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**Preliminary Engineering Report
Contaminated Groundwater Seeps
317/319/ENE Area**

October 1, 1996

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Preliminary Engineering Report Contaminated Groundwater Seeps 317/319/ENE Area

Argonne National Laboratory

1 INTRODUCTION

When the Resource Conservation and Recovery Act Facility Investigation (RFI) in the 317/319/ENE Area of Argonne National Laboratory-East (ANL-E) was being completed, groundwater was discovered moving to the surface through a series of seeps. The seeps are located approximately 600 ft south of the ANL fence line in Waterfall Glen Forest Preserve. Samples of this water were collected and analyzed for selected parameters. Two of five seeps sampled were found to contain detectable levels of organic contaminants. Three chemical species were identified: chloroform (14-25 µg/L), carbon tetrachloride (56-340 µg/L), and tetrachloroethylene (3-6 µg/L). The other seeps did not contain detectable levels of volatile organic compounds (VOCs). The water issuing from these two contaminated seeps flows into a narrow ravine, where it is visible as a trickle of water flowing through sand and gravel deposits on the floor of the ravine. Approximately 100-ft downstream of the seep area, the contaminated water is no longer visible, having drained back into the soil in the bed of the ravine. Figure 1 shows the location of the 317/319/ENE Area in relation to the ANL-E site and the Waterfall Glen Forest Preserve.

The seeps are in a ravine that carries stormwater discharges from the 317 and 319 Areas. They are located in a heavily wooded section of the Forest Preserve. A developed trail (paved gravel path approximately 10-ft wide) is located approximately 450-ft south of the seeps. A small undeveloped trail (an earthen path less than 2-ft wide) crosses the ravine approximately 200-ft south of the seeps. Figure 2 shows the location of the five seeps sampled. Figure 3 is a more detailed sketch of the area containing the contaminated seeps. Photo 1 (all photos are in Appendix A) depicts the area downstream of the contaminated seeps.

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FIGURE 1 317/319/ENE Study Area and Surrounding Area

FIGURE 2 Groundwater Seeps in Waterfall Glen Forest Preserve South of ANL-E

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FIGURE 3 Sketch of Seep Area

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2 DESCRIPTION OF CONTAMINATED SEEPS

Both contaminated seeps are located within 20 ft of each other. One of them, SP04, is located on a slightly elevated terrace of soil located in the bottom of the ravine. This seep is approximately 18 in. above the bottom of the ravine. Approximately 30 ft north of this seep is a stone structure resembling a shallow, hand-dug well. The well is about 28 in. in diameter and 27 in. deep. Photo 2 shows this structure. The depth of water inside the well varies, depending on the season. During the sampling event in July, the well was full of water, and there was a continuous flow of water into the ravine (the July sample was collected from this overflowing well). In August, the water level was 10 in. below the top of the well. Since the water was stagnant at that time, the seep sample was collected from a nearby location that exhibited groundwater flowing to the surface. Since these two seeps are so close to one another, they are both designated Seep SP04. The other contaminated seep, SP01, occurs in the bottom of the ravine. The elevation of the seep correlates with a layer of coarse sand and gravel, exposed in the western bank of the ravine. Photo 3 shows this coarse unit.

In addition to these two seeps, groundwater flow was noted at several other locations in the ravine bottom. Since these seeps were submerged under flow from upstream, they were not sampled. These seeps emanated from an exposed layer of coarse gravel and boulders. Photo 4 shows the seep area. Figure 4 is a conceptual depiction of the area surrounding Seeps SP01 and SP04.

Seep SP02, which is located on a separate branch of the ravine, 100-ft southwest of Seeps SP01 and SP04, was not contaminated. This seep was located in a sandy layer of soil that was directly above a dense, gray, silty clay layer. The elevations of Seeps SP01, SP02, and SP04 indicate that all three seeps probably originate in the same coarse sand and gravel horizon. However, since Seep SP02 is not contaminated, the flow that discharges at this location must have originated in an area that is not contaminated with VOCs.

Two additional seeps, SP03 and SP05, were located to provide a background reference for the other seep locations. These seeps are located 1,200-ft southwest of the contaminated seeps, in an entirely different surface water runoff catchment. Seep SP03 is located in a shallow ravine. Flow from this seep was observed only during the winter and spring. Seep SP05 is located on an earthen roadway adjacent to the ravine where Seep SP03 was found. Flow from this seep was observed only during the summer.

The area where the seeps are located is heavily wooded, and the hillsides near the ravines are steep. The portion of the Waterfall Glen Forest Preserve located between the 319/319 Area and the Des Plaines River has been categorized by the Forest Preserve District as a very high quality woodland. It is carefully managed to protect certain species of threatened and endangered plant and animal species.

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FIGURE 4 Conceptual Sketch of Seep Area (not to scale)

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3 OVERLAND FLOW OF CONTAMINATED SEEP WATER

The water exiting the contaminated groundwater seeps flows in the bottom of the eastern branch of the ravine. The bottom of the ravine varies in composition from clean clay to deposits of gravel and sand. A series of depressions in the ravine bottom is filled with up to 6 in. of ponded water. In other locations, the water is seen to flow in narrow, shallow flow streams, less than 1/2-in. deep. The flow passes through the sand and gravel deposits, completely disappearing under these deposits in several locations. The rate of water flow downstream of Seeps SP01 and SP04 was measured and found to be approximately 1,850 mL/min (700 gal/d).

The water in the ravine coming from Seeps SP01 and SP04 flows into a gravel and rock-filled section. No flow is visible in this section, which extends almost 50 ft before it merges with the other branch of the ravine. Holes were dug through this sand and gravel into underlying clay to determine if the water was flowing under the gravel. The underlying clay was visibly dry. The test holes did not fill with water, even after sitting open for several days. The flow is apparently reabsorbing into underlying porous material, moving into a deeper layer of the soil.

The flow from Seep SP02 flows down the western part of the ravine and into the conjoined ravine. Flow is visible from the seep all the way to the junction of the ravines. The flow at this point was found to be approximately 460 mL/min (170 gal/d).

Flow is visible beyond the stream confluence for a distance of approximately 140 ft. The flow at this point, near the small undeveloped trail, was estimated to be 570 mL/min (210 gal/d).

Below the point where this flow was measured, the stream flow stops, and the water appears to drain into an underlying sand and gravel bed. No flow is visible beyond 140-ft south of the junction. Three shallow test holes were dug through overlying sand and gravel, exposing the underlying clay. No water was observed in these holes. Photo 5 shows the stone-filled downstream portion of the ravine where it crosses the developed trail.

4 SEEP AREA SAMPLING AND ANALYSIS RESULTS

4.1 SEEP SAMPLES

Samples of water from the five seeps were collected and analyzed for volatile organics, tritium, gross alpha and gross beta radioactivity, and toxic metals. The samples were collected by digging a shallow hole into the bottom or side of the ravine, near a location where water was seen to be moving to the surface. The hole was allowed to fill with water, and a sample was collected. In several instances (such as the sample from Seep SP04, which was collected from the overflowing well), sufficient flowing water was present to allow the sample container to be dipped directly into the water.

The samples were analyzed by using analytical methods developed by the U.S. Environmental Protection Agency (SW-846 methods), in accordance with the approved RFI Work Plan. The results of the analyses are discussed in this section and summarized after the relevant discussion in Tables 1-3.

Three rounds of VOC samples were collected, with each seep being sampled at least once. Unfortunately, the sample bottles from the first round of VOC samples (from Seeps SP01, SP02, and SP03) arrived at the laboratory at a temperature higher than that specified in the RFI Work Plan. As a result, these data need to be considered estimated values. Because of seasonal fluctuations in flow from the seeps, it was not possible to collect more than one sample from Seep SP03 or SP05.

The VOC data from these samples (Table 1) indicate that two of the seeps, SP01 and SP04, contain part-per-billion levels of carbon tetrachloride, chloroform, and tetrachloroethylene. No volatile organics were found in the other seeps.

The results of the metals analysis of Seeps SP01 and SP02 (Table 2) indicate that the concentrations of several elements were slightly higher than those found in background groundwater collected in the 317 Area. At Seep SP03, nearly all the elements were at higher concentrations than those of the background samples. However, all metal concentrations were low, and the elevated levels detected may be related to the presence of soil particles in the water samples, caused by disturbance of the soil during sampling activities. The collection of seep samples involved digging a shallow hole to allow sufficient water to accumulate for sampling. Thus, more soil particles were suspended in these samples than in the groundwater samples, which were removed from properly developed wells. This relatively large amount of soil could have caused the concentrations of metals (which are present in the native soils) to be higher in these seep samples than in the background samples. The RFI has not detected significant sources of metal contamination in soil or groundwater in the 317 or 319 Areas.

