NOTICE CONCERNING COPYRIGHT RESTRICTIONS

Article 166

ANOMALOUS STREAMFLOW–GROUND-WATER REGIMEN IN THE MAD RIVER BASIN, NEAR SPRINGFIELD, OHIO

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Work done in cooperation with the Ohio Department of Natural Resources, Division of Water

Abstract.—Streamflow measurements of the Mad River downstream from Springfield to the mouth of Mud Run indicated a loss in flow in this reach. Precise measurements of ground-water levels showed that ground-water flow had been diverted by drainage ditches, thereby reversing the normal ground-water gradient.

The Mad River, in west-central Ohio, has the best sustained dry-weather flow of any major stream in the State, a situation indicative of large potential ground-water supplies in the basin. Because widespread and thick permeable gravels underlie most of the Mad River valley the river is an effluent, or gaining, stream throughout most of its length. However, spot measurements of streamflow indicated that, at least at some times under dry-weather conditions, there was a loss in flow downstream from Springfield. This anomaly suggested that for some reason the yield of aquifers in that reach was lower than would be expected from the known hydrogeology. As ground-water withdrawals, recharged by infiltration from the river, were being increased in both the Springfield and Dayton areas, an investigation was made during 1959 and 1960 with the purpose of accounting for the loss in streamflow.

The Mad River rises on the eastern side of the Bellefontaine outlier, a bedrock high in Logan County, the highest terrain in the State. The river flows southward across Champaign and northern Clark Counties over a gravel-filled buried valley as much as 3 miles wide. At Springfield the valley fill is constricted by a bedrock gorge approximately ⅛ mile wide. The drainage area above the stream-gaging station west of Springfield, at the lower end of the gorge, is 485 square miles. Downstream from Springfield the river flows west-southwest across a gravel-filled valley as much as 2 miles wide in Clark County and the northwestern corner of Greene County. Near the boundary between Greene and Montgomery Counties the river enters a second constriction, a bedrock gorge at Huffman Dam, one of five flood-control dams of the Miami Conservancy District. The dam forms a dry detention-type reservoir, and does not affect low and medium stages of flow. Between Huffman Dam and the mouth of the river at Dayton, the Mad River again flows over a gravel-filled valley. The drainage area above the gage just downstream from Huffman Dam is 632 square miles. Figure 166.1 shows the main features of the drainage basin and the inferred direction of ground-water movement.

Except at the two gorge sections, the Mad River valley is underlain by large volumes of highly permeable gravels. Some of this highly permeable material is hydraulically connected to the stream, and as the hydraulic gradient is toward the stream, large inflows are contributed to the river. A series of flow measurements along such a stream, called a seepage investigation or seepage run, reveals the zones of ground-water contribution by showing large increases in flow between measuring points. Lack of gains indicated by the measurements does not eliminate the possibility that permeable water-bearing deposits are separated from the stream by relatively impermeable material or that the hydraulic gradient is not toward the stream. It was such a lack of gains in a seepage investigation in September 1948 that focused attention on the reach downstream from Springfield.

The glacial features of the Mad River valley in Clark County have been described by Goldthwait

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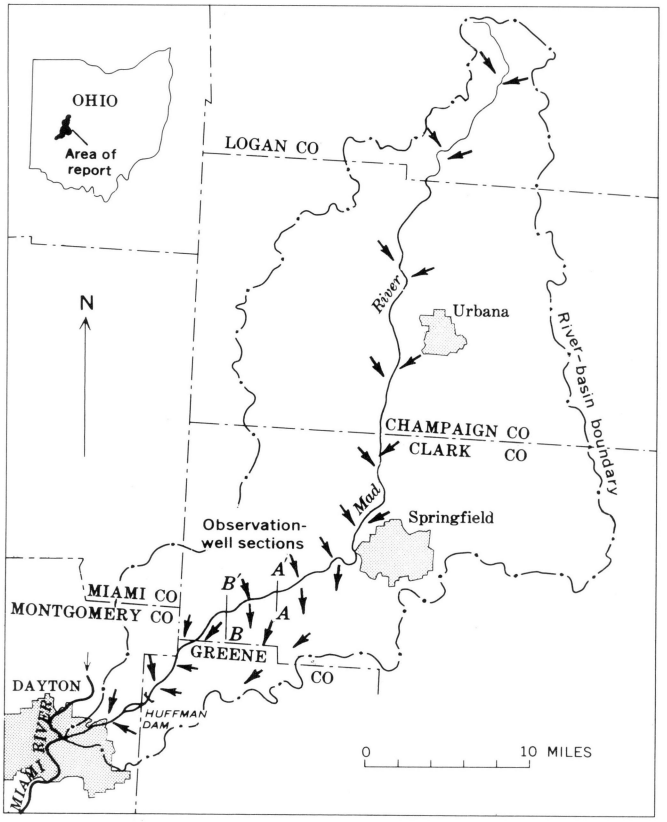

FIGURE 166.1.—Mad River drainage basin and inferred direction of ground-water movement (arrows) in the basin.

