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REMEDIAL MEASURES PLAN FOR A SPILL OF SOLVENT REFINED COAL LIQUID AT THE SRC PILOT PLANT, FT. LEWIS, WASHINGTON

Final Report

By
Thomas W. Grimshaw
William M. Little

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Radian Corporation
Austin, Texas

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22 August 1980

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IV TECHNICAL MEMORANDUM

1.0 INTRODUCTION

The U.S. Department of Energy (DOE), as a part of its efforts to develop technology for deriving petroleum-like products from coal, owns a pilot plant for the solvent refined coal (SRC) process. The pilot plant is operated by Pittsburg and Midway Coal Mining Company (P&M), which is a subsidiary of Gulf Mineral Resources Company (GMRC). The plant is located on Fort Lewis Military Reservation, a U.S. Army installation about 12 miles south of Tacoma, Washington (Figure 1-1).

On 19 December 1979, a spill of SRC liquid occurred during transfer of the liquid from a storage tank to sample drums. Approximately 2,300 gallons of fluid flowed into the floor of the tank farm and infiltrated into the porous and permeable gravels at the site. Because of concern for the possible impact of the SRC fluid on the quality of ground water, surface water, and water supply sources at and near the site, GMRC commissioned Radian to evaluate the problem and recommend specific measures to mitigate any known or anticipated impacts.

This report presents the results of Radian's investigations. Section 2 contains the recommended Remedial Measures Plan, and the remaining sections provide supporting data, interpretations, and conclusions.

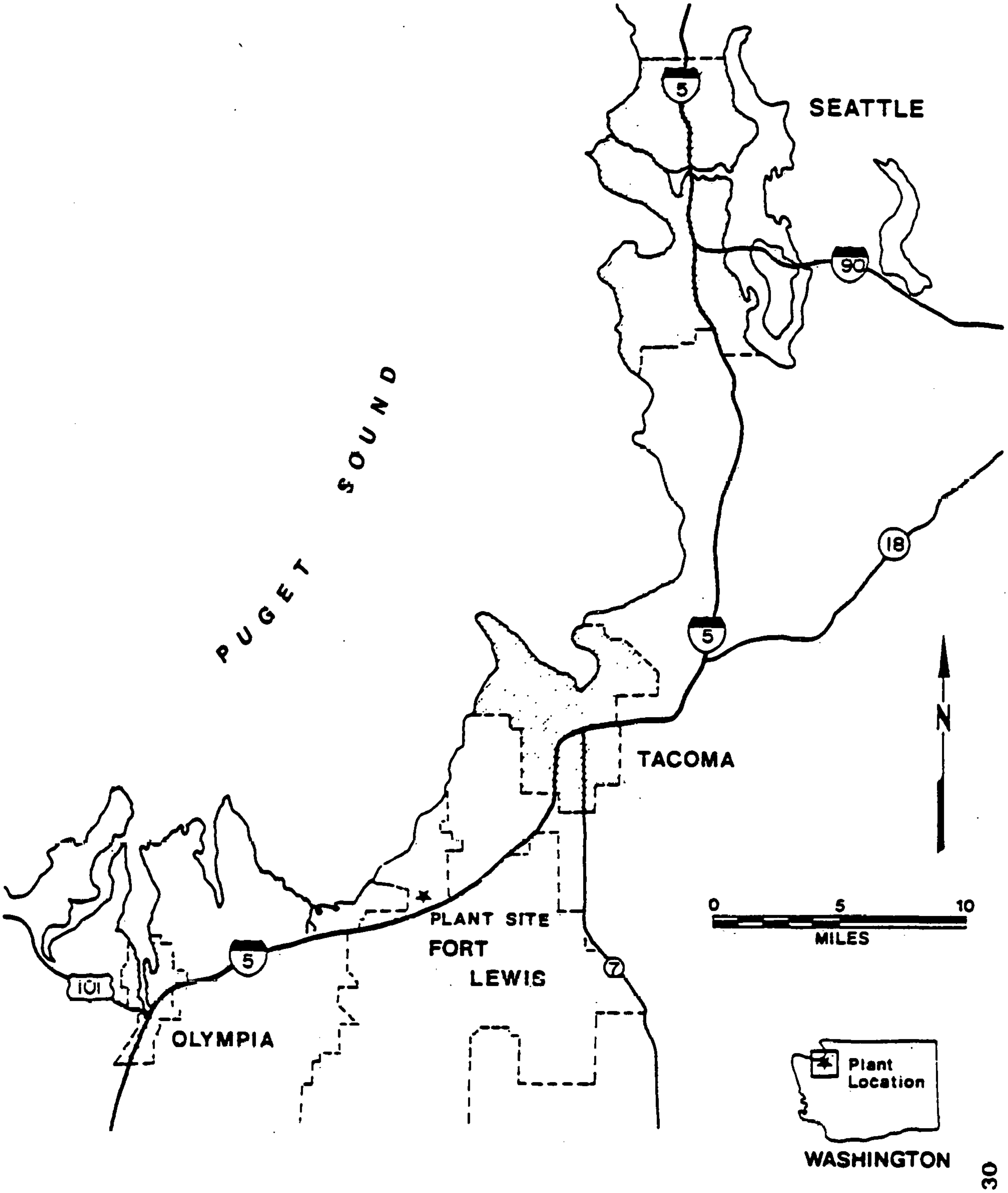


Figure 1-1. Regional Location of the Solvent Refined Coal Pilot Plant.

2.0 RECOMMENDED REMEDIAL MEASURES PLAN

When a liquid contaminant is spilled at the land surface and migrates downward to ground water, remedial measures may be applied in the vadose zone above the water table and in the underlying aquifer. In the vadose zone, the contaminated soil may be physically removed for off-site treatment or disposal, or the contaminating fluid may be immobilized in place. In the aquifer, the movement of contaminants may be controlled by ground-water control measures (passive barriers), plume management measures (pumping or injecting water to control the direction of plume migration), or by in-situ treatment (chemical immobilization or biological degradation).

The Remedial Measures Plan presented here consists of treatment of the problem both in the vadose zone and in the aquifer. Some parts of the plan have been undertaken, and other parts remain to be implemented in whole or in part. The Remedial Measures Plan consists of the following elements:

- Excavate soil contaminated by the spill. Backfill with clean material. South of tank 010, the depth of soil to be removed is 11 feet; north of tank 010, at the original spill site, soil is to be removed to a depth of 20 feet.

- Seal the land surface at the spill site, along with the whole tank farm floor, to prevent further infiltration of precipitation.

- Pump Well 20 to control the ground-water transport of contaminants away from the spill site.

- Install and place in service a new well 500 feet downgradient of the spill to control such contaminants as may have migrated beyond the zone of influence of Well 20. This well and well #20 should remain in service until such time as discharge from each drops below 0.060 mg/ℓ and remains below that level for 3 months.

- Relocate one of the surface water sampling points in Lake Sequalitchew to coincide with the most probable exit point of the plume.

- Institute a long-term monitoring program consisting of monthly sampling of Wells 20, 21, 22, 24, and the new pump well.

Details of the Remedial Measures Plan and the basis for the recommendations are contained in Section 13.0. Also contained in that section are the expected results of implementing the Plan.

3.0 DESCRIPTION OF THE SRC PLANT AND THE SPILL EVENT

As noted in Section 1.0, the DOE/P&M SRC pilot plant is in the northwestern part of the State of Washington. This section contains a description of the plant and surrounding features and a narration of the events related to the spill event.

The SRC plant is situated south of Lake Sequalitchew on the Fort Lewis Military Reservation. The plant is generally about 700 feet from the lake shore. Other important nearby features are Sullivan Well, Sequalitchew Springs, Hamer Marsh, American Lake, and the community of DuPont (Figure 3-1).

The tank farm where the spill of 19 December 1979 occurred is on the west end of the pilot plant between the wastewater treatment plant and the storage piles for coal and solid SRC product. The tank farm is shown in Figure 3-2 with the approximate point of discharge of the spilled SRC fluid and resulting pond of SRC fluid. The spill occurred when a bleeder drain valve was inadvertently left open during transfer operations of SRC fluid from a tank to sample drums. Measurements of the level in the tank from which the fluid was spilled indicated a loss of 2,336 gallons of the liquid (Meyer, 1980). The site of the spill is about 900 feet from the south shore of Lake Sequalitchew.

Because the tank farm was designed to absorb any spilled liquids in order to minimize fire hazard, the SRC fluid infiltrated into the subsurface almost immediately after the pool formed. Several days after the spill occurred, plastic liner material was spread over the spill area to reduce infiltration of precipitation. The configuration and emplacement of the liner

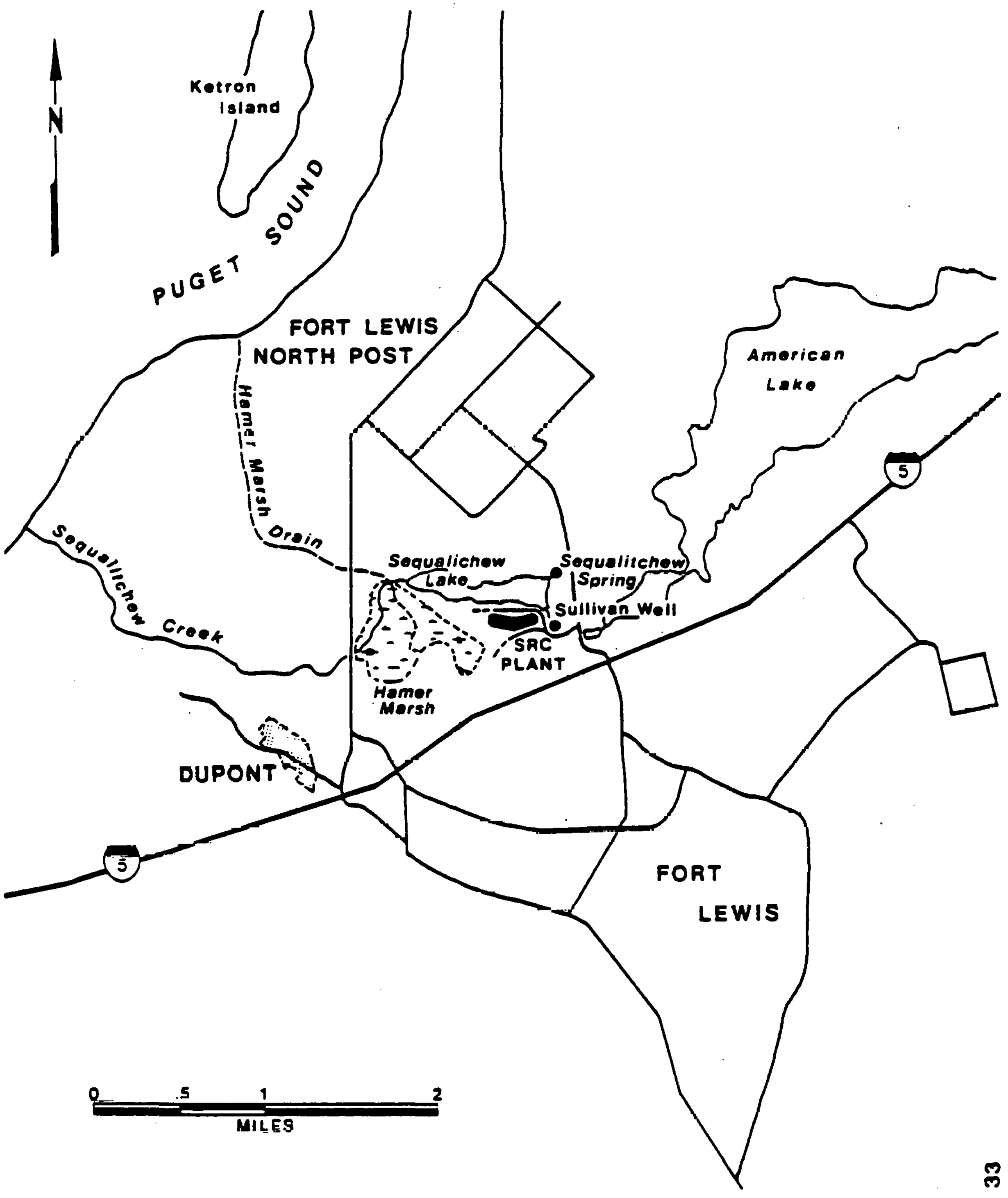


Figure 3-1. Major Features Near the SRC Pilot Plant.

