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REPORT OF INVESTIGATIONS/1995

Well-Point Containment of Impoundment Leakage

UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES

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Well-Point Containment of Impoundment Leakage

By C. W. Smith

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Metric Units

cm	centimeter	m^3/min	cubic meter per minute
ha	hectare	ppm	part per million
L	liter	rpm	revolution per minute
L/min	liter per minute	µm	micrometer
m	meter		

U.S. Customary Units

f^3/min	cubic foot per minute	in	inch
ft	foot	gal/min	gallon per minute

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ABSTRACT

Research was conducted to evaluate the effectiveness of a well-point dewatering system in conjunction with a french drain to intercept waste impoundment leakage while reducing the volume of waste water requiring treatment. A well-point dewatering system composed of 585 production wells was installed around the perimeter of a leaking impoundment that previously used only a french-drain system for leakage control. The placement of the well-point system was designed to intercept and remove the leakage from the groundwater before the contaminant reached the french drain. Groundwater monitoring at this site revealed that after a period of approximately 40 days the well-point dewatering system had stabilized and effectively prevented the further spread of contamination to the french drain.

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INTRODUCTION

The contamination of soils and groundwater is unfortunately a common problem of many industries, including mining and mineral processing operations. In the United States alone, there are over 1,200 sites on the National Priorities List requiring remediation, with a total estimate of 45,000 contaminated sites (*1*).[2] The protection of groundwater resources and aquifers requires isolation and containment of contaminated soil or water in order to control the migration of contaminants or leachate. The National Contingency Plan identifies containment as "a tactic by which the spread of contaminants can be prevented or minimized by controlling the contamination at or near the area where the hazardous substances were originally located or where hazardous substances have migrated from the area of or near their original location" (*2*). This research furthers the goal of the U.S. Bureau of Mines (USBM) of improving the Nation's environmental quality.

There are numerous containment and leachate control methods in use today; however, each system is dependant on site-specific conditions. Among the more common methods used in controlling contaminate migration are slurry walls, sheet piling, grout curtains, subsurface treatment walls, subsurface or french drains, and well-point systems.

Slurry walls are constructed in trenches that have been excavated down to the bedrock or a stratum of extremely low permeability such as clay. The trench is then filled with a slurry of materials that form an impermeable barrier to confine any contaminated water within the wall and to prevent groundwater penetration from outside the wall. Slurry mixtures are most commonly composed of soil mixed with bentonite. Bentonite absorbs copious quantities of water and expands within the trench to seal the void spaces and prevent the migration of groundwater and other fluids. Other commonly used materials are concrete and concrete-soil-bentonite mixtures (*3*).

Sheet piling uses interlocking wood, concrete, or steel sections that are driven into the ground or placed into pre-dug trenches, with steel being the most commonly used material. Sheet piling is generally used as a temporary containment measure until more durable containment structures can be installed. Sheet piling can be removed and reused, making it a cost-effective method for temporary containment (*4*).

[2]Italic numbers in parentheses refer to items in the list of references at the end of this report.

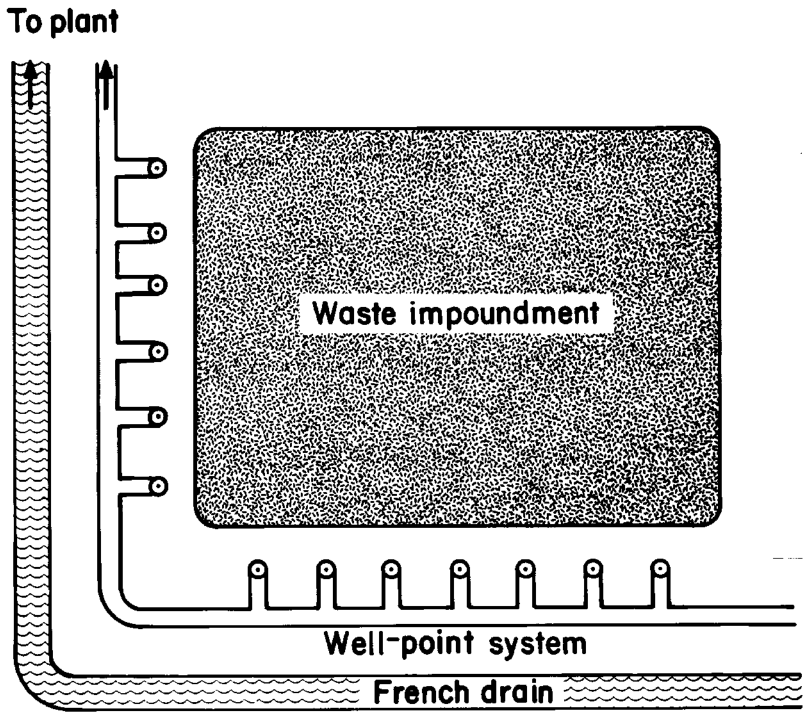
Installation of a grout curtain requires the injection of a grout mixture to fill voids in fractured rock or to consolidate rocky soils. The grout, typically a phenolic resin or portland cement mixture, is injected as a fluid under pressure through holes drilled into the geological strata of the site. Under ideal conditions, the injected fluids fill the gaps in the subsurface matrix and cure to form an impervious, continuous barrier (*4*).

