20	8	21	7	--	--
Iron, Total (Fe)	3.85	0.95	1.4	1.9	0.36	.05
Manganese Mn	2.5	2.5	.45	1.2	1.9	--
Chloride (Cl)	10	7	29	10	24	54
Fluoride (F)	0.3	0.3	0.3	0.5	0.6	1.5
Silica (SiO_2)	8	8	7	10	4.6	7.6
Calcium (Ca)	37	48	44	47	80	150
Magnesium (Mg)	2	17	15	24	19	34
Nitrate (NO_3)	--	--	--	--	1.1	8.1
Sodium and Potassium (Na + K)	--	--	--	--	21	32
Bicarbonate (HCO_3)	--	--	--	--	64	180
Sulfate (SO_4)					225	335

* Analysis made by Department of Health, State of Ohio
** Analysis made by Division of Quality of Water, U.S. Geological Survey, Washington, D.C.

TABLE 29B

CHEMICAL ANALYSES OF MISCELLANEOUS WATER SAMPLES COLLECTED IN THE VICINITIES OF BARBERTON AND RITTMAN ON SEPTEMBER 5, 1946*

(Dissolved constituents in parts per million)

	Tuscarawas River 1 mi. E. of Turkey Foot Jct.	Tuscarawas River Barberton Branch	Wolf Creek at U.S. Highway 224	Chippewa Creek S.W. of Warwick
Total Alkalinity	970	148	181	282
Hardness, Non-Carbonate	7400	70	10	285
Hardness, Total	7497	218	191	567
Chloride	9500	22	12	5750
Calcium	3104	62	50	164
H_2S	--	--	--	Present
Sulphate	Light	Very light	Light	Very heavy

