EFFECTS OF THE PROPOSED PROSPERITY RESERVOIR ON GROUND WATER AND WATER QUALITY IN LOWER CENTER CREEK BASIN, MISSOURI

U. S. GEOLOGICAL SURVEY

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Effects of the proposed Prosperity Reservoir on ground water and water quality in lower Center Creek basin depend partly on the effectiveness of Grove Creek as a hydrologic boundary between the reservoir site and the Oronogo-Duenweg mining belt. Results of two dye traces indicate that Grove Creek probably is not an effective boundary. Therefore, higher water levels near the reservoir could cause more ground water to move into the mining belt and cause a greater discharge of zinc-laden mine water into Center Creek.

Fertilizer industry wastes discharged into Grove Creek resulted in significant increases of nitrogen and phosphorus in lower Center Creek. Results of seepage runs confirm that mine-water discharge and seepage account for the increased zinc concentrations in Center Creek during base flow. The nutrient and zinc concentrations in Center Creek, after the completion of the proposed reservoir, would depend upon the release schedule.

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By Wayne R. Berkas and James H. Barks

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November 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For use of those readers who may prefer to use the International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply inch-pound units	By	To obtain SI units
acre	0.4047	hectare (ha)
foot (ft)	0.3048	meter (m)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
mile per day (mi/d)	1.609	kilometer per day (km/d)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)

To convert temperature in °C (Celsius) to °F (Fahrenheit) multiply by 1.8 and add 32.

Effects of the proposed Prosperity Reservoir on ground water and water quality in lower Center Creek basin, Missouri

By Wayne R. Berkas and James H. Barks

ABSTRACT

Effects of the proposed Prosperity Reservoir on ground water and water quality in lower Center Creek basin depend partly on the effectiveness of Grove Creek as a hydrologic boundary between the reservoir site and the Oronogo-Duenweg mining belt. Results of two dye traces indicate that Grove Creek probably is not an effective boundary. Therefore, higher water levels near the reservoir may cause more ground water to move into the mining belt and cause a greater discharge of zinc-laden mine water into Center Creek.

Ground-water-level measurements and seepage runs on Center Creek indicate a relationship between ground-water levels, mine-water discharge and seepage, and base flow in Center Creek. From March to October 1979, ground-water levels generally decreased from 5 to 20 feet at higher elevations (recharge areas) and from 1 to 3 feet near Center Creek (discharge area); total mine water discharged to the surface before entering Center Creek decreased from 5.4 to 2.2 cubic feet per second; mine-water seepage directly to Center Creek decreased from an estimated 1.9 to 1.1 cubic feet per second; and the discharge of Center Creek near Carterville decreased from 184 to 42 cubic feet per second.

Fertilizer industry wastes discharged into Grove Creek resulted in significant increases of nitrogen and phosphorus in lower Center Creek.

INTRODUCTION

The U.S. Army, Corps of Engineers has proposed construction of Prosperity Dam and Reservoir on Center Creek in southwestern Missouri. The proposed reservoir would be called Prosperity Lake and would have a surface area of 1,880 acres. The major benefits of the reservoir would be flood control, water supply, and recreation.

The proposed reservoir would be located south of Carthage, Mo., and north of Interstate Highway I-44 (fig. 1). Grove Creek, which receives fertilizer industry wastes, enters Center Creek about 1 mi downstream from the proposed damsite. The Oronogo-Duenweg mining belt is located in the lower Center Creek basin. Zinc and lead were mined from this area until the mid-1950's when the mines were abandoned because of economic reasons and ground-water intrusion. All of the abandoned mines contain moderately mineralized water that has relatively large zinc concentrations and a few of the mines discharge water that eventually reaches Center Creek. The mining belt crosses Center Creek near Oronogo where mine water seeps directly into Center Creek. Barks (1977) attributed increased concentrations of dissolved zinc in Center Creek during base flow to the mine-water discharge and seepage.

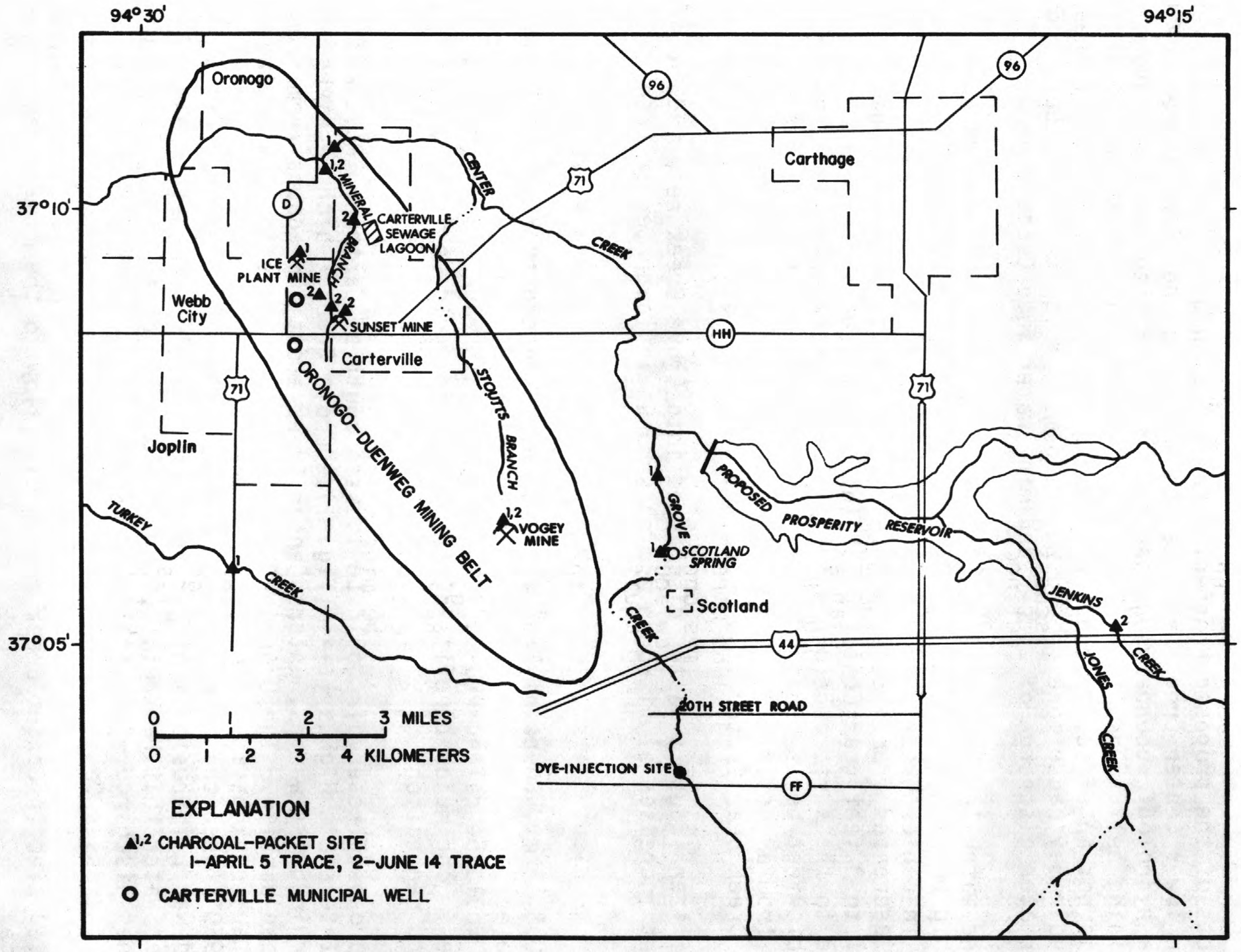

Figure 1.-- Study area showing dye-injection site on Grove Creek and charcoal-packet locations for dye traces.

Early in the planning phase of Prosperity Lake, two previous investigations were made (Barks and Berkas, 1979; Harvey and Emmett, 1980). The report by Barks and Berkas documents existing water-quality conditions in the upper part of Center Creek basin and speculates on the quality of water that could be expected in the impoundment. The report by Harvey and Emmett describes ground water in the area, and through use of a ground-water model, estimates potential changes in ground-water levels due to the reservoir.