Subsurface or french drains are placed end to end in trenches excavated below groundwater level, and in most cases consist of continuous lengths of perforated pipe. The contaminated groundwater flows under a natural or induced hydraulic gradient to the french drain where it is then intercepted and conveyed to a sump or storage tank prior to waste water treatment. Two major advantages of a french-drain system are the elimination of the hydraulic head that commonly builds up inside a slurry wall or grout curtain, and the removal of contaminated fluids for further treatment. When functioning properly, french-drain systems are a cost-effective containment strategy at shallow depths where the subsurface permeability is high and there is an active hydraulic gradient (*4*).

Well-point systems are another versatile technique used in containing and controlling leachate. This system can be used to alter the water table to facilitate construction, remove leachate for treatment, divert groundwater around a contaminated area, or control the movement of a plume. Well-point systems can consist of one or a series of production wells that intercept and withdraw contaminated fluids from saturated soils that are then pumped to waste water treatment or storage facilities (*3*).

Based on a survey of prospective test sites, a research project was undertaken to determine the effectiveness of a well-point system for capturing impoundment leakage. The test site chosen was a waste impoundment that was leaking acidic waters containing elevated levels of lead and iron. The impoundment was surrounded by a french-drain system that had been installed to contain the leakage. The well-point system was strategically placed between the outer base of the leaching impoundment and the french drain to intercept the contaminated water, allowing the french drain to act as a cut-off mechanism; thus, preventing the encroachment of uncontaminated groundwater. Figure 1 shows the location of the well-point system in relation to the impoundment and french drain.

Figure 1



Location of well-point system and french drain relative to the waste impoundment.

DESCRIPTION OF TEST SITE

The test site under study consists of an impoundment having an areal extent of approximately 7.7 ha (19 acres) and 6.6 m (22 ft) of average depth. The impoundment was constructed in 1976 and used to store iron oxide wastes from a manufacturing process. Compacted clay was used as an interior liner for the bottom and sidewalls to prevent leakage. When leakage was discovered from the impoundment, a french-drain system was installed around the perimeter approximately 2.4 m (8 ft) below ground level in an effort to prevent the spread of contamination into the surrounding area.

Geologically, the impoundment is located in the Coastal Plain physiographic province. Land surface in the area lies at approximately 6 m (20 ft) above mean sea level. The upper 4.5 to 6 m (15 to 20 ft) of the soil consists of unconsolidated alluvial deposits made up of fine-textured silty sands and sandy clays with intermixed organic materials. This unit acts as an unconfined aquifer with a potentiometric surface typically between 1.2 and 2.4 m (4 and 8 ft) below natural ground level. Underlying the alluvial deposits is a clayey stratum extending to a depth of 16.5 to 18 m (55 to 60 ft) below natural ground level. The stratum consists primarily of silt- to clay-sized particles with intermixed organic materials. The transmissivity of this unit is extremely low; thus, it serves as an effective aquitard to prevent the vertical movement of groundwater. Underlying the aquitard is a semiconfined groundwater aquifer consisting of unconsolidated sands. This aquifer is commonly used as a source of water for wells in the area (*4*).

A french-drain system was installed around the perimeter of the impoundment approximately 5 years after the initial construction. The french drain consists of a 15.2-cm-diam (6-in-diam), perforated schedule-40 PVC pipe embedded within a blended bed of filtration gravel in a trench 0.9 m (3 ft) wide. The trench was constructed with a slope of 0.15 to 0.19 pct from the northwest corner of the impoundment pond to the collection sump in the southeast corner. The water is pumped from the sump to the plant for waste water treatment.

