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STREAM POLLUTION BY MINE WATERS, AND THE RECOVERY OF IRON IN MINE WATERS FROM ZINC-LEAD MINES IN SOUTHEASTERN KANSAS

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Purpose of Investigation

The Kansas State Geological Survey is interested in promoting the mineral industries within the state. The disposal of mine waters high in both acid and iron is a serious matter confronting much of the Kansas zinc-lead mining district. Production in the Tri-State District is now at the rate of almost $18,000,000 per annum, zinc and lead concentrates accounting for 83% and 17% of this respectively. Approximately 27% of the production, or $4,860,000 is from Kansas. Of this, $1,000,000 is from the Baxter Springs Area where the situation regarding the disposal of mine water is acute. Here the operators hesitate to increase production for fear of retaliation if additional mine water is dumped into the Spring River. Even now suits are pending which might have the effect of curtailing production. The commercial recovery of iron from mine water would benefit the state. In this investigation, the Survey is interested in two closely connected problems; first, to learn the facts and advise operators as to how mine water can best be disposed of; second, to recover the valuable iron from these mine waters. The State Water Department, as guardian of our water resources, is also deeply interested.

The commercial production of iron from this source would benefit the state.

Methods and content of present study.-- (1) Stream samples. Samples were obtained from all streams that might be contaminated by zinc and lead mine water originating or flowing through Kansas and entering Oklahoma. The map shown in figure 1 indicates the locations where such samples were obtained, and gives both the total iron content and the acidity (expressed as pH) for each sample. Included also are the same data for samples collected by the State Water and Sewage Laboratory, working with the Tri-State Ore Producers' Association. The investigations of the Water and Sewage Laboratory were also made in 1940.

(2) Analysis of samples. Table 2 shows the analyses of all samples. Each analysis reports the amount of total iron, iron in solution, and total acidity, expressed in parts per million parts of water, and the pH of the samples.

(3) Laboratory tests. Tests were made on the efficiency of water from Spring river, which is alkaline and therefore neutralizes acid, in precipitating iron from mine water, which is acid. A tabulation of results of these tests, showing the effects of various amounts of river water, analyses of the precipitated iron mixture, and various other data, is given in table 3. Ten parts of river water neutralized one part of mine water, and 78 percent of the iron was precipitated as hydroxide. Use of a larger amount of river water causes a greater percent of the iron to be precipitated.

(4) Iron and acid content of mine water. Figure 1, shows a part of the Kansas zinc and lead mining field, which may be divided into two areas, according to the iron and acid content of water from mines located in these areas. In the Baxter Springs area the mine waters contain large amounts of these substances. Waters from the Treece-Hockerville area, on the other hand, seem to contain only harmless amounts of iron and acid. The ore produced in the Waco area occurs in

a calcareous gangue, and mine waters from this district (not shown on the map) cause no significant stream pollution.

(5) The cost of chemicals for purification is given in table 1.

(6) A map of the Baxter Springs drainage district (figure 2) is presented.

Acknowledgments.-- Special thanks are due to the following persons who have given valued aid in connection with the study leading to this report: Ernest Boyce, Director, Division of Sanitation, State Board of Health, Lawrence, for analyses of water samples; H. H. Utley, Manager of the St. Louis Smelting & Refining Company, Baxter Springs; O. W. Bilharz, Bilharz Mining Company, Baxter Springs; Frank C. Brewster, Baxter Springs; Chester Scott, Federal Mining Company, Baxter Springs; James L. Smith, Baxter Chat Company, Baxter Springs; and Evan Just, Secretary, Tri-State Ore Producers' Association, Picher, Okla.

DISCUSSION OF PROBLEM

Iron pyrite is probably the source of most of the iron and acid that is present in the mine waters under consideration. In the presence of water and air, the pyrite is converted to iron sulphate, as shown in the following equation:

$$FeS_2 + 3\frac{1}{2}O_2 + H_2O = FeSO_4 + H_2SO_4$$

(pyrite) + (oxygen) + (water) = (iron sulphate) + (sulphuric acid)

The zinc-lead ore occurs in Mississippian (Keokuk and Warsaw) limestone, and is associated with varying amounts, generally small, of iron sulphide (pyrite and marcasite). The ore-bearing strata are overlain by the Cherokee shale, of Pennsylvanian age. The basal part of the Cherokee shale is exposed at places along the belt of outcrop west and north of Spring river, principally in the vicinity of Baxter Springs, and the shale also contains pyrite and marcasite. The upper workings of some mines in the Baxter Springs region penetrate the shale formation. It is in this area where the greatest trouble with mine water is experienced. Alternate working and closing of mines has aggravated this condition, inasmuch as oxidation of the iron sulphide occurs when the mines are dewatered and solution of the oxidized substances occurs when the water rises during periods of inactivity.

Mine waters in the Greece and Waco area contain no great amount of objectionable impurities, and will not be discussed.

The following is a list of prominent mines in the Baxter Springs area, together with analyses and other data.

Water from Mines in the Baxter Springs Area

Mine and map index number	Direction from Baxter Springs	Water pumped, gal. per 24 hrs.	Iron, ppm	Acid, ppm	Where mine water flows
Brewster & Bilharz (1)	West		2600	8370	Willow creek to Spring river
Ebenstein (53)	West		5000-6000 a/		Willow creek to Spring river
Homestake (54)	West		5000-6000 a/		Willow creek to Spring river
Leopard (55)	West		2500-3000 a/		Willow creek to Spring river
Liza Jane (56)	West		2500-3000 a/		Willow creek to Spring river
Hartley (57)	Southwest		2000-2500 a/		7th Ave. creek (Spring creek) to Spring river
Ballard (2) St. Louis Smelting & Refining Co.	Southwest	2,800,000	1050	4100	7th Ave. creek (Spring creek) to Spring river
Opperman (4)	South	1,500,000 (estimated)	350	860	7th Ave. creek (Spring creek) to Spring river

a/ Estimated by O. W. Bilharz

The Sunflower (no. 58 on map) (old Euterpe), Iron Mountain (no. 3 on map), and Peru (no. 59 on map) mines are near the extreme southwest border of this area. The water from these mines contains large amounts of iron and acid, but the mines yield only a small amount of water, which flows westward, eventually reaching the

Neosho river. Only the Sunflower mine is operating now and there is no mine-water problem at the present time.

When the field work for this investigation was being done, from June 16 to July 16, 1940, the Ballard mine of the Baxter Springs area was being pumped, and had been pumped for several years. Pumping from the Opperman mine started July 7, 1940, but water from this mine is not included in Table 2.

There are several variables in the problem of mine-water disposal. Both the volume of mine water in a stream and its composition can change, depending on how many and what mines are being pumped. The mines are more or less connected by underground water courses, as is shown by the fact that continuous pumping at the Ballard mine has lowered the water somewhat in other mines of the neighborhood.

It is estimated that if the mines were once entirely dewatered it would be necessary to pump between 2,000,000 and 3,000,000 gallons of water a day to keep them in this condition. Most of the mines have been idle for some time, however, and must be dewatered before mining can be resumed. It is estimated that steady pumping at all these mines would remove the water in three months. Such a campaign would raise the daily output of mine water by 7,000,000 gallons, to a total of 10,000,000 gallons, and place an excessive burden on any treating plant during this time. A plant for treatment of the mine water requires relatively constant feed in order to operate efficiently. Accordingly, it would be better to pump out accumulated excess mine water at a lower rate and to take more time to do it. For instance, over a period of twelve months, the extra water from this source would amount to only 1,750,000 gallons daily. This amount, added to the other 3,000,000 gallons, would make 4,750,000 gallons, an amount that could be treated readily.