This report contains a discussion of the effects of the proposed reservoir on the movement of ground water in the Oronogo-Duenweg mining belt and on water quality in lower Center Creek.

GROUND WATER

The hydrogeology of the Prosperity area is discussed by Harvey and Emmett (1980); therefore, an in-depth discussion of the hydrogeology will not be presented in this report. They defined two aquifers underlying the study area. The Mississippian limestone aquifer extends from the surface to about 300 ft below the surface. In most places a confining layer, the Northview Formation (5 to 10 ft thick), separates the Mississippian aquifer from the 1,400-ft thick Cambrian and Ordovician dolomite and sandstone section. The Mississippian aquifer is under water-table conditions, and water-level elevations range from 850 ft to 1,100 ft; the Cambrian-Ordovician aquifer is artesian, and water-level elevations range from 700 ft to 1,000 ft (Harvey and Emmett, 1980). The majority of rural wells obtain their water from the Mississippian limestone, while municipalities obtain their water from the Cambrian and Ordovician dolomite. The workings of the zinc and lead mines in the Oronogo-Duenweg mining belt are located in the Mississippian limestone. In this report the Mississippian limestone aquifer will be called the shallow aquifer, and the Cambrian and Ordovician dolomite will be called the deep aquifer.

Harvey and Emmett (1980) state that the reservoir should cause additional water to be stored in the shallow aquifer adjacent to the proposed reservoir. Ground-water levels would rise sharply next to the reservoir with slight rises a few miles away. Grove Creek is located between the proposed reservoir site and the Oronogo-Duenweg mining belt (fig. 1). If Grove Creek is an efficient hydrologic boundary, effects of the reservoir on ground water in the mining area would be minimal or nonexistent; if not, the reservoir could result in slightly higher water levels in the mining belt and a greater discharge of zinc-laden water into Center Creek.

Dye Traces

Observations of the flow at several sites along Grove Creek showed that it is a losing stream between County Highway FF and Scotland Spring (fig. 1). Water levels in wells open in the Mississippian limestone near the losing reach of the stream stand a few feet below the channel, thus substantiating the losing character of the stream.

Dye traces were made to determine if all of the flow lost from Grove Creek emerged in Scotland Spring or if part of the flow was diverted to the mining belt. Dye traces in other limestone or dolomite terranes have proved that recharge water injected at a specific point can emerge at more than one point (Feder and Barks, 1972; Skelton and Miller, 1978). Inasmuch as a projection of the strike of the mining belt intersects Grove Creek in the losing reach, emergence of recharge water or dye in the mining belt was a distinct possibility.

On April 5, 1979, and June 14, 1979, dye traces were made on Grove Creek. The area and method of the traces were the same. They differed in the amount of dye released, initial flow conditions, and locations of sampling sites.

Methods

Rhodamine WT dye (20 percent solution) was used in the two studies because it does not adhere well to most substances; thus very few losses will occur. The dye is not toxic to humans or other organisms in relatively small concentrations (Wilson, 1968). The dye was injected into the losing reach of Grove Creek at a constriction in the channel where the flow was turbulent to insure good lateral mixing of the dye.

Fiberglass wire-mesh packets containing activated charcoal granules were placed at various locations where there was a possibility of recovering dye. The packets adsorb dye during intervals between visits insuring recovery. This is especially helpful when the dye may take several months to appear. The disadvantages of using the charcoal packets is that a quantitative value cannot be obtained because all the dye is not adsorbed by the charcoal.

The dye was extracted from the charcoal packets using the method outlined by Skelton and Miller (1978). The charcoal was placed in a glass container with enough 5 percent solution of ammonium hydroxide in ethyl alcohol to cover the charcoal. After 2 hours, the solution was filtered. The solution from the charcoal packets was examined with a Turner Model 111 fluorometer[1] for traces of the dye, as were some water samples.

[1]The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

April 5, 1979, dye trace

On April 5, 1979, at 1345 hours, 3 liters of rhodamine WT dye were injected into Grove Creek between County Highway FF and 20th Street Road near Scotland (fig. 1). The flow at the injection site was 4.4 ft^3/s, but at 20th Street Road the flow was only 0.08 ft^3/s. There was no flow at the Interstate Highway I-44 crossing, 0.5 mi downstream from 20th Street Road. At Scotland Spring, about 2.2 mi downstream from the injection site, the springflow was 17 ft^3/s.

Beginning April 5, water samples were collected periodically at Scotland Spring. Charcoal packets were placed in Scotland Spring, Grove Creek, Center Creek, Mineral Branch, Turkey Creek, Vogey Mine, and Ice Plant Mine (fig. 1).

The fluorometer dial readings for the Scotland Spring water samples are shown in figure 2. These readings show that the dye arrived at Scotland Spring at approximately noon on April 6, about 22 hours after its injection into the losing reach of Grove Creek. The apparent underground travel rate based on straight-line distance from the injection point was about 2.4 mi/d or 0.1 mi/h. However, the travel rate probably would be faster with larger streamflows and slower with smaller streamflows.

Packets collected from Scotland Spring, Grove Creek and Center Creek were discontinued after the dye passed through Scotland Spring. The packets from the other sites were analyzed periodically and the results are given in table 1.

On June 7, 1979, an unusually large reading occurred for the filtrate from the charcoal packet from Mineral Branch. This indicated that the dye might have traveled through the mining belt to appear in Mineral Branch. However, the dye could have come from sewage lagoons that discharge into Mineral Branch upstream from the charcoal-packet site. Because of this possibility, a second dye trace was made using more dye and additional sampling sites on Mineral Branch.

June 14, 1979, dye trace

On June 14, 1979, at 1145 hours, 6 liters of rhodamine WT dye were injected into Grove Creek at the same location as the previous study. The flow at the injection site was 1.8 ft^3/s, but at the 20th Street Road there was no flow. At Scotland Spring the springflow was 12 ft^3/s.

Beginning June 14, water samples were collected periodically from Scotland Spring and analyzed for dye using the same methods as in the April 5, 1979, dye trace. The resulting curve is shown in figure 3. Due to instrument problems, the peak could not be defined. The curve shows that the dye reached Scotland Spring in 42 hours under low-flow conditions. The apparent underground