* Analyses by Department of Health, State of Ohio

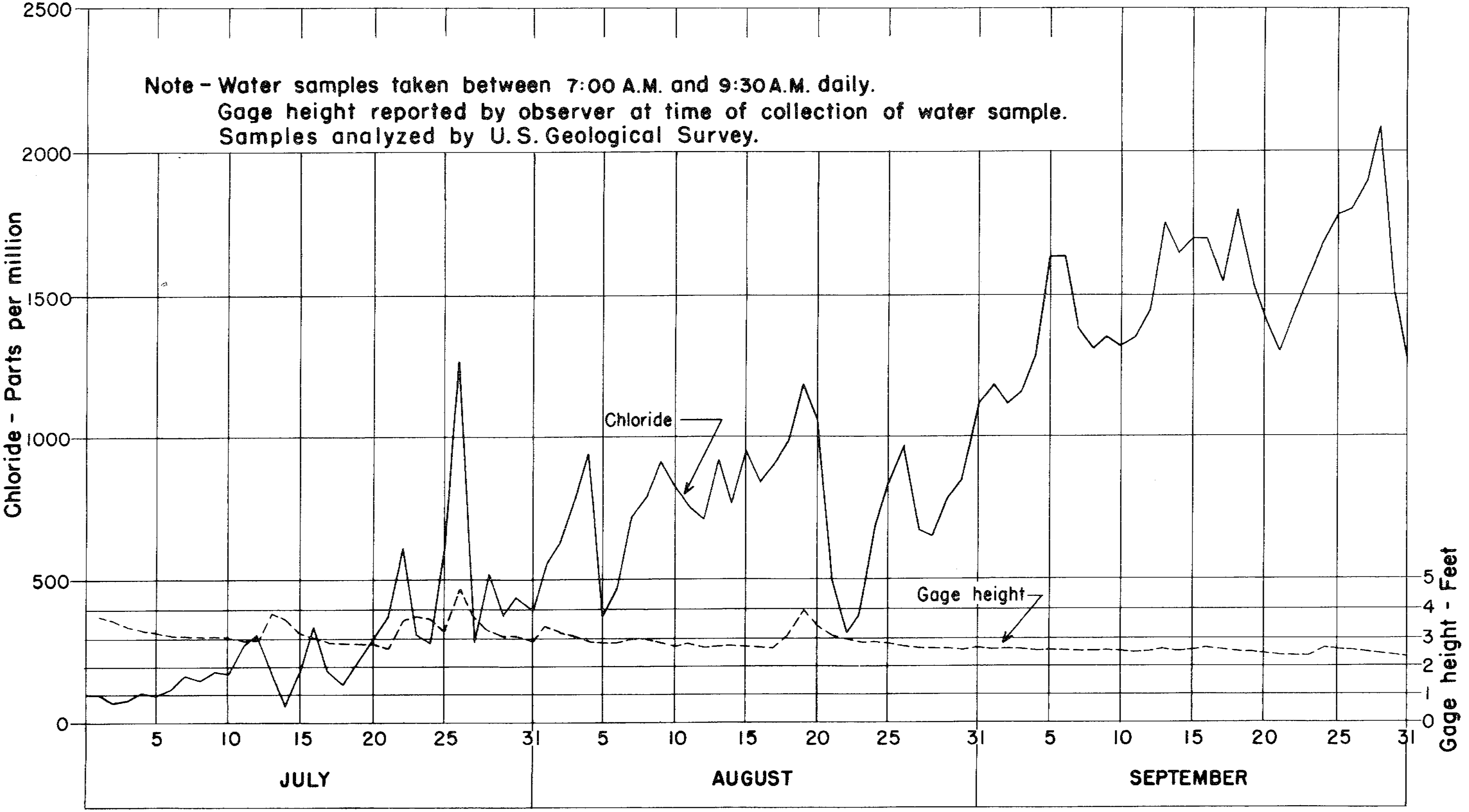


Plate 18 - Daily chloride analysis - Tuscarawas River at Newcomerstown, Ohio.

Because the analyses are for single samples, there is no way, at this time, of knowing how closely they represent the composition of the water throughout the year at the various sampling points.

Source and Signification of Mineral Constituents in Natural Waters (18)

The characteristics and mineral constituents of natural waters here considered include those found in quantities sufficient to have practical effect on the value of the waters for ordinary uses.

Color.--In water analysis the term "color" refers to the appearance of water that is free from suspended solids. Water for domestic use and some industrial uses should be free from perceptible color. Natural color in surface waters is caused almost entirely by organic matter extracted from plants and by minerals. A color less than 20 usually passes unnoticed. Some swamp waters have natural color of 200 or 300. At many places, however, high color in water results from industrial wastes.

pH.--The intensity of acidity or alkalinity of a water, as indicated by the hydrogen-ion concentration, is of importance with reference to the corrosiveness of water, and to proper treatment of coagulation at water-treatment plants. The symbol pH is commonly used to indicate the hydrogen-ion concentration. It represents the negative logarithm of the number of moles of ionized hydrogen per liter of water. For practical purposes, the pH scale may be used with reference to acidity and alkalinity, as a temperature scale is used with reference to heat conditions. A neutral water has a pH of 7.0. The pH of most natural waters ranges between 6.0 and 8.0. Some alkaline waters have pH values greater than 8.0 and waters containing free mineral acid usually have values less than 4.5.

Corrosion index.--The corrosion index is a measure of the degree to which water will cause corrosion or form scale. It is determined by the relationship of the hydrogen-ion concentration (pH) of the water before and after the addition of $CaCO_3$. If the pH increases with this addition the water is corrosive; if it decreases the water is scale-forming.

Specific conductance.--The specific conductance of a water is a measure of its ability to conduct a current of electricity. It varies with the concentration and degree of ionization of the different minerals in solution.

When considered in conjunction with results of determinations for other constituents, specific conductance is a useful determination and plays an important part in following changes in concentration of the total quantity of dissolved minerals in surface waters.

Silica(SiO_2).--Silica is dissolved from practically all rocks. A few natural waters contain less than 3 parts per million of silica and some contain more than 50 parts, but most of them contain from 10 to 30 parts per million. Silica affects the usefulness of a water because it contributes to the formation of boiler scale.

Aluminum and manganese (Al and Mn).--Aluminum and manganese are not regularly determined in the practical analysis of water. However, acid waters may have relatively large quantities of these constituents that can be troublesome to certain users of the waters. Manganese is especially objectionable in laundry work and in textile processing that involves washing.

Iron (Fe).--Iron is dissolved from many rocks and soils. On exposure to the air water that contains more than a few tenths of a part per million of iron soon becomes turbid with the insoluble compound produced by oxidation; surface waters therefore seldom contain as much as 1 part per million of dissolved iron. Some acid waters carry large quantities of iron in solution. Excessive iron causes stains on white porcelain or enameled ware and fixtures and on clothing or other fabrics washed in the water.