TABLE 1 Volatile Organic Compound Concentrations Detected in the Seep Samples ($\mu\text{g/L}$)^a

Volatile Organic Compound	SP01			SP02		SP03	SP04		SP05
	5/3/96 ^b	7/12/96	8/29/96	5/3/96 ^b	7/12/96	5/3/96 ^b	7/12/96	8/29/96	7/12/96
Chloroform	13	25	14	<5 U	<5 U	<5 U	24	15	<5 U
Carbon tetrachloride	85	82	56	<5 U	<5 U	<5 U	340	120	<5 U
Tetrachloroethylene	3 J	3 J	4 J	<5 U	<5 U	<5 U	6	3 J	<5 U

^a Acetone and methylene chloride were also detected in several of these samples at concentrations near or below quantitation limits. These compounds were also detected in laboratory blanks at similar concentrations and thus are considered laboratory contaminants. U indicates that the compound was not detected. The practical quantitation limit of 5 $\mu\text{g/L}$ is shown in the table. J indicates the compound was detected but was below the practical quantitation limits of the procedure.

^b Samples collected May 3, 1996, were received at the laboratory at above the acceptable temperature. Data should be considered estimated.

TABLE 2 Metal Concentrations Detected in the Seep Samples ($\mu\text{g/L}$)^a

Metal	SP01	SP02	SP03	95% UTL Background Groundwater ^b
Silver	6.8 U	6.8 U	6.8 U	10
Arsenic	29.2	32.9	83.5	43
Barium	362	150	2530	293
Beryllium	2.1	3.0	19.6	2
Cadmium	3.7 U	3.7 U	12.7	4
Cobalt	36.6	35.3	248	45
Chromium	64.7	72.2	477	113
Copper	115	101	830	150
Mercury	0.34	0.38	2.1	0.1 U
Nickel	90.9	90.6	733	116
Lead	107	121	550	65
Antimony	54.1	31.5	139	48
Selenium	2.2 U	2.2 U	2.2 U	1.9 U
Tin	11.2 U	14.5	11.2 U	45.9 U
Thallium	0.8 U	0.8 U	2.7	2
Vanadium	96.0	110	578	98
Zinc	406	372	2,610	227

^a Seeps SP04 and SP05 were not analyzed for metals.

^b Background concentrations shown represent the 95th percentile upper tolerance limit (95% UTL) for the background wells used for the RFI investigation, including upgradient wells in the 317 Area as well as several background wells in the 800 Area of ANL-E.

Radiological analysis results (Table 3) indicate that the water from Seeps SP01 and SP02 contains levels of gross alpha and gross beta activity consistent with background groundwater levels, obtained from upgradient wells north of the 317 Area. Seeps SP04 and SP05 were not analyzed for gross alpha and beta activity. Tritium was not found above the analytical detection limits except in Seep SP01, which was found to contain 580 pCi/L (the detection limit was approximately 530 pCi/L). A duplicate sample from Seep SP01 did not show any detectable tritium. Thus, there does not appear to be a significant amount of added radioactivity present in the contaminated seeps.

The background seep, SP03, demonstrated unexpectedly high levels of gross alpha and beta radioactivity (as well as the presence of numerous metals, as discussed above). The reason for the elevated gross alpha and beta radioactivity is unknown. Both elevated levels could have been the result of the fact that higher amounts of soil were entrained in the background sample than in Seeps SP01 and SP02. An attempt to resample Seep SP03 to verify the unexpectedly high levels of metals

TABLE 3 Radiological Analysis Results of Seep Samples (pCi/L)^a

Radiological Parameter	SP01	SP02	SP03	SP04 ^b	SP05 ^b	95% UTL Background Groundwater
Gross alpha	30	170	760	NA	NA	323
Gross beta	69	403	1550	NA	NA	383
Tritium	<539 ^c	<528	NA	<531	<526	354

^a Na = not available.

^b Gross alpha and beta measurements were not taken for Seeps SP04 and SP05.

^c The duplicate tritium sample for seep SP01 contained 580 PCi/L of tritium.

and gross alpha and beta radioactivity was unsuccessful, since the seep had dried up. Once flow is again detected, confirmatory information will be obtained.

4.2 SURFACE WATER SAMPLES

Four samples of water flowing through the ravine were collected at the locations shown as diamonds in Figure 3. The samples were collected and analyzed for VOCs in accordance with the approved RFI Work Plan for surface water samples. The results are contained in Table 4. The analysis shows that the water downstream of Seeps SP01 and SP04 contained chloroform and carbon tetrachloride at low levels (much lower than the levels in samples collected directly from the seeps) and that the water downstream of Seep SP02 was free of contamination (as was the seep itself). In addition, the two samples collected downstream of the confluence of the ravines were also free of contamination. Since the flow of contaminated water from Seeps SP01 and SP04 was four times the flow of water from Seep SP02, the combined flow should have contained easily detectable amounts of carbon tetrachloride (chloroform would have been below detection limits because of dilution). The lack of detectable carbon tetrachloride and the fact that the combined flow was much lower than expected indicate that the water from Seeps SP01 and SP04 does not flow past the gravel-filled depression and the stream confluence but instead flows into the porous formation underlying the ravine.

TABLE 4 Surface Water Volatile Organic Compounds Analytic Results ($\mu\text{g/L}$)^a

Volatile Organic Compound	SPSW01 (near developed trail)	SPSW02 (near undeveloped trail)	SPSW03 (discharge from SP02)	SPSW04 (discharge from SP01 and SP04)
Chloroform	<5 U	<5 U	<5 U	3 J
Carbon tetrachloride	<5 U	<5 U	<5 U	21
Tetrachloroethylene	<5 U	<5 U	<5 U	<5 U

^a U indicates that the compound was not detected. The practical quantitation limit of 5 $\mu\text{g/L}$ is shown in the table. J indicates the compound was detected, but it was below the practical quantitation limits of the procedure.

5 DESCRIPTION OF SUBSURFACE GEOLOGY AND HYDROGEOLOGY

The RFI investigation has generated a large body of information about the geology and hydrogeology in the study area. However, the investigation did not extend into Waterfall Glen Forest Preserve. Thus, knowledge about the subsurface conditions between the 317/319 Area and the seeps is limited. The following discussion is based on the RFI data, supplemented by limited visual geological classification of surface soils and outcrops conducted near the seeps.

5.1 GEOLOGY

Geological characterization information about the 317/319 Area, developed during the RFI, indicates that groundwater is present in a series of sand and gravel lenses, ranging in depth from 10 to 50 ft below ground surface. The Forest Preserve area south of the 317 and 319 Areas contains a series of steeply incised ravines, formed by stormwater runoff flowing to the Des Plaines River. These ravines have exposed several coarse sand and gravel layers that are believed to be associated with similar sand and gravel layers on the ANL site. The elevation of groundwater in these permeable coarse-grained layers in the 317/319 Area suggests that it is flowing to the southeast, toward the Des Plaines River.

The entire 317/319 Area, including the portion of the Forest Preserve located between the 317/319 Area and the floodplain of the Des Plaines River, is underlain by unconsolidated sediments of the Pleistocene glacial epoch. These Quaternary sediments lie directly on the glacially eroded bedrock surface of the Silurian Racine Formation.

The local Quaternary deposits are composed of two depositional sequences, the Wadsworth Member and the Lemont Drift. These two units together form the Wedron Formation (Hansel and Johnson 1987). The Wadsworth Member consists of a silty clay till, deposited subglacially. Sand and gravel layers are present throughout this till. Both the base and top of the Lemont Drift contain coarse-grained glacio-fluvial sediments interpreted as being deposited in a proglacial environment. Between these two sand and gravel units is a mixed sequence of ice: marginal (fluvial, lacustrine, and gravity flow) deposits and subglacial till. This sequence is composed predominantly of clayey silt but contains units of both coarse- and finer-grained material.

A depiction of a geologic section taken from the draft RFI report is presented in Figure 5. Figure 2 shows the location of this cross section, which is labeled section line. Four relatively consistent coarser-grained units are identified in the section: Units A, B, C, and D. The series of sandy layers in Unit A occurs within the till of the Wadsworth Member. Units B and C are interpreted as being correlated with the proglacial fluvial deposits at the top of and in the Lemont Drift. Unit D consist of weathered limestone situated on top of the dolomite bedrock. Units B, C, and

D occur in the Lemont Drift. The total thickness of the Quaternary deposits in the 317/319 Area varies between 65 and 70 ft.

The degree of interconnectedness of the thin, often discontinuous sand and gravel layers in Units A, B, and C is unknown. The only coarse-grained layer found consistently in all borings is Layer D, which represents the weathered top of the bedrock. This layer, however, does not appear to have been impacted by activities in the 317/310 Area. As a result of this uncertainty, the conceptualization of the movement of groundwater through and between these layers is somewhat speculative.