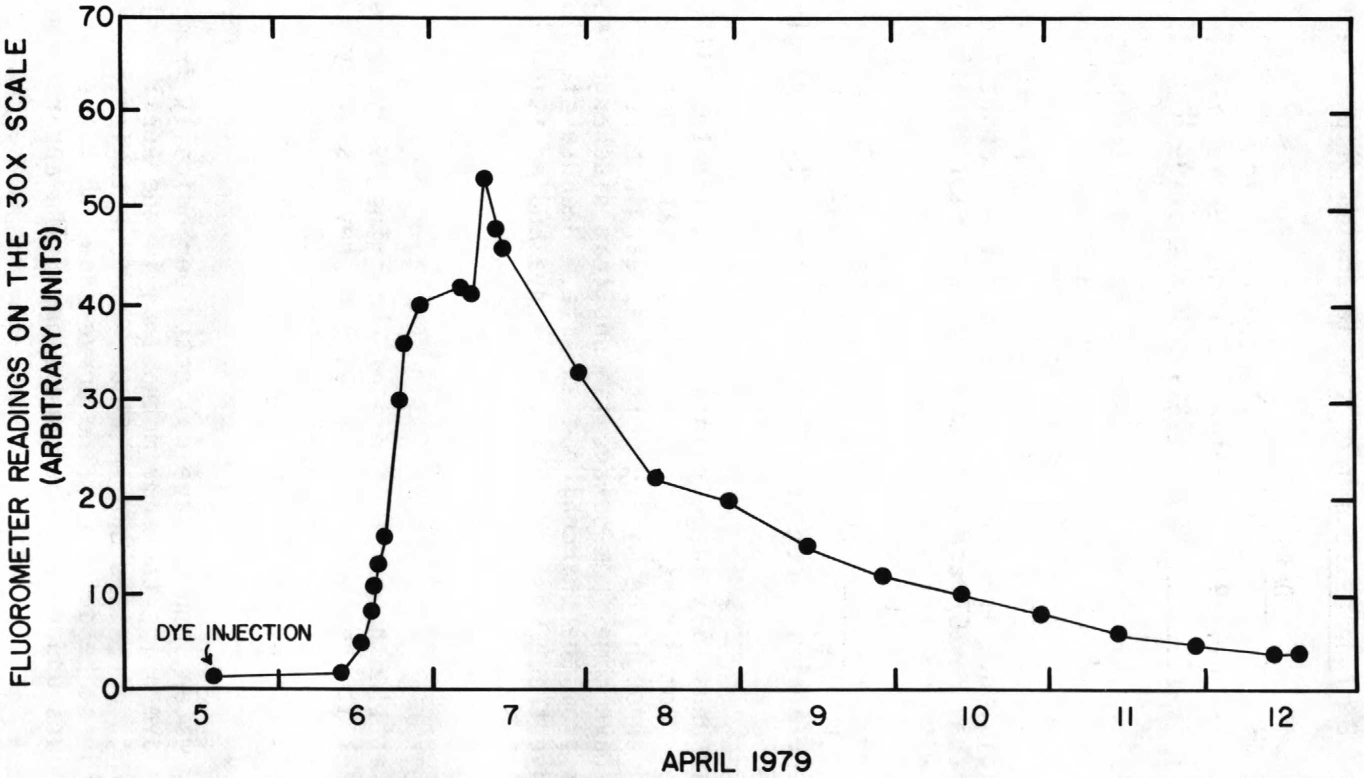

Figure 2.-- Fluorometer readings of water samples obtained from Scotland Spring after the April 5, 1979, dye injection into Grove Creek.

Table 1.--Fluorometer readings for the April 5, 1979, dye trace, converted to the 30X scale

Packet location	Date 3-29-79	4-5-79	4-12-79	5-2-79	6-7-79
Mineral Branch at Center Creek----	------	25	44	43	380
Turkey Creek------	24	29	27	31	46
Vogey Mine--------	------	67	17	50	84
Ice Plant Mine----	31	20	14	21	21

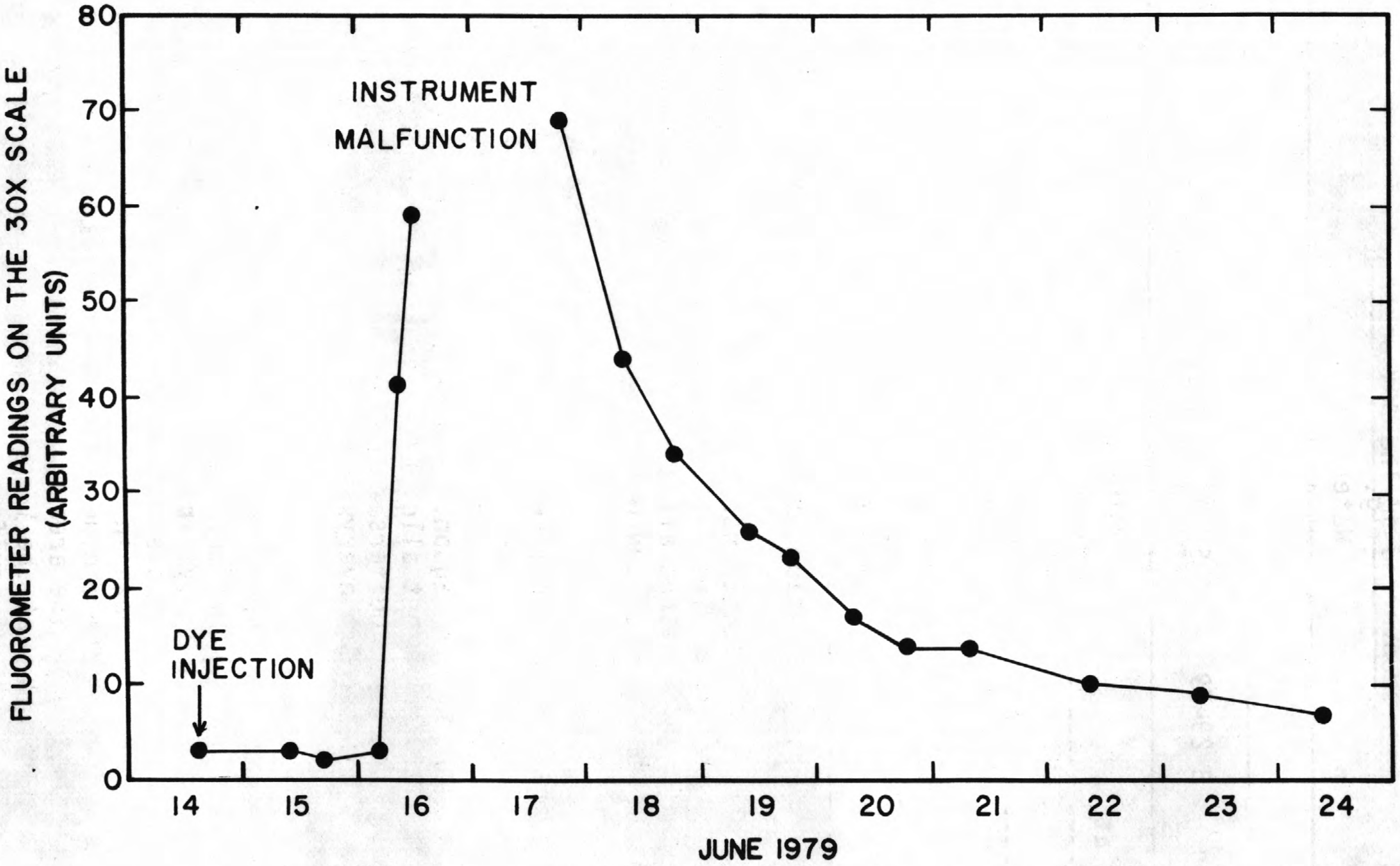

Figure 3.-- Fluorometer readings of water samples obtained from Scotland Spring after the June 14, 1979, dye injection into Grove Creek.

travel rate, based on a straight-line distance from the injection point, was about 1.2 mi/d or 0.05 mi/h. As expected, this was slower than the previous study because of lower flow conditions.

Charcoal packets were placed in Mineral Branch at Center Creek, Mineral Branch at Carterville (three packets), outflow from Carterville sewage lagoon, Jenkins Creek, and the Vogey Mine (fig. 1). The packets were analyzed monthly and results are given in table 2. Water samples also were collected weekly at Mineral Branch at Carterville, but never had a reading great enough to indicate the presence of dye.

Beginning on September 13, relatively high fluorescence occurred for the filtrate of charcoal from Mineral Branch at Center Creek and from the outflow of the sewage lagoon at Carterville. The presence of dye in the outflow of the sewage lagoon indicates that water which was pumped from the deep aquifer and used by the community contained dye. Carterville has no industries whose wastes would interfere with the fluorescence readings. The wells supplying water to Carterville are located in and operated by Webb City. These wells are completed in the deep aquifer with pressure grouting to a depth of 640 ft.

Beginning on November 15, moderately high fluorescence readings occurred for filtrate from the Vogey Mine about 4 mi from the injection site. Water in the Vogey Mine comes from the shallow aquifer.

Interpretation of dye-trace data

Dye was found at three locations; Scotland Spring, the sewage lagoon at Carterville, and the Vogey Mine. Fluorometer readings following both injections indicated that not all of the dye emerged at Scotland Spring. This means that part of the water lost in upper Grove Creek remains in the shallow aquifer.