Calcium (Ca).--Calcium is dissolved from practically all rocks, but particularly from limestone, dolomite, and gypsum. Calcium and magnesium make water hard and are the active agents in forming boiler scale. Most waters from granite contain less than 10 parts per million of calcium; many waters from limestone contain from 30 to 70 parts; and waters that leach deposits of gypsum may contain even larger quantities.

Magnesium (Mg).--Magnesium is dissolved from many rocks but particularly from dolomite. Its effects are similar to those of calcium, but waters that contain much magnesium and chloride are likely to be corrosive, especially in steam boilers. The magnesium in soft waters may amount to only 1 or 2 parts per million, but water in areas that contain large quantities of dolomite may contain 20 to 50 parts per million or more of magnesium.

Sodium and potassium (Na and K).--Sodium and potassium are dissolved from practically all rocks, but they make up only a small part of the dissolved mineral matter in most waters in humid regions. Natural waters that contain only 3 or 4 parts per million of the two together are likely to carry about equal quantities of sodium and potassium. As the total quantity of these constituents increases the proportion of sodium becomes greater. Moderate quantities of these constituents have little effect, but waters that carry more than 50 or 100 parts per million of the two may require careful operation of steam boilers to prevent foaming. Waters that contain large quantities of sodium salts injure crops and some waters contain so much sodium that they are unfit for nearly all uses.

Carbonate and bicarbonate (CO_3 and HCO_3).--Carbonate and bicarbonate occur in waters largely through the action of carbon dioxide, which enables the water to dissolve carbonates of calcium and magnesium. Carbonate is not present in appreciable quantities in most natural waters. The bicarbonate in waters that come from insoluble rocks may amount to less than 10 parts per million; many waters from limestone contain from 200 to 400 parts per million; and certain waters that contain sodium bicarbonate may carry 1,000 or more parts of bicarbonate per million. Water containing large quantities of bicarbonates are unsatisfactory for use in boilers or in condensers without treatment because upon heating the soluble bicarbonates of calcium and magnesium are converted to insoluble carbonates which are deposited as a hard scale in the boiler tubes or condensing system. A large quantity may make water unsatisfactory for drinking and other domestic uses.

Sulfate (SO_4).--Sulfate is dissolved in large quantities from gypsum and from deposits of sodium sulfate. It is also formed by the oxidation of sulfides of iron and is therefore present in considerable quantities in waters from mines and from many beds of shale. Sulfate in waters that contain much calcium and magnesium contributes to the formation of hard scale in steam boilers and may increase the cost of softening the water.

Chloride (Cl).--Chloride is dissolved in small quantities from soil materials in most parts of the country. The chloride in waters normally has little effect on their use unless it is present in excessive quantities, as in brines. Chloride in excess of 250-300 parts per million can generally be detected by taste but it is not too distasteful for domestic use when in the range of 300 to 500 parts per million. Because of the highly corrosive nature of waters containing excessive amounts of chloride salts, industries necessarily require water relatively free of these salts.

Fluoride (F).--Fluoride has been reported as present in the rocks of the earth's crust to about the same extent as chloride. However, the quantity present in natural waters is usually much less than that of chloride. Fluoride in water is known to be associated with the dental defect known as mottled enamel, if the water is used for drinking by young children during calcification or formation of the teeth. This condition becomes more noticeable as the quantity of fluoride in water increases above 1 part per million. It is reported that the incidence of dental caries (decay of teeth) is decreased or prevented by quantities of fluoride that are not sufficient to cause permanent disfigurement from mottled enamel.

Nitrate (NO_3).--Nitrate in water is considered a final oxidation product of nitrogenous organic material. The quantities usually present have little effect on the value of water for ordinary use.

Dissolved solids.--The quantity reported as dissolved solids (the residue on evaporation) consists mainly of the dissolved mineral constituents in the water. It may also contain some organic matter and water of crystallization. Waters with less than 500 parts per million of dissolved solids are usually satisfactory for domestic and most industrial uses. Waters with more than 1,000 parts per million of dissolved solids are likely to be unsuitable for most domestic and industrial uses.

Hardness.--Hardness is usually expressed as the quantity of calcium carbonate ($CaCO_3$) equivalent to the calcium and magnesium present. Water that has less than 50 parts per million of hardness is usually rated as soft and its treatment for removal of hardness is seldom justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for many purposes, but its removal by softening processes may be profitable for laundries and other industries. Water with hardness beyond 150 parts per million usually requires some treatment for removal of hardness before being used.