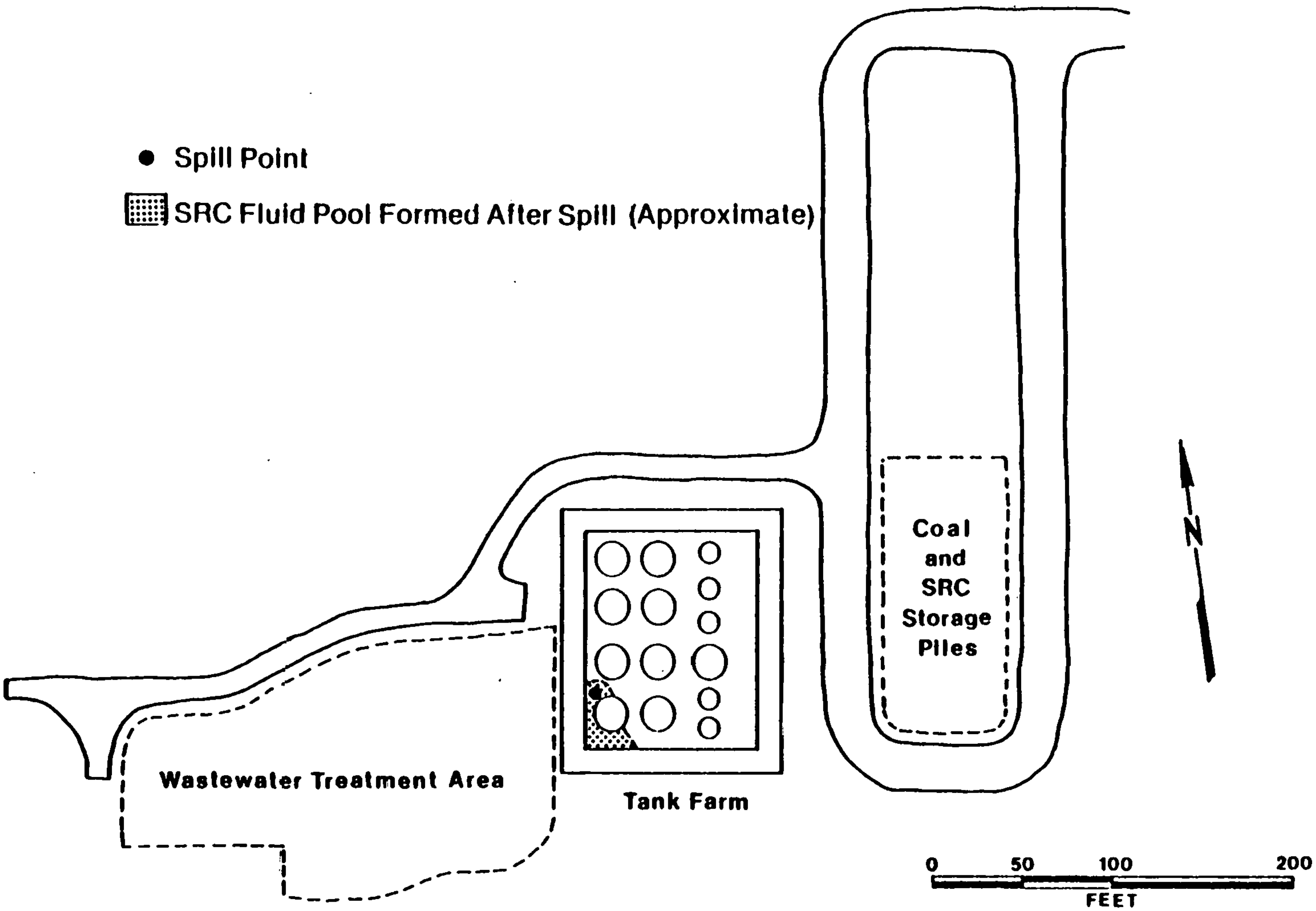


Figure 3-2. West End of SRC Plant, Showing Location of Spill

was later substantially improved by elevating the edges and providing a drain point at the drain in the tank farm. This improved configuration was completed after coring operations by Radian which occurred during the period 24 March to 9 April 1980.

The wastewater discharge permit for the SRC plant (Permit No. 5092 issued on 27 October 1978 by the Washington Department of Ecology, WDOE) has a requirement for a Spill Prevention, Containment, and Countermeasure Plan. The plan requires that WDOE be notified of any spills greater than 500 gallons (Meyer, 1980). Pursuant to that requirement, P&M notified WDOE of the spill on 9 January 1980. Coordination meetings have been held with WDOE personnel on 15 February, 11 March, 24 March, 11 April, and 11 June. A Notice of Violation (Docket No. DE 80-207) was issued on 6 March and an Order (same docket number) was issued on 23 April. A second order (Docket No. DE 80-324) amending the first order was issued on 7 May. P&M has responded to the requirements of the Notice of Violation and the Orders. This report and Remedial Measures Plan constitute a part of P&M's responses.

P&M has maintained an environmental monitoring program for the SRC plant since the plant began operating. This program includes provision for monitoring air quality, surface water quality, and vegetation impacts. No requirements existed for intensive ground-water quality monitoring prior to the 19 December spill, although Sullivan Well and Sequalitchew Springs have been included in the environmental monitoring program.

Prior to Radian's involvement in the events related to the SRC spill, the firm of Rittenhouse-Zeman & Associates (R-Z) was commissioned to begin investigations of the groundwater impacts. This firm, which was engaged on 7 January 1980, installed the first ten wells at the site. The investigation reported here utilizes the wells installed by R-Z and includes all results reported by that firm (Bekey and Zeman, 1980; LaVielle and Zeman, 1980).

4.0 SRC FLUID ANALYSIS

Samples of SRC-II product fluid, similar to that which was spilled, have been analyzed by both Radian and Gulf Science and Technology Center at Harmarville, Pennsylvania. The fluid analyzed is described as follows:

> Fuel Oil Blend, 2.9:1 Middle Distillate: Heavy Distillate, Lot 4/2 - 5/79 from Tank 92011.

The reports from each laboratory are provided as Appendix I. Each laboratory followed an independent method of separation and analysis, but the results obtained are qualitatively compatible. While the Gulf report is presented in its entirety for reference and comparison, the discussion of chemical constituents is based upon results of the Radian analysis.

Approximately 60 percent by weight of the product was identified by GC-MS. Table 4-1 shows a comparison of GC-MS weight percent data with the weight percent data by simple separation.

TABLE 4-1. SUMMARY OF SAMPLE RESULTS OF SRC-II FLUID

Fraction Type	% Found After Extraction	% Found by GC-MS
Aromatic and aliphatic compounds	82	52
Phenolic compounds	11	5.4
Basic compounds	6.9	2.3
TOTAL	99.9	59.7

Of these classes of organic compounds, attention has been focused on the phenol and phenolic compounds, since they are soluble in water and thus mobile in the environment. The phenolic (base extractable) compounds comprise 11 percent of the fluid that was spilled, for a total release of approximately 2100 pounds.

The basic (acid extractable) compounds are generally nitrogenous, such as amines, and are slightly soluble in water. Approximately 1350 pounds of these compounds were released.

The calculations of release quantities are based on simple separation results. There may have been significant neutral carry-over into the base and acid extracts, since only a portion of these classes were identified by GC-MS. (The balance of each portion is "unidentified base or acid extractable material.") If release quantities are based on the identified portion only, the phenolic compounds total 1050 pounds and the basic compounds released total 450 pounds.

The largest portion of the SRC fluid (82 percent) consists of aromatic and aliphatic hydrocarbons, which are substantially insoluble in water. However, these hydrocarbons may be present in water at levels of a few parts per billion. In the case of some toxic or otherwise hazardous materials, available water quality criteria are also at levels of parts per billion. Nearly all of this material, however, was deposited and remains within the vadose zone beneath the spill site, as described below. The regulatory framework and health and environmental criteria for the SRC fluid constituents are discussed in Section 11.0.

The inorganic chemical content of the SRC fluid was not determined for this study. However, data are available describing the metal content of SRC-II process streams (Shields et al, 1979).

The elemental content of the fluid that was spilled should be similar to that shown in Table 4-2.

5.0 HYDROGEOLOGIC FRAMEWORK

The SRC pilot plant is located in the Puget Sound Lowland, a regional low area between the Cascade Mountains to the east and the Olympic Mountains to the west. The aquifers in this lowland region are primarily in unconsolidated deposits left by glacial advances southward down the lowland.