Typically, groundwater occurring inboard the french drain has a pH of 2.5 to 2.8 and contains elevated levels of dissolved metals as a result of leakage from the impoundment. The ambient groundwater outside the french drain typically has a pH of 5.5 to 6.0. Calculations show that over 95 pct of the water captured by the french drain is uncontaminated groundwater from outside the drain system. When the waters mix in the french drain, the pH of the inboard water rises, resulting in precipitation of many of the dissolved metals. To prevent clogging of the french drain by the precipitate, frequent cleaning is necessary.

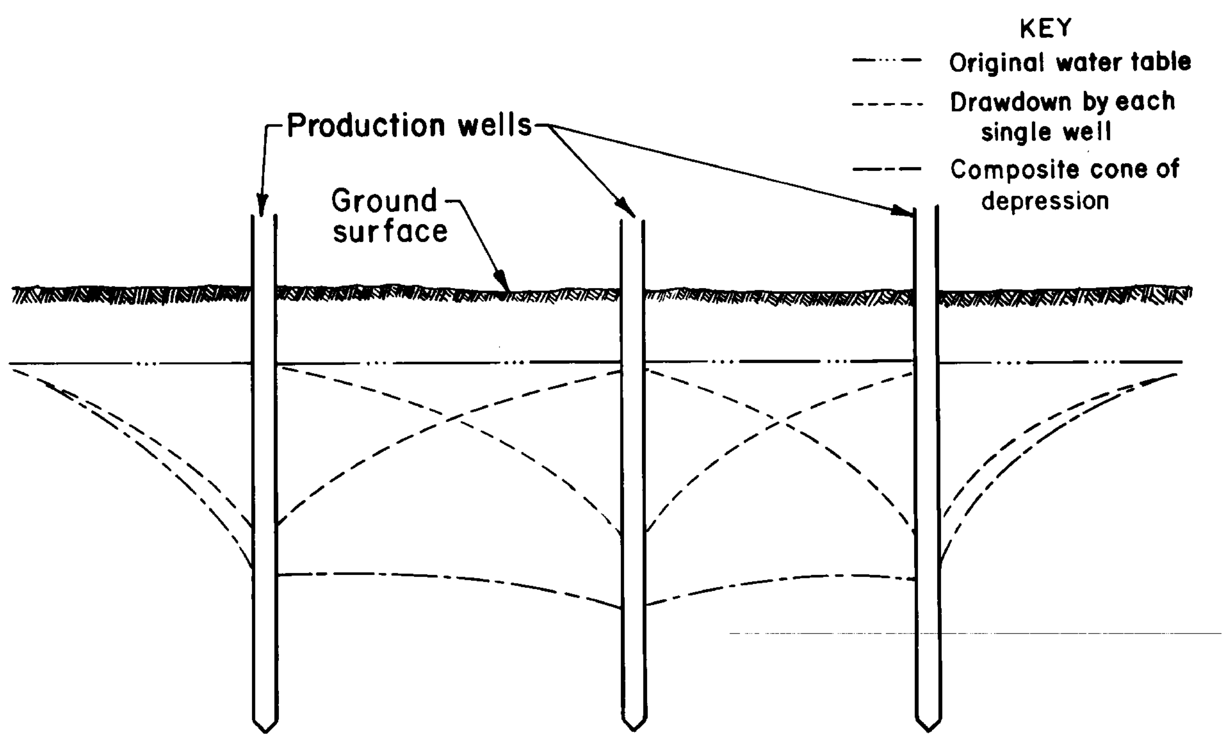
DESCRIPTION OF WELL-POINT SYSTEM

When a well is pumped in a groundwater system the water level in the area of the pumped well is lowered from its normal level, with the greatest drawdown occurring nearest the well. Because the water level is lowest in the vicinity of the well, water flows to the well from every direction to replace the water being withdrawn. This movement of water creates a cone of depression in the water table surrounding the well as shown in figure 2. Each cone differs in size and shape depending upon the pumping rate, pumping duration, aquifer characteristics, slope of the ambient water table, and recharge within the cone of depression of the well.