(Norris and others, 1952, p. 44–51), and those of Greene County by Norris and others (1950, p. 13–19). In its upper reaches the Mad River flows over a buried valley filled with sediments deposited in an interlobate zone between the Scioto (east) and the Miami (west) lobes of the Wisconsin glacier. This valley fill consists largely of permeable sand and gravel lain down as kames, kame terraces, high-level outwash, and valley-train deposits. The gorge through which the stream passes at Springfield is cut in limestone. This gorge, as well as the one which cuts through limestone and shale at Huffman Dam, has relatively impermeable bedrock walls. Downstream from each of the gorges the buried valley again widens, and is filled with highly permeable glaciofluvial deposits.

Estimates of the permeability of the gravel deposits both upstream and downstream from the Springfield gaging station have been made at various times. An average for the permeability of all gravel deposits in the Mad River valley is between 2,500 and 4,000 gallons per day per square foot. This high value is in marked contrast to that of the relatively impermeable limestone and shale that form the valley walls in the two gorge sections. Walton and Scudder (1960, p. 38) estimate that the amount of water passing through the bedrock constriction as underflow beneath Huffman Dam is about 0.6 million gallons per day. The ungaged underflow at the gage near Springfield probably is less than this figure.

On the basis of extensive stream gaging at many selected locations during a period of low flow in September 1948, it is estimated that additions of ground water to the Mad River in Champaign County exceed 1 mgd per day per mile of stream. Farther south, in Clark County, more than 2 mgd per mile of stream was added during this low-flow period. Cross (1949, p. 563) estimated the amount of water stored in the gravel deposits contributing to streamflow north of the Springfield gaging station to be as much as 2 to 3 billion cubic feet (15 to 22 billion gallons).

The following low-flow measurements were made on September 15, 1948, west of Springfield: 204 cubic feet per second at the gage near Springfield, 191 cfs at Spangler Road (*B-B'*, figs. 166.1 and 166.2), and 201 cfs at the gage downstream from Huffman Dam (Mad River near Dayton) (Norris, and others, 1952, p. 29). Because of the limitations in the accuracy of current-meter measurements, the flow loss in this reach cannot be reliably determined, but there undoubtedly was some loss. Flow-duration curves for the two stations indicate that on the average there are no losses, even at extreme low flows (Norris and others, 1952, p. 26).

Increases in flow between Springfield and Dayton are less than the contributions north of Springfield, but generally they are substantial. The low flow at Midway (Spangler Road) suggested that the river was losing water within this area, and to study this condition the U.S. Geological Survey and the Division of Water, Ohio Department of Natural Resources, cooperated in constructing 18 observation wells, leveling to the wells, making observations of water levels, and obtaining streamflow measurements. All the observation wells except four, which are near the Springfield gaging station, are shown on figure 166.2. The wells averaged about 18 feet in depth, and the screened portion of the casing was placed in gravel deposits below the normal water level in the area. The holes were drilled along two cross-section lines, extending to both sides of the Mad River. Elevations of ground surface and measuring points were determined by a level traverse, including elevations of measuring points at four stream crossings. Twelve sets of well observations and four sets of streamflow measurements were made during 1959 and 1960. Two of the sets of observations are illustrated in the cross sections of figure 166.3. These are for May 21, 1959, when the flow in the river was about the mean, and for August 25, 1959, when the water levels were at the lowest point during the period of observation. The other 10 sets of observations are

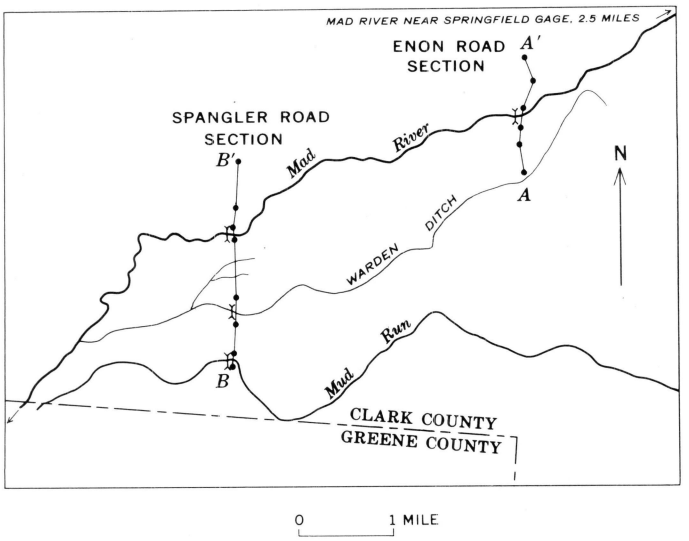

FIGURE 166.2.—Map of the Mad River basin south of Springfield, showing observation-well locations.