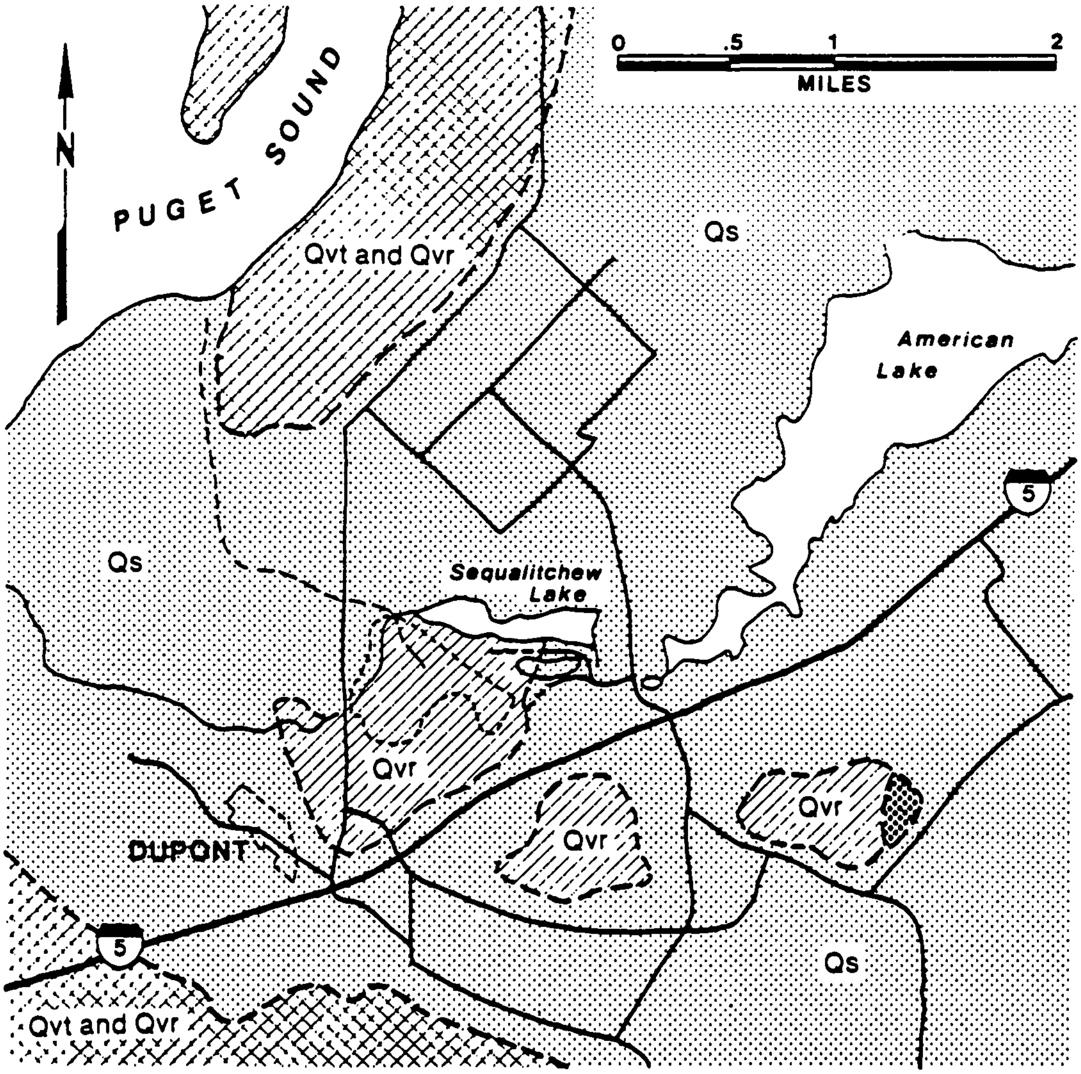
The major geomorphic unit in the area of the SRC plant is the Tacoma Upland, which is bounded by the Puyallup River on the north and northeast, by the Ohop River on the southeast, by the Nisqually River on the southwest, and by Puget Sound on the west (Griffin et al, 1962). This surface is an upland glacial drift plain having several typical glacial features, including outwash channels, drumlins (hills formed by the movement of glacial ice over unconsolidated materials), and kettles (depressions formed by collapse of glacial deposits when underlying residual ice blocks melt). Sequalitchew Lake, American Lake, Gravelly Lake, and Steilacoom Lake are an arcuate string of ground-water lakes formed as kettles over a ridge of ice. All surface features and near-surface deposits of the Tacoma Upland were formed during the last glacial advance (Vashon glaciation).

The subsurface materials at the spill site consist of layers of unconsolidated sand and gravel that were deposited during various glacial and human-related events. The uppermost layer consists of fill material which was transported in from nearby gravel pits before plant construction. This layer of fill material is generally above the water table. The fill thickness varies, but is generally less than 20 feet.

The next two layers consist of sand and gravel deposited when the Vashon glacier retreated. The upper layer consists of material transported in by streams flowing from a glacial lake that was located in what is now the valley of the Puyallup River. This layer, the Steilacoom Gravel, occurred at the surface over most of the SRC plant (Figure 5-1) prior to emplacement of the fill material. The lower layer consists of material derived from the Vashon glacier as it melted back and is referred to as recessional outwash. The recessional outwash occurred at the west end of the SRC plant before emplacement of the fill. The recessional outwash and Steilacoom Gravel together comprise the shallowest aquifer at the plant site. No distinction is made between these two units in this report. The thickness of the combined unit ranges up to 50 feet on the east end of the plant.

Below the Steilacoom Gravel and recessional outwash is a layer of till, which consists of mixed clay, silt, sand, and gravel. This layer is less porous and permeable than the sand and gravel unit above, and it is therefore considered to be a lower confining layer for the upper aquifer. The till has not been drilled through at the plant, so its thickness is not known, but the thickness elsewhere ranges generally from 5 to 30 feet (Walters and Kimmel, 1968).

Another aquifer comprising two geologic units -- the advance gravel and the Colvos Sand -- underlies the till unit. The advance gravel was deposited by glacial meltwaters that flowed from the glacier as it was advancing down the Puget Sound Lowland. The Colvos Sand has not been confirmed at the SRC plant site. Where it occurs, it was apparently deposited by glacial streams flowing from some distance to the north. The aquifer below the till layer has not been explored or evaluated at the SRC plant. If the till is an effective confining layer, as seems likely, the plant would have no impact on this lower aquifer.



░ Qs: Steilacoom Gravel. Pebble to cobble gravel and boulders.

▨ Qvr: Recessional outwash. Principally stratified sand and gravel, but locally contains silt and clay.

▓ Qvt: Compact, unstratified clay, sand, and gravel. Locally contains cobbles and boulders.

░ Qvt and Qvr

(Source: Walters and Kimmel, 1968, Plate 1)

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Figure 5-1. Geologic Map of the SRC Plant Vicinity.

Other strata and associated aquifers occur at greater depths. However, these aquifers would not be affected by activities at the plant and they are not considered further in this report. The aquifer of greatest concern for this study is the water-table aquifer in the recessional outwash and Steilacoom Gravel above the till layer. The remainder of this report will focus on this upper aquifer.

6.0 SUMMARY OF FIELD AND LABORATORY STUDIES

A comprehensive laboratory and field program has been undertaken to address water quality effects of the 19 December 1979 SRC fluid spill. These studies include:

- analysis of the SRC fluid spilled (described in Section 4.0),
- description of substrate lithology,
- definition of quantitative properties (coefficients of transmissivity and storage) of the upper aquifer,
- determination of ground-water hydraulic gradient and flow velocity,
- ground-water and surface-water sampling and analysis, and
- coring and sampling for definition of contaminated soil to be excavated and removed.

Most of the field work has been undertaken by P&M, Radian, and a previously engaged soils testing consultant, Rittenhouse-Zeman Associates.

A total of 24 wells have been drilled for this program. The locations of the wells are shown in Figure 6-1, and their characteristics are summarized in Table 6-1. The wells are functionally grouped and discussed in the following sections.