The water from the Ballard mine that now reaches the river contains total iron in the amount of 465 p.p.m., and an acidity of 1540 p.p.m. This water would normally deposit about 6 tons of iron in the river each day, but about one half of the iron in the water coming from the mine is being removed along the way in settling ponds constructed by the St. Louis Smelting & Refining Company. In this system there are two shallow ponds, each several acres in extent, and shallow canals through which the mine water passes. It is reported that 1 ton of hydrated lime is added to this mine water each day. This part of the drainage is 1 mile long. The water then passes into a creek bed and without dilution finds its way to Spring river. The total distance from the Ballard mine to Spring river is about 4 miles. The following analyses show results in this settling system.

Analyses of water in Ballard mine water-treating system

	Acid	Iron in solution ppm	Iron separated ppm	pH
Water as discharged from mine	4100	980	70	2.65
At $\frac{1}{2}$ mile, through one pond	4290	950	50	2.45
At $\frac{3}{4}$ mile, after receiving lime and passing through second pond	4220	860	40	2.40
Water as it enters the river a/	1540	440	25	2.45

a/ This is the water utilized in our tests.

The reactions causing the iron to settle are as follows:

$$Fe_2(SO_4)_3 + 6H_2O = \underline{2Fe(OH)_3} + 3H_2SO_4$$

$$FeSO_4 + 2H_2O = \underline{Fe(OH)_2} + H_2SO_4$$

$$2Fe(OH)_2 + H_2O + \tfrac{1}{2}O_2 = \underline{2Fe(OH)_3}$$

Iron hydrolyses best in neutral solutions, the ferric iron being the more active. Iron in the ferrous condition is difficult to oxidize and precipitate. The bottoms of ponds and canals are covered with 2 to 4 inches of iron deposits.

Assuming 500 p.p.m. iron and 10,000,000 gallons of mine water a day reaching the river, the iron would amount to about 21 tons per day, or actually about twice that amount of iron hydroxide. The same amount is obtained by assuming 1000 p.p.m.

of iron and 5,000,000 gallons of mine water a day. The latter figures might represent conditions if the district should have a fair increase in production, for it is to be remembered that most of the mine waters contain more iron than that from the Ballard mine. On the other hand, it might be expected that after long-standing mine water is pumped out, the water subsequently pumped would contain less iron. The greater the volume of mine water, --especially if it contains a large amount of impurities, --the greater the amount of river water that is needed to treat it, and the larger the settling capacity that is required for accumulating the iron. The mechanical features of treating so large a volume of mine water create a problem. The following analyses show well how thoroughly the iron in solution has been removed after mine water reaches the river.

Precipitation of Iron by water from Spring river

	pH	Total iron p.p.m.	Iron in solution p.p.m.	Acidity p.p.m.	Alkalinity p.p.m.
Water from Spring river	7.55	0.77	0.12		102
Ballard mine water in 7th Ave. creek, just before reaching Spring river.	2.45	465.	440.	1540.	
Mouth of 7th Ave. creek (Spring river).	7.05	8.1	0.1		94
60 yards below mouth of 7th Ave. creek in Spring river	8.2	8.0	0.06		94
One-fourth mile below mouth of 7th Ave. creek.	7.4	3.8	0.07		84
Three miles south, in Oklahoma. .	6.85	0.68	0.31		64

Seemingly, the use of any other reagent, such as limestone, would make the cost of purification far greater than if water from Spring river were used.

Table 1.

Comparative Cost of Various Chemicals Used in Neutralizing Acid and Precipitating Iron a/

Chemical	Cost per pound, cents	Assumed purity, percent	Pounds per million gal. per p.p.m. acidity removed	Pounds per million gal. per p.p.m. iron precipitated.	Estimated cost per million gal. one p.p.m. removed	
					Acid	Iron
$Ca(OH)_2$	0.5-1.0	90	7.0	18.4	$0.035-.07	$0.138 Av.
CaO	0.5	88	5.4	14.2	0.027	0.071
$CaCO_3$ (10 mesh)	0.1	95	9.0	23.5	0.009	0.0235
Na_2CO_3	2.0	98	9.2	27.0	0.184	0.54
NaOH	2.0	100	6.8	17.9	0.136	0.34

a/ All the figures except those for iron are from U. S. Public Health Service, Office of Stream Sanitation, Cincinnati, Ohio.

Cost of Crushed Limestone

No.	Mesh	Price per ton	Price per pound	Remarks
18	18	$3.00	$0.0015	In bulk
24	24	3.00	0.0015	In bulk
200	-200	9.00	0.0045	100-lb. paper bags
200	92%-200	7.00	0.0035	100-lb. paper bags

Quotations on limestone in car lots, supplied by the Carthage Crushed Limestone Co. of Carthage, Mo., August 6, 1940.

Cost of transportation of limestone from Carthage, Mo., to Baxter Springs, Kans., is $0.75 per ton.

Example of Cost of Mine water Treatment with Limestone

1 million gallons of mine water, 4100 p.p.m. acid, 1000 p.p.m. iron
Limestone 0.1 cent per pound.

Acid removal	4100 x $.009	= $36.90
a/Iron precipitation	1000 x .0235	= 23.50 b/
Total cost 1,000,000 gallons		$60.40

a/

a/ Assuming that the iron is in the ferric condition. Ferrous iron would not be precipitated by limestone. In neutral solution, however, it quickly oxidizes in air to the ferric state.

b/ On the basis of 10-mesh limestone at 0.1 cent per pound, a very low cost. Using limestone at 0.19 cent the cost would be $115.71.

The figures do not include the cost of unloading or feeding the limestone.

Some system for purification of mine water is of vital importance to the zinc-mining industry of the Baxter Springs area. The St. Louis Smelting & Refining Company, the most active producer in the district, has been the defendant in several law suits. These have been instituted by farmers, fish and game associations, and municipalities, all in Oklahoma. Spring river flows into that state a few miles below Baxter Springs. It is contended that river water contaminated by mine water is injurious to fish, livestock, and crops, and is unfit for human consumption. Most of the suits have been settled out of court. Regardless of the merits of these claims, the Kansas operators are in a vulnerable position and hesitate to discharge additional mine water into the river for fear of consequences. As a result, production in Kansas is lower than it normally would be if this condition did not exist. Other conditions also have a bearing on the problem.

The Empire District Electric Company operates a hydroelectric plant at Riverton, on Spring river several miles above Baxter Springs. Water is impounded behind a dam and released through turbines once a day to help generate the electric output needed to meet the peak load requirements. As a consequence, the water at Baxter Springs rises 1.5 feet in the course of an hour and stays at the new level for two or three hours. This sudded onrush of water is said to scour the river bed, raising iron hydroxide that had settled. This statement is probably true, at least in part. In any event, the periodic sudden increase of the flow of water does not improve the situation.

Maximum and minimum rates of flow in Spring river are important considerations in plans for the use of this water. Shoal creek is a tributary of Spring river that enters the river above Baxter Springs. Rates of flow in the two streams (Pierce and Courtier, 1938, p. 17) are as follows:

Flow of Spring river and Shoal creek

Spring river above Shoal creek, period April, 1924, to September, 1933:

Maximum flow 57,400 second-feet, Aug. 17, 1927
Minimum flow 22 second-feet, Sept. 8, 1925

Shoal creek, same period:

Maximum flow 17,200 second-feet, Jan. 21, 1932
Minimum flow 8 second-feet, Oct. 9, 1931

Assuming the minimum of the combined streams to be 30 second-feet: 30 x 7.5 x 60 x 60 x 24 = 19,444,000 gallons a day. This quantity of water is sufficient to precipitate the iron from only 2,000,000 gallons of mine water, but of course the low rate of flow represented by the minimum is not normal.

Undiluted mine water from some of the zinc-lead mines in southeastern Kansas will kill fish quickly, but in the summer of 1940 no dead fish were observed in Spring river below the point where the mine water is being added. On the contrary, numerous live fish were observed. It is asserted that iron hydroxide settles on the bottom of the streams into which the mine water is emptied, destroying spawning beds of the fish. The hydroxide is also said to get into the gills of fish and do some damage. The truth or importance of these assertions is not known.