Dye detected in the downstream reach of Mineral Branch may have passed through the shallow aquifer into the deep aquifer where it was pumped out by deep wells at Webb City, used in the municipal supply, and discharged through the Carterville sewage lagoon. Faults or fractures near the losing reach in Grove Creek might allow water to pass through the confining layer that separates the two aquifers. The Northview Formation, the confining layer, is not present everywhere and may be missing near the losing reach.

Some of the leakage from Grove Creek remains in the shallow aquifer and moves into the mining belt as evidenced by the presence of dye in samples from the Vogey Mine. Detecting dye in samples from the Vogey Mine was unexpected because water has to move contrary to the flow pattern indicated by the ground-water contours shown in a subsequent section of the report. A projection of the strike of the mining belt to the losing reach of Grove Creek would pass through the Vogey Mine area, providing an avenue of ground-water flow. Dye occurring in water at the Vogey Mine shows the complexity of three-dimensional flow in karst aquifers and the problems of displaying it with two-dimensional illustrations.

Table 2.--Fluorometer readings for the June 14, 1979, dye trace, converted to the 30X scale

Packet location	Date 7-12-79	8-15-79	9-13-79	10-18-79	11-15-79	12-11-79
Mineral Branch at Center Creek-----	168	26	400	370	310	-----
Mineral Branch at Carterville, left branch-----	20	13	45	33	31	30
Mineral Branch at Carterville, right branch----	28	20	21	13	31	28
Mineral Branch at Carterville-----	23	10	23	18	-----	-----
Jenkins Creek-----	75	38	85	36	55	40
Vogey Mine--------	49	28	61	65	133	130
Outflow from Carterville sewage lagoon---	----	----	380	203	350	190

The dye traces indicate that Grove Creek is not an efficient hydrologic boundary. Therefore, increases in ground-water levels near Grove Creek also could occur in the mining area.

Water-level Data and Analysis

On April 4, 1979, four water-level recorders were installed in the study area. The depth to water from land surface in each well, daily rainfall at the Joplin airport, and stage of Center Creek near Carterville are shown in figure 4. The location of the four water-level recorders are shown in figure 5.

The Patrick, Clark, and Scotland recorders were installed on abandoned domestic wells located outside the mining district, while the Nowata recorder was installed on an abandoned mine shaft. There is no significant pumpage near any of these sites.

The total decline in water levels from June to November was greater in the mine shaft than in the wells (fig. 4). This is probably due to the relatively large permeability of the mining area and the hydraulic connection between the mining area and Center Creek. The subdued response of water levels in the mine shaft to rainfall indicates a large amount of water storage in the mining belt compared to the adjacent area.

On March 14, June 18, September 19, and October 16, 1979, ground-water-level measurements were made at 34 wells and mines in the basin along with seepage runs on Center Creek and Mineral Branch to relate changes in the potentiometric surface to the changes in base flow. The locations of the wells and mines measured are shown in figure 5, along with the elevation of the potentiometric surface of the March 14, 1979, measurements. The elevations of the potentiometric surface at each well and mine are listed in table 3 for each measurement date.

The data in table 3 show a decline in water levels from March to October. The water levels generally fluctuated from 1 to 3 ft near the rivers and 5 to 20 ft in the uplands. The greatest declines during the season occurred from September 19 to October 16, 1979. The rainfall record at Joplin shows that this was the driest period during this study.

The dye trace showed that some water lost in Grove Creek may enter the shallow aquifer and travel in a northwesterly direction. According to figure 5, ground water in the vicinity of Grove Creek should move toward the creek. This discrepancy again illustrates the problem of trying to show the three-dimensional flow in a karst aquifer with a two-dimensional illustration.

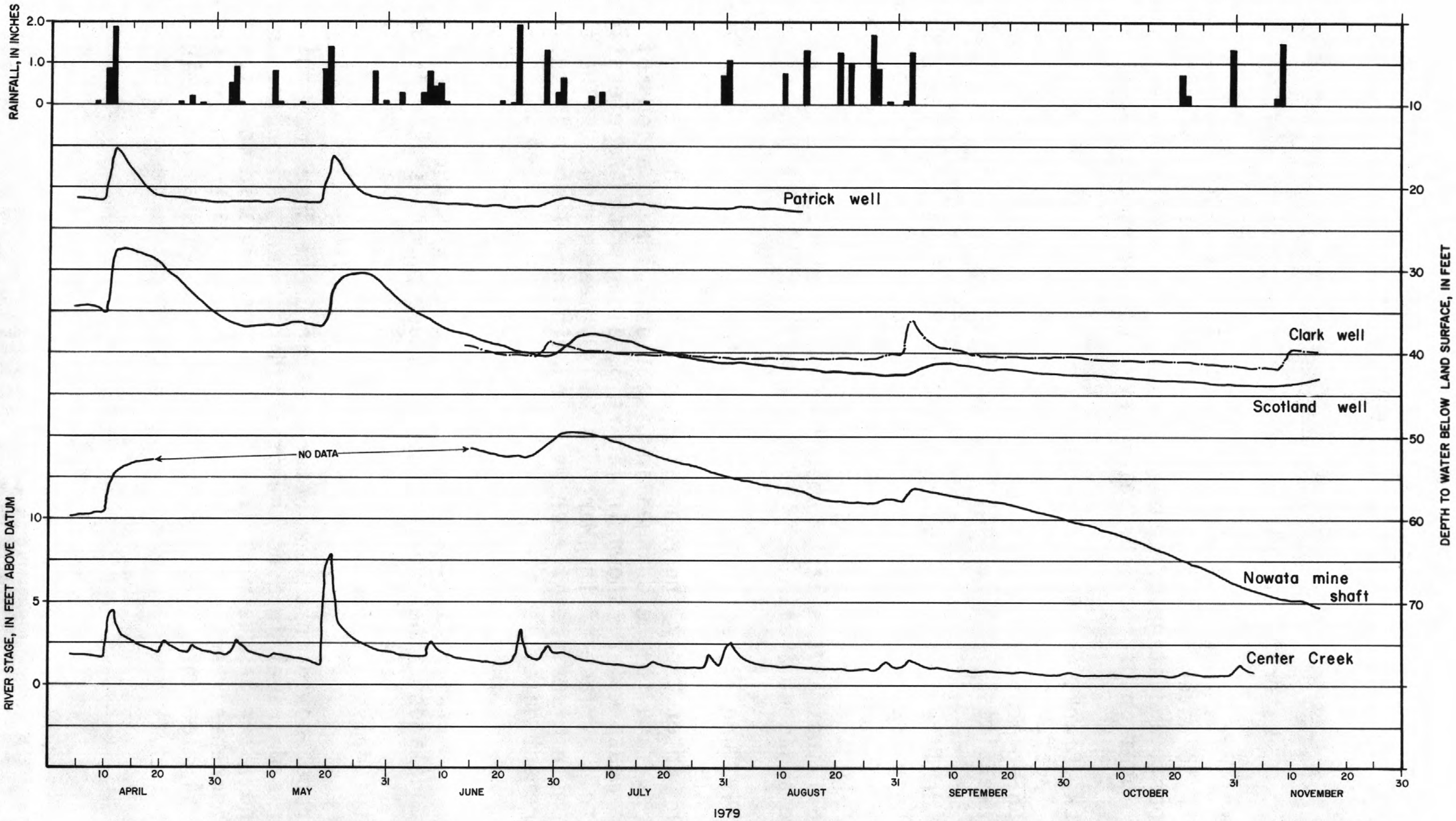

Figure 4.-- Rainfall at Joplin airport, stage of Center Creek near Carterville, and ground-water levels in a mine shaft and three wells.