Well-point systems are groups of closely spaced wells that are usually connected to a header pipe or manifold and pumped by suction lift. During operation a central pump creates a vacuum in the system that lifts water from each well by producing a partial vacuum in the header and riser pipes. The partial vacuum, or suction lift, that the pump can maintain determines the drawdown that can be obtained in the water-bearing formation. In theory, suction lifts of up to 8.7 m (28.5 ft) can be attained at sea level. In practice; however, suction lifts of only 6.6 to 8.1 m (22 to 27 ft) can be attained due to frictional and other losses in the pump and piping system.

The diameter of well points used in dewatering systems is usually 3.7 or 5 cm (1.5 or 2 in), yielding maximum flows of 37.8 to 94.5 L/min (10 to 25 gal/min). Points are typically spaced 0.9 to 3.6 m (3 to 12 ft) apart depending

Figure 2



Composite cone of depression formed by interference among three wells.

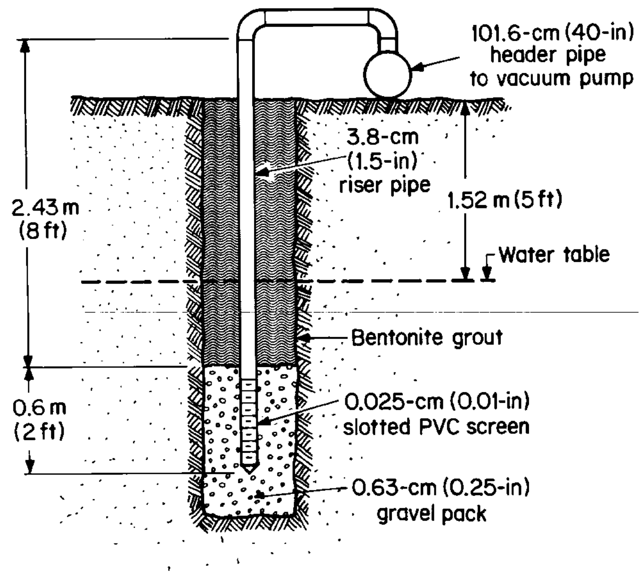
on the transmissivity of the saturated formation, the depth to which the water must be lowered, and the depth to which the wells can be installed in the water-bearing formation. In general, closer spacings are required in finer-grained soils (*6*).

Lowering the groundwater level at a site using a well-point system involves creating a composite cone of depression. The wells must be spaced close enough that the cones of depression overlap with each other and thus pull the water table down a certain distance at intermediate points between wells. Figure 2 illustrates how the overlapping areas of influence around three wells produce an enhanced drawdown of the water table. The water table will remain at this level as long as pumping continues and hydraulic equilibrium is maintained.

A single well-point installation of the type used in this study is shown in figure 3. In each installation, a 19-cm-diam (7.5-in-diam) hole was drilled to a depth of 3 m (10 ft) using a hollow-stem auger drill. A 3.7-cm-diam (1.5-in-diam) schedule-40 PVC riser pipe fitted with a 0.6-m (2-ft) section of 0.025-cm (0.010-in), slotted PVC well screen was lowered into each hole. The annulus surrounding the well screen was backfilled with 0.62-cm-diam (0.25-in-diam) quartz pebble. The remainder of the hole was filled with bentonite to form an airtight seal in the zone above the well screen to the ground surface. The wells were spaced approximately 1.5 m (5 ft) on centers. The top of each riser pipe was connected to a common 10.1-cm-diam (4-in-diam) PVC header pipe that was routed to a vacuum pump. The vertical riser pipe in each installation was adjusted to the same elevation to ensure equal suction lifts and to minimize short circuiting of the vacuum system.

The well-point system was installed in two stages. Initially, a series of 235 well points was placed along the northern side of the impoundment. Based on the preliminary results obtained along this side, the decision was made to extend the system around the eastern and

Figure 3



Design details of each well-point installation.