Suggested Methods of Mine-Water Treatment

Suggested methods for settling iron hydroxide and recovering iron, discussed in following paragraphs, include (1) Settling in a slough, (2) Settling in Spring river, and (3) Settling in a Dorr Thickener, filtering the thickened pulp in a continuous filter of the drum type.

Treatment by settling in a slough.-- This idea was advanced by H. H.

Utley, manager of the St. Louis Smelting & Refining Company (Ballard mine). Mr. Utley has been very active in the work of mine-water disposal and has spent much time and money on the problem. Whether or not other persons and companies are cooperating financially is not known. There is a slough, 1 mile long, which parallels Spring river on the east across the river from Baxter Springs, where mine water is now discharged. An abandoned concrete railroad bridge crosses the river at this point. The plan involves damming the river above the mouth of Willow creek in order to force some river water into the slough. Another dam would be required at the lower end of the slough in order to control the flow where the slough enters the river. River water added to the mine water would cause the iron to be precipitated and to settle in the slough. This plan was temporarily discarded when a survey showed the bed of the slough to be higher than the river bed. The William M. Stewart Engineering Company, of Joplin, Mo., estimated the cost of the project as follows:

Estimated cost of treating mine water by settling in slough

Excavation, 20,000 cu. yd. at $1	$20,000
Masonry Dams, 1,500 cu. yd. at $15	22,000
Rip Rap - Retarding Dams, 1,500 cu. yd. at $10 .	15,000
Pipe & Wooden Conduits, 3,500 ft..	7,000
Gates, Engineering Supervision, other expenses .	16,000
Total.	$80,000

This plan should not be abandoned without further consideration (figures 2 and 3).

Treatment by settling in Spring river.-- A later plan, also devised by Mr. Utley, involves building a dam approximately 225 feet long and 6 feet high across Spring river at a point 2 miles below the point where mine water enters, and settling the iron in still water behind the dam. This plan assumes that clear water would pass over the dam under normal river conditions. Iron sludge would be pumped from behind the dam to the river bank, filtered, and prepared for market. There is some question as to just how effective this plan might be. Still water would extend for a mile behind the dam and the iron might settle over a wide area, rather than just behind the dam. Collection of iron sludge probably would not be very efficient, at least until a sizeable deposit had accumulated in the river bed, and even then the iron might be lost over the dam in times of high water. To deflect the iron precipitate so that it would settle behind the dam on the west side of the river would require construction of a 6-foot wall on the river bottom, running diagonally up the river from a point on the east side of the dam located three-fourths of the way along its length. A lift gate in the dam near the end of the east side would be necessary in order to lower the water level, without disturbing the precipitated iron, when it was desired to pump the sludge. Most of the iron would probably settle behind the dam except in periods of high water, but its recovery would very probably present difficult problems. In any event, Mr. Boyce, Director of the State Water and Sewage Laboratory, is opposed to the plan as outlined. He believes that the Kansas Fish and Game Commission would object to any dam that would prevent the free movement of fish up and down the river. Fish ladders are not thought to be effective in this particular case. A road could be built to this location easily.

Treatment by thickening and filtering.-- Precipitating the iron with river water in a thickener and filtering the thickened sludge on a continuous filter represents an ideal engineering method of procedure, but it involves pumping a very large volume of mine and river water, --possibly as much as 5,000,000 gallons a day of the former and 70,000,000 gallons a day of the latter. The amount of solids to be settled would be relatively small, possibly 40 tons daily, but individual particles of iron hydroxide probably require a settling period of one hour, a condition that limits the amount of feed that could be pumped without using very large units or a series of smaller units.

In answer to an inquiry, the Dorr Company, Inc. advises that it is perfectly feasible to run 90,000,000 gallons per day in a Dorr thickener.

It should be recalled that mine water is coming to the river now by way of 7th Avenue creek. Other mines, not operating now, discharge through Willow creek. These creeks are 0.5 mile apart at the river. If a treating plant were erected, it would be necessary to receive mine water from one stream only. It might be possible to divert the flow of Willow creek into 7th Avenue creek. There is probably enough ground available for a treating plant at the mouth of either stream.

Possible market for recovered iron

At least one market for iron recovered from mine waters has been found close at hand. Several large portland cement plants are located in southeastern Kansas. Additional iron, over and above that occurring in the natural ingredients used in the manufacture of cement, is required by these plants in making a certain new type of cement. The extra amount of iron is reported to be 2 percent by weight of the cement. So far as is known, there is no good source of iron available anywhere near the cement-manufacturing area. At present, pyrite cinder is being shipped to the cement plants from St. Louis. The cinder is a by-product obtained in the roasting of pyritic concentrates to obtain sulphur dioxide, which is used in the manufacture of sulphuric acid.

The possibility of revenue from the sale of iron hydroxide recovered from mine waters has not generally been appreciated by mine operators. Additional investigation is needed in order to ascertain probable demands and prices, but it now seems that the possible revenue from sale of iron precipitated from the southeastern Kansas mine waters might figure largely in offsetting the cost and maintenance of a water-purification plant.

A purification plant treating 5,000,000 gallons a day of mine water containing 1,000 p.p.m. iron, would produce, in 365 days, the equivalent of 10,845 tons of Fe_2O_3, if operating at 100 percent efficiency.

Following is a summary of the information obtained from some of the cement manufacturers of eastern Kansas, all using iron now, concerning the use of iron oxide: (1) The chemist of a company that is using iron oxide at the rate of about 5,000 tons annually writes, "It is my personal opinion that the A.S.T.M. type 2 cement will grow in use and that we will undoubtedly use many tons of pyrite ash or other types of iron-bearing materials in the future". (2) From an official of another company-- "We use iron ore only at such times as we are manufacturing special cements for mass concrete work. Consequently the usage is restricted to the volume of this kind of business which we are able to secure and it is impossible to foretell what our requirements might be for this type of work". (3) Another letter states: "From the analysis submitted, this material (iron hydroxide from mine water) would be desirable for use in the manufacture of cement where it is necessary to increase the amount of iron oxide compounds to produce a special cement. To produce some of these will require as much as 10 pounds iron addition per barrel of cement". (4) "What is generally used is iron scale, a waste product at most of the steel roller mills, and sold at prices varying from $1.00 to $2.50 per ton. The R_2O_3 content is about 99 percent".

CONCLUSIONS

So far as the chemical aspects of this problem are concerned, it can be stated that alkaline river water has proved to be a good medium for purifying mine water. Also, considering the volume of water to be treated and the cost of other precipitants, river water seems to be the only reagent that can be employed satisfactorily for precipitating iron and reducing acidity of southeastern Kansas mine waters. Unsolved is the problem of determining what kind of reservoir or tank is best for purification of the water and precipitation of the iron in a manner that is suited for marketing the iron.