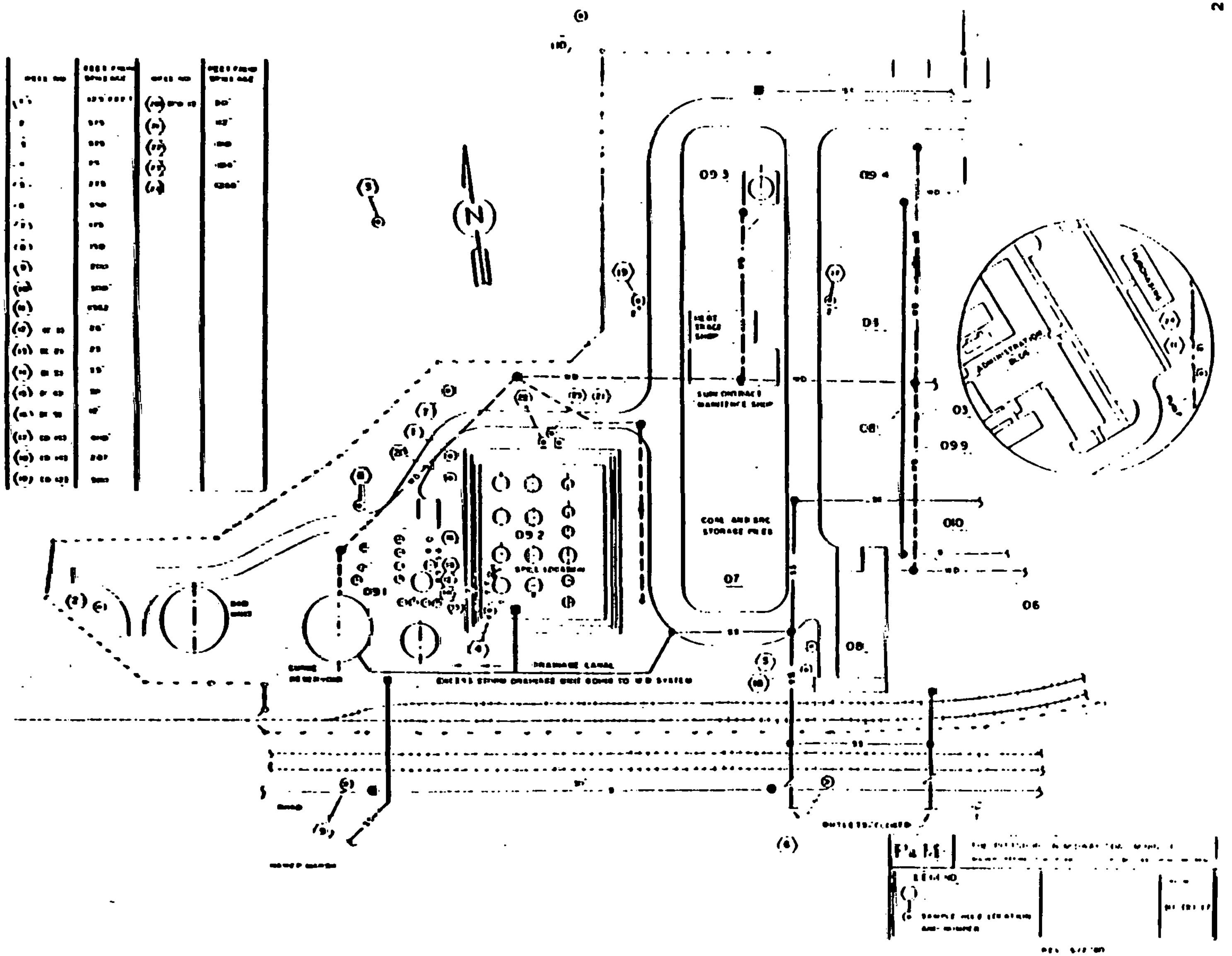


Figure 6-1. Well Locations

TABLE 6-1. TABULATION OF WELL CHARACTERISTICS

P&M Coal No.	Radian No. (obsolete)	Function	Depth (feet)	Diameter (inches)	Wellhead Elevation (feet above MSL)	Screened Interval (feet)
1	B1	Water Quality Sampling, Piezometer[1]	42.5	2	239.39	32.5–42.5
2	B2	Water Quality Sampling, Piezometer	42.5	2	224.52	32.5–42.5
3	B3	Water Quality Sampling, Piezometer	35.0	2	226.46	25.0–35.0
4	B4	Plugged	33.5	2	N/A[2]	N/A
5	B5	Not Used (Above Water Table)	22.0	2	N/A	N/A
6	B6	Water Quality Sampling, Piezometer	49.0	2	240.13	39.0–49.0
7	B7	Water Quality Sampling, Piezometer	44.0	2	238.23	34.0–44.0
8	B8	Water Quality Sampling, Piezometer	40.0	2	236.05	20.0–40.0
9	B9	Water Quality Sampling, Piezometer	36.0	2	230.97	16.0–36.0
10	B10	Water Quality Sampling, Piezometer	34.5	2	239.89	14.5–34.5
11	B11	Water Quality Sampling, Piezometer	51.0	2	252.35[3]	41.0–51.0
12	C1	Corehole, Plugged	30.5	N/A	N/A	N/A
13	C2	Corehole, Plugged	34.5	N/A	N/A	N/A
14	C3	Corehole, Plugged	33.0	N/A	N/A	N/A
15	C4	Corehole, Plugged	34.5	N/A	N/A	N/A
16	C5	Corehole, Plugged	34.0	N/A	N/A	N/A
17	B13	Piezometer	39.5	2	249.81	34.5–39.5
18	B14	Piezometer	34.5	2	243.95	24.5–34.5
19	B12	Piezometer	42.0	2	250.39	37.0–42.0
20	PW	Pump Well, Piezometer	41.0	8 (6 5/8" ID screen)	237.62	26.0–41.0
21	B15	Water Quality Sampling, Piezometer	46.0	6 (4 7/8" ID screen)	243.67	43.5–45.0
22	B16	Water Quality Sampling, Piezometer	39.5	6 (4 7/8" ID screen)	243.43	37.0–38.5
23	B17	Water Quality Sampling, Piezometer	35.0	6 (4 7/8" ID screen)	244.10	31.5–33.0
24	-	Pump Well, Piezometer	59.0	12 (10 3/8" ID screen)	252.08	44.0–54.0

[1] Well plugged on 14 May 1980.

[2] N/A = Not applicable.

[3] Eelvation after 2 May 1980. Pipe was cut off for drilling Well 24.

6.1 Wells 1 to 10:

Ten small-diameter (two-inch) wells were installed by Rittenhouse-Zeman Associates in early attempts to ascertain if the SRC fluid spill had an adverse impact on ground-water quality. They were to serve as piezometers and for soil and water quality sampling. Well 4 (drilled in the tank farm floor) was plugged to prevent accelerated percolation of precipitation, and Well 5 was not successful.

These wells had the advantage that they were quick and easy to install (using the hollow-stem auger method), they were inexpensive, and it was possible to collect soil samples during well construction. However, it is difficult to obtain fresh formation water from them because of low productivity. It is not possible in the silty and sandy gravel aquifer to do an adequate job of well development, which would increase well productivity, in the small-diameter wells.

These wells were completed by installing two-inch diameter galvanized steel casing in the hollow-stem auger after the hole had been drilled to total depth. Perforations were provided by cutting slots in the lower end of the pipe (Bekey and Zeman, 1980; Lavielle and Zeman, 1980). Sampling of the wells is accomplished by a portable vacuum pump and flask. Permanent sample extraction tubes (3/8-inch diameter stainless steel tubing) extend to the bottom of the hole.

6.2 Well 11

This well was drilled as a piezometer and interim water quality sampling well at the east end of the plant. The casing, a two-inch inside diameter iron pipe with a ten-foot long wirewound screen, was emplaced with a hollow-stem auger. A sketch of construction details of Well 11 is shown in Figure 6-2. As a means of obtaining appropriate ground-water quality samples, Well 11 suffered many of the problems of Wells 1-10. Sampling was suspended when Well 24 was completed nearby.

6.3 Holes 12 to 16

As a means of defining the depth of contamination at the spill site, coreholes 12 to 16 were drilled by hollow-stem auger to a depth of approximately 30 feet. The corehole locations are shown in Figure 6-1. Logs of the cores are presented in Appendix II. Soil samples recovered with a split spoon sampler were analyzed as discussed in Section 13.2. At the end of the coring operation, the auger was pulled and the holes allowed to collapse. The surface was covered with a temporary plastic sheet to prevent infiltration.

6.4 Wells 17 to 19

Because of the need for better water level control to the east of spill site, three additional piezometers were installed (Wells 17, 18, and 19). The piezometer installation holes were drilled by hollow-stem auger. The holes were logged and sampled at 2-1/2 ft. intervals with a split spoon. The piezometers are 2 inch i.d. galvanized iron pipe with a 3-foot 78/1000-inch continuous slot galvanized well point. A continuous cement grout was installed from the top of the screen to the land surface. The geometry of the installed piezometers is shown in Figure 6-3. Logs of the piezometer holes are shown in Appendix II.

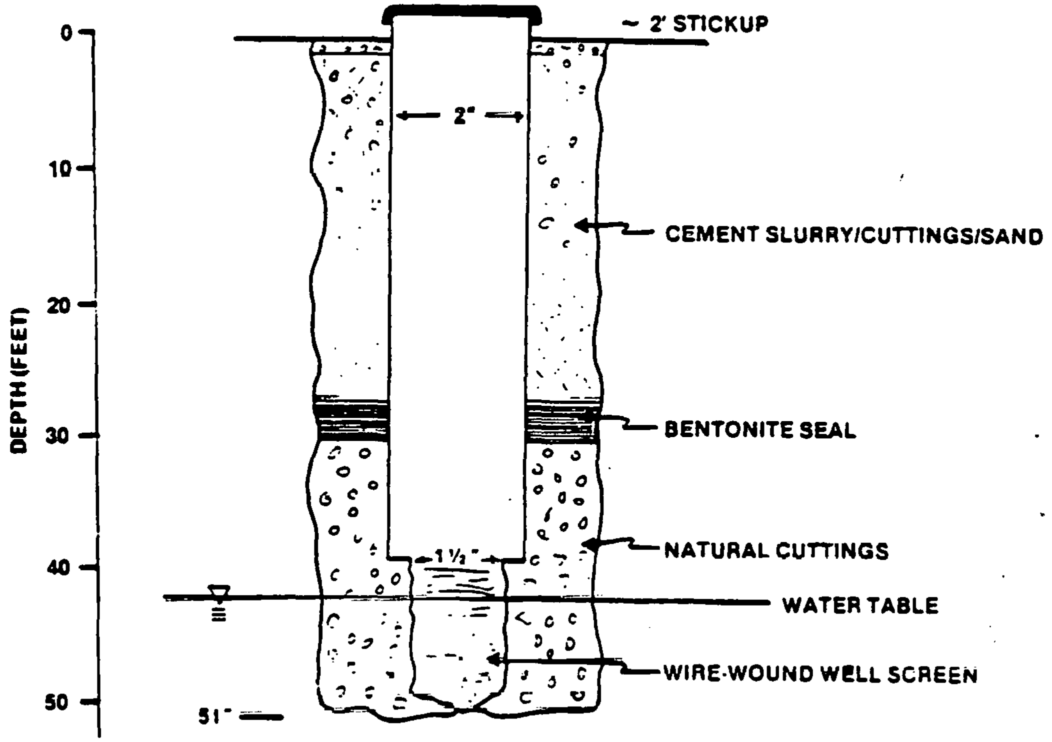


Figure 6-2. Construction Details of Well 11.

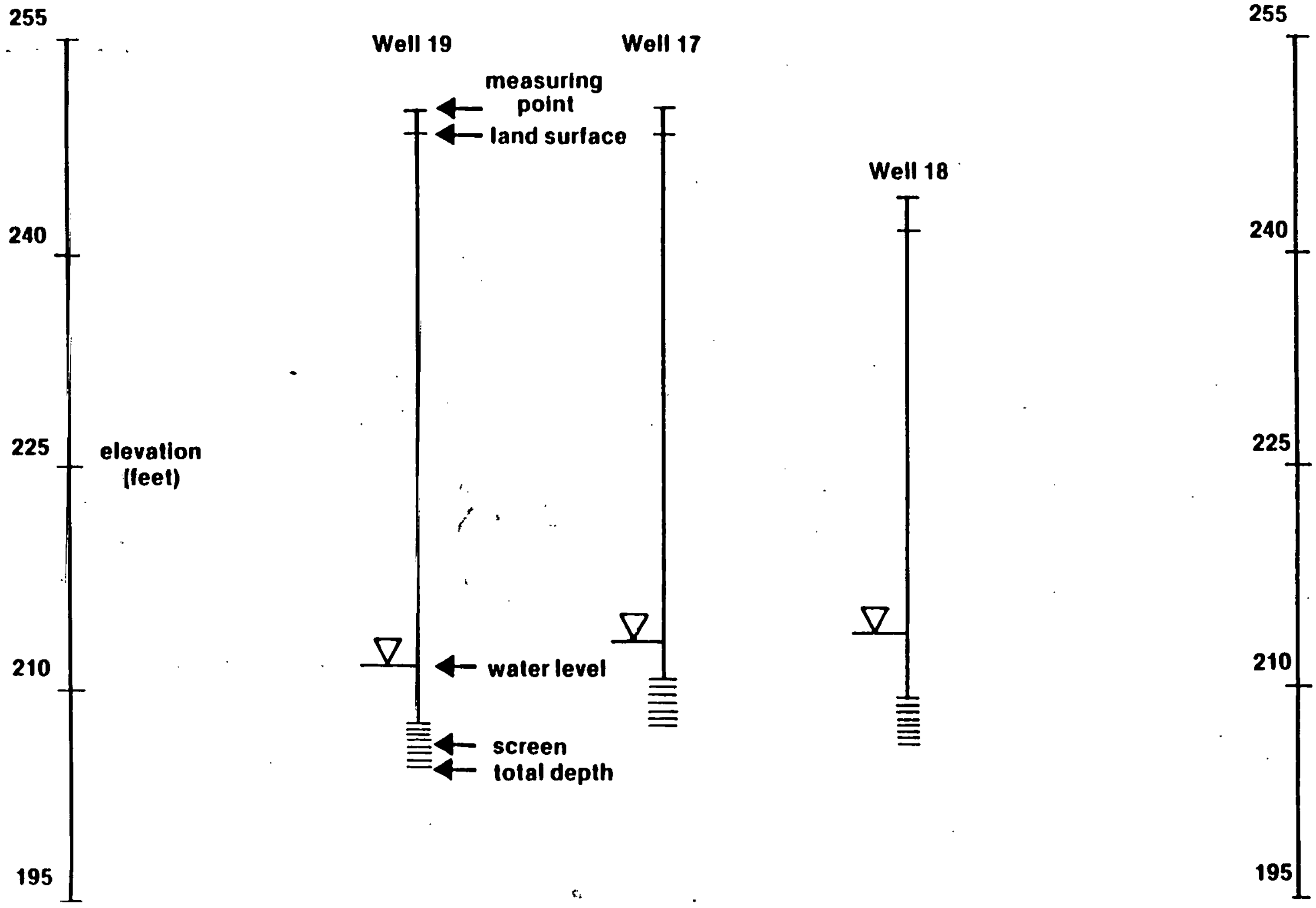


Figure 6-3. Piezometer Construction.