5.2 HYDROGEOLOGY

Water levels measured in the monitoring well clusters shown on the geologic section line are presented in a hydrogeologic section in Figure 6. Unit A is saturated in the vicinity of Monitoring Wells MW001 and MW003. Soil boring samples in this unit near the ANL-E fence line were found to be only partially saturated, indicating that this layer is not water-bearing south of the 317/319 Area. Units B and C are both discontinuous along this section line. Unit B has been found to be saturated and yields significant amounts of water in the monitoring wells placed in sand layers in this unit. Several RFI wells completed in Unit C were dry or showed water only seasonally. The water levels in the wells screened in Unit D and the dolomite indicate that the coarse-grained unit at the base of the Lemont Drift is unsaturated, with perched aquifer conditions occurring in the overlying units.

Hydraulic conductivity tests (slug tests) were conducted in the RFI wells; results are summarized in Table 5. The test results show significant ranges in hydraulic conductivities for all the water-bearing units. The results in the summary table indicate that Unit C is the least permeable of the units and that Unit D (above the dolomite aquifer) is the most permeable. Unit B was consistently thicker and more permeable than the other water-bearing horizons in the Quaternary deposits. The depiction of the geologic cross section in the draft RFI report indicates that Units A, B, and C are horizontally connected in places. Inter-unit flow is judged to occur both where the units intersect and by downward flow through the intervening finer-grained and less permeable zones.

TABLE 5 Summary of Hydraulic Conductivity Values from Slug Testing of RFI Wells (cm/s)

Hydrogeologic Unit	K Minimum	K Maximum	K Geometric Mean
A	8.2×10^{-6}	7.4×10^{-3}	2.2×10^{-4}
B	2.9×10^{-5}	3.6×10^{-2}	5.9×10^{-4}
C	1.5×10^{-6}	9.1×10^{-3}	6.2×10^{-5}
D	2.8×10^{-6}	1.0×10^{-1}	3.3×10^{-3}

FIGURE 5 North-South Geologic Cross Section of the 317 Area

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FIGURE 6 North-South Hydrogeological Cross Section of the 317 Area

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The four units shown in the geologic cross section in Figure 5 are identifiable throughout the 317/319 Area. Similar units were observed in the ravine, near the seeps. Figures 7 and 8 depict a conceptual cross section that describes the current understanding of geologic characteristics of the area between the 317 Area and the seep area. To create these figures, the elevations of the coarse-grained units in the 317 Area were extended laterally in a north-south direction, into the Forest Preserve, where they were found to outcrop as exposed Quaternary coarse-grained deposits in the eroded ravines in the Forest Preserve. The seeps in the Forest Preserve occur at an elevation consistent with the base of Unit C. The material in the bed of the ravine, downstream of the seep, correlates with the porous, coarse-grained basal unit of the Quaternary deposits, Unit D. It should be noted that this cross section is based on an interpretation of the limited data currently available and has not yet been corroborated by collecting subsurface geological information (soil borings) in the Forest Preserve.

A comparison of the elevations of the various coarse-grained units with the elevations of the seeps and exposed porous layers indicates that the most likely route of contaminated groundwater migration is through Units B and C. This understanding is supported by the fact that the only groundwater samples near the fence line that contained the three compounds found in the seeps were collected from Units B and C. Figure 9 presents the VOC analytical data for carbon tetrachloride, chloroform, and tetrachloroethylene next to the wells and strata from which the data were collected. The concentrations of these compounds in the monitoring wells toward the fence line (MW002, 317021) are lower than the concentrations found in the seeps. In addition to these three compounds, low levels of other similar chlorinated organic compounds were also detected in these wells (26-170 µg/L of 1,1,1-trichloroethane and 23-52 µg/L of 1,1-dichloroethene). These constituents were not found in the seeps, however.

FIGURE 7 Map Showing the Location of the Geologic Cross Section of the 317 Area and Waterfall Glen Forest Preserve

FIGURE 8 Conceptual Geologic Cross Section of the 317 Area and Waterfall Glen Forest Preserve

FIGURE 9 Hydrogeological Cross Section of the 317 Area Showing VOC Analytical Results

FIGURE 9 Hydrogeological Cross Section of the 317 Area Showing VOC Analytical Results

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6 SOURCE OF CONTAMINATION AND POSSIBLE PATHWAYS

The RFI investigation of the various waste sites in the 317/319/ENE Area has identified one possible source of the organics in the groundwater seeps. Soil and groundwater in the 317 Area French Drain were found to contain the same three compounds as those found in the seeps as well as numerous other volatile organic compounds. The maximum soil concentration of chloroform was 21,000 µg/kg and of carbon tetrachloride was 54,000 µg/kg, and the highest concentration of tetrachloroethylene was 190,000 µg/kg. Other VOCs found in the French Drain soil included 1,1,1-trichloroethane at 140,000 µg/kg, trichloroethylene at 47,000 µg/kg, 4-methyl-2-pentanone at 78,000 µg/kg, isobutyl alcohol at 39,000 µg/kg, and other chlorinated solvents. The highest levels of contaminated soil were located immediately north of the north row of waste storage vaults in the northern part of the 317 Area.

During construction of these vaults, a subsurface drainage system termed the East Vaults Footing Drain (Illinois Environmental Protection Agency Solid Waste Management Unit 13) was constructed. This drainage system was a gravity sewer that collected groundwater in a series of footing drains at the base of the Map Tube Facility and Deep Vault (two storage vaults located in the northeast corner of the vault complex) and discharged the groundwater into an outfall located in the ravine south of the 317 Area. It was also used to discharge rainwater that would leak into the other three, shallow vaults (south middle, south east, and north vaults). This system was installed in the early 1950s and expanded as other vaults were constructed. At the time of construction, the outfall pipe was located on ANL property. However, in 1973, this land, as well as other portions of the ANL site, were given to DuPage County and turned into a forest preserve. This land exchange resulted in the discharge pipe now residing on DuPage County Forest Preserve property. In 1987, flow from this discharge pipe was sampled and found to contain low levels of tritium, strontium-90, and cesium-137. It was also discovered that this water contained several VOCs, some at concentrations of nearly 1,000 µg/L. To stop the discharge of water, the drain pipe was plugged near the vault area by excavating and removing a 5-ft- to 10-ft-long section. The third manhole in the system, located near the southeast corner of the 317 Area fence line, was also removed. Several years later, after a trickle of flow was observed coming from the pipe, the outfall pipe and about 20 ft of the drain pipe near the outfall were removed, and the remainder of the off-site pipe was plugged with concrete. To prevent the vaults from flooding, water accumulating in the system has been periodically pumped from the second manhole in the system, Manhole 2-E, and discharged to the on-site wastewater treatment system. Until 1993, this pumping was done manually, by periodically pumping water into a tanker truck. In mid 1993, an automatic pumping system was installed. This system pumps the water directly into the ANL-E sewer system.

The footing drain system consisted of perforated clay tile around the base of the vaults, which transitioned into cast-iron pipe from the vaults to the outfall. The pipe was laid in a bed of crushed stone, and additional crushed stone was placed on top. The trench was then backfilled with

soil. The location of the drain is shown in Figure 10. The cross sections shown in Figures 5 and 6 also show this structure in profile view.

The water in the footing drain system has been monitored on a monthly basis ever since the contaminants were discovered. The most commonly found contaminants were chloroform, carbon tetrachloride, and tetrachloroethylene; however, several other volatile organics have been found from time to time, including 1,2-dichloroethene, 4-methyl-2-pentanone, and trichloroethylene. These compounds were typically found at much lower concentrations than the carbon tetrachloride and chloroform. Figure 11 shows the chloroform, carbon tetrachloride, and tetrachloroethylene data from Manhole 2-E for the last five years. The dramatic decrease in the concentrations of chloroform and carbon tetrachloride appears to coincide with the start-up of an automatic pump system in mid 1993.

The proximity of the 317 Area French Drain contaminated soil to the footing drain system around the Map Tube Facility and the Deep Vault, as well as the documented presence of identical contaminants at concentrations similar to those in the seep, indicates that this system is the likely source of the contaminants in the seeps. However, other, as yet unidentified, potential sources cannot be completely ruled out. One possible conceptual model of the likely migration pathway from the 317 French Drain to the seep area is as follows.

1. Precipitation falling in the 317 Area migrates through the region of contaminated soil, mobilizing VOC constituents.
2. This shallow groundwater flow then migrates toward the footing drain system, where it either enters the pipe through the drain tiles or flows along the porous backfill material outside the pipe.
3. Once contaminated groundwater enters the footing drain system, it is rapidly transported toward the fence line because of the porous nature of the pipe and backfill and the relative downward slope of the footing drain.
4. Contamination of the groundwater then occurs by one of two mechanisms. Before 1987, it may have been discharged into the ravine at the outfall and subsequently drained into sediments in the stream bed. The second possibility is that it infiltrates from the footing drain pipeline backfill material into the shallow groundwater (which could still be happening today, although at a lower rate because the drain line is plugged and sections of the gravel bedding have been removed).
5. Subsurface flow in the permeable horizons in the Quaternary deposits then transports the water to the southeast, parallel to the natural slope of the surface. The existence of the abandoned well, which flows freely under

FIGURE 10 Map Showing the Location of the East Vaults Footing Drain System

artesian conditions during parts of the year, may have also influenced the movement of contaminated water in this direction.