LIST OF ZINC-LEAD CONCENTRATING MILLS

(The numbers correspond with the numbers on figure 1)

1. Bilharz - Brewster
2. St. Louis Smelting & Refining Co.
3. Iron Mountain
4. Opperman (Mine and pump)
5. Baxter Chat Co.
6. Black Eagle
7. Federal - Muncie
8. Early Bird
9. Federal Jarrett
10. American Robinson
11. Mid Continent
12. Captain
13. Wilbur
14. Chubb
15. Kans. Ex. Jarratt
16. Webber
17. New Blue Mound
18. West Side
19. Barr
20. Youngman & Youse
21. Evans-Wallower No. 24
22. Dines Blue Mound
23. Pelican
24. Federal-Gordon
25. Tri-State Ottawa
26. Tri-State Sooner
27. Cortez
28. Andrews
29. Beck
30. Brewster
31. Bird Dog
32. Beaver
33. Cortez-New York
34. Royal
35. Atlas
36. Indian
37. Mission
38. St. Louis Smelting & Refining Co. No. 4
39. Kansas Ext. Ritz
40. Blue Goose
41. Woodchuck
42. See-Sah
43. Baird
44. Rialto
45. American Douthat
46. Cardin No. 3
47. Admirality
48. Lavrion
49. Skelton
50. Lawyers
51. Central, Eagle-Picher
52. Romo
53. Ebenstein
54. Homestake
55. Leopard
56. Liza Jane
57. Hartley
58. Sunflower
59. Peru

TABLE 2

Analyses of Water Samples

Source	pH	Total iron p.p.m.	Iron in solution p.p.m.	Acidity p.p.m.	Alkalinity p.p.m.	District
a/ Spring creek - 100 yards above mouth	2.45	465.	440.	1540.		Baxter Springs
15 feet above mouth of Spring creek in Spring river	7.55	0.77	0.12		182.	Baxter Springs
Mouth Spring creek	7.05	8.1	0.1		94.	Baxter Springs
60 yards below mouth of Spring creek in Spring river	8.2	8.0	0.06		94.	Baxter Springs
After Spring river had risen and filled Spring creek to this point. Spring creek 100 yards above mouth	3.7	25.	3.3	68.		Baxter Springs
½ mile below Spring creek in Spring river. Above sewer	7.4	3.8	0.07		84.	Baxter Springs
3 miles south of Baxter Springs on Spring river	6.85	0.68	0.31		64.	Northeast Oklahoma
End of launder, 60 yards from mine pump, St. Louis Smelting & Refining Company	2.65	1050.0	980.	4100.		Baxter Springs (Ballard mine)
Just above lime plant, St. Louis Smelting & Refining Company	2.45	1000.	950.	4290.		Baxter Springs (Ballard mine)
¾ mile from mine, St. Louis Smelting & Refining Company	2.40	900.	860.	4220.		Baxter Springs (Ballard mine)
Opperman mine, Baxter Springs	3.9	350.	240.	860.		Baxter Springs
Brewster mine, Baxter Springs	2.8	2715.	2600.	8370.		Baxter Springs
Just below Federal Jarrett Mill, Kansas-Oklahoma line, sec. 15.	6.5	1.4	0.04		30.	Treece-Hockerville
Semple Early Bird tailings mill stream	8.0	0.14	0.04		34.	Treece-Hockerville
Just below Wilbur mill, Kansas-Oklahoma line	6.9	3.0	0.03		64.	Treece-Hockerville

TABLE 2 (continued)

Analyses of Water Samples

Source	pH	Total iron p.p.m.	Iron in solution p.p.m.	Acidity p.p.m.	Alkalinity p.p.m.	District
Just below Chubb mill, Kansas-Oklahoma line	7.8	0.14	0.08		168.	Treece-Hockerville

a/ Sometimes called 7th Avenue creek.

Samples taken July 7, 1940

TABLE 3

LABORATORY TESTS ON MINE WATER

Volume mine water a/	Volume river water b/	Iron Precipitation Condition after settling 45 minutes	Percent Fe_2O_3	Precipitate c/ Percent Al_2O_3	Percent insoluble	Percent iron recovered
100	300	Very turbid	77.0	0.00	23.0	29.1
100	500	Turbid ½ settled	76.5	3.5	20.0	57.2
100	600	Turbid 2/3 settled	74.1	3.9	22.0	61.7
100	700	Turbid 3/4 settled	73.0	2.0	25.0	63.5
100	800	Slightly turbid 4/5 settled	75.4	0.0	24.6	70.8
100	1000	Nearly clear 9/10 settled	68.9	4.1	27.0	77.7
100	800	Slightly turbid after 6 hours	72.3	3.7	24.0	73.9
100	1500	Slightly turbid after 6 hours	58.6	9.4	32.0	84.9

a/ Filtered mine water, containing 589 p.p.m. iron.

b/ Contained 26 p.p.m. insoluble matter.

c/ Settled out after 45 minutes except as noted. Actually the precipitate contained $Fe(OH)_3$, $Al(OH)_3$, and insoluble matter. It was burned to give oxides and so weighed. Iron calculated on basis of Fe_2O_3.

STREAM POLLUTION BY MINE WATERS, AND THE RECOVERY OR IRON IN MINE WATERS FROM THE ZINC-LEAD MINES IN SOUTHEASTERN KANSAS

E. D. Kinney

INTRODUCTION

Purpose of investigation.-- The principal function of the Kansas Geological Survey is to promote the mineral industries of the state. In the southeastern Kansas zinc and lead-mining industry, a serious problem confronting operators is the disposal of mine waters that contain large amounts of both acid and iron. The value of production in the Tri-State District is now almost $18,000,000 a year, zinc concentrates constituting 83 percent of this amount and lead concentrates 17 percent. Approximately 27 percent of production in the district is produced in Kansas, and the annual value of zinc and lead production in Kansas is about $4,860,000. Of the Kansas total, $1,000,000 represents the value of the yield from the Baxter Springs area, where the problem of disposal of mine water is acute. The operators in this area are deterred from an increase in ore production by difficulties in disposal of enlarged quantities of acid mine waters. There is undoubtedly a limit to the amount of untreated mine water that can be dumped into surface drainage without danger of harmful effects on the streams. Indeed, damage suits now pending may lead to a curtailment of lead and zinc production in Kansas.

The purpose of the investigation that is here reported was to study two closely connected problems,-- how deleterious features of the mine water can best be reduced or removed, and whether the valuable iron content of the mine waters can be recovered economically. All citizens, including the mine operators, are concerned in safeguarding the quality of surface waters, and this is a special function of the State Water and Sewage Laboratory, which, accordingly, is also deeply interested in the problem of mine-water disposal in southeastern Kansas.

Results and Data Obtained

1. Stream samples. Samples were obtained from all streams contaminated by zinc mine water originating or flowing through Kansas and entering Oklahoma. A map has been made showing locations where samples were taken, together with the total iron content, and the pH of each. Included also is the same kind of data for samples collected by the State Water Department, working with the Tri-State Ore Producers' Association. See Map No. 1.

2. Analysis of samples. A table has been made showing analyses of all samples taken. Each analysis gives the following: total iron, iron in solution, total acidity, all in parts per million parts of water, and the pH of samples. See Table No. 1.

3. Laboratory Tests. Tests were made on the efficiency of Spring River water, which is alkaline and neutralizes acid, in precipitating mine water, which is acid. A tabulation of these tests, showing the effects of varying amounts of river water, analyses of precipitated iron mixture, and various other data, is given. In the ratio of ten to one, river water to mine water, the acid of the mine water was neutralized, and 74% of the iron precipitated as hydroxide. More river water will give almost 100% precipitation. See Table No. 2.

4. Iron and acid content of mine water. A map is shown in which the Kansas mining field is divided into three small areas, according to the iron and acid content of mines located in these areas. In the Baxter Springs Area, the mine waters are high in these substances. The Treece-Hockerville Area contains what are probably harmless amounts. The Waco Area ore occurs in

a calcereous gangue. Mine waters from this district give no damaging stream pollution. See Map No. 2.

Discussion of Problems

Iron pyrite is probably responsible for most of the iron and acid present in mine waters. In the presence of water and air, it is converted to iron sulphate, as follows: $FeS_2 + 7\ O + H_2O = FeSO_4 + H_2SO_4$. The zinc ore occurs in Mississipian limestone, which is overlain with Cherokee shale. The basal part of the Cherokee is exposed at places along the belt of outcrop west and north of Spring River, principally in the vicinity of Baxter Springs. The upper workings of some mines in that region show the shale formation. The shale contains pyrite and it is in this area where by far the greatest trouble with mine water is experienced. Alternate working and closing of mines has aggravated this condition. Oxidation occurs when the mines are dewatered; solution occurs when the water rises during shut downs.

Mines in the Treece and Waco areas contain no great amount of objectionable impurities, and will not be discussed.