6.5 Well 20

A pump well (Well 20) was installed on 2 April near the spill site to enable an aquifer test to be conducted and at the same time to provide a second function as an Interim Remedial Measure in the event that an excursion of highly contaminated water was found. The specifications of the pump well are as follows:

Total depth: 41 feet
Casing diameter (i.d.): 8 inches
Screen: 15 feet of Johnson stainless steel
6 5/8" i.d.
Screened interval: (lsd) 26-41
(elev.) 210-195
Screen slot: 0.016"
Major producing zone: one foot bed of medium gravel at 30-31 feet below land surface.
Depth to water: 25 feet from land surface
Elevation of measuring point: 237.62 (1.8 feet above lsd)

Well 20 was drilled by air rotary, a high capacity method which introduces no contaminants, such as drilling mud, into the formation. Materials encountered are brought up as drill cuttings. Well construction consisted of the following steps:

- simultaneously drive surface casing and drill with air-rotary method to approximately 25 feet;
- simultaneously drive well casing and air-rotary drill to the depth of interest;

- install continuous slot stainless steel screen with lead packer;
- pull back well casing to expose screen; swedge lead packer;
- pull surface casing out while attempting to keep the annulus between casings filled with cement slurry;
- develop the well using a horizontal air jet and air lift pumping method.

The well construction procedures produced satisfactory results. Some difficulty was encountered with cement slurry loss into the sands and gravels. As a result, cementing is probably not continuous. However, all wells have sufficient cemented intervals to prevent ground-water sample contamination caused by well construction.

Well 20 was completed through the entire length of the upper aquifer and thus provides an integrated sample of the water in the aquifer. The method of completion included cementing in of the upper part of the casing to prevent sample contamination as well as the use of well screen and good development procedures. These methods ensure that a fresh, representative sample of the formation waters is obtained. Samples were collected by submersible pump.

6.6 Wells 21 to 23

Wells 21 to 23 are a "triad", a set of three water quality monitor wells emplaced at varying depths in the aquifer for defining the vertical variations in ground-water contamination. Well 23 is completed just below the water table; Well 21, at the base of the aquifer; and Well 22, at mid-depth in the aquifer. All three wells were drilled by air rotary, using the same procedure as for Well 20. They are 6-inch diameter, with steel casing and a 20-inch continuous slot stainless steel screen (0.004 inch slot). A two-foot section of blank casing is welded on the base of the screen to facilitate sampling. Construction details of wells 21 to 23 are shown in Figure 6-4. Drilling logs are in Appendix II. Samples were collected with a small (1 gpm) pump that was lowered into the hole for sampling. The wells were pumped to remove a volume equivalent to four times the volume of standing water in the well before samples were collected.

6.7 Well 24

Well 24 was installed as a piezometer and water quality sampling well to replace Well 11. It is also designed to serve as a production well, providing a cone of depression to prevent migration of contaminants from the SRC plant area toward Sullivan Well, as discussed in Section 13.0. The specifications of Well 24 are as follows:

Total depth: 59 feet
Casing diameter (i.d.): 12 inches
Screen: 10 feet of Johnson stainless steel
10 3/8" i.d. with 5-foot blank 10-inch casing
on bottom of screen.
Screened Interval (lsd): 44-54
(elev): 207-197
Screen Slot: 0.020"
Depth to water: 40 feet from land surface
Elevation of measuring point: 252.08 (1 foot above lsd)
Drilling Method: Air rotary with foam (a mixture of water
and Proctor and Gamble, Inc. ORVUS-K®
synthetic detergent.

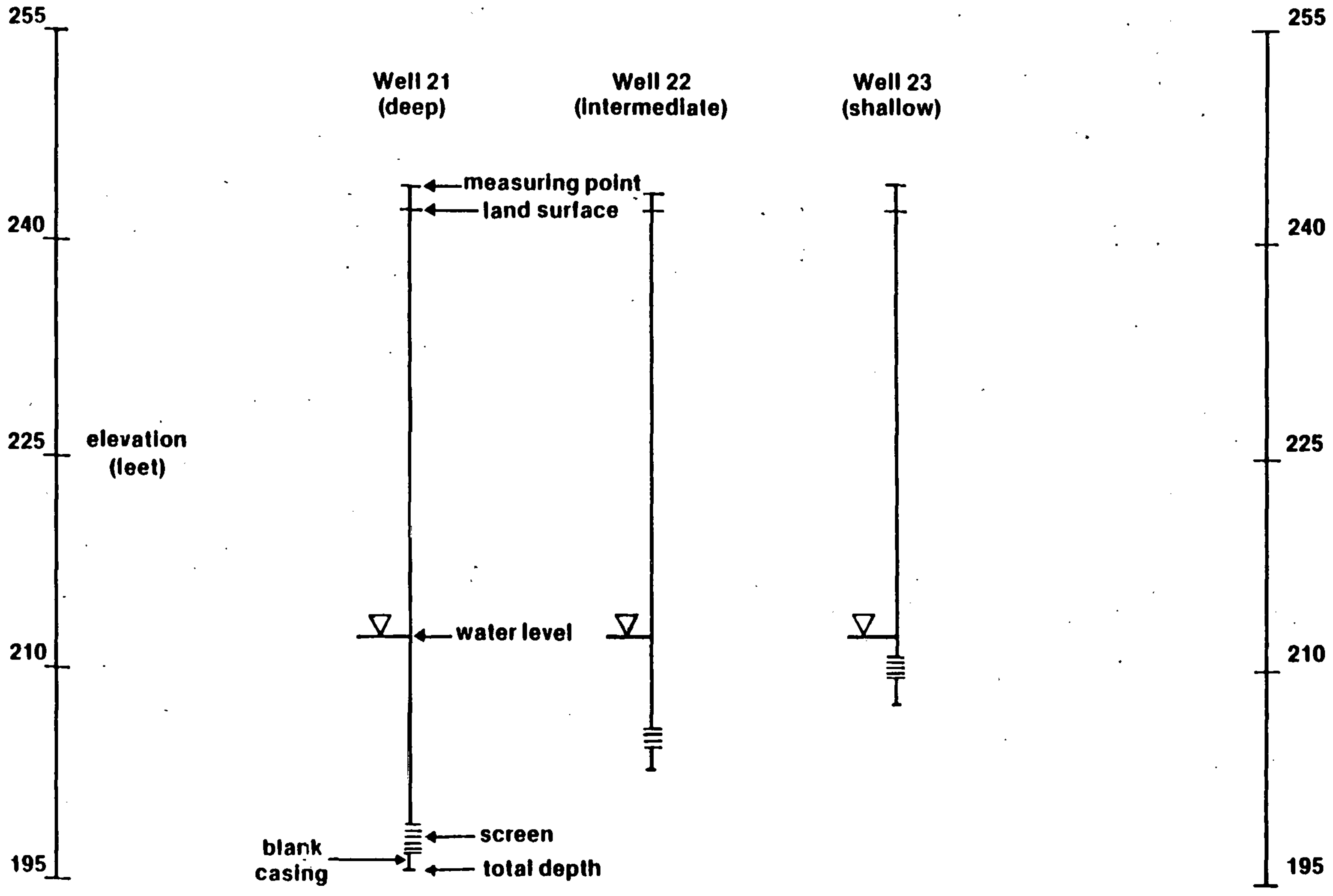


Figure 6-4. Construction of Triad Wells.

The drilling log is in Appendix II. Water quality samples are collected with the installed submersible pump.

7.0 AQUIFER CHARACTERISTICS

The aquifer characteristics of primary concern for defining the impacts of the SRC fluid spill and for preparing the Remedial Measures Plan are the aquifer lithology and the aquifer constants (coefficients of transmissivity and storage). As noted in Section 5.0, only the upper water-table aquifer is likely to have been affected by the SRC fluid spill. The depth to the water table is about 32 feet at the spill site. The depth to water varies with elevation elsewhere in the SRC plant.

7.1 Aquifer Lithology

As noted in Section 5.0, the upper water-table aquifer at the spill site consists of gravel, sand, silt, and clay deposited by meltwater streams. The till below the aquifer consists of similar materials (but with a higher proportion of the finer grained fraction) that were deposited directly by glacial ice.

Textural (grain-size) analyses have been conducted on samples collected for the current program and on samples collected for foundation studies that were made before the SRC pilot plant was built (Druebert and Bestwick, 1972). A map showing the locations of two boreholes and a test pit from which samples were collected near the spill site is shown in Figure 7-1. Because of the small diameter of the split-spoon sampler used to collect samples from boreholes, a representative sample is difficult to obtain from coarse-grained soils at the site. Textural analyses of samples from the test pit are more reliable than analyses of samples from the boreholes.

Grade maps for the SRC plant indicate that about 10 to 12 feet of sand and gravel fill was emplaced in the vicinity

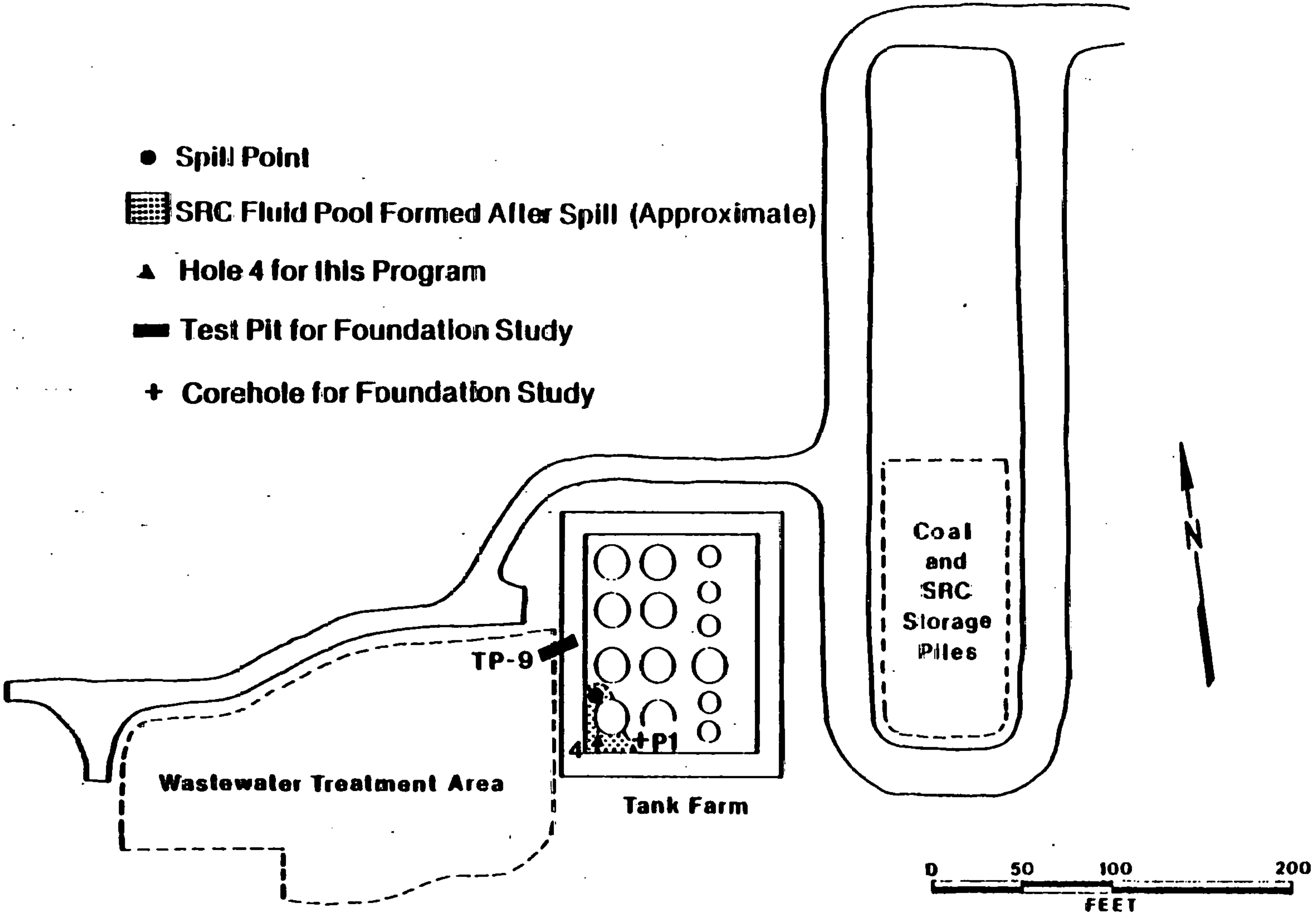


Figure 7-1. Location of Substrate Sampling Points.

of the spill site. Below the fill is a thin soil zone and about 20 feet of unsaturated sand and gravel above the water table. The total depth to water is about 32 feet.