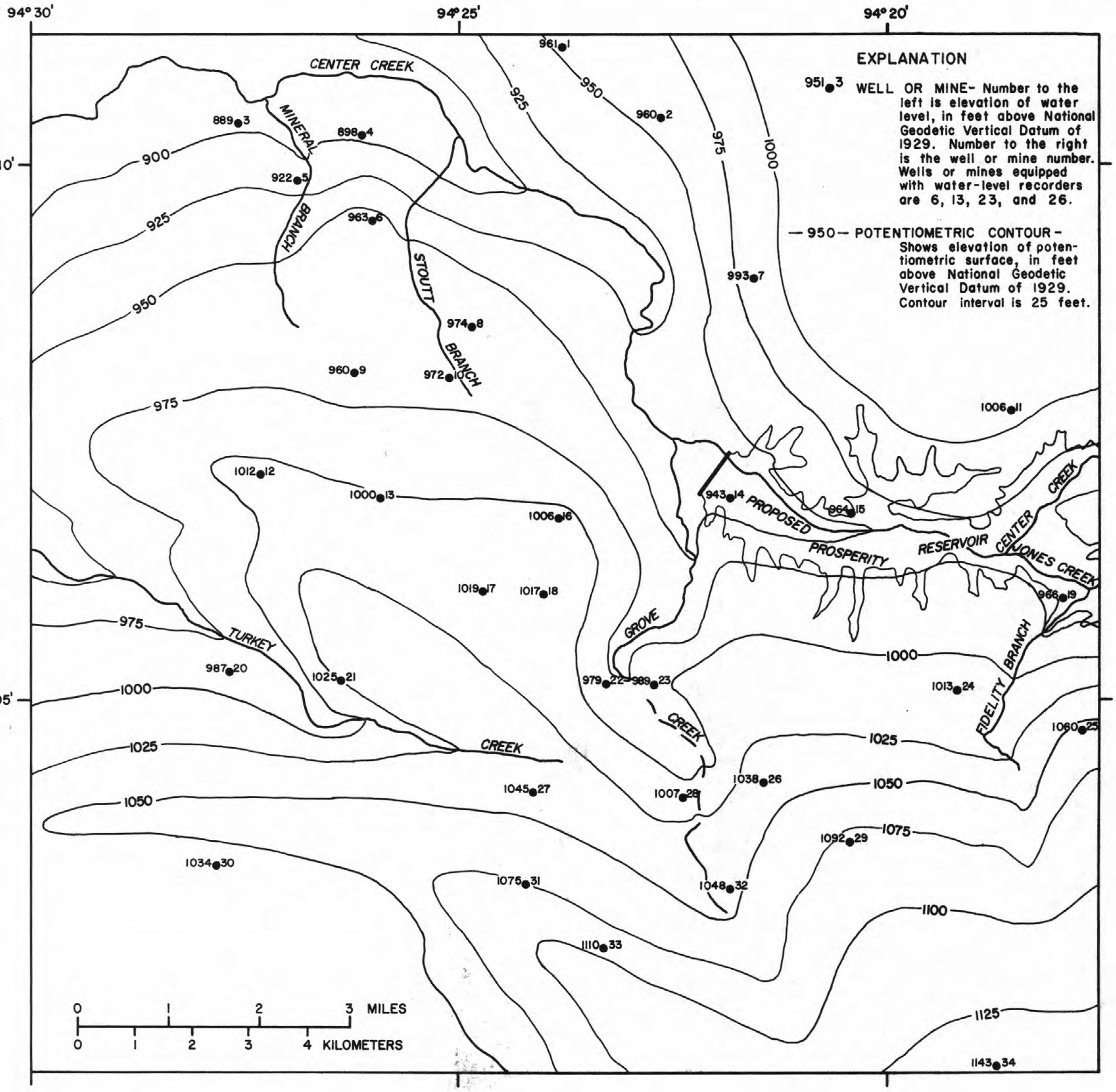

Figure 5.-- Potentiometric surface of the shallow aquifer during March 14, 1979.

Table 3.--Water levels in wells and mines from March to October, 1979

Well and mine number (fig. 5)	Well and mine name	Water level, in feet above datum[1] 3-14-79	6-18-79	9-19-79	10-16-79
1	Ling------------	961	961	957	954
2	Heisten---------	960	960	951	943
3	Spicer----------	889	887	888	887
4	Danielson-------	898	896	895	894
5	Rhea------------	922	922	922	921
6	Clark[2]----------	963	960	960	958
7	McNew-----------	993	991	988	979
8	Brown-----------	974	972	968	964
9	McGregor--------	960	962	960	962
10	Allen-----------	972	975	---	973
11	Krummel---------	1,006	999	992	988
12	Cox-------------	1,012	999	1,002	993
13	Nowata[2]---------	1,000	1,007	1,001	996
14	Hornbeck--------	943	941	---	---
15	Bishop----------	964	960	957	956
16	Harper----------	1,006	1,010	1,002	998
17	Hyde Park-------	1,019	1,023	1,016	1,015
18	Jeffries--------	1,017	1,018	---	1,006
19	Smith-----------	966	965	966	965
20	Patterson-------	987	986	985	986
21	Nichols---------	1,025	1,023	1,021	1,019
22	Griffiths-------	979	974	---	970
23	Scotland[2]-------	989	981	978	976
24	Compton---------	1,013	1,015	1,007	1,004
25	Miller----------	1,060	1,059	---	---

Table 3.--Water levels in wells and mines from March to October, 1979--Continued

Well and mine number (fig. 5)	Well and mine name	Water level, in feet above datum[1]			
		3-14-79	6-18-79	9-19-79	10-16-79
26	Patrick[2]--------	1,038	1,038	1,037	1,036
27	Spoon-----------	1,054	1,048	1,042	1,037
28	Patty-----------	1,007	1,000	---	983
29	Harrison--------	1,092	1,088	1,084	1,082
30	Harrod----------	1,034	1,029	1,024	1,023
31	Delamatter------	1,075	1,076	1,075	1,074
32	Schneider-------	1,048	1,045	1,041	1,038
33	Bobski----------	1,100	---	---	1,096
34	Wood------------	1,143	1,143	---	1,142

[1]National Geodetic Vertical Datum of 1929 (NGVD).
[2]Equipped with water-level recorder.

WATER QUALITY

Storage in and releases from Prosperity Reservoir would change the flow regimen of Center Creek. At the present (1980), flow has a large variability The reservoir would reduce the variability by reducing storm runoff peaks. A minimum base flow of 11 ft^3/s would be maintained by the reservoir (U.S. Army, Corps of Engineers, 1977). The 7-day Q_{10} (the average minimum flow for 7 consecutive days that has a recurrence interval of 10 years) for the station Center Creek near Carterville, 2.4 mi downstream from the damsite, is 9.4 ft^3/s (Skelton, 1976). The overall effect of the reservoir would be to reduce peak flows and cause all flows to be greater than 11 ft^3/s.

The low-flow regimen has an effect on the water quality in downstream reaches of lower Center Creek. Water containing relatively large concentrations of nutrients enters Center Creek from Grove Creek where a fertilizer industry and an explosive industry are located. Water containing relatively large zinc concentrations also is discharged into Center Creek from the Oronogo-Duenweg mining belt. The water quality in Center Creek depends upon the diluting capability of flow in the creek. Thus, the larger the flows are in Center Creek, the smaller the concentrations of nutrients and zinc.

Grove Creek

Water-quality samples were collected monthly from Grove Creek and from Center Creek about 1.5 mi downstream from Grove Creek (fig. 6), beginning January 10, 1979, and ending November 14, 1979. Samples were analyzed for physical characteristics, zinc, lead, and major nutrients. The results are given in tables 4 and 5.

The analyses in tables 4 and 5 show that the water in Grove Creek contained larger concentrations of dissolved carbon dioxide, all forms of nitrogen, all forms of phosphorus, zinc, and lead than did water from Center Creek. The water in Center Creek near Carterville had smaller concentrations because the constituents were diluted and were partly removed by aquatic plants.