Total acidity.--The total acidity of a natural water represents the content of free carbon dioxide, mineral acids, and salts, especially sulfates of iron and aluminum, which hydrolyze to give hydrogen ions. Acid waters are very corrosive and generally contain excessive amounts of other objectionable constituents, such as iron, aluminum, or manganese.

Parts per million (ppm) is a measure of the concentration of a dissolved constituent by weight in a million parts of the water by weight. Thus, a water may contain one part per million of calcium by weight in one million parts of the water by weight. To convert parts per million to grains per gallon divide parts per million by 17.1.

An equivalent per million (epm) is a unit chemical equivalent weight of a constituent in a million unit weights of water. A unit chemical equivalent weight may be calculated by dividing the concentration of a constituent in parts per million by the chemical combining weight of the constituent.

In order to compare analyses it is desirable to express them in equivalents per million. In this form the concentrations of the constituents are directly comparable, whereas in parts per million they are not. This is because elements or radicals of different atomic weights unite to form compounds. For example, 23 grams of sodium (Na) are equivalent chemically to 35.5 grams of chlorine (Cl). They combine to form the compound sodium chloride, or common salt.

Temperature

The temperature of water available for industrial use is often of greater importance than the proper chemical characteristics. Streams that otherwise might provide sufficient water of good chemical quality for industrial use may not be suitable for many purposes because the temperature either is too high or varies too greatly. Temperatures of water are measured regularly at stream-gaging stations by the U. S. Geological Survey at the time stream-flow measurements are made. Temperatures are measured in the flowing water near the middle of the stream. Observed water temperatures at various stream-gaging stations in Tuscarawas County are shown in table 30.

Temperatures vary from a minimum of 30° F. to between 70° and 80° in all streams in Tuscarawas County. Sufficient data are not available to make detailed comparisons of one stream with another or to establish a relation between volume of flow and temperature. Temperature of surface water appears to be more closely related to average atmospheric temperature and other climatic conditions than to volume of flow.

CONCLUSIONS

Tuscarawas County is well supplied with both ground and surface water. The upland areas are generally agricultural lands in which sufficient water is derived from bedrock aquifers for farm and domestic purposes. The industrial activity is largely confined to towns and villages in the valley flood plains, where Pleistocene and Recent gravel and sand deposits provide ample water supplies for most municipal and industrial purposes.

New and additional supplies are probably available in these valley areas. In the development of any new supply, consideration must be given to the fact that the water of the Tuscarawas River is high in chloride, and heavy pumping from wells near this stream may induce infiltration of such water. The valley of Sugar Creek between Dover and Beach City, where well-sorted gravels are present in considerable thickness adjacent to a stream of good chemical quality and good sustained flow, should yield quantities of water in excess of 10 million gallons a day at a number of places.

Many other areas along Sandy and Conotton Creeks and the Tuscarawas River offer good possibilities of yields from 1 to 5 million gallons a day.

Drilling of wells below depths of 350 feet is not recommended because of the presence of brine in most formations below this depth.

TABLE 30

TEMPERATURE OF SURFACE WATER

Sta. 1
Tuscarawas River near Dover

Date	Temp. °F
Nov. 29, 1943	38
Feb. 18, 1943	32
Mar. 11, 1943	36
July 28, 1943	72
Aug. 17, 1943	78
Oct. 16, 1943	42
Dec. 21, 1944	32
Jan. 3, 1945	30
Feb. 3, 1945	32
Mar. 9, 1945	40
Apr. 7, 1945	50
Apr. 15, 1945	45
May 3, 1945	50
May 5, 1945	46
June 4, 1945	58
June 26, 1945	70
Jan. 3, 1946	33
Jan. 11, 1946	40
Jan. 14, 1946	36
Jan. 18, 1946	30
Feb. 28, 1946	37
Mar. 15, 1946	52
Mar. 29, 1946	56
Apr. 15, 1946	50
May 1, 1946	60
May 15, 1946	63
June 14, 1946	70
July 1, 1946	75
Aug. 19, 1946	69
Sept. 19, 1946	68
Dec. 2, 1946	24