The following is a list of more prominent mines in the Baxter area, together with analyses and other data:

Name of Mine	Direction from Baxter Spgs.	Water (gals.) Pumped per 24 hrs.	Analyses Iron P P M	Analyses Acid P P M	Where Mine Water Flows
Brewster & Bilharz	West		5000-6000	8370	Willow Creek to Spring River
Ebenstein	West		5000-6000	As Reported by O.W. Bilharz	Willow Creek to Spring River
Homestake	West		5000-6000	As Reported by O.W. Bilharz	Willow Creek to Spring River
Leopard	West		2500-3000	As Reported by O.W. Bilharz	Willow Creek to Spring River
Liza Jane	West		2500-3000	As Reported by O.W. Bilharz	Willow Creek to Spring River
Hartley	S.West		2000-2500	As Reported by O.W. Bilharz	7th Ave. Creek (Spring Creek) to Spring River
Ballard St. Louis Mining Co.	S.West	2,800,000	1050	4100	7th Ave. Creek (Spring Creek) to Spring River
Opperman	South	1,500,000 (estimated)	350	860	7th Ave. Creek (Spring Creek) to Spring River

The Sunflower (old Euterpe), Iron Mountain, and Peru mines lie in the extreme southwest border of this area. They are high in iron and acid, but make little water. The very small amount of water that may be occasionally pumped flows to the west, eventually reaching the Neosho River. Only the Sunflower is operating now and there is no mine water problem at the present time.

At the time the field work of this investigation was made, from June 16 to July 16, 1940, the Ballard mine of the Baxter Springs Area was pumping and had been doing so for several years. The Opperman mine started pumping July 7, 1940, but its water is not included in the laboratory tests.

There are several variables in the problem of mine water disposal. Both the volume of mine water and its composition can change, depending on how many and what mines are pumping. Mines are more or less connected by underground water courses. Continuous pumping at the Ballard has lowered the water somewhat in the other mines.

It is said that if the mines were once dewatered the total daily pumping required to keep them in this condition would be between 2,000,000 and 3,000,000 gallons. However, most of the mines have been idle for some time and must be dewatered before mining can be resumed. It is estimated that steady pumping at all these mines would do this in three months. Such a campaign would raise the daily output by 7,000,000 gallons, to a total of 10,000,000 gallons, and place an excessive burden on any treating plant during this time. A plant requires constant feed. It would be better to pump this excess mine water out at a lower rate and take more time doing it. For instance, if twelve months were taken, the extra water from this source would amount to only 1,750,000 galls daily. This added to the other 3,000,000 would make 4,750,000, an amount which a treating plant might handle.

The Ballard mine water reaching the river now has the following composition: Total iron 465 P P M; Acidity 1540. This water would deposit approximately six tons of iron in the river daily, except that some 50% of the iron is being settled out along the way by settling ponds constructed by the St. Louis Mining Company. In this system there are two shallow ponds of several acres, each alternating with shallow canals through which the mine water passes. A ton of lime is added daily also. This part of the drainage is one mile long. The water then passes into a creek bed and without dilution finds its way to Spring River. The total distance is about four miles. The following analyses show results in this settling system:

Ballard Mine Water Treating System

	Acid	Iron Solution	Separated	pH
	PPM	PPM	PPM	
Water as discharged from mine	4100	980	70	2.65
At 1/2 mile & through one pond	4290	950	50	2.45
At 3/4 mile and after having lime added (1 ton daily) & passing through second pond	4220	860	40	2.40
* Water as it enters the river	1540	440	25	2.45

* This is the water utilized in our tests.

The reactions causing the iron to settle out are as follows:

$$Fe_2(SO_4)_3 + 6H_2O = \underline{2Fe(OH)_3} + 3H_2SO_4$$

$$FeSO_4 + 2H_2O = \underline{Fe(OH)_2} + H_2SO_4$$

$$Fe(OH)_2 + H_2O + 1/2O_2 = \underline{Fe(OH)_3}$$

Iron hydrolyses best in neutral solutions, the ferric being more active. Iron in the ferrous condition is difficult to oxidize and precipitate. The bottoms of ponds and canals are covered with two to four inches of iron deposits.

Assuming 500 P P M iron and 10,000,000 gallons daily reaching the river, the iron would amount to about 21 tons, or actually twice that amount of iron hydroxide. The same figure would obtain with 1000 P P M iron and 5,000,000 gallons daily. The latter figure might represent what conditions would be if the district should have a fair increase in production. It should be remembered that most of the mine waters have a higher iron content than the Ballard. On the other hand, it might be expected that after pumping out long standing mine water, the water subsequently would be lower in iron. The greater the volume of mine water, especially if high in impurities, the greater the amount of river water needed and the larger the settling capacity required for the iron. It is the mechanical features necessary in treating such large volumes of mine water that create a problem. The chemical phase of the matter can be considered as settled. The following analyses show well how thoroughly is the removal of iron in solution when mine water reaches the river.

	pH	Total Iron	Iron in Solution	Acidity	Alkalinity
		PPM	PPM	P.P.M.	P.P.M.
Spring River water. . . .	7.55	0.77	0.12		102
Ballard mine water in 7th Ave. Creek, just <u>before</u> reaching Spring River	2.45	465.	440.	1540.	0
Mouth of 7th Ave. Creek and Spring River.	7.05	8.1	0.1		94
60 yards below mouth of 7th Ave. Creek in Spring River.	8.2	8.0	0.06		94
One-fourth mile below mouth of 7th Ave. Creek.	7.4	3.8	0.07		84
Three miles south in Oklahoma.	6.85	0.68	0.31		64

The necessity for some system for purification of mine water is of vital importance to the zinc mining industry of the Baxter Springs area. The St. Louis Mining Company, by reason of being the most active producer in the district, has been the object of a number of law suits. These have been instituted by farmers, fish and game associations, and municipalities, all in the State of Oklahoma. Spring River flows into that State a few miles below Baxter Springs. It is contended that river water contaminated by mine water is injurious to fish, livestock, crops, and unfit for human consumption. Most of the suits have been compromised out of court. Regardless of the merits of these claims, the Kansas operators are in a vulnerable position and actually afraid to discharge additional mine water into the river for fear of consequences. As a result, production in Kansas is lower than it normally would be if this condition did not exist.

Other conditions bearing on this problem are as follows. The Empire District Electric Company operates a hydroelectric plant at Riverton, several miles above Baxter Springs, on Spring River. Water is impounded behind a dam and released through turbines once a day to help generate the peak load of electric output. As a consequence, the water at Baxter Springs rises one and a half feet in the course of an hour and stays at the new level two or three hours. This suddðn onrush of water is said to scour the river bed, raising iron hydroxide which has settled. This statement is probably somewhat true. In any event, the sudden flow of water does no good.

Maximum and minimum water flow in Spring River is of importance in considering the use of this water. Shoal Creek is a tributary of Spring River above Baxter Springs.

*Spring River above Shoal Creek, period April, 1924, to September, 1933:

Max. discharge	57,400	second-feet,	Aug. 17, 1927
Min. "	22	"	"	Sept. 8, 1925

*Shoal Creek, same period:

Max. discharge	17,200	second-feet,	Jan. 21, 1932
Min. "	8	"	"	Oct. 9, 1931.

Assuming the combined minimum is 30 second-feet: 30 x 7.5 x 60 x 60 x 24 = 19,444,000 gallons daily. This would suffice to precipitate the iron from only 2,000,000 gallons of mine water, but of course such a condition of low water is very unusual.

Undiluted mine water will kill fish quickly. However, no dead fish were observed in Spring River below where the mine water is added; although numerous live fish were observed. It is claimed iron hydroxide settles on the bottom of the streams, destroying spawning beds. It is also said to get in the gills of fish and do damage.