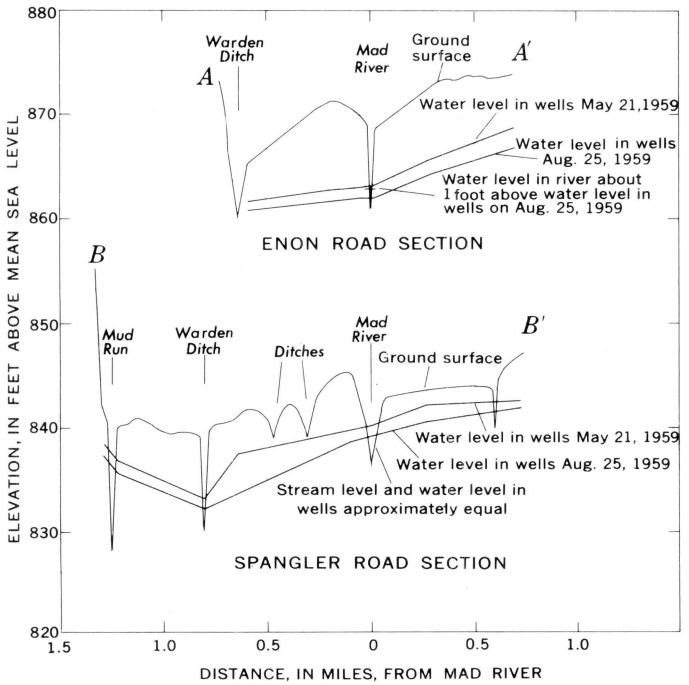

FIGURE 166.3.—Cross sections of the Mad River valley southwest of Springfield, showing water levels on May 21 and August 25, 1959.

intermediate between the two extremes shown, but have the same general shape in cross section.

The reason for the losses in the reach of the Mad River from Springfield to Huffman Dam is apparent from figure 166.3. The low area south of the river must have been very swampy in earlier times as the topographic map surveyed in 1904 shows an extensive system of drainage ditches. The map surveyed in 1955 shows that the channel now called Warden Ditch had been deepened and its drainage area more than doubled by capture of the upstream ends of other ditches between 1904 and 1955. As the ditches are lower than the river bottom, and the gravels of the valley fill are highly permeable, the direction of ground-water flow is from north to south, under the river, to Warden Ditch, which flows into the river above Huffman Dam. There is no indication of ground-water flow out of the drainage basin to the Little Miami River tributaries to the south. The accompanying table confirms these conclusions by indicating a loss (a slight gain occurred on August 30, 1960) between the Springfield gage and Spangler Road which is recovered at the Huffman Dam gage (Mad River near Dayton). Thus the Mad River is an influent or losing stream for all stages up to the mean, in the reach between Springfield and the mouth of Warden Ditch.

Streamflow measurements for the Mad River between Springfield and Dayton, Ohio, 1959 and 1960

Location on Mad River	Drainage area (sq mi)	Discharge (cfs)			
		1959		1960	
		May 21	Aug. 25	Aug. 30	Oct. 6
Near Springfield (gage)	485	462	216	166	166
Enon Road	492	------	217	------	------
Spangler Road	539	------	214	171	157
Near Dayton (gage)	632	670	263	195	184

The investigation illustrates the one-sided nature of a seepage run as a reconnaissance tool for locating potential ground-water supplies. Analogous to the null hypothesis of statistics, the hypothesis of potential ground-water supplies may be accepted if there is gain in the seepage run. On the other hand, in the event of a lack of gain, additional information is needed before a decision can be made. In this specific situation, the potential ground-water yield was there, but gains were not measured in the reach because the hydraulic gradient had been reversed locally, perhaps inadvertently, by drainage ditches.

REFERENCES

Cross, W. P., 1949, The relation of geology to dry-weather streamflow in Ohio: Trans. Am. Geophysical Union, v. 30, p. 563–566.

Kaser, Paul, 1962, Ground-water levels in the vicinity of Eagle City, Clark County, Ohio: Ohio Dept. Nat. Resources, Div. Water, Report to Ohio Water Commission, p. 1–82.

Norris, S. E., Cross, W. P., and Goldthwait, R. P., 1950, The Water Resources of Greene County, Ohio: Ohio Dept. Nat. Resources, Div. Water Bull. 19, p. 1–52.

Norris, S. E. and others, 1952, The Water Resources of Clark County, Ohio: Ohio Dept. Nat. Resources, Div. Water Bull. 22, p. 1–82.

Walton, W. C., and Scudder, G. D., 1960, Ground-water resources of the valley-train deposits in the Fairborn area, Ohio: Ohio Dept. Nat. Resources, Div. Water Tech. Rept. 3, p. 1–51.