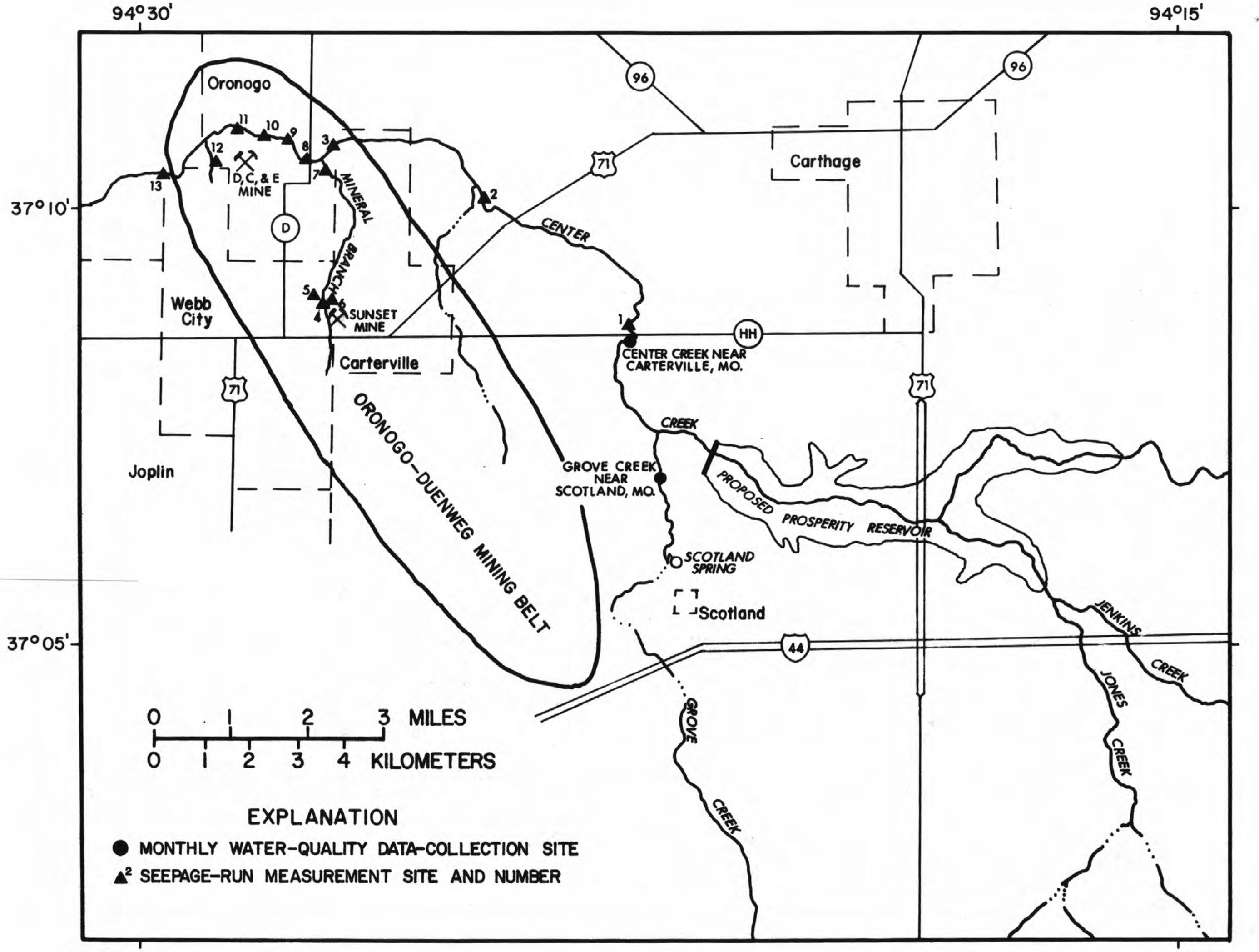

Figure 6.-- Location of seepage-run measurement sites and monthly water-quality data-collection sites in the proposed Prosperity Reservoir area.

Table 4.--Water-quality data for Grove Creek near Scotland, Missouri

[FT^3/s=cubic feet per second, MICROMHOS=micromhos per centimeter at 25° Celsius, DEG=degrees Celsius, MG/L=milligrams per liter, UG/L=micrograms per liter]

DATE	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEMPER-ATURE, WATER (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	CAR-BONATE (MG/L AS CO3)	ALKA-LINITY (MG/L AS CACO3)	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	NITRO-GEN, NITRATE TOTAL (MG/L AS N)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NITRITE TOTAL (MG/L AS N)
JAN , 1979												
10...	4.5	2000	7.7	2.0	6.6	48	0	131	5.1	73	76	.47
FEB												
14...	24	725	7.6	11.5	9.4	86	0	107	4.8	31	33	.65
MAR												
07...	32	435	7.5	10.5	10.0	94	0	79	4.9	15	14	.34
APR												
04...	24	435	7.6	10.5	8.2	73	0	82	4.0	12	13	.71
MAY												
09...	16	550	7.5	21.5	10.0	112	0	92	5.7	22	22	.93
JUN												
06...	--	1100	6.7	18.0	7.2	75	0	79	31	18	--	1.0
JUL												
24...	--	950	7.3	27.5	7.3	91	0	115	11	42	22	3.9
AUG												
15...	5.7	900	7.3	20.5	6.4	71	0	92	9.0	41	--	3.2
SEP												
12...	--	925	7.4	21.0	7.6	84	0	98	7.6	--	31	--
OCT												
03...	4.0	975	7.6	17.0	6.4	66	0	120	6.0	45	47	3.9
NOV												
14...	4.4	1300	7.6	10.0	9.8	87	0	140	6.8	71	61	.88

Table 4.--Water-quality data for Grove Creek near Scotland, Missouri--continued

DATE	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, TOTAL (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, DIS-SOLVED (MG/L AS P)	PHOS-PHORUS, ORTHO. TOTAL (MG/L AS P)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	LEAD, DIS-SOLVED (UG/L AS PB)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	ZINC, DIS-SOLVED (UG/L AS ZN)
JAN , 1979												
10...	.48	38	44	110	2.80	2.50	2.4	1.0	6	1	360	550
FEB												
14...	.38	18	17	53	2.10	1.70	1.6	1.5	220	120	450	220
MAR												
07...	.17	6.0	5.7	23	.690	.470	.52	.33	13	3	220	180
APR												
04...	.44	7.0	6.4	21	.850	.680	.68	.16	14	0	210	160
MAY												
09...	.78	8.1	7.3	32	.600	.470	.44	.34	4	0	140	100
JUN												
06...	--	6.7	7.9	27	.790	.550	.53	.27	73	60	--	160
JUL												
24...	.83	20	8.1	53	.680	.310	.59	.16	17	0	700	420
AUG												
15...	--	20	17	65	.970	.940	.87	.81	5	0	250	220
SEP												
12...	.00	--	20	--	.790	.770	.11	.79	28	4	160	350
OCT												
03...	2.3	26	27	74	.660	.620	.59	.52	4	2	220	180
NOV												
14...	7.6	30	30	100	1.50	1.10	4.8	4.1	3	0	3600	2700

Table 5.--Water-quality data for Center Creek near Carterville, Missouri

[FT^3/s=cubic feet per second, MICROMHOS=micromhos per centimeter at 25° Celsius, DEG=degrees Celsius, MG/L=milligrams per liter, UG/L=micrograms per liter]

DATE	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEMPER-ATURE, WATER (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	CAR-BONATE (MG/L AS CO3)	ALKA-LINITY (MG/L AS CACO3)	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	NITRO-GEN, NITRATE TOTAL (MG/L AS N)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NITRITE TOTAL (MG/L AS N)
JAN , 1979												
10...	44	480	8.0	.5	10.8	75	0	139	2.7	8.3	--	.04
FEB												
14...	125	352	7.7	7.0	10.0	83	0	123	5.2	6.6	7.5	.18
MAR												
07...	340	265	7.5	10.0	10.0	88	0	107	6.6	4.0	4.1	.12
APR												
04...	224	305	7.6	9.0	9.6	83	0	123	6.0	3.6	3.6	.21
MAY												
09...	216	320	7.7	21.0	9.0	100	0	123	4.8	3.9	4.0	.25
JUN												
06...	165	500	7.3	21.0	6.4	71	0	123	12	3.5	3.9	.34
JUL												
24...	72	345	7.5	26.0	6.3	76	0	115	7.1	7.4	7.2	.49
AUG												
15...	81	362	7.6	21.5	5.6	63	0	131	6.4	7.7	8.1	.47
SEP												
12...	74	418	7.8	21.0	6.0	67	0	110	3.6	--	7.5	--
OCT												
03...	40	365	7.7	17.5	5.8	60	0	120	4.8	6.8	7.4	.53
NOV												
14...	36	460	7.6	5.5	8.5	67	0	130	6.4	14	13	.27