Suggested methods for settling iron hydroxide, and recovering iron are:

A. Settling in a slough.

B. Settling in Spring River.

C. Settling in a Dorr Thickener, followed by filtration of thickened pulp, using a continuous filter of the drum type.

A. This idea was conceived by Mr. H. H. Utley, manager of the St. Louis Smelting & Refining Company (Ballard mine). Mr. Utley has been most active in the work of mine water disposal and has spent much time and money on the problem. Whether other

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*From Bulletin 24, page 17, Kansas State Geological Survey operators are cooperating financially is not known. There is a slough one mile long which parallels Spring River on the east across the river from Baxter Springs, where mine water is now discharged. An abandoned concrete railroad bridge crosses the river at this point. The plan involved daming the river above to force a certain amount of river water into the slough. A dam would be required at the lower end of the slough also to control the flow where the slough contacts the river again. River water mixed with mine water would cause the iron to be precipitated and settle in the slough. This plan was temporarily discarded when a survey showed the bed of the slough to be of about the same elevation or above that of the river bed. An engineer estimated the cost of the project; excavation, dams, conduits for carrying mine water across the river, etc., to be $80,000. In view of other developments, this plan should not be abandoned without further consideration. For full details and estimated cost, see Map No. 3.

B. A later plan, also by Mr. Utley, involved building a dam approximately 225 feet by 6 feet across Spring River two miles below where mine water enters, and settling the iron out in still water behind the dam. This assumes that clear water would pass over the dam under normal river conditions. Iron sludge would be pumped from behind the dam to the river bank, filtered, and prepared for market. There is some question as to just how effective such a plan might prove. Still water would prevail for one mile behind the dam and the iron might settle over a wide area, not just behind the dam. Iron sludge collection would probably not be very efficient, at least until a sizeable deposit had built up in the river bed, and even then the iron might be lost over the dam in times of high water. It would be necessary to construct a six foot wall on the river bottom running diagonally up the river from a point on the dam located three-fourths of the way along its length to deflect the iron precipitate so it would settle behind the dam on the other side of the river. A lift gate in the dam near the end of the first mentioned side would be necessary in order to lower the water level, without disturbing settled out iron, when it was desired to pump same. Most of the iron would probably settle behind the dam except in high water periods, but its recovery would very likely present some problems. In any event, Mr. Boyce, Director of the State Water Department, is opposed to the plan as outlined. He believes the Kansas Fish and Game Commission would object to any dam which would prevent the free movement of fish up and down the river. Evidently fish ladders are not considered effective in this particular case. A road could easily be built to this location.

C. Precipitating the iron in a thickener with river water and filtering the thickened sludge on a continuous filter would represent the ideal engineering method of procedure. Here, however, we are handicapped with the necessity of handling a very large volume of mine and river water, possibly 5,000,000 gallons of the former and 50,000,000 to 70,000,000 gallons of the latter daily. The amount of solid to be settled would be small, possibly 40 tons daily, but individual particles of iron hydroxide probably require a settling period of one hour, a condition which limits the amount of feed which could be handled without going into very large sized units or a series of smaller units.

It should be recalled that mine water is coming to the river now by way of 7th Avenue Creek. Other mines, not operating now, discharge through Willow Creek. These creeks are one-half mile apart at the river. If a treating plant were erected, it would be necessary to receive mine water from one stream only. It might be possible to divert the flow of Willow Creek into the 7th Avenue Creek. There is probably enough ground available for a treating plant at the mount of either stream.

Conclusions

So far as the chemical phase of this problem is concerned, alkaline river water has proved a good medium for purifying mine water. Also, considering the volume of water to be treated and the cost of other precipitants, this is the only reagent which can be satisfactorily employed. We still face the problem of determining what kind of reservoir or tank should be used in the purification in order that the precipitated iron can be removed from circulation and prepared for market.

The various schemes proposed have been discussed in the foregoing pages. Until further information is received from manufacturers of settling equipment, and until plants in operation have been visited, no recommendations can be made.

A market for iron which might be recovered from mine waters has apparently been found close at hand. There are several large cement plants in southeastern Kansas. Additional amounts of iron are required by these plants in the new type of cement now being made. The amount is said to be 2% of the weight of the cement. So far as is known there is no good iron ore available anywhere near the cement manufacturing area. At present, pyrite cinder is being shipped from St. Louis to the cement plants. The cinder results from the roasting of pyritic concentrates to obtain sulphur dioxide, the latter being utilized in the manufacture of sulphuric acid. This matter of the sale of iron would require further investigation as to prices, etc., but for the present the cement concerns indicate they will have constant use for iron ore.

Acknowledgements.

The following individuals have given great help and cooperation in this report:

Mr. Ernest Boyce, Director, Division of Sanitation, State Board of Health, Lawrence, Kansas, who furnished all analyses.

Mr. H. H. Utley, Manager of the St. Louis Smelting & Refining Company, Baxter Springs, Kansas.

Mr. O. W. Bilharz, Bilharz Mining Company, Baxter Springs, Ks.

Mr. Frank C. Brewster, Baxter Springs, Kansas.

Mr. Evan Just, Secretary, Tri-State Ore Producers' Association, Miami, Oklahoma.

Mr. Chester Scott, Federal Mining Company, Baxter Springs, Ks.

Mr. James L. Smith, Baxter Chat Company, Baxter Springs, Ks.

Analyses of Water Samples - TABLE No. 1

Bottle No.	Source	pH	Total Iron	Iron in Solution	Acidity	Alkalinity	District
C78) 748)	100 yds. from mouth of Spring Creek*	2.45	465.	440.	1540.		Baxter Springs
C40) S69)	15' up from mouth of Spring Creek in Spring River	7.55	0.77	0.12		102.	Baxter
602) 667)	Mouth Spring Creek " " "	7.05	8.1	0.1		94.	Baxter Springs
C33) 560)	60 yds. below mouth of Spring Creek in Spring River	8.2	8.0	0.06		94.	Baxter Springs
Y44) 101)	Same as sample 748 and C78 after spring River had risen and filled creek bed to this point. Spring Creek 100 yds. from mouth	3.7	25.	3.3	68.		Baxter Springs
L47) W77)	1/4 mi. below Spring Creek in Spring River. Above sewer	7.4	3.8	0.07		84.	Baxter Springs
C1) 385)	End of launder. 60 yds. from mine pump. St. Louis Min. Co.	2.65	1050.	980.	4100.		Baxter (Ballard mine)
B79) W96)	Just above lime plant 4:45 p.m. St. Louis Min. Co. 100°F. in shade.	2.45	1000.	950.	4290.		Baxter (Ballard mine)
R31) 89)	3 mi. south Baxter Springs on Spring River	6.85	0.68	0.31		64.	N. E. Okla.
961) 362)	3/4 mi. from mine. St. Louis Min. Co. Spring Creek 7-10-40 10:35 a.m.	2.40	900.	860.	4220.		Baxter (Ballard mine)

*Sometimes called 7th Avenue Creek.

Analyses of Water Samples - TABLE No. 1
(continued)