7. At the ravine, where natural erosion processes have exposed these sand and gravel layer (Units B and C, as discussed above), the groundwater migrates to the surface, where it appears as a series of groundwater seeps.
8. Downstream of the seep area, where a subsequent porous layer of soil (Unit D) has been exposed by erosion, the flow reenters the subsurface, becoming groundwater once again.

FIGURE 11 VOC Data from Manhole 2

October 1, 1996

7 RISK ANALYSIS RESULTS

To determine if the presence of contaminated groundwater at this location could constitute a risk to human health or to the wildlife that use the Forest Preserve, a risk assessment was performed. This assessment, described in Appendix B, estimated the potential impacts from ingestion, inhalation, and dermal contact as well as risk to wildlife. The human health risk was judged to be extremely small, well within the U.S. Environmental Protection Agency standard for acceptable risk. Even though very conservative assumptions were made (i.e., a hiker drinking two cups of water from the seep 20 times per year for 10 years), the estimated probability of increased cancer risk was extremely low, approximately 2×10^{-6} . This risk level means that if one million people were exposed at the assumed dosage rate for 10 years, two would have an increased risk of developing cancer over their lifetime. Noncarcinogenic risk was determined to be well below acceptable levels. The risk to wildlife was similarly judged to be minimal, since contaminant concentrations were well below acceptable levels.

8 POTENTIAL REMEDIAL ACTIONS

Remedial measures to mitigate releases of this nature typically proceed by implementing two types of actions, interim actions and long-term, final actions. Interim actions are simple, relatively rapid actions typically performed when an imminent risk to life or health exists or immediate action is required to ensure that control of the site is achieved. The seep situation does not appear to warrant such an interim action for the following reasons:

- The concentrations of contaminants are such that, even if the seep water was consumed on a regular basis, there would be minimal adverse health effects. The extremely low probability of adverse health effects would occur only over many years of chronic exposure to this material. Incidental contact, such as a hiker walking through the water in the bed of the ravine (which is the only reasonable exposure pathway), should have no deleterious effect on individuals. Adverse impacts to wildlife are also very unlikely.
- The part of the ravine where contaminated groundwater is exposed is isolated from normal contact with users of the Forest Preserve. The nearest pathway (a small, unimproved dirt trail) through the steeply eroded area is almost 150-ft south of the seeps. The area immediately surrounding the contaminated seeps is accessible only by leaving the small undeveloped trail and walking up the ravine through underbrush and fallen trees. The water flowing in the ravine where this pathway crosses it was found to contain no volatile organic species. The larger, developed pathway, which is used by the majority of the Forest Preserve users, is located approximately 400-ft south of the seep area. There is no flow of groundwater at this point. Thus, except for the instance of an individual who may walk up the ravine, it is highly unlikely that anyone will come in contact with this water.
- An interim action to collect and treat the contaminated water would most likely require erecting a fence around the seep area, constructing a small dam or groundwater collection system, and installing electrical power to the site. Such actions would be highly problematic. The ravine where the seeps appear is very steep. There is no vehicular access to the area; thus, all installation work would need to be done by hand, or a new access road would need to be built. Construction of this magnitude in this area would damage important forest land and species of unusual flora, which the Forest Preserve District wishes to protect. In addition, the construction would likely interfere with normal use of this part of the Forest Preserve.

On the basis of this analysis, there appears to be no significant benefit derived from conducting an interim action at the seep site when compared with the difficulty of conducting such an action. The detrimental effects to the highly sensitive ecosystem of the Forest Preserve appear to outweigh any benefit achieved.

However, if it is determined that an interim action is desired at the point of discharge, several options are feasible. One interim action that could prevent humans and wildlife from contact with the contaminated water would be to dismantle the abandoned well and fill the well and the bottom of the ravine with 12-18 in. of coarse gravel from the point where the seeps emerge to the point where flow disappears. Groundwater seepage would flow under the gravel until it passed into underlying porous soil. This action would eliminate any concern about potential ingestion or dermal contact with the contaminated water while the final remedial action is being designed and implemented. However, insects and invertebrates would lose access to the water in the ravine, because this action would change the nature of the micro-environment around the seeps, possibly degrading the quality of the ecosystem.

A second alternative for an interim action would be to construct a passive groundwater treatment system upgradient of the seep discharge point. Such a system, which would use activated carbon or an innovative iron filing reaction wall, would remove the contaminants from the groundwater before their discharge to surface water. Such a passive system would result in limited disturbance to the Forest Preserve while efficiently providing a high degree of contaminant removal. The design of such an action could be time-consuming. In addition, ongoing operation and maintenance of the system would be required.

Final remedial actions in the area could take several forms. Three such actions have been evaluated: (1) natural attenuation of the existing groundwater plume in the Forest Preserve; (2) installation of a series of groundwater recovery wells and a pumping system; and (3) installation of a groundwater interceptor trench. All three options are based on simultaneous remediation of the source area, which is contaminated soil in the 317 Area French Drain. The methods for remediating the source area are beyond the scope of this report but will be discussed in subsequent reports.

The first option would not result in any removal or treatment of contaminated groundwater that has already migrated past the ANL-E property line, nor would it change the rate of discharge of contaminated groundwater from the seeps. The second and third options would be designed to slow the migration of contaminated groundwater from the seeps. The relative advantages and disadvantages of each system are presented below.

8.1 NATURAL ATTENUATION OF THE GROUNDWATER PLUME

This option involves conducting studies of the site hydrogeology, surface water hydrology, land use patterns, potential human and ecological receptors, and other parameters. These data would

then be used to develop a basis for claiming that the plume is unlikely to cause harm to human or ecological receptors and that there is no need to capture and treat the contaminated water. The remedial actions undertaken would be limited to remediation of the source area and elimination of the footing drain system, which currently functions as a manmade groundwater flow path. Since these actions are already planned and included in the ANL-E Remedial Action Project, the only additional action required would be to conduct the required investigations and perform more exhaustive risk analysis than has already been done.

- Advantages
 - The option is the least-cost option.
 - It would not disturb Forest Preserve property nor interfere with the use of this land.
 - It would not alter the natural discharge of groundwater into the Forest Preserve, thus preserving the fragile ecosystem near the seeps.
 - It would not divert funds and effort away from the remediation of the source area.
- Disadvantages
 - This option would not reduce the ongoing release of contaminated groundwater.
 - Ongoing monitoring of surface water and groundwater would be required.

8.2 GROUNDWATER RECOVERY WELL SYSTEM

This system would consist of a series of wells installed in the various saturated sand and gravel units located near the fence within the current ANL-E property line. Water migrating into the wells would be pumped into a common header, which would discharge the water to the 317 Area lift station. Because groundwater flowing through these units would be removed, the movement of groundwater across the fence line would be reduced, reducing the rate of discharge of contaminated groundwater from the seeps.

- Advantages
 - The installation cost would be considerably less than that for the interceptor trench.

- The system could be installed in phases, with additional wells added or removed as the performance of the system is monitored during operation.
- The volume of potentially contaminated surplus soil, generated by the installation of the system, would be much less than that from the interceptor trench.
- Extending the system into the Forest Preserve to capture more of the plume of contaminated water would be relatively easy once approval is obtained from the Forest Preserve District.
- Disadvantages
 - Proper design and placement of the wells require a very detailed knowledge of the geology and hydrogeology of the area near and south of the current fence line. Although there is a large amount of data available regarding the geology of the 317 and 319 Areas, there is very little data on the hydrogeology of the area between the fence line and the seep area. Aquifer pump testing and additional soil borings and groundwater monitoring wells would be required before the system could be designed properly.
 - Since groundwater is present in a number of relatively thin sand layers, with the possibility of limited hydraulic interconnectedness, a large number of wells may be required to ensure that the proper layers are intercepted. Also, the relatively low permeability of the silty sand layers reduces the effective radius of the wells, requiring a larger number of wells to completely intercept the flow.
 - Groundwater recovery systems are typically designed with the aid of groundwater numerical modeling tools. However, these tools are of limited value when used for the heterogeneous glacial till materials occurring at this site. As a result, the design would be associated with a high degree of uncertainty. The system would demand careful observation and modification after installation so it could be expanded, if necessary, to ensure effective dewatering and remedial action.