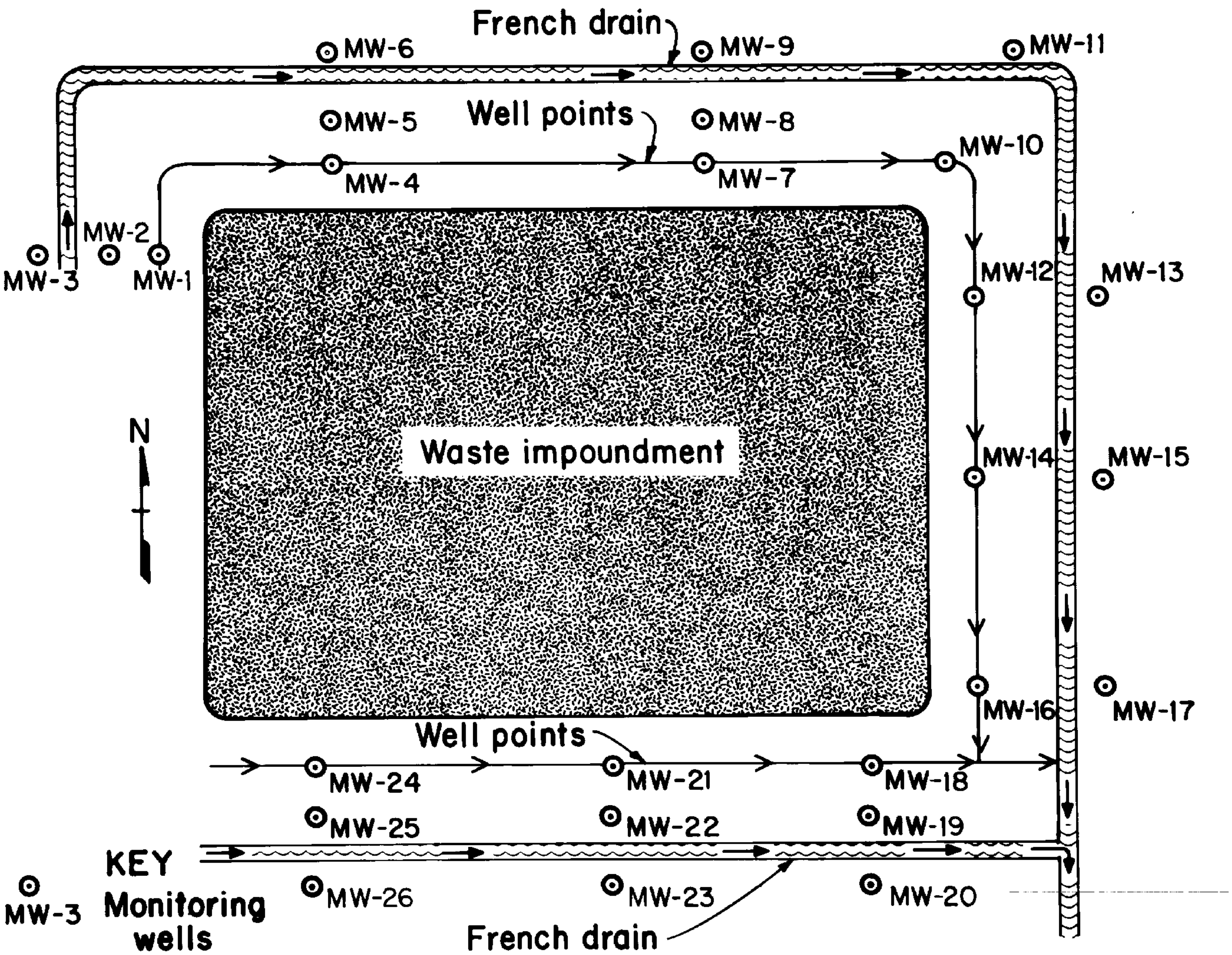
southern sides. The completed system contained 585 well points and nearly 1,524 m (5,000 ft) of 10.1-cm (4-in) header pipe. Each side of the system was plumbed separately and operated independently.

Removal of the groundwater was achieved using a high-capacity vacuum centrifugal pump. The vacuum pump was of the oil-seal type having a total displacement of 1.75 m^3/ min (60 f^3/min). At 1,460 rpm, rated water capacity was 456 L/min (120 gal/min) at a total discharge head of 9.4 m (31 ft). Discharge from the pump was routed to the french-drain sump for transfer to the waste water treatment facility.