Corehole 4 by R-Z was drilled to 33.5 feet. Two samples were collected, one at 19.5 to 21.0 feet and one at 29.5 to 31.0 feet, and subjected to grain size analysis. These samples are from below the fill and above the water table. The grain size distribution curves for these samples are shown in Figure 7-2. The median grain size (D_{50}) of the upper sample is about six mm (fine gravel), and the D_{50} of the lower sample is about 2.1 mm (coarse sand). Both samples are poorly sorted. The upper sample has a uniformity coefficient (D_{60}/D_{10}) of about 12.5 and the lower sample has a uniformity coefficient of about 16.

Test pit 9 (TP-9) was dug and sampled for foundation investigations prior to fill emplacement, so sampling depths are depths below the base of the fill. A sample was collected at a depth of about four feet below the fill (about 15 feet below present grade). The sample is described as follows:

> Brownish gray, silty, gravelly, poorly graded SAND. Maximum size 1-1/2 inches, about 11 percent subrounded gravel, 68 percent subrounded sand and 21 percent non-plastic silt. Moist.

The grain-size distribution curve is shown in Figure 7-3. The median grain size of the sample is about 0.26 mm (fine sand).

Corehole P2, which was also drilled prior to fill emplacement, was drilled to a depth of about 53 feet below present grade. Textural descriptions for the saturated zone part of this corehole offer insight into the lithology of the water-table aquifer (Figure 7-4). The aquifer to a depth of about 42 feet below present grade consists of medium to coarse

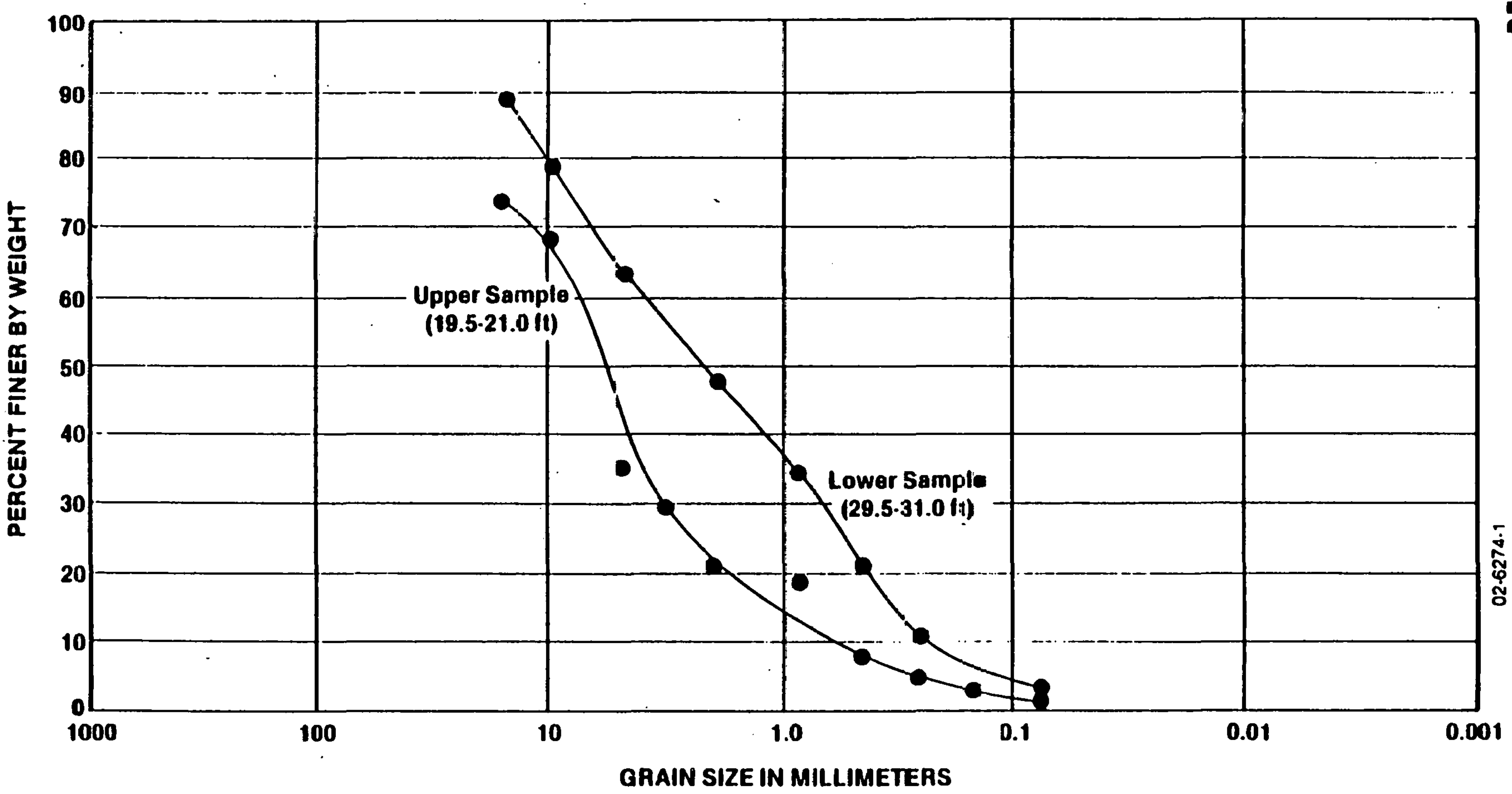


Figure 7-2. Grain Size Distribution Curves for Samples from Hole 4.

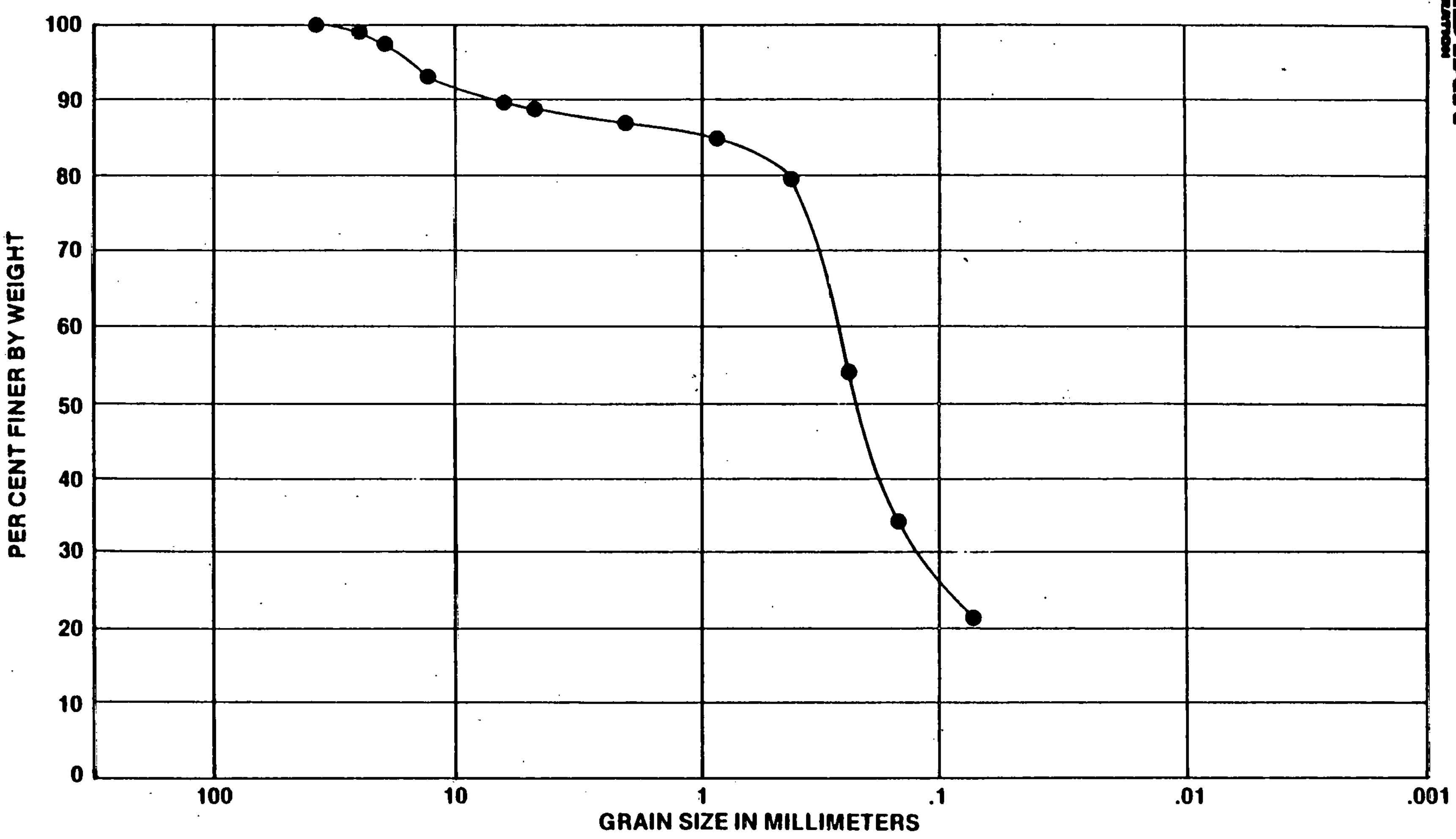
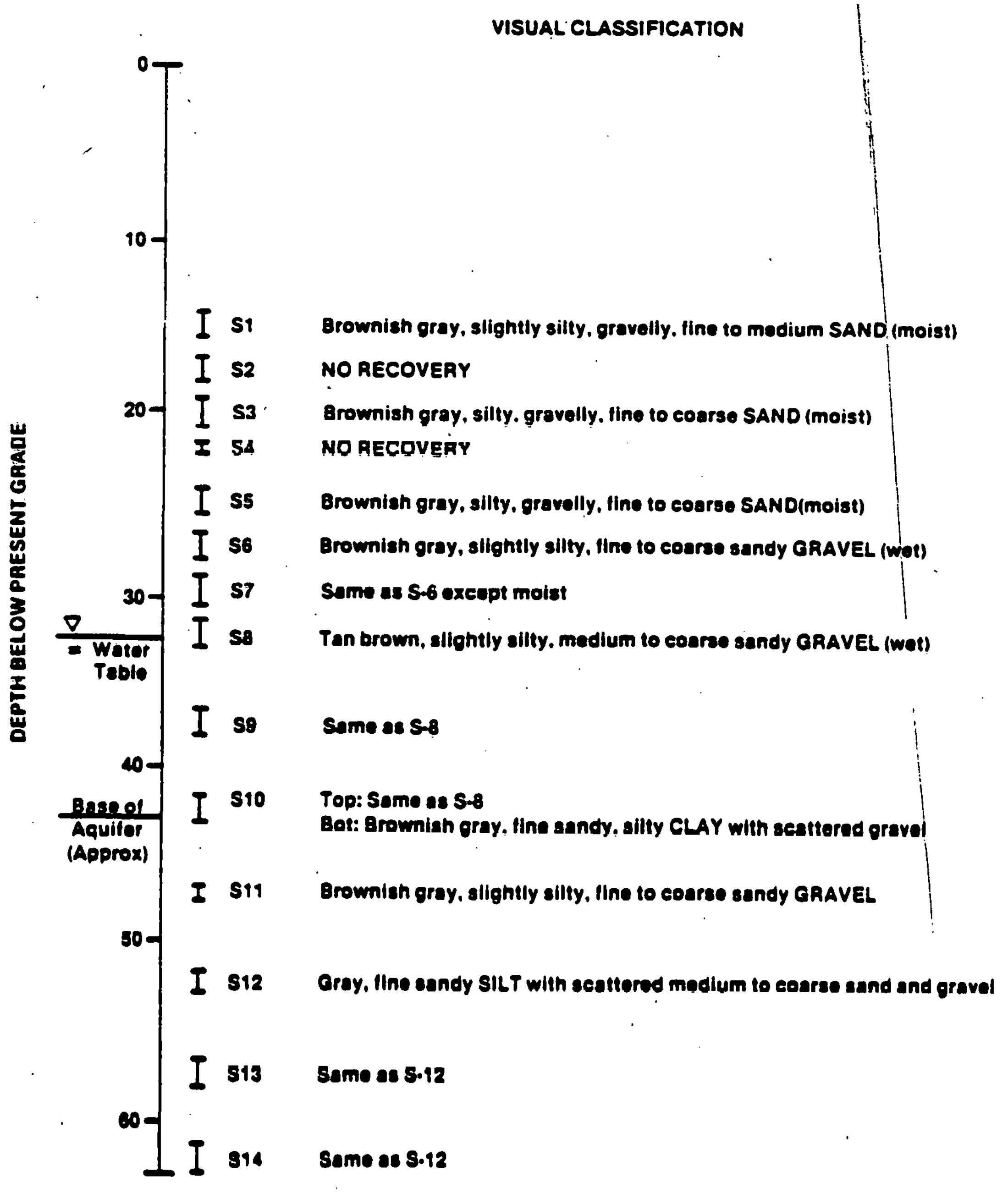