8.3 GROUNDWATER INTERCEPTOR TRENCH

A trench, backfilled with granular porous materials, would be installed in the path of the groundwater migration. The trench would extend down to the deepest known contaminated layer,

approximately 40-ft deep. The trench would intersect all porous layers, allowing any groundwater present to flow into it, where the groundwater would be captured and pumped to the 317 Area lift station. As would the well system, the trench would reduce the flow of water into the Forest Preserve, which would reduce the discharges from the seeps.

- Advantages

- Since the trench intersects all sand layers encountered, it is more effective at capturing groundwater from the highly heterogeneous soils, reducing the need for postconstruction monitoring, refinements, and adjustments.
- Less detailed hydrogeological knowledge is required, making the design process more straightforward. The only additional design data required are more accurate delineations of the groundwater flow paths and the lateral extent and depth of the plume, so the required length and location of the trench can be accurately identified.

- Disadvantages

- Once installation is complete, there is very little flexibility in the operation of the trench should groundwater flow conditions or contaminant characteristics change. The correct initial placement of the trench is crucial to ensure the desired capture effect.
- The primary disadvantage is the higher cost of the trench system. The added cost is the result of the special construction equipment and procedures needed to excavate a narrow trench 40-ft deep.
- Extending remediation into the Forest Preserve would be more difficult if the trench system were used. Extending the trench into the Forest Preserve would cause a major disturbance of heavily wooded areas.

Both the well and trench systems have the disadvantage of being located on ANL property, approximately 600 ft from the discharge point. As a result, much of the plume of contamination may have already passed this point and would not be effectively captured by either groundwater recovery system. The chosen system may reduce the flow of groundwater significantly, but it should not result in the removal of the plume outside the ANL-E fence line. This part of the plume would be remediated by natural attenuation processes, such as dilution with new recharge water into the sand layers, biodegradation of material in the soil, and continued discharge through the seeps (although at a lower flow rate).

9 ESTIMATED COSTS

Preliminary cost estimates have been prepared for these three final remedial options (estimates for the interim options were not calculated). Table 6 shows the estimated costs. These costs are determined on the basis of the assumption that this work will be performed as a standalone project in fiscal year 1997. Appendix B contains summary sheets of these three estimates.

All three options would be implemented in conjunction with the remediation of the source area, which has already been planned. The costs shown are only the additional costs needed to deal with the off-site releases. No interim actions, except for periodic monitoring of the seeps, are assumed. Costs shown include additional characterization, preparation of plans and reports for submittal to regulatory agencies, preparation of design documents, and implementation of the proposed remedy.

**TABLE 6 Cost Estimates for
Remedial Action Options**

Option	Estimated Cost (\$)
Natural attenuation	225,000
Well system	454,000
Interceptor trench	867,000

10 SUMMARY AND RECOMMENDATIONS

10.1 SUMMARY

Two groundwater seeps, located in a natural ravine in Waterfall Glen Forest Preserve south of the 317/319 Area of ANL-E, are releasing groundwater containing low levels of VOC contamination. The contaminated water flows through the bottom of the ravine for a distance of less than 100 ft before it disappears, apparently moving into porous soil underlying the ravine.

The potential health risk and ecological risk from the discharge of contaminated groundwater were estimated and found to be very small. The low estimate of risk is a result of the low concentration of the contaminants and the low likelihood of human exposure because the location is remote. In addition, the concentrations of contaminants are well below accepted limits for consumption by wildlife.

Several types of remedial actions were investigated. Remedial actions at the point of discharge of the seeps were found to be difficult to implement because of the rugged topography and inaccessibility of the seep site. In addition, the highly sensitive micro-environment surrounding the seeps would be damaged by such an action. The extremely low level of risk, coupled with the inaccessibility of the area and the ecologically sensitive nature this section of the Forest Preserve, suggests that conducting an interim action in this area would likely cause more harm than good.

Three remedial actions for the off-site contaminated groundwater plume were also examined. The first approach involved using natural physical and biological processes to remove the contaminants. This natural attenuation approach would involve monitoring the ongoing natural processes to ensure that the present low level of risk gradually decreases, as anticipated. The second approach would involve installing a series of groundwater removal wells on the ANL-E property. Groundwater, which is present in a series of saturated sand and gravel layers, would be removed and pumped to the ANL-E wastewater treatment facility. The wells would not only stop the future migration of contaminated groundwater through these layers but, by intercepting groundwater flow at the fence line, would reduce the rate of discharge of water from the seeps. The third approach would achieve this same objective by means of a subsurface interceptor trench. The trench would effectively remove groundwater from all of the porous zones in the soil, preventing any movement of water through the area where the trench was installed.

None of the three plume remediation options would facilitate the removal of that portion of the contaminated groundwater plume that has already moved beyond the ANL-E property line. To remove this portion of the plume, a series of wells or an interceptor trench would need to be installed on Forest Preserve land, close to the point of seep discharge. Such an action would have a major detrimental impact on the Forest Preserve, reducing its ecological value and limiting future recreational use of the area.

The data currently available are inadequate to accurately model contaminant transport and groundwater movement mechanisms or to permit design of a groundwater remediation system, if one is needed. Although detailed hydrogeological data are available for the 317/319 Area, only a small amount of data on the subsurface conditions between the fence line and the seep area has been generated so far. Therefore, additional characterization work is needed to expedite collection of the required hydrogeological data.

10.2 RECOMMENDATIONS

The following course of action is recommended:

1. Additional data regarding the nature and location of the off-site groundwater plume and migration pathway for this plume should be collected. Because of the sensitive nature of the Forest Preserve property, this data collection should be accomplished by means of minimally intrusive exploratory techniques acceptable to the Forest Preserve. However, use of such techniques could limit the quantity and quality of information generated.
2. A program of routine inspections and monitoring of the seep area should be instituted. This program should be designed to detect if the pattern of land use in the area changes in such a way that the potential for human exposure increases above the current low estimate. It should also monitor the long-term characteristics of the discharge. Data generated during this monitoring period will also contribute to a more thorough understanding of the processes causing the seep.
3. The remediation of the source area in the 317 Area French Drain should be expedited. This remediation would treat or contain VOC-contaminated soil so that future releases of contaminated groundwater are reduced. It would also result in closure of the footing drain system, so that groundwater could no longer migrate through the remaining pipe and porous backfill.
4. On the basis of new data to be collected in the Forest Preserve, a system for remediating contaminated groundwater should be developed. This system should be designed to achieve the optimal balance between the reduced risk to human health and wildlife it could achieve and the detrimental impacts such a system could have on sensitive forest ecosystems. Selection of this remedy should proceed only after consultation with the Illinois Environmental Protection Agency and the DuPage Forest Preserve District. Once the system is developed and agreed to by all involved stakeholders, it should be implemented quickly.

11 REFERENCE

Hansel, A.K., and W.H. Johnson, 1987, "Ice Marginal Sedimentation in a Late Wisconsinan End Moraine Complex, Northwestern Illinois, USA," pp. 97-104 in *Tills and Glaciotectonics*, Van Der Meer, J.J.M. (editor), Balkema, Rotterdam, the Netherlands.

APPENDIX A:
PHOTOGRAPHS

Photo 1 - View of Seep SP04 and Ravine South of Seep Area

Photo 2 - Abandoned Well Structure

Photo 3 - Layer of Coarse Granular Material in Ravine
Bank, Near SP01

Photo 4 - Seep in Sand and Gravel Layer in Bottom of Ravine, Near Seep SP01

Photo 5 - Dry Ravine Downstream of Seep Area, Near
Developed Trail

Photo 6 - Collection of Surface Water Samples Downstream
of Seep SP04

APPENDIX B:
RISK ASSESSMENT REPORT

RISK ASSESSMENT OF SEEPS FROM THE 317 AREA
OF ARGONNE NATIONAL LABORATORY

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RISK ASSESSMENT OF SEEPS FROM THE 317 AREA OF ARGONNE NATIONAL LABORATORY

1 INTRODUCTION

Chlorinated hydrocarbon contaminants have recently been detected in groundwater seeps on forest preserve property south of the 317 Area at Argonne National Laboratory (ANL). The 317 Area is near ANL's southern boundary and is considered the source of the contamination (Figure 1). Five seeps are about 200 m (600 ft) south of the ANL property line and about the same distance from the nearest developed trails, in an area not frequently accessed by visitors to the forest preserve. Seep water reaches the ground surface in small amounts, forming a series of small puddles in the bottoms of several steep ravines. The flow disappears entirely within several hundred feet of the seeps as a result of evaporation and/or reabsorption into the soil.