Table 5.--Water-quality data for Center Creek near Carterville, Missouri--continued

DATE	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, TOTAL (MG/L AS P)	PHOSPHORUS, DISSOLVED (MG/L AS P)	PHOSPHORUS, ORTHO. TOTAL (MG/L AS P)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)	LEAD, TOTAL RECOVERABLE (UG/L AS PB)	LEAD, DISSOLVED (UG/L AS PB)	ZINC, TOTAL RECOVERABLE (UG/L AS ZN)	ZINC, DISSOLVED (UG/L AS ZN)
JAN , 1979												
10...	--	2.4	--	12	.220	--	.15	--	4	0	50	80
FEB												
14...	.08	2.1	2.0	9.9	.220	.190	.18	.15	110	96	220	140
MAR												
07...	.05	.52	.51	4.9	.140	.090	.10	.03	11	0	50	50
APR												
04...	.10	.64	.58	4.6	.110	.080	.09	.05	8	0	50	60
MAY												
09...	.12	.34	.32	4.7	.100	.070	.08	.06	7	0	90	40
JUN												
06...	.14	.28	.16	4.2	.110	.090	.08	.02	38	12	100	30
JUL												
24...	.28	.56	.64	8.7	.110	.100	.10	.07	21	0	180	40
AUG												
15...	.32	1.8	1.7	11	.100	.110	.10	.11	4	0	20	30
SEP												
12...	.26	--	.90	--	.820	.100	.71	.11	41	5	240	140
OCT												
03...	.34	.80	.76	8.5	.090	.080	.08	.07	2	0	30	40
NOV												
14...	.12	2.3	2.4	17	2.60	.150	4.3	4.2	2	0	210	200

In a previous study (Barks and Berkas, 1979), five low-flow samples were collected from Center Creek upstream from the confluence with Grove Creek and analyzed for nutrients. These data have been combined with data presented in table 5 to give the following average nutrient concentrations in Center Creek upstream and downstream from the confluence with Grove Creek:

	Milligrams per liter			
	Nitrite plus Nitrate, total as N	Ammonia nitrogen, total as N	Nitrogen, total as N	Phosphorus, total as P
Average concentration upstream from confluence with Grove Creek------	2.4	0.02	2.8	0.04
Average concentration downstream from confluence with Grove Creek------	5.9	1.1	7.5	0.14

This table shows that the discharge of nutrients into Grove Creek has a major effect on the water quality in Center Creek during low-flow periods.

Seepage Runs

Degraded water enters Center Creek from the Oronogo-Duenweg mining belt as surface runoff and ground-water seepage or discharge. During base-flow conditions, mine-water discharge and seepage increase zinc concentrations in Center Creek and the increased concentrations are sustained during storms by runoff from tailings areas (Barks, 1977). If the base flow in Center Creek decreases and the ground-water levels in the mining belt increase, more mine water would enter Center Creek, and the concentrations of zinc would increase.

Seepage runs were made March 14, June 20, September 20, and October 17, 1979, on Center Creek. Each seepage run consisted of discharge measurements and water-quality sampling. Water-level measurements were made in 34 wells and mines each time a seepage run was made. The discharge and water-quality data are given in tables 6 through 9. The water-level data and the location of the wells and mines are shown in table 3 and figure 5. The locations of the discharge and sampling points in the seepage runs are shown in figure 6.

Table 6.--Water-quality data for the seepage run on Center Creek, March 14, 1979

[ft^3/s=cubic feet per second, µg/L=micrograms per liter, µmho/cm=micromhos per centimeter at 25° Celsius, mg/L=milligrams per liter, °C=degrees Celsius]

Map no. (fig. 6)	Station name	Discharge (ft^3/s)	Zinc Dissolved (µg/L)	Zinc Total (µg/L)	Specific conductance (µmho/cm)	Calcium (mg/L)	Sulfate (mg/L)	Temperature (°C)	pH (units)
1	Center Creek near Carterville----	184	40	60	295	51	11	10.0	7.9
2	Center Creek below Lakeside------	214	100	90	313	55	16	10.5	7.8
3	Center Creek above Mineral------- Branch.	221	120	140	313	52	18	10.5	7.8
4	Mineral Branch above Sunset------ Mine.	.17	19,000	20,000	760	130	350	15.5	7.4
5	Left Fork Sunset Mine------------	2.0	9,000	9,100	1,800	480	1,100	16.0	6.8
6	Right Fork Sunset Mine-----------	1.1	9,100	9,300	1,850	450	980	14.5	7.0
7	Mineral Branch at mouth----------	3.6	2,800	3,300	1,300	260	590	18.0	8.0
8	Center Creek below Mineral------- Branch.	225	150	160	328	54	23	10.5	7.8
9	Center Creek near Oronogo-------- R.R. Bridge.	-----	160	170	335	55	25	11.5	8.0
10	Center Creek near Oronogo--------	-----	190	220	343	56	23	11.5	8.0
11	Center Creek at Oronogo----------	245	210	260	346	59	29	12.0	8.0
12	D.C. and E Mine outflow----------	2.3	7,000	7,600	1,350	300	680	17.5	7.4
13	Center Creek below D.C. and E---- Mine.	240	280	350	366	65	39	12.5	8.0

Table 7.--Water-quality data for the seepage run on Center Creek, June 20, 1979

[ft^3/s=cubic feet per second, µg/L=micrograms per liter, µmho/cm=micromhos per centimeter at 25° Celsius, mg/L=milligrams per liter, °C=degrees Celsius]

Map no. (fig. 6)	Station name	Discharge (ft^3/s)	Zinc: Dissolved (µg/L)	Zinc: Total (µg/L)	Specific conductance (µmho/cm)	Calcium (mg/L)	Sulfate (mg/L)	Temperature (°C)	pH (units)
1	Center Creek near Carterville-----	124	20	40	319	52	17	23.5	8.0
2	Center Creek below Lakeside-------	130	30	80	379	55	20	23.0	7.7
3	Center Creek above Mineral-------- Branch.	129	80	70	353	59	30	23.5	7.9
4	Mineral Branch above Sunset------- Mine.	.13	--------	--------	1,300	---	---	31.0	7.2
5	Left Fork Sunset Mine-------------	1.4	--------	--------	1,800	---	---	19.0	6.6
6	Right Fork Sunset Mine------------	2.1	--------	--------	1,800	---	---	26.0	6.9
7	Mineral Branch at mouth-----------	2.0	4,300	4,800	1,362	310	640	24.0	7.5
8	Center Creek below Mineral-------- Branch.	131	100	140	347	62	29	24.5	8.0
9	Center Creek near Oronogo--------- R.R. Bridge.	--------	110	--------	354	61	33	25.0	8.1
10	Center Creek near Oronogo---------	--------	200	180	359	63	36	25.0	8.1
11	Center Creek at Oronogo-----------	129	200	270	364	63	38	25.0	8.1
12	D.C. and E Mine outflow-----------	1.3	4,400	4,800	1,322	310	620	26.0	7.6
13	Center Creek below D.C. and E----- Mine.	143	270	400	387	68	50	25.5	8.2

Table 8.--Water-quality data for the seepage run on Center Creek, September 20, 1979

[ft^3/s=cubic feet per second, µg/L=micrograms per liter, µmho/cm=micromhos per centimeter at 25° Celsius, mg/L=milligrams per liter, °C=degrees Celsius]