Figure 7-3. Grain Size Distribution Curve for Sample from Test Pit TP-9.



S1	Brownish gray, slightly silty, gravelly, fine to medium SAND (moist)
S2	NO RECOVERY
S3	Brownish gray, silty, gravelly, fine to coarse SAND (moist)
S4	NO RECOVERY
S5	Brownish gray, silty, gravelly, fine to coarse SAND(moist)
S6	Brownish gray, slightly silty, fine to coarse sandy GRAVEL (wet)
S7	Same as S-6 except moist
S8	Tan brown, slightly silty, medium to coarse sandy GRAVEL (wet)
S9	Same as S-8
S10	Top: Same as S-8 Bot: Brownish gray, fine sandy, silty CLAY with scattered gravel
S11	Brownish gray, slightly silty, fine to coarse sandy GRAVEL
S12	Gray, fine sandy SILT with scattered medium to coarse sand and gravel
S13	Same as S-12
S14	Same as S-12

(Source: Druebert and Bestwick, 1972)

Figure 7-4. Lithologic Log of Corehole P-2.

sandy gravel. Below that level, the lithology consists primarily of clay and silt with occasional gravel layers. The 42-foot depth is interpreted to be the contact between the outwash and the till, and is thus the base of the upper aquifer.

In summary, the subsurface at the spill site consists of about 11 feet of sand and gravel fill material underlain by interbedded sand and gravel layers. The water table occurs in the sand and gravel layers at a depth of about 32 feet. The base of the aquifer is a clay and silt layer which begins at a depth of 42 feet and extends to at least 63 feet below the tank farm floor. Logs of wells and coreholes emplaced by Radian (Appendix II) confirm these findings.

7.2 Aquifer Constants

Aquifer constants for the upper aquifer were determined at two locations by recording time and drawdown data during constant-discharge pumping tests. Well discharges were measured using 55-gallon drums. Depths to water were measured using electric water-level tapes. Electric submersible pumps were used for all tests.

Initial plans for the aquifer test included complete evaluation of the possibility of utilizing Sullivan Well in order to avoid having to drill a pump well and associated piezometers. The analysis of Sullivan Well showed that it is a manmade alteration of a previously existing spring. The installation was deemed unsuitable for pump testing to determine the aquifer characteristics in the vicinity of the spill site, and the option of utilizing Sullivan Well was discarded.

7.2.1 Pump Test Near Spill Site

A pump well (Well 20) was installed near the spill site to enable an aquifer test to be conducted. The specifications of the pump well were presented in Section 6.5. Well 20 was constructed near (14.0 feet) existing Well 1 so that Well 1 could be used as an observation well. Well 20 was developed for about one hour with compressed air, and about 40 gpm (gallons per minute) were eventually produced during development. The water level in observation Well 1 dropped about two inches during development.

A pump which would produce 60 gpm was installed in Well 20, and an aquifer test was conducted on 16 April. Well 20 was pumped for 220 minutes (3.67 hours) at 60 gpm. Significant rainfall did not occur during the test. Drawdowns were 0.61 feet for Well 20 and 0.28 for observation Well 1. Water level recovery data were then taken in Well 1. After 17 minutes, recovery was 0.44 feet. Figure 7-5 shows time-drawdown data plotted for observation Well 1. These data were analyzed using type curves for aquifers with delayed yield from storage (Lohman, 1972, p. 36).

Calculated values for transmissivity and storage coefficient are 65,480 gallons per day/foot (gpd/ft) and 0.17, respectively. For an aquifer thickness of 15 feet, a permeability value of about 4,365 gpd/ft^2 is indicated.

On 17 April a second pump test using Wells 20 and 1 was started with the intention of continuing the second test for several days. Well 20 was pumped at 60 gpm. After about 24 hours, a rainfall event began which eventually produced several inches of rain. Water levels in both wells eventually rose above pre-pumping levels. Time-drawdown data for this pumping test were found to be uninterpretable.