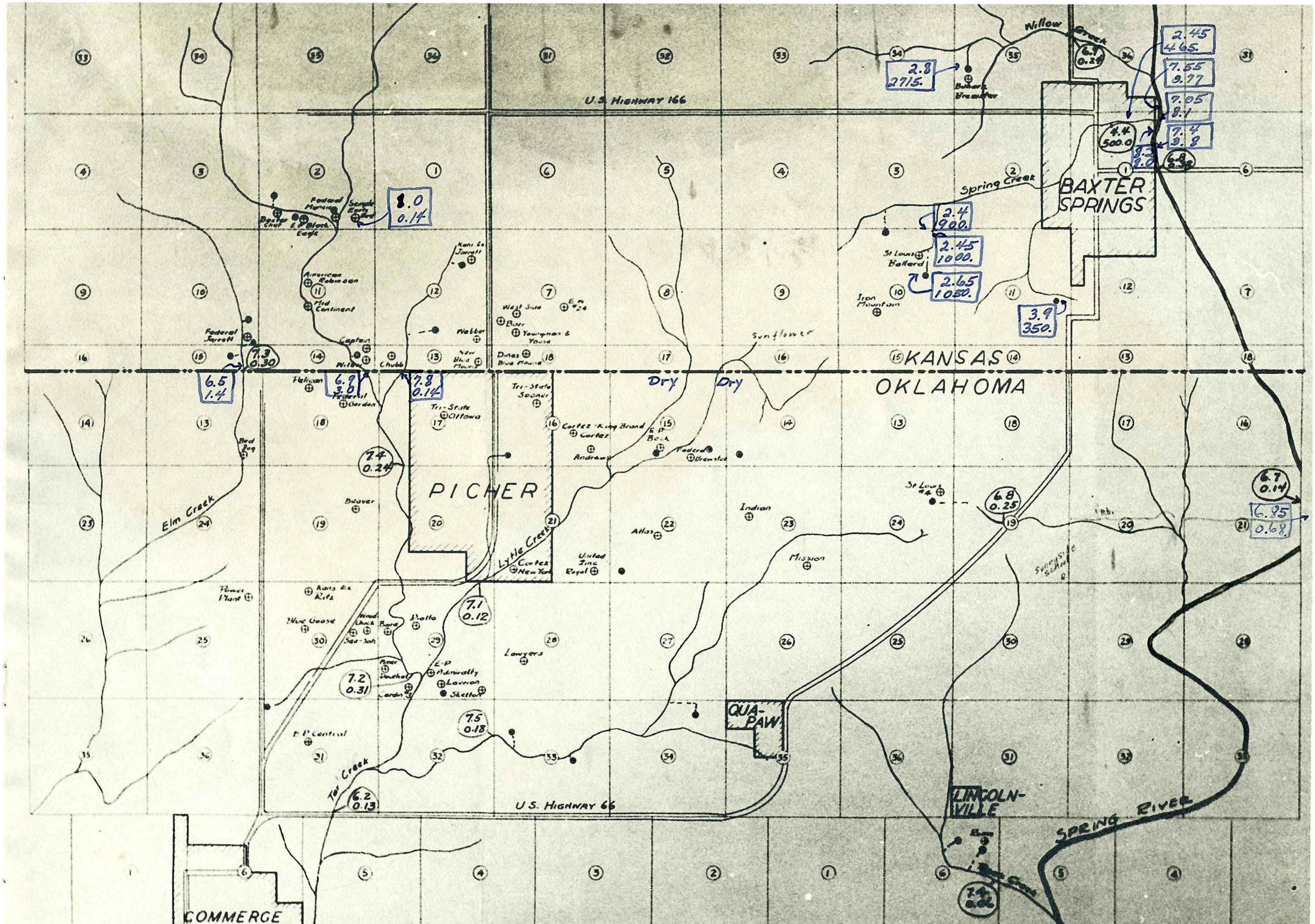
Bottle No.	Source	pH	Total Iron	Iron in Solution	Acidity	Alka-linity	District
218) N7)	Opperman mine. Baxter Springs (Was a lot of CO_2 in this?)	3.9	350.	240.	860.		Baxter Springs
209) H95)	Brewster mine. Baxter Coll. 7-1-40	2.8	2715.	2600.	8370.		Baxter Springs
680) 997)	Just below Federal Jarrett Mill. Kansas.-Okla. line. Sec. 15	6.5	1.4	0.04		30.	Treece-Hocker-ville
267) 33)	Semple Early Bird tailings mill stream	8.0	0.14	0.04		34.	Treece-Hocker-ville
149) 872)	Just below Wilbur mill. Kans.- Okla. line	6.9	3.0	0.03		64.	Treece-Hocker-ville
H241) Y24)	Just below Chubb mill. Kans.-Okla. Line	7.8	0.14	0.08		168.	Treece-Hocker-ville

Laboratory Tests - TABLE No. 2.

No.	Amount Mine Water*	Amount River Water	Condition Settling 45 min.	Precipitate** Total Weight (grams)	% Fe_2O_3	% Al_2O_3	% in-soluble	% Iron Recovered From Mine Water	Remarks
1.	100 CC	300 CC	very turbid	0.0315	77.0	0	23.0	29.1	Actually the precipitate contained $Fe(OH)_3$, $Al(OH)_3$ and insoluble. It was burned to give oxides, and so weighed. Iron calculated on basis of Fe_2O_3.
2.	100 CC	500 CC	turbid 1/2 settled	0.063	76.5	3.5	20.0	57.2	
3.	100 CC	600 CC	turbid 3/4 settled	0.070	74.1	3.9	22.0	61.7	
4.	100 CC	700 CC	turbid 3/4 settled	0.073	73.0	2.0	25.0	63.5	
5.	100 CC	800 CC	sl. turbid 4/5 settled	.079	75.4	N.1	24.6	70.8	
6.	100 CC	1000 CC	quite clear 9/10 settled	.095	68.9	4.1	27.0	77.7	
7.	100 CC	800 CC	sl. turbid after 6 hrs.	.086	72.3	3.7	24.0	73.9	
8.	100 CC	1500 CC	turbid after 6 hrs.	0.122	58.6	9.4	32.0	84.9	
9.	100 CC	None						This contained .0589 gm. iron. Equivalent to 0.0842 gms. Fe_2O_3. Equal to 589 P P M mine water.	

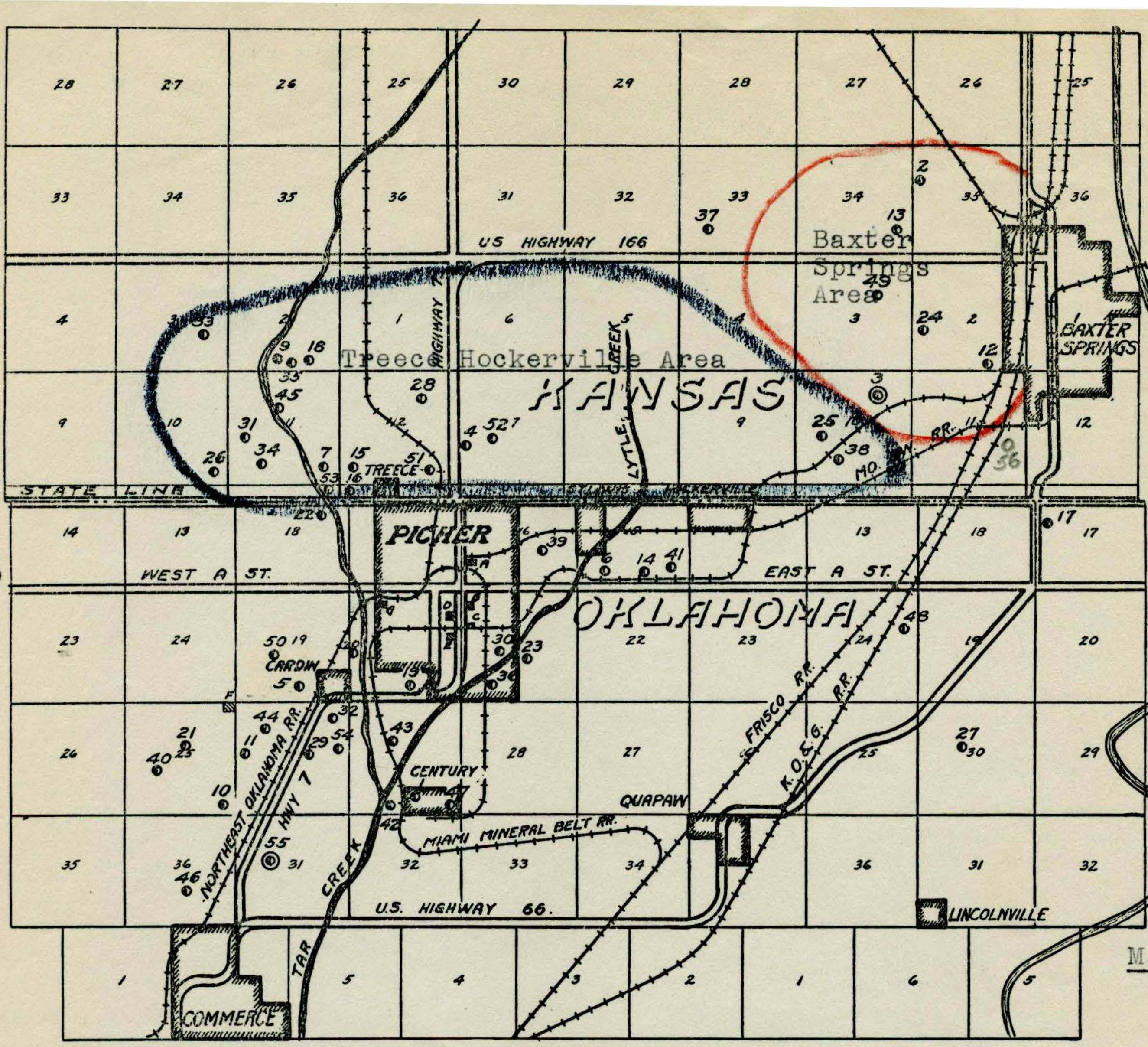
*Filtered mine water.