GROUNDWATER MONITORING

A series of monitoring wells was installed to determine the effectiveness of the well-point dewatering system. The monitoring wells were placed in groups of three in a line running perpendicular to the impoundment dike and french drain. Figure 4 shows the general layout of the well-point dewatering system and the location of each of the monitoring wells. For each group of three wells the first well was placed within the area between the line of well points and the leaking impoundment, the second was placed between the well points and french drain, and the third was placed outside the perimeter of the french drain. Each monitoring well consisted of a 3-m (10-ft) length of 5-cm (2-in) well screen with 0.025-cm (0.010-in) slots connected to a 5-cm (2-in) PVC casing. Each well was

Figure 4



Location of monitoring wells in relation to the well-point system and french drain.

lowered into a 19-cm-diam (7.5-in-diam) hole and the annulus was filled with 0.62-cm (0.25-in) washed quartz pebble to the top of the well screen. The remainder of the hole was filled to ground level with bentonite. Table 1 summarizes the installation data and other information for each monitoring well.

Samples were collected periodically from each of the monitoring wells to determine the effectiveness of the well-point system for containing the migration of groundwater contaminants. Samples were collected using a 5-cm-diam (2-in-diam) teflon bailer. Prior to sampling, each well was purged by bailing at least 5 well volumes from the well. The samples were then collected and filtered through a 0.45-µm cellulose nitrate filter to remove suspended particulates. The samples were then treated to adjust the pH to less than 2.0 with nitric acid for preservation. Each sample was analyzed for dissolved metals with primary attention being focused on lead analyses.

Table 1.—Monitoring-well data, m (ft)

Monitor well	Depth of well from casing top		Height of casing top		Elevation of casing top, MSL	
1	5.22	(17.42)	0.33	(1.11)	6.10	(20.35)
2	5.12	(17.08)	0.49	(1.65)	6.32	(21.09)
3	5.12	(17.08)	0.49	(1.64)	6.31	(21.05)
4	5.07	(16.92)	0.48	(1.61)	6.35	(21.19)
5	5.19	(17.33)	0.47	(1.59)	6.20	(20.68)
6	5.37	(17.92)	0.88	(2.96)	6.75	(22.50)
7	4.80	(16.00)	0.02	(0.70)	6.08	(20.27)
8	4.92	(16.42)	0.64	(2.15)	6.33	(21.12)
9	3.87	(12.92)	1.02	(3.42)	6.63	(22.13)
10	4.20	(14.00)	0.36	(1.22)	6.04	(20.15)
11	4.22	(14.08)	0.76	(2.56)	6.72	(22.43)
12	4.20	(14.00)	0.49	(1.66)	6.45	(21.53)
13	4.14	(13.83)	0.44	(1.48)	6.14	(20.47)
14	4.37	(14.58)	0.57	(1.92)	6.65	(22.19)
15	3.65	(12.17)	0.54	(1.83)	6.49	(21.66)
16	4.50	(15.00)	0.67	(2.26)	6.72	(22.41)
17	5.45	(18.17)	0.71	(2.39)	6.36	(21.23)
18	5.49	(18.33)	0.55	(1.86)	6.64	(22.14)
19	5.30	(17.67)	0.82	(2.76)	6.34	(21.14)
20	5.07	(16.92)	0.77	(2.58)	6.56	(21.87)
21	5.27	(17.58)	0.63	(2.12)	6.77	(22.58)
22	5.34	(17.83)	0.82	(2.76)	6.68	(22.27)
23	3.60	(12.00)	0.66	(2.20)	6.44	(21.49)
24	5.52	(18.42)	0.54	(1.80)	6.71	(22.39)
25	5.37	(17.92)	0.75	(2.53)	6.73	(22.45)
26	6.05	(20.17)	0.83	(2.79)	6.69	(22.32)

MSL Mean sea level.

DISCUSSION OF TEST RESULTS

As previously stated the well-point system was installed in two stages, the first stage being along the northern side of the impoundment while the second stage of production wells was installed along the eastern and southern extremity. Table 2 gives the lead analyses over a 131-day period from the monitoring wells (Nos. 1, 4, and 7) located in the vicinity of the string of well points along the northern side of the impoundment. Figure 5 shows the data in graphic form. In each case, once pumping was initiated lead levels began to fluctuate. In the initial stages of pumping, lead analyses showed some variations as the local hydrology in the area of the well points was changing and a composite cone of depression was being developed. After approximately 40 days of pumping, lead levels stabilized, indicating that steady state conditions had been established. At this point a "trough" of depression had been established along the line of well points; thus, capturing fluids leaking from the impoundment.