Sta. 11
Stillwater Creek at Uhrichsville

Date	Temp. °F
Feb. 5, 1944	34
Mar. 8, 1944	36
Jan. 8, 1945	32
Feb. 5, 1945	31
Mar. 8, 1945	42
Mar. 22, 1945	45
Apr. 10, 1945	53
May 17, 1945	56
June 12, 1945	67
July 3, 1945	73
Oct. 23, 1945	54
Jan. 22, 1946	32
Mar. 11, 1946	37
May 8, 1946	56
May 23, 1946	60
June 7, 1946	64
Aug. 15, 1946	70
Sept. 13, 1946	65
Nov. 12, 1946	48

Sta. 2
Tuscarawas River at Newcomerstown

Date	Temp. °F
Feb. 17, 1944	32
Feb. 10, 1945	32
Feb. 24, 1945	36
Apr. 11, 1945	56
May 15, 1945	60
June 11, 1945	65
Sept. 10, 1945	74
Oct. 25, 1945	50
Nov. 21, 1945	43
Jan. 21, 1946	32
Feb. 25, 1946	32
Mar. 19, 1946	52
Apr. 3, 1946	54
May 10, 1946	56
Sept. 16, 1946	64
Nov. 12, 1946	50

Sta. 4
Sandy Creek at Sandyville

Date	Temp. °F
Nov. 24, 1943	40
Dec. 21, 1943	33
Mar. 9, 1944	35
Jan. 9, 1945	38
Feb. 7, 1945	36
Mar. 12, 1945	43
Mar. 23, 1945	45
Apr. 13, 1945	62
July 5, 1945	74
Sept. 11, 1945	60
Nov. 14, 1945	52
Dec. 21, 1945	31
Jan. 23, 1946	33
Feb. 22, 1946	34
Mar. 19, 1946	50
Apr. 8, 1946	50
May 10, 1946	58
June 13, 1946	67

Sta. 9
Home Creek near New Philadelphia

Date	Temp. °F
May 24, 1944	77
Mar. 12, 1945	39
Mar. 21, 1945	45
Apr. 11, 1945	65
May 17, 1945	58
June 16, 1945	71
July 11, 1945	60
Nov. 21, 1945	38
Dec. 22, 1945	34
Jan. 21, 1946	33
Mar. 11, 1946	46
Apr. 22, 1946	65
May 29, 1946	70
June 13, 1946	65
Aug. 16, 1946	68
Sept. 13, 1946	65
Oct. 12, 1946	50

Sta. 3
Sandy Creek at Waynesburg

Date	Temp. °F
Nov. 24, 1943	38
Dec. 21, 1943	33
March 10, 1944	35
May 9, 1944	60
July 28, 1944	74
Aug. 25, 1944	60
Jan. 9, 1945	33
Feb. 6, 1945	34
Mar. 23, 1945	44
July 6, 1945	68
Nov. 8, 1945	54
Dec. 21, 1945	33
Jan. 23, 1946	35
Mar. 19, 1946	47
Apr. 8, 1946	50
May 7, 1946	54
June 13, 1946	67
Sept. 10, 1946	67

Sta. 6
Indian Fork near New Cumberland

Date	Temp. °F
Jan. 5, 1944	38
Mar. 9. 1944	35
Mar. 12, 1945	40
Apr. 6, 1945	52
May 9, 1945	54
June 12, 1945	62
July 2, 1945	65
Mar. 27, 1946	52
Apr. 9, 1946	50
Apr. 30, 1946	56
May 13, 1946	54
June 6, 1946	60
Aug. 19, 1946	72
Sept. 3, 1946	66

Sta. 7
Sugar Creek near Beach City

Date	Temp. °F
Nov. 23, 1943	38
Feb. 11, 1944	35
Mar. 11, 1944	36
Dec. 19, 1944	32
Dec. 30, 1944	37
Apr. 28, 1945	48
June 13, 1945	64
Sept. 11, 1945	70
Sept. 28, 1945	68
Oct. 26, 1945	48
Nov. 14, 1945	50
Dec. 20, 1945	32
Jan. 25, 1946	32
Feb. 27, 1946	38
Feb. 28, 1946	36
June 11, 1946	68
Dec. 2, 1946	34

Flow in the major streams of Tuscarawas County is well sustained at all times, even during periods of protracted drought, except for the streams draining the unglaciated areas south and east of the county. The low flows can be increased by releases from the conservation pools of the Muskingum Watershed Conservancy dams completed in 1939.