Map no. (fig. 6)	Station name	Discharge (ft^3/s)	Zinc Dissolved (µg/L)	Zinc Total (µg/L)	Specific conductance (µmho/cm)	Calcium (mg/L)	Sulfate (mg/L)	Temperature (°C)	pH (units)
1	Center Creek near Carterville-----	60	20	40	371	65	17	18.0	7.9
2	Center Creek below Lakeside-------	63	30	50	376	53	20	18.5	7.9
3	Center Creek above Mineral-------- Branch.	62	70	130	384	55	23	18.5	7.8
4	Mineral Branch above Sunset------- Mine.	.09	16,000	16,000	1,420	160	690	22.0	7.2
5	Left Fork Sunset Mine-------------	1.8	8,500	7,500	1,880	450	860	16.5	6.6
6	Right Fork Sunset Mine------------	2.1	6,800	6,100	1,770	400	1,000	19.5	7.0
7	Mineral Branch at mouth-----------	1.7	4,300	4,000	1,310	300	570	18.5	7.6
8	Center Creek below Mineral-------- Branch.	63	180	240	427	73	44	19.0	7.7
9	Center Creek near Oronogo--------- R.R. Bridge.	----	240	240	417	68	46	19.0	7.9
10	Center Creek near Oronogo---------	----	280	340	427	68	50	19.0	7.8
11	Center Creek at Oronogo----------	67	360	420	436	70	55	19.0	7.8
12	D.C. and E Mine outflow----------	1.5	4,500	4,500	1,340	300	600	18.5	7.6
13	Center Creek below D.C. and E----- Mine.	72	490	540	487	77	77	19.0	7.7

Table 9.--Water-quality data for the seepage run on Center Creek, October 17, 1979

[ft^3/s=cubic feet per second, µg/L=micrograms per liter, µmho/cm=micromhos per centimeter at 25° Celsius, mg/L=milligrams per liter, °C=degrees Celsius]

Map no. (fig. 6)	Station name	Discharge (ft^3/s)	Zinc Dissolved (µg/L)	Zinc Total (µg/L)	Specific conductance (µmho/cm)	Calcium (mg/L)	Sulfate (mg/L)	Temperature (°C)	pH (units)
1	Center Creek near Carterville-----	42	190	220	449	82	51	15.5	7.9
2	Center Creek below Lakeside-------	45	100	100	461	76	53	15.5	7.8
3	Center Creek above Mineral-------- Branch.	43	140	220	456	77	53	15.5	7.9
4	Mineral Branch above Sunset------- Mine.	.23	20,000	21,000	1,661	410	970	20.5	7.0
5	Left Fork Sunset Mine-------------	.91	7,800	7,900	1,894	460	1,100	17.0	6.9
6	Right Fork Sunset Mine------------	.84	6,300	6,000	1,855	450	1,100	17.0	7.0
7	Mineral Branch at mouth-----------	.65	2,000	2,400	1,087	240	420	18.5	8.1
8	Center Creek below Mineral-------- Branch.	45	130	280	462	76	58	15.5	8.0
9	Center Creek near Oronogo--------- R.R. Bridge.	-----	190	180	462	77	58	16.5	8.0
10	Center Creek near Oronogo---------	-----	250	280	475	81	66	16.5	8.0
11	Center Creek at Oronogo-----------	49	340	380	488	80	72	16.5	8.0
12	D.C. and E. Mine outflow----------	.41	4,800	5,000	1,364	350	670	19.0	7.9
13	Center Creek below D.C. and E----- Mine.	52	460	540	516	83	92	16.5	8.0

The data in tables 6, 8, and 9 show that zinc, calcium, and sulfate concentrations decrease in the reach of Mineral Branch between the Sunset Mine and the mouth. Sewage effluents from Carterville and Webb City, which are discharged into Mineral Branch downstream from the Sunset Mine, dilute the mineralized water from the Sunset Mine. The discharge data from June to October indicate that during dry periods Mineral Branch is a losing stream, so much of the water from the Sunset Mine does not reach Center Creek as surface flow. This is especially true for the October data that show that flow in Mineral Branch at the Sunset Mine, which includes the discharge from the Left Fork Sunset Mine (0.91 ft^3/s) and Right Fork Sunset Mine (0.84 ft^3/s), was three times greater than the flow at the mouth of Mineral Branch. The ground-water data show that the ground-water levels in this area declined the most between September and October.

The data in tables 6 through 9 show that zinc concentrations in Center Creek increase significantly between the mouth of Mineral Branch and Oronogo. This increase can only be attributed to ground water from the mining district seeping into Center Creek. An estimate of the amount of additional flow contributed by seepage from the mining district can be found by subtracting the total load of dissolved zinc in Center Creek below Mineral Branch from the total load in Center Creek above the D.C. and E Mine outflow, and then dividing by an assumed average concentration of 9,400 mg/L (Barks, 1977). Using this method, the following discharges were determined: 1.9 ft^3/s for March; 1.4 ft^3/s for June; 1.4 ft^3/s for September; and 1.1 ft^3/s for October. As expected, the values decreased during the year due to the lowering of ground-water levels.

The information collected during the seepage runs showed that mine water enters Center Creek as discharge from the Sunset and D.C. and E Mines. The water from the Sunset Mine is mixed with sewage outflow in Mineral Branch before it enters Center Creek. As ground-water levels decline during the summer, much of the water in Mineral Branch infiltrates into the streambed causing less flow at the mouth. The sewage effluent discharged into Mineral Branch remains relatively constant while the flow in Mineral Branch at the Sunset Mine decreases, causing smaller concentrations of zinc at the mouth. If the proposed reservoir raised water levels in the mining district, the Sunset and D.C. and E Mines would discharge more water, most of which would eventually reach Center Creek.

SUMMARY AND CONCLUSIONS

Dye traces on Grove Creek show that not all of the water lost in the upstream reaches of Grove Creek reappears at Scotland Spring. Water also travels to the shallow aquifer and the deep aquifer. Therefore, Grove Creek may not be an effective hydrologic boundary that would prevent increased ground-water levels near the proposed Prosperity Reservoir from increasing ground-water flow through the Oronogo-Duenweg mining belt.

Water-level recorders in the study area show that the shallow aquifer around the mining belt has different hydrologic properties than in the mining belt. Ground-water-level measurements show seasonal fluctuations ranging from 1-3 ft near the streams and 5-20 ft in the divides. The greatest change in ground-water levels occurred from September 19 to October 16, 1979.

Results of seepage runs confirm that mine-water discharge and seepage account for the increased zinc concentrations in Center Creek during base flow. Ground-water-level measurements and seepage runs on Center Creek indicate a relationship between ground-water levels, mine-water discharge and seepage, and base flow in Center Creek. From March to October 1979, ground-water levels declined from 5 to 20 ft at higher elevations and from 1 to 3 ft near Center Creek; total mine-water discharge from the Sunset and D.C. and E Mines decreased from 5.4 to 2.2 ft^3/s; mine-water seepage into Center Creek just upstream from Oronogo decreased from an estimated 1.9 to 1.1 ft^3/s; and the discharge of Center Creek near Carterville decreased from 184 to 42 ft^3/s. If, as indicated, Grove Creek is not an effective hydrologic boundary, the reservoir could cause water levels to rise in the mining belt with a resulting increased discharge of zinc-laden mine water to Center Creek.

Fertilizer industry wastes discharged into Grove Creek resulted in the following average concentrations at Center Creek near Carterville: 5.9 mg/L of nitrite plus nitrate, total as N; 1.1 mg/L of ammonia nitrogen, total as N; 7.5 mg/L of nitrogen, total as N; and 0.14 mg/L of phosphorus, total as P. These average concentrations are greater than the concentrations in Center Creek upstream from the confluence with Grove Creek: 2.4 mg/L of nitrite plus nitrate, total as N; 0.02 mg/L of ammonia nitrogen, total as N; 2.76 mg/L of nitrogen, total as N; and 0.04 mg/L of phosphorus, total as P.

The nutrient and zinc concentrations in Center Creek, after the completion of the proposed reservoir, would also depend upon the release schedule.

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