Table 2.—Lead analyses, ppm, for monitoring wells located in vicinity of the northern string of well points

Days from start	Well 1	Well 4	Well 7
0	39.40	41.67	35.67
8	40.06	42.92	39.78
15	43.90	48.84	37.63
37	44.69	42.07	38.90
43	42.89	44.47	39.80
52	44.62	45.10	40.48
80	44.97	44.85	40.21
105	44.10	45.25	39.92
131	44.25	45.10	40.54

Table 3 gives the lead analyses for the monitoring wells (Nos. 2, 5, and 8) located between the well points and french drain for the same time period. Figure 6 shows the data in graphic form. In each case, once pumping was initiated, lead levels began to decline, which suggests the influx of uncontaminated groundwater. Once again, after a period of approximately 40 days, lead levels reached a somewhat steady state indicating that leakage from the impoundment had been effectively intercepted by the well-point dewatering system. Even after 40 days, a gradual decline in lead levels can be noted. As time progresses, lead levels will continue to decline as further contamination is flushed from the area by rainfall events. With the interception of impoundment leakage and the gradual decontamination of soils outside the well-point system, clogging problems with the french drain will decrease. During the test period, pH of the fluids captured by the french drain rose from a low of 2.8 prior to pumping to a high of 3.7 at the end of 140 days. Once decontamination of the area is complete, the 855 L/min (225 gal/min) of fluids captured by the french drain will no longer require waste water treatment. Figure 7 illustrates steady-state groundwater conditions established after approximately 40 days of pumping.

Table 3.—Lead analyses, ppm, for monitoring wells located between northern string of well points and the french drain

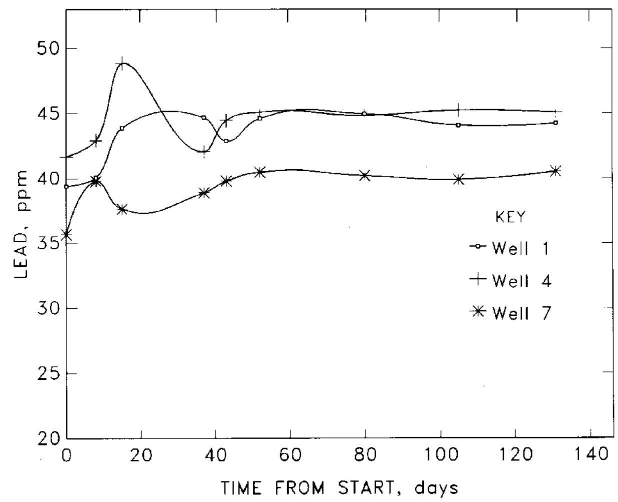
Days from start	Well 2	Well 5	Well 8
0	36.42	26.01	24.96
8	34.05	22.82	19.85
15	29.91	21.37	16.76
37	28.95	21.21	12.15
43	28.28	20.76	12.36
52	28.89	21.30	11.86
80	28.10	20.90	11.82
105	28.35	21.43	11.98
131	27.84	21.06	11.42

Table 4 gives the lead analyses for the same time period for the monitoring wells outside the french-drain system. Removal of groundwater by the well-point system appeared to have no effect on lead concentrations outside the french drain. The slight variations in lead analyses noted between sampling periods were attributed to analytical error and rainfall events.

Table 4.—Lead analyses, ppm, for monitoring wells located outside the french drain

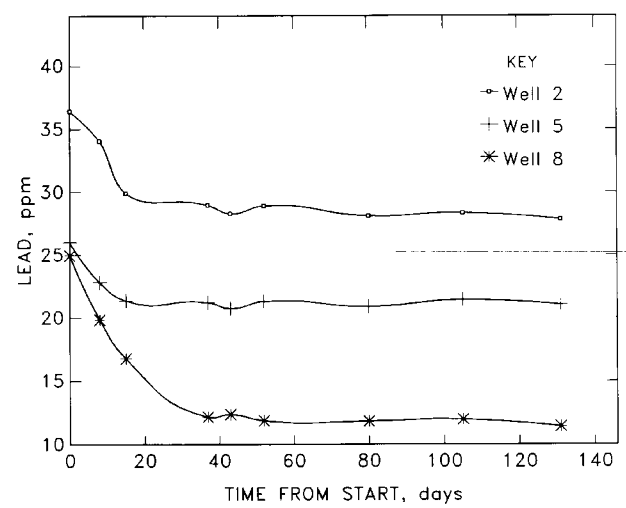
Days from start	Well 3	Well 6	Well 9
0	0.00	4.34	0.48
8	0.03	3.61	0.10
15	0.13	1.46	0.19
37	0.22	3.55	0.65
43	0.00	0.56	0.05
52	0.10	3.62	0.04
80	0.05	3.42	0.15
105	0.10	3.05	0.22
131	0.06	3.65	0.08

Figure 5



Lead analyses versus time for monitoring wells located in the line of well points.