** Filtered out after 45 min., except as noted.



⊕ Mill ○ Pump

Map No. 1. Key: 7.2 Upper figure pH value
0.4 Lower figure Total Iron P.P.M.
○ Figures circled--samples by State Water Dept. & Tri-State Ore Prod. Assn. June, 1940
▭ Figures in rectangle--samples by State Geological Survey July, 1940.



Map No. 2.

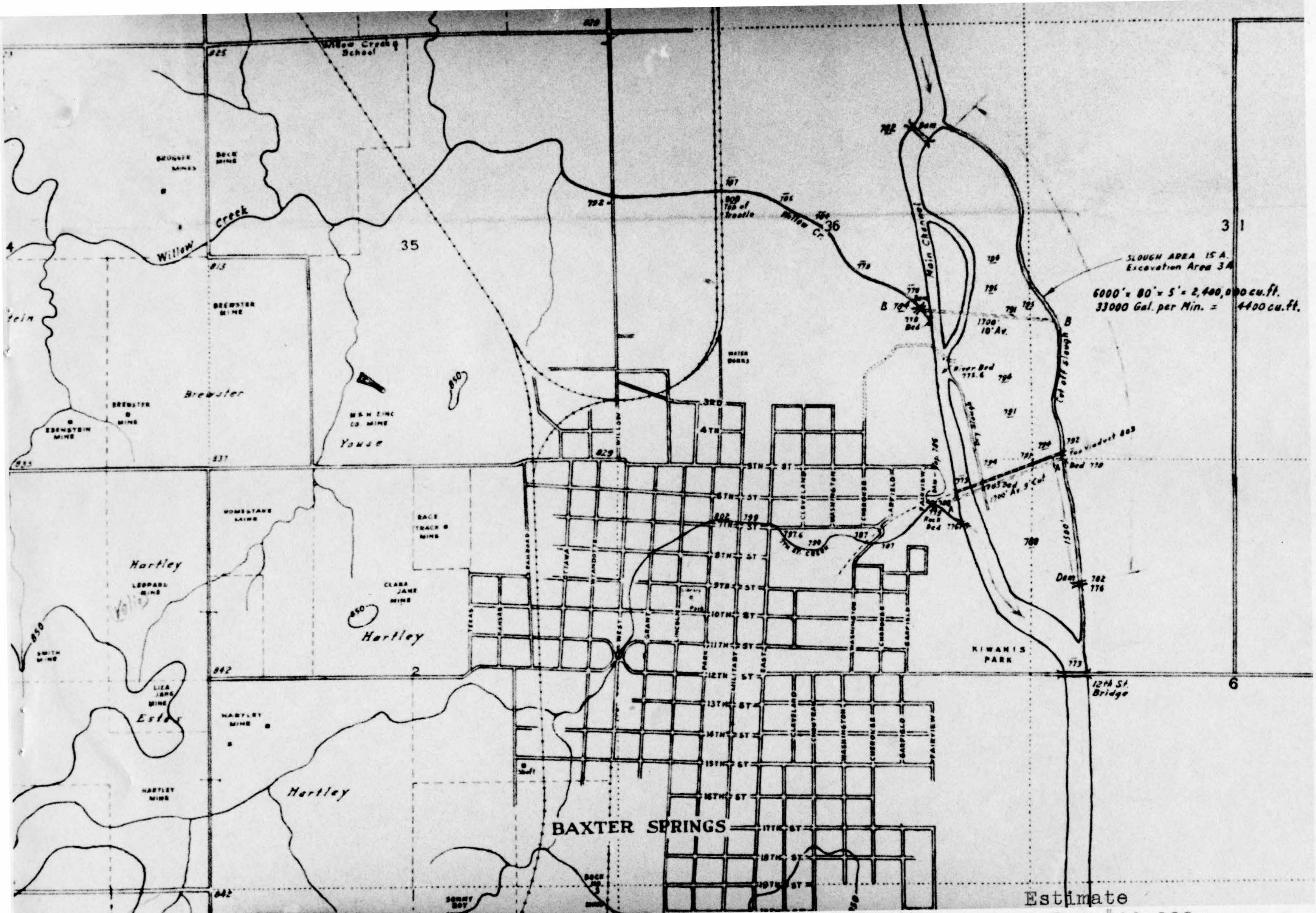
ZINC-LEAD MINES & CONCENTRATING MILLS

The Waco District is 10 miles north of Baxter Springs.

1 Admiralty #3 } Brewster
2 Beck #2 } Bilharz
3 Ballard
4 Barr
5 Beaver
6 Mary M. Beck
7 Bendelari
8 Bird Dog
9 Black Eagle #2
10 Bluebird
11 Blue Goose
12 Beck #3 } Ebenstein
13 Barnsdall } Homestake
14 Brewster
15 Cherokee
16 Chubb
17 Discard
18 Early Bird
19 Evans-Wallower #4
20 Evans-Wallower #7
21 Goodeagle
22 Gordon
23 Grace Walker
24 Hartley
25 Iron Mountain Sunflower
26 Jarrett (Federal M & S Co.)
27 John L
28 Jarrett (Kansas Ex., Inc.)
29 Jay Bird
30 Just Right
31 King Brand
32 Lucky Bill
33 Lucky Jay Hawk
34 Mid-Continent #2
35 Muncie
36 New York
37 Paxton
38 Peru
39 Peru-Laclede
40 Pioneer
41 Rightley
42 Ramage
43 Rialto
44 Ritz
45 Robinson
46 Scammon Hill
47 Skelton #5
48 St. Louis #4
49 Velie Leopard Liza Jane
50 Velie Lion
51 Webber
52 West Side
53 Wilbur
54 Woodchuck
55 Eagle-Picher Central Mill
A Joplin Junction Depots
B U.S. Post Office
C Miami-Mineral Belt Depot
D Picher Hospital
E American Hospital
F 10,000 H.P. Power Plant
G Community High School.
56 The Opperman

INTERESTING INFORMATION ABOUT THE MINING DISTRICT

Shipments of Zinc and Lead Concentrates First Quarter 1934 ------ 74,850 Tons
Value of Combined Zinc and Lead Concentrates First Quarter 1934 -- $2,212,127
Average Number of Men Employed During 1929 --------------- 7,540
Average Number of Men Employed During First Quarter 1934 ----- 4,200
Average Weekly Payroll During 1929 -------------------- $180,960
Average Weekly Payroll During First Quarter 1934 --------- $57,750



Baxter Springs Drainage District
Wm. M. Stewart Engr. Co.
Joplin, Mo.

Map No. 3.

Estimate

Excavation 20,000 cu yd at 1 = $20,000
Masonry Dams 1500 " " " 15 = 22,000
Rip Rap - Retarding Dams 1500 " " " 10 - 15,000
Pipe & Wooden Conduits 3500 ft. = 7,000
Gates, Engr. Supr., other expenses = 16,000
Total = $80,000