Low levels of three volatile organic compounds (VOCs) — chloroform, carbon tetrachloride, and tetrachloroethylene — were recently detected in two seeps, at a combined concentration of less than 1 part per million (ppm). Exposures and related impacts are unlikely because water is only present on the surface in small, localized areas that are not typically accessed. Further, contaminant concentrations are low. However, potential health and ecological impacts have been quantitatively assessed to evaluate the safety of visitors and biota in the forest preserve. Potential health effects were assessed using standard methodology developed by the U.S. Environmental Protection Agency (EPA). Conservative assumptions that overestimate likely exposures were used for these analyses to bound possible impacts. Ecological effects were evaluated by comparing contaminant concentrations to EPA criteria and benchmark values for surface water, which were developed to be protective of wildlife. The health and ecological assessments are presented in Sections 2 and 3, respectively.

2 HUMAN HEALTH ASSESSMENT

2.1 Contaminant Information

Water from five seeps was sampled in the summer of 1996 and analyzed for the 51 VOCs on EPA's standard analyte list. No VOCs were detected in three seeps, and three VOCs were detected in the other two, with concentrations ranging from 3 to 340 $\mu\text{g/L}$ (parts per billion, or ppb). The sampling results are presented in Table 1. Seeps SP-01 and SP-04 are very close to one another and discharge to the same ravine. Figure 1 shows the locations of these seeps.

TABLE 1 Contaminant Data from the Seep Samples

Sample	Contaminant Concentration ($\mu\text{g/L}$) ^a		
	Carbon Tetrachloride	Chloroform	Tetrachloroethylene
SP-01	82	25	3
SP-02	-	-	-
SP-03	-	-	-
SP-04	340	24	6
SP-05	-	-	-

^a A dash indicates that the contaminant was not detected.

FIGURE 1 Seep Sampling Locations

2.2 Exposure Assessment

In order for the assessment to be conservative, an unlikely "maximum exposure" scenario was developed to estimate potential impacts for a hypothetical adult visitor to the forest preserve. This person was assumed to visit the seep area 20 times a year for the next 10 years. To represent a bounding exposure estimate, it was assumed that on each visit the individual drinks 400 mL (2 cups) of water from the seeps. It was also assumed that the water contains all three contaminants at their highest measured concentrations.

These assumptions are conservative (i.e., protective) for the following reasons. First, the seeps are a considerable distance from developed hiking trails and are not readily accessed, so 200 routine visits to that area over 10 years are unlikely. Second, the flow from the seep area is extremely low (less than 1 gal/min), and water is generally present as a thin layer on the ground surface but sometimes dries up completely. (More water tends to be present in the ravine during periods of heavy rain, but these conditions are associated with lower hiking activity, so the likelihood of frequent exposures under those conditions would be very low.) For someone to successfully collect and drink two cups of water during each visit would be highly unlikely, especially given that drinking water is provided nearby in the forest preserve. Because of its low volume, the seep water cannot possibly serve as a long-term drinking water source. Finally, contaminants are not expected to be at maximum levels throughout a 10-year period.

Nevertheless, the amount of each contaminant taken in by the hypothetical visitor to the forest preserve was calculated with these conservative assumptions, using the standard framework developed by EPA for health assessments (EPA 1989). In addition to the ingestion scenario, intakes from inhalation and dermal contact were also assessed to ensure that all possible (albeit unlikely) scenarios are considered in evaluating the safety of the seeps.

For the inhalation assessment, air concentrations of the three VOCs were estimated on the basis of seep emissions calculated with standard EPA methodology (EPA 1993). Again, the maximum measured concentrations of the three contaminants were used for this assessment. A conservative dispersion model (Screen3, EPA 1995) was then applied to estimate maximum air concentrations for hypothetical receptors. Additional conservative assumptions (including ground-level inhalation) were applied to estimate intakes. The hypothetical receptor was assumed to visit the area 20 times a year for 10 years and to breathe the air at the seeps for 1 hour during each visit. Standard EPA values were used for the basic intake parameters, such as the breathing rate (EPA 1989, 1991a).

To assess potential effects from dermal exposures, it was conservatively assumed that the visitor would walk barefoot in ankle-deep seep water for 1 hour during each of the 20 visits per year over a 10-year period. Maximum contaminant concentrations were also used for this analysis. Standard values for intake parameters were used, such as for the surface area of feet and the permeability of skin (EPA 1992).

For completeness, exposures were also evaluated for a hypothetical child who might visit the seep area. Standard EPA values were used for these analyses.

2.3 Toxicity Assessment

Two types of human health endpoints are addressed in evaluating chemical exposures: cancer and noncarcinogenic effects. The EPA has developed contaminant-specific toxicity values for

these endpoints in cases where scientific evidence indicates the potential for a health effect. These values are also specific to the route of exposure (e.g., ingestion versus inhalation).

The potential for a chemical to cause cancer in humans is based on laboratory studies (mammal) in combination with human epidemiological data, where they are available. From an evaluation of these data, the EPA assigns a weight-of-evidence classification to individual contaminants as follows: A — known human carcinogen; B1 — probable human carcinogen, for which limited human data are available; B2 — probable human carcinogen, as indicated by sufficient evidence in animals but inadequate or no evidence in humans; C — possible human carcinogen; D — not classifiable as to human carcinogenicity; and E — evidence of noncarcinogenicity in humans.

All three seep contaminants have been evaluated by EPA with regard to their potential human carcinogenicity. Carbon tetrachloride and chloroform are classified as group B2 carcinogens on the basis of an increased incidence of liver and kidney tumors in laboratory rats and mice. Tetrachloroethylene is not currently classified because its potential carcinogenicity is under review by EPA. The EPA has developed cancer slope factors for many chemicals that generally represent an upper-bound (conservative) estimate of the probability of a response (cancer) per unit intake over a lifetime. The slope factors for carbon tetrachloride and chloroform are shown in Table 2 (EPA 1996b). No slope factors are currently available for tetrachloroethylene, as previous values have been withdrawn per the ongoing review.

With regard to noncarcinogenic effects, all three contaminants have been shown to cause liver damage at relatively high concentrations in laboratory tests with mammals, as is typical of chlorinated hydrocarbons. However, little data exist for human exposures to environmental concentrations. Studies have shown that inhalation of higher concentrations of these compounds (more than a thousand ppm) can cause dizziness, and long-term exposures to lower levels (e.g., hundreds of ppm) have also been linked to liver and kidney damage. (Air concentrations associated with the seeps are less than one-millionth to one-billionth of study levels.) Ingestion of relatively high concentrations (orders of magnitude higher than in the seeps) over long periods also may affect the nervous system, liver, and kidney (ATSDR 1993a,b; 1994).

The relative noncarcinogenic potencies of the seep contaminants are reflected in their reference doses (RfDs). The RfD is an estimate of the average daily exposure that is likely to be without deleterious effects to humans during a lifetime. These toxicity values are derived primarily from animal studies, and to be protective they incorporate a number of order-of-magnitude "safety factors" to account for such adjustments as extrapolating from animals to humans and addressing sensitive subpopulations. The RfDs for the seep contaminants are shown in Table 2 (EPA 1996b).

2.4 Risk Characterization

The risk of developing cancer from exposure to a specific contaminant can be calculated by multiplying the intake estimated for a given receptor by the appropriate slope factor. The result represents the incremental risk (probability) of developing cancer from that exposure. The EPA has identified a target range of 10^{-4} to 10^{-6} — or 1 in 10,000 to 1 in 1 million — for the risk of excess (above background) cancer incidence associated with contaminated sites (40 *Code of Federal Regulations* Part 300). To put this target range in context, it is estimated that one in three Americans will develop cancer from all sources. Thus, EPA's target range for incremental risks from exposures to site contaminants represents a very small fraction of the overall cancer rate.

TABLE 2 Estimated Health Effects from Potential Exposures to Seep Contaminants^a

Seep Contaminant	Maximum Measured Concentration (µg/L)	Slope Factor ^b (mg/kg-day) ⁻¹		Estimated Cancer Risk ^c			Reference Dose ^d (mg/kg-day)		Estimated Hazard Quotient ^e		
		Ingestion	Inhalation	Ingestion	Inhalation	Dermal	Ingestion	Inhalation	Ingestion	Inhalation	Dermal
Carbon tetrachloride	340	0.13	0.053	2×10^{-6}	2×10^{-9}	3×10^{-7}	0.0007	0.00057	0.15	0.0004	0.02
Chloroform	25	0.0061	0.081	7×10^{-9}	3×10^{-9}	3×10^{-10}	0.01	0.01	0.005	0.00002	0.00004
Tetrachloroethylene	6	NA ^f	NA	NA	NA	NA	0.01	0.01	0.0002	0.000005	0.000007

^a Shown are results for a hypothetical adult visitor to the forest preserve; results for a hypothetical child are similar.

^b The EPA has not developed slope factors to quantify dermal exposures, so values have been extrapolated from those for ingestion, consistent with EPA guidance.

^c Using conservative assumptions, the total risk combined across all pathways is represented by that for ingestion of carbon tetrachloride, 2×10^{-6} . This is well below the level of potential concern above which action is generally indicated (10^{-4}).