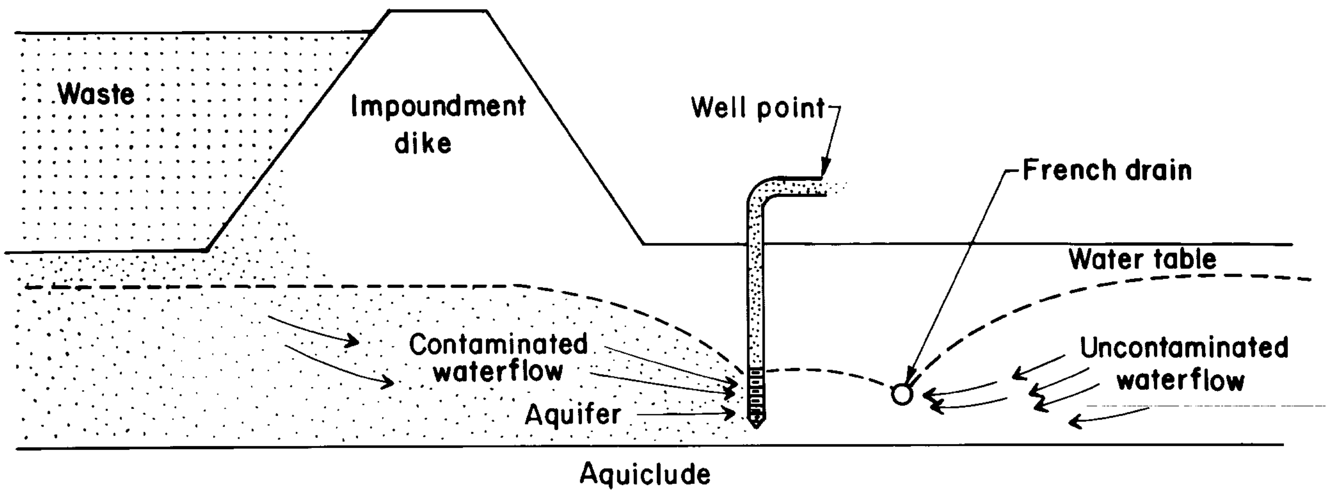
Figure 6



Lead analyses versus time for monitoring wells located between the well points and french drain.

Based on preliminary results obtained in the first stage, the decision was made by the cooperating company to extend the well-point system around the eastern and southern sides of the impoundment. The continuation of the system was identical to the first stage and a similar

Figure 7



Steady state groundwater conditions after 40 days of pumping.

monitoring network was installed. Due to the corrosive nature of the waste water and wear of the pump, extensive maintenance was required. In addition, time limitations for the USBM's involvement with the project made it necessary to terminate the study before the full effectiveness of the system extension could be evaluated. However, the well-point system continues to be operated by the cooperating company and has been incorporated in the long-term containment strategy for the impoundment.

CONCLUSIONS

The well-point dewatering system was shown to be an effective method to intercept shallow (<6 m[<20 ft]) impoundment leakage. Once the leakage was intercepted, the lead levels in the groundwater outside the well-point system began to decline. With continued operation of the system; decontamination of the area will progress, aided by rainfall, which gradually flushes the contaminants from the water table and surficial soils. Once decontamination of the area between the french drain and well-point system is complete, waste water presently requiring treatment will be reduced from the 855 L/min (225 gal/min) from the french-drain system to 106 L/min (28 gal/min) using the well-point system.

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Figure 1

Location of well-point system and french drain relative to the waste impoundment.

Figure 2

Composite cone of depression formed by interference among three wells.

Figure 3

Design details of each well-point installation.

Figure 4

Location of monitoring wells in relation to the well-point system and french drain.

Figure 5

Lead analyses versus time for monitoring wells located in the line of well points.

Figure 6

Lead analyses versus time for monitoring wells located between the well points and french drain.

Figure 7

Steady state groundwater conditions after 40 days of pumping.