The small streams will provide reliable sources of water suitable for domestic and industrial use with a moderate amount of treatment.

The natural chemical constituents in the surface waters are comparable with those of other natural streams in Ohio.

The Tuscarawas River contains high concentrations of chloride during periods of low flow. The concentrations are reduced by dilution downstream but generally are too high for domestic and many industrial uses.

Flood flows in all the major streams are controlled by reservoirs of the Muskingum Watershed Conservancy District. The system adds greatly to the flood security of Tuscarawas County.

Bibliography

(1) Alexander, W.H., The climate of Ohio: Ohio Agricultural Experiment Station Bulletin 445, 1929.

(2) U.S. Department of Agriculture Yearbook, 1941: Climate of the States.

(3) U.S. Department of Commerce, Weather Bureau: Climatic summary of the United States, secs. 68-71, 1930.

(4) Wilson, J.D., and Savage, J.R., An evaporation survey of Ohio: Ohio Agricultural Experiment Station Bulletin 564, 1936.

(5,6) U.S. Department of Commerce, Bureau of Census, Sixteenth census of the United States, first and second series, 1940.

(7) U.S. Department of Commerce, Statistics of population, 1900-1940.

(8) Ohio Agricultural Experiment Station, Ohio agricultural statistics, 1945.

(9) Ohio Department of Industrial Relations, Division of Labor Statistics, Annual coal report, 1945.

(10) Ireland, H.A., New evidence for an Illinoian glacial boundary in northeastern Ohio: Geological Society of America Bulletin, volume 51, pp. 1337-1358, 1941.

(11) Stout, W., Water in Ohio: Geological Survey of Ohio, fourth series, Bulletin 44, pp. 108-109, 1943.

(12) Stout, W., Generalized section of the coal-bearing rocks of Ohio: Geological Survey of Ohio, fourth series, information Circular 2, 1939.

(13) Conrey, G.W., Geology of Wayne County: Geological Survey of Ohio, fourth series, Bulletin 24, p. 101.

(14) Lamborn, R.E., unpublished data in files of Geological Survey of Ohio.

(15) Condit, D.D., Conemaugh formation in Ohio: Geological Survey of Ohio, fourth series, Bulletin 17, 1912.

(16) Ohio Department of Health, Division of Sanitary Engineering, Incorporated communities in Ohio with water works, 1945.

(17) Ohio Department of Health, Analyses of municipal water supplies in Ohio, 1945.

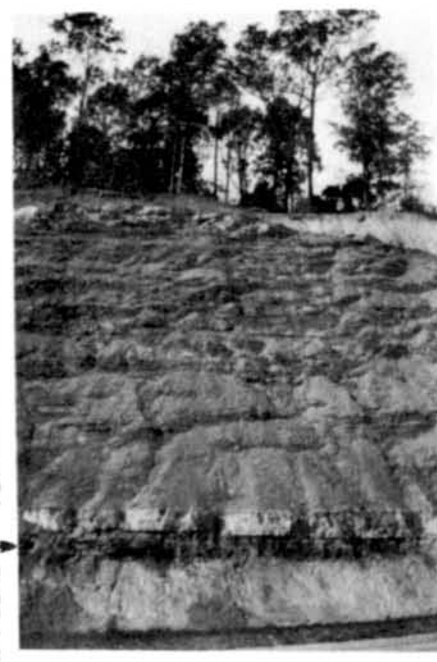
(18) White, W.F., Jr., The industrial utility of the surface waters of Ohio: Ohio Water Resources Board. Bulletin 4, Jan. 1947.