^d The EPA has not developed reference doses to quantify dermal exposures, so values have been extrapolated from those for ingestion, consistent with EPA guidance. Similarly, route-to-route extrapolations were made for the inhalation reference doses for chloroform and tetrachloroethylene because those values are not available.

^e The sum of hazard quotients represents the hazard index. Using conservative assumptions, the hazard index summed across all contaminants and pathways is well below 1; hence, no noncarcinogenic effects are indicated.

^f NA = not available. The potential carcinogenicity of tetrachloroethylene is currently under review by EPA, so no slope factors are available to quantify risks. However, using previous EPA values results in risk estimates on the order of 10^{-8} (for ingestion) and lower.

In applying EPA's target range, no remedial action (such as access restrictions or containment) is indicated unless the estimated risk exceeds 10^{-4} , and in those cases further evaluation is typically warranted. For example, more realistic exposure assumptions are applied to assess the risks, and various control options are evaluated if reasonable estimates of risk exceed the 10^{-4} level. Once action is indicated (e.g., when reasonable estimates exceed 10^{-4}), EPA strives to manage incremental risk to within the target range. Risks below the range are generally not considered of concern (EPA 1991b).

The potential for noncarcinogenic health effects is calculated by dividing the estimated intake by the appropriate RfD to generate a hazard quotient for each contaminant. The hazard index represents the sum of the hazard quotients. If this sum exceeds 1, a potential for noncarcinogenic effects is indicated and further evaluation is often conducted. Conversely, a sum of less than or equal to 1 indicates that noncarcinogenic effects are not a concern.

The cancer risks and noncarcinogenic effects estimated for various exposures to seep contaminants are presented in Table 2. Using conservative assumptions, estimates exceed neither the target risk nor the noncarcinogenic threshold level developed by EPA to protect human health. The total risk combined across all pathways is 2×10^{-6} , and ingestion of carbon tetrachloride is the major contributor. The estimated risks for all other chemicals and pathways are much lower (below EPA's target range). Further, only if an individual were to regularly ingest carbon tetrachloride would the estimated risk be at the low end of EPA's range; applying more realistic exposure assumptions would result in an ingestion risk well below this range.

Risks from exposure to tetrachloroethylene were not quantified because of the current unavailability of slope factors. In such cases, the potential health effect is qualitatively evaluated. Given its low concentration and similar chemical structure, it is unlikely that exposure to tetrachloroethylene would pose a risk greater than carbon tetrachloride and chloroform. In fact, using toxicity values previously available from EPA, estimated risks are lower than those for carbon tetrachloride (i.e., 10^{-8} for ingestion, and lower for the other exposure routes).

2.5 Summary

Conservative assumptions were used to assess the possibility of adverse health effects associated with forest preserve seeps impacted by the 317 Area at ANL. The results of this health assessment indicate that neither cancer risks nor noncarcinogenic effects associated with exposures to seep contaminants are a concern. That is, the area is safe for all visitors.

3 ECOLOGICAL IMPACTS

An evaluation of carbon tetrachloride, chloroform, and tetrachloroethylene in the seeps indicates that the maximum reported concentrations pose no risks to aquatic biota that may be in extended contact with the water or to terrestrial wildlife (mammals) that may drink the water. The maximum measured concentrations of 340 $\mu\text{g/L}$ for carbon tetrachloride, 25 $\mu\text{g/L}$ for chloroform, and 6 $\mu\text{g/L}$ for tetrachloroethylene are well below available EPA benchmark values that were developed to protect wildlife. Further, these compounds are readily metabolized in animals, so biomagnification in the food chain is not expected to be important to the protection of wildlife or humans. For example, ingestion of deer that may be exposed would not pose a threat to human health.

The EPA ambient water quality criterion for chloroform is 1,240 µg/L for the protection of chronically exposed freshwater aquatic biota (EPA 1986). The highest concentration measured in the seeps is only about 2% of this level. Although no criteria have been developed for carbon tetrachloride or tetrachloroethylene, EPA has identified a "lowest observed adverse effect level" (LOAEL) of 35,200 µg/L for carbon tetrachloride (EPA 1986) and a surface water ecotox threshold value of 350 µg/L for tetrachloroethylene (EPA 1996a). The highest seep concentrations of these compounds are less than 1% and 2% of the respective EPA values.

In addition, the nature of the groundwater discharge further precludes the likelihood of adverse impacts to aquatic biota. The flow is very low, with most surface water disappearing within several hundred feet of the original discharge point either by loss to the subsurface or evaporation. Because of its limited presence, the water likely provides very little suitable habitat capable of supporting aquatic biota year-round, and biota that may exist likely are limited to invertebrates.

Terrestrial wildlife may use the water as a drinking water source, although it is unlikely that the stream provides a sole-source water supply for any area wildlife because of the nature of the flow. Scientists at Oak Ridge National Laboratory (Opresko et al. 1995) have developed guidelines for certain contaminants in surface water that represent safe concentrations in waters consumed by mammalian wildlife. Concentrations below these levels are considered to pose no risk to terrestrial wildlife that may drink the water. The lowest safe concentrations are 45,600 µg/L for carbon tetrachloride, 42,800 µg/L for chloroform, and 1,800 µg/L for tetrachloroethylene. Maximum concentrations in the seeps are much lower than these safe levels, which were based on exposures of white-tailed deer. These deer represent the most sensitive of the animal species for which benchmark values are available, and they are also a species of special concern in the ANL area.

In summary, the presence of the three contaminants in the seep water does not pose a risk to biota in the area. Thus, no adverse ecological impacts are associated with the seeps.

4 REFERENCES

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U.S. Environmental Protection Agency, 1995, *User's Guide for Screen3 Dispersion Model*, EPA/454/B-95-004, Office of Air Quality Planning and Standards, Research Triangle Park, N.C.

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APPENDIX C:
COST ESTIMATES

Site: 317 area French Drain WBS Title: ANL-E REMEDIAL ACTIONS PROJECT WBS #:							Authorizations Estimator: Bob Swale/ Vic Mora Date: 23-Sep-96 PM Approved: Date: Dir Offc Approved: Date				Containment site Sheet # 1			
Remedial Action Item Title: NATURAL ATTENUATION SWMU # 11														
							Unit Price at Safety Level			Total Cost				
WBS #	TASK #	Assembly/Line Item	Resource Code	Safety Level	Unit Man-Hr (conver)	Quantity	Unit	Labor	Equipment	Materials	Labor	Equipment	Materials	Total
		Project Management Subtotal	PMD			280	hrs				\$23,800	\$0	\$0	\$30,800
		Direct Management		n/a		200	hrs	\$85			\$17,000	\$0	\$0	\$17,000
		Support Services		n/a		80	hrs	\$85		\$7,000	\$6,800	\$0	\$7,000	\$13,800
		Environment, Safety, & Health Subtotal				100					\$8,500	\$0	\$0	\$8,500
		Environmental Protection	ENV			60	hrs	\$85			\$5,100	\$0	\$0	\$5,100
		Safety and Health	SAF			40	hrs	\$85			\$3,400	\$0	\$0	\$3,400
		Engineering, Design, & Inspection												
		Engineering and Design Subtotal	ENG			1,250	hrs				\$106,880	\$40,000	\$15,000	\$161,880
		Review		n/a		20	hrs	\$94			\$1,880	\$0	\$0	\$1,880
		Publication		n/a		30	hrs	\$100			\$3,000	\$0	\$0	\$3,000
	4-7	Draft Task 4-7 Document		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0
	4-8	Final Task 4-8 Document		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0
	6-3	Gather Design Data		D		400	hrs	\$85			\$34,000	\$40,000	\$15,000	\$89,000
	6-4	Analyze All Data		D		200	hrs	\$85			\$17,000	\$0	\$0	\$17,000
	6-5	Draft preliminary design report		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0
	6-6	Final preliminary design report		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0
	6-7	Draft final design report		n/a		500	hrs	\$85			\$42,500	\$0	\$0	\$42,500
	6-8	Final final design report		n/a		100	hrs	\$85			\$8,500	\$0	\$0	\$8,500
		Field Work												
		Inspection Subtotal	INS			0					\$0	\$0	\$0	\$0
		Construction inspection EMO				0	hrs	\$85	\$0	\$0	\$0	\$0	\$0	\$0
		Construction inspection PFS				0		\$94	\$0	\$0	\$0	\$0	\$0	\$0
		Procurement effort	ENG	n/a		0	hrs	\$85	\$0	\$0	\$0	\$0	\$0	\$0
	6-9	Subcontract Subtotal	FWS	D										\$0
		Pre-tax subtotal												\$0
		ANL Effort Subtotal	FWA			0					\$0	\$0	\$0	\$0
	6-10	Draft Corrective Measures Report		N/A		0	hrs	\$85		\$0	\$0	\$0	\$0	\$0
	6-11	Final Corrective Measures Report		N/A		0	hrs	\$85		\$0	\$0	\$0	\$0	\$0
	8-10	Stakeholder Accept & Client Appr	PMD	N/A		40	hrs	\$85		\$600	\$3,400	\$0	\$600	\$4,000
	10-1	Total Remedial Action Cost				1,670					\$142,580	\$40,000	\$15,600	\$205,180
Contingency														\$20,518
Grand Total (w/o Escalation)														\$225,698