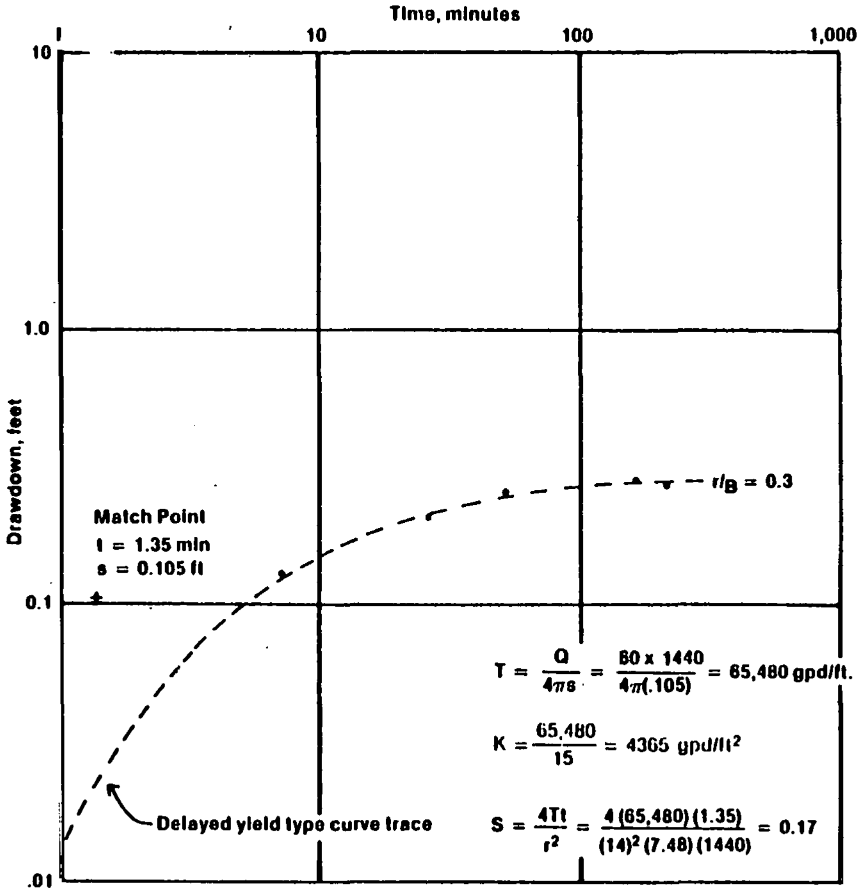


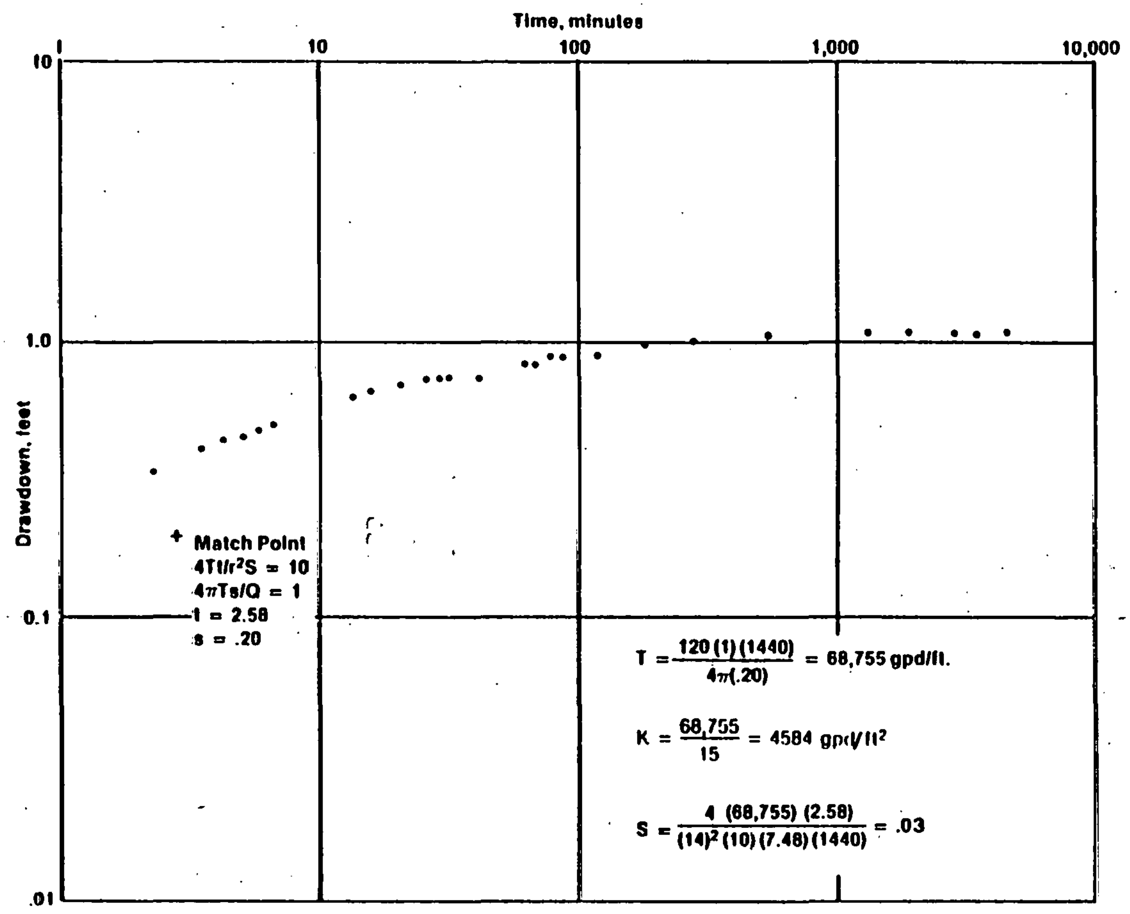
Figure 7-5. Time-Drawdown Data for Well 1, First Pump Test.

On 1 May a larger pump was installed in Well 20. A long-duration pump test was conducted using Wells 1 and 20 on 3 May through 7 May. Well 20 was pumped at 120 gpm (maximum production with this pump) for about 74 hours. Rainfall during the pump test was 0.01 inches, as reported by the P&M laboratory. After 4,440 minutes, drawdowns were 1.08 feet for the observation well and 1.96 feet for the pumping well. Water level recovery data were measured in observation Well 1 for about 26 hours. After 1,535 minutes, recovery was 0.99 feet. Appendix III shows raw data obtained during this pump test.

Time-drawdown and time-recovery data for observation Well 1 are plotted on Figures 7-6 and 7-7. These data were analyzed using type curves for aquifers with delayed yield from storage (Lohman, 1972, p. 36). Calculated values for transmissivity, storage coefficient, and permeability (assume 15-foot aquifer thickness) are:

	Transmissivity (gpd/ft)	Storage Coefficient	Permeability (gpd/ft^2)
Pumping Data	68,755	0.03	4,584
Recovery Data	68,755	0.04	4,584

The calculated storage coefficients are very low; .03 (pumping) and .04 (recovery). The actual storage coefficient is probably about 0.17, as indicated in the 220-minute pumping test on 16 April. The very low storage coefficients calculated from the 3 May through 7 May test data are probably indicative of "intermediate" pump test times, when ground-water level declines are primarily controlled by flows which have significant non-radial components.

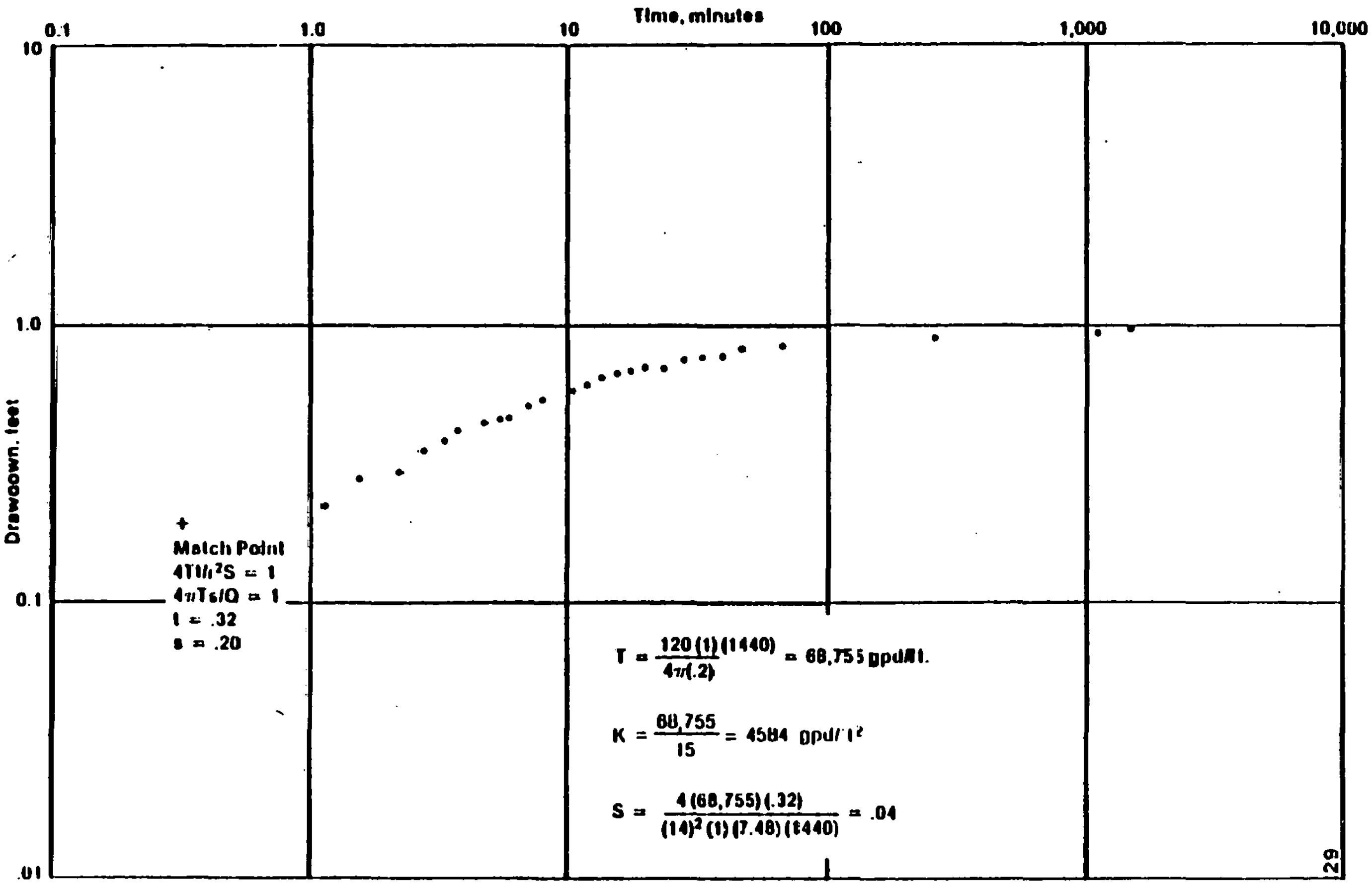


$$T = \frac{120\,(1)\,(1440)}{4\pi(.20)} = 68{,}755 \text{ gpd/ft.}$$

$$K = \frac{68{,}755}{15} = 4584 \text{ gpd/ft}^2$$

$$S = \frac{4\ (68{,}755)\ (2.58)}{(14)^2\,(10)\,(7.48)\,(1440)} = .03$$

Figure 7-6. Time-Drawdown Data for Well 1, Second Pump Test.



$$T = \frac{120(1)(1440)}{4\pi(.2)} = 68,755 \text{ gpd/ft.}$$

$$K = \frac{68,755}{15} = 4584 \text{ gpd/ft}^2$$

$$S = \frac{4(68,755)(.32)}{(14)^2(1)(7.48)(1440)} = .04$$

Figure 7-7. Recovery Data for Well 1, Second Pump Test.

7.2.2 Pump Test at East End of SRC Plant

An additional pumping well, Well 24, was constructed on 2 May through 8 May. This well is located east of the plant, near Well 11 (13.3 feet). Well 11 was used as an observation well. Well 24 was developed using a bailer and produced an unexpectedly small discharge. Using the large pump from Well 20, the well was quickly pumped dry on 9 May, and the discharge was throttled back to 6.7 gpm. After about 72 hours the discharge was 6.7 gpm and the pump was shut off. Recovering water levels were measured in Well 24 for 20 hours; total recovery was 2.49 feet. Observation Well 11 recovery data showed 1.14 foot of recovery. On 13 May, after a 4-hour pumping and recovery preliminary test, Well 24 was restarted at 20 gpm. Drawdown data for Well 24 and Well 11 were recorded for about 24 hours. Discharge dropped to about 14 gpm during the last 17 hours of the test. Total drawdown was seven feet for Well 24 and 2.55 feet for Well 11. No significant rainfall occurred during these tests.

Recovery data from 12-13 May (after 72 hours of pumping at 6.7 gpm) were analyzed. Pumping well (Well 24) recovery data were analyzed using type curves for aquifer with delayed yield from storage (Lohman, 1972, p. 36), and observation well (Well 11) data were analyzed using the standard Theis type-curve method.

Calculated values for transmissivity are 450 gpd/ft for the pumping well data and 4,131 gpd/ft for the observation well data. Using specific capacity data, transmissivity estimates of 2,300 and 2,900 gpd/ft were calculated. Actual transmissivity for the water-table aquifer at this location is estimated to be 3,000 to 4,000 gpd/ft. For an aquifer thickness of 14 feet, the corresponding range for permeability is 214 to 285 gpd/ft^2. These smaller aquifer constants reflect the higher proportion of silt and clay observed in samples from Well 24.

8.0 GROUND-WATER FLOW

Data are available for defining ground-water flow in the Fort Lewis region and in the immediate vicinity of the SRC plant.

8.1 Regional Flow Pattern

On the Tacoma Upland, ground-water recharge occurs by direct infiltration of the surface and by flow losses from streams. The highly porous and permeable Steilacoom gravel which covers much of the upland is amenable to high rates of recharge. The annual average precipitation in the area is about 38 inches, of which 21 inches (55 percent) infiltrates as ground-water recharge (Griffin, et al., 1962).

From the upland area, ground water flows generally northwestward toward Puget Sound (Figure 8-1). Most of the ground-water discharge occurs by springflow along Puget Sound; a total of eight springs are present along the Sound north and west of the plant site (Walters and Kimmel, 1968, Plate 2). Ground-water discharge to the surface also occurs at springs in the upland (such as Sequalitchew Springs) and in submarine springs in Puget Sound.

As noted, Sequalitchew Lake, American Lake, Gravelly Lake, and Steilacoom Lake are ground-water lakes whose surfaces are generally at the same elevation as the water table at their respective locations. Thus, the lakes are an integral part of the ground-water flow system; they receive ground-water flow from the upgradient (east and south) sides, and they discharge to ground water on the downgradient (west and north) sides. Most of the lakes also have surface stream outlets.