UMBRELLA ROCK: OUTLIER OF BUFFALO SANDSTONE
FOUR MILES NORTH OF NEWCOMERSTOWN, OHIO

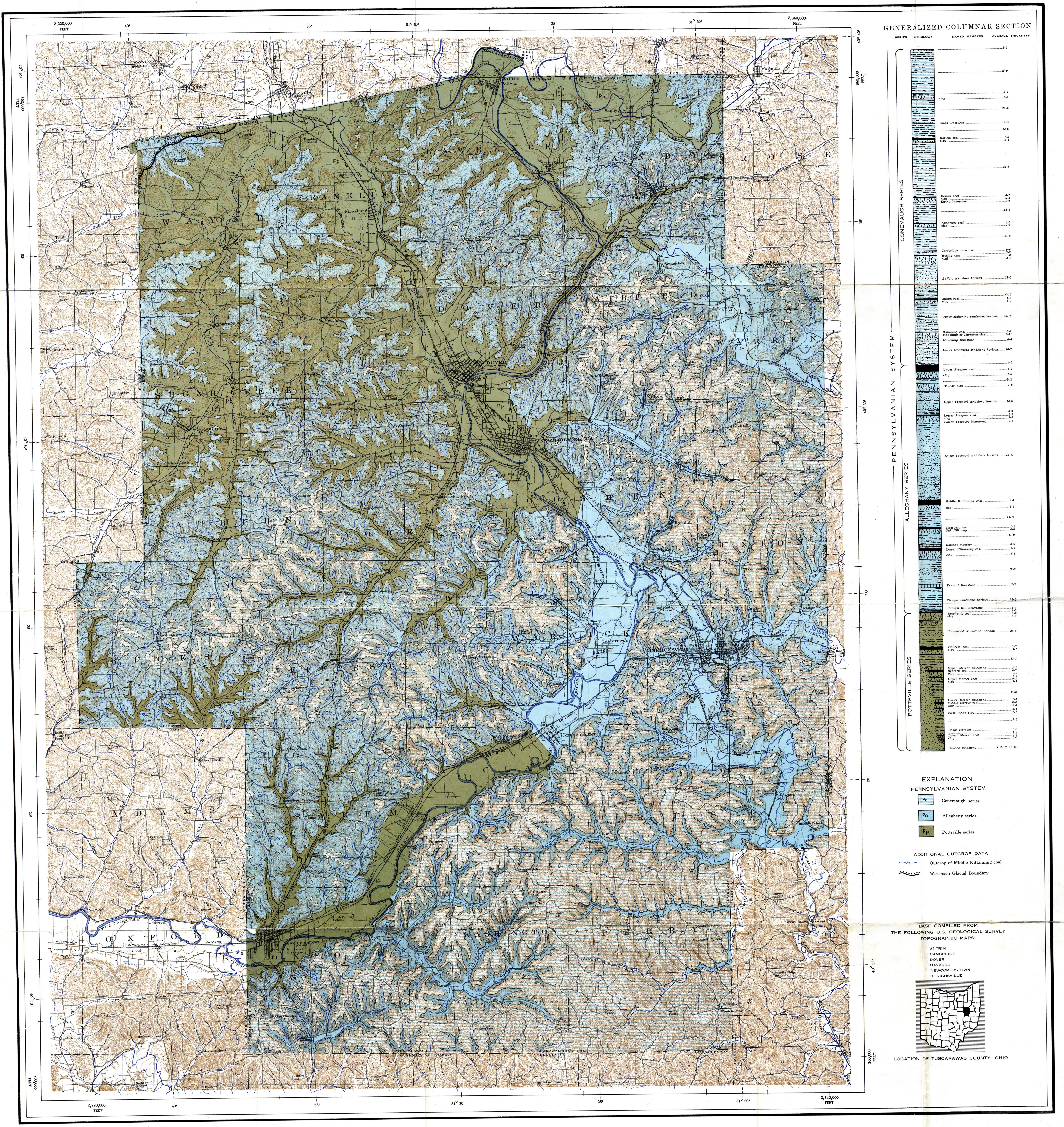
GRAVEL TERRACE
TWO MILES SOUTH OF NEW PHILADELPHIA, OHIO

PUTMAN HILL LIMESTONE

BROOKVILLE
NUMBER 4 COAL



POTTSVILLE-ALLEGHENEY CONTACT
FOUR MILES NORTH-EAST OF DOVER, OHIO



GEOLOGIC MAP OF TUSCARAWAS COUNTY, OHIO

GEOLOGY BY
RAYMOND E. LAMBORN

1955

Scale 1/62500

Contour interval 20 feet
Datum is mean sea level

STATE OF OHIO
FRANK J. LAUSCHE, GOVERNOR
DEPARTMENT OF NATURAL RESOURCES
A. W. MARION, DIRECTOR
DIVISION OF GEOLOGICAL SURVEY
JOHN H. MELVIN, CHIEF

10,000 FOOT GRID BASED ON OHIO COORDINATE SYSTEM

DRAFTING BY HAROLD J. FLINT