Site	317 area French Drain	WBS Title	ANL-E REMEDIAL ACTIONS PROJECT	WBS #		Remedial Action Item Title	WELL POINT SYSTEM	SWMU #	11
Authorizations	Estimator: Bob Swale/Vic Mora	Date:	20-Sep-96	PM Approved:		Dir Offc Approved:		Date	
Containment site	Sheet #	1							
Total Cost									
WBS #	TASK #	Assembly/Line Item	Resource	Code	Safety Level	Unit	Quantity	Unit	Man-Hr
		Project Management Subtotal	PMD			607 hrs		Labor	\$61,595
		Direct Management				470 hrs		Materials	\$39,950
		Support Services				137 hrs		Equipment	\$11,645
		Environment, Safety, & Health Subtotal				100		Labor	\$8,500
		Environmental Protection	ENV			60 hrs		Materials	\$5,100
		Safety and Health	SAF			40 hrs		Equipment	\$3,400
		Engineering, Design, & Inspection							
		Engineering and Design Subtotal	ENG			800 hrs		Labor	\$68,630
		Review				20 hrs		Materials	\$1,880
		Publication				30 hrs		Equipment	\$3,000
		Draft Task 4-7 Document				0 hrs		Labor	\$0
		Draft Task 4-8 Document				0 hrs		Materials	\$0
		Gather Design Data	D			300 hrs		Labor	\$25,500
		Analyze All Data	D			100 hrs		Materials	\$8,500
		Draft preliminary design report				0 hrs		Equipment	\$0
		Draft preliminary design report				0 hrs		Labor	\$0
		Draft final design report				0 hrs		Materials	\$0
		Draft final design report				300 hrs		Labor	\$25,500
		Final final design report				50 hrs		Equipment	\$4,250
		Field Work							
		Inspection Subtotal	INS			230		Labor	\$20,450
		Construction Inspection EMO				130 hrs		Materials	\$11,050
		Construction Inspection PFS				100		Equipment	\$9,400
		Procurement effort	ENG			80 hrs		Labor	\$6,800
		Subcontract Subtotal	FWS						
		Pre-tax subtotal							
		Install power feed system	SC					Labor	\$15,204
		Install phone line to pump station	D					Materials	\$2,480
		Install extraction well system	D					Equipment	\$92,450
		Install underground piping	D					Labor	\$21,335
		Install Piezometers; 6 ea.; 180'	D					Materials	\$19,700
		Terminate systems, restore area	D					Equipment	\$4,800
		Direct subtotal						Labor	\$155,769
		General conditions						Materials	\$23,365
		Subtotal without overhead & profit						Equipment	\$179,134
		Overhead and profit 10%-10%						Labor	\$0
		ANL Effort Subtotal	FWA			120		Materials	\$10,200
		Draft Corrective Measures Report				100 hrs		Equipment	\$8,500
								Labor	\$0
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Site: 317 area French Drain WBS Title: ANL-E REMEDIAL ACTIONS PROJECT WBS #						Authorizations Estimator: Bob Swale/ Vic Mora Date: 20-Sep-96 PM Approved:				
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Site: 317 area French Drain WBS Title: ANL-E REMEDIAL ACTIONS PROJECT WBS #:							Authorizations Estimator: Bob Swale/ Vic Mora Date: 20-Sep-96 PM Approved: Date: Dir Offc Approved: Date					Containment site Sheet # 1			
Remedial Action Item Title: BIODEGRADABLE SLURRY COLLECTION TRENCH SWMU # 11															
							Unit Price at Safety Level				Total Cost				
WBS #	TASK #	Assembly/Line Item	Resource Code	Safety Level	Unit Man-Hr (conver)	Quantity	Unit	Labor	Equipment	Materials	Labor	Equipment	Materials	Total	
		Project Management Subtotal	PMD			607	hrs				\$51,595	\$0	\$0	\$58,595	
		Direct Management		n/a		470	hrs	\$85			\$39,950	\$0	\$0	\$39,950	
		Support Services		n/a		137	hrs	\$85		\$7,000	\$11,645	\$0	\$7,000	\$18,645	
		Environment, Safety, & Health Subtotal				100					\$8,500	\$0	\$0	\$8,500	
		Environmental Protection	ENV			60	hrs	\$85			\$5,100	\$0	\$0	\$5,100	
		Safety and Health	SAF			40	hrs	\$85			\$3,400	\$0	\$0	\$3,400	
		Engineering, Design, & Inspection													
		Engineering and Design Subtotal	ENG			800	hrs				\$68,630	\$10,000	\$12,000	\$90,630	
		Review		n/a		20	hrs	\$94			\$1,880	\$0	\$0	\$1,880	
		Publication		n/a		30	hrs	\$100			\$3,000	\$0	\$0	\$3,000	
	4-7	Draft Task 4-7 Document		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0	
	4-8	Final Task 4-8 Document		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0	
	6-3	Gather Design Data		D		300	hrs	\$85			\$25,500	\$10,000	\$12,000	\$47,500	
	6-4	Analyze All Data		D		100	hrs	\$85			\$8,500	\$0	\$0	\$8,500	
	6-5	Draft preliminary design report		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0	
	6-6	Final preliminary design report		n/a		0	hrs	\$85			\$0	\$0	\$0	\$0	
	6-7	Draft final design report		n/a		300	hrs	\$85			\$25,500	\$0	\$0	\$25,500	
	6-8	Final final design report		n/a		50	hrs	\$85			\$4,250	\$0	\$0	\$4,250	
		Field Work													
		Inspection Subtotal	INS			360					\$31,500	\$0	\$0	\$31,500	
		Construction inspection EMO				260	hrs	\$85	\$0	\$0	\$22,100	\$0	\$0	\$22,100	
		Construction inspection PFS				100		\$94	\$0	\$0	\$9,400	\$0	\$0	\$9,400	
		Procurement effort	ENG	n/a		80	hrs	\$85	\$0	\$0	\$6,800	\$0	\$0	\$6,800	
	6-9	Subcontract Subtotal	FWS	D										\$543,326	
		Pre-tax subtotal												\$498,464	
	a-1	Prepare area; 12000 sf	SC	D										\$2,076	
	a-2	Excavate, line pit, stockpile; 40x40x4		D										\$12,240	
	a-3	Install electrical power to area; 400'		D										\$15,204	
	b1-b5	Install collection trench; 300'x40'2'		D										\$310,000	
	b6-b7	Earth work		D										\$21,950	
	c1-c6	Install underground piping		D										\$21,335	
	d-1	Install Piezometers; 6 ea.; 180'		D										\$19,700	
	e1-e5	Terminate systems, restore area		D										\$18,962	
	f1-f5	Install new access road ; 7500 sf		D										\$31,682	
		Direct subtotal												\$453,149	
		General conditions												\$45,315	
		Subtotal without overhead & profit												\$498,464	
		Overhead and profit 10%-10%												\$0	

Site: 317 area French Drain						Authorizations					Containment site: Sheet # 1			
WBS Title: ANL-E REMEDIAL ACTIONS PROJECT						Estimator: Bob Swale/ Vic Mora								
WBS #:						Date 20-Sep-96								
Remedial Action Item Title: BIODEGRADABLE SLURRY COLLECTION TRENCH						PM Approved:								
SWMU # 11						Date:								
						Dir Offc Approved:					Date			
								Unit Price at Safety Level			Total Cost			
WBS #	TASK #	Assembly/Line Item	Resource Code	Safety Level	Unit Man-Hr (conver)	Quantity	Unit	Labor	Equipment	Materials	Labor	Equipment	Materials	Total
		ANL Effort Subtotal	FWA			120					\$10,200	\$0	\$0	\$10,200
	6-10	Draft Corrective Measures Report		N/A		100	hrs	\$85		\$0	\$8,500	\$0	\$0	\$8,500
	6-11	Final Corrective Measures Report		N/A		20	hrs	\$85		\$0	\$1,700	\$0	\$0	\$1,700
	8-10	Stakeholder Accept & Client Appr	PMD	N/A		40	hrs	\$85		\$600	\$3,400	\$0	\$600	\$4,000
	10-1	Total Remedial Action Cost				2,107					\$180,625	\$10,000	\$12,600	\$753,551
Contingency														
Grand Total (w/o Escalation)														\$113,033
														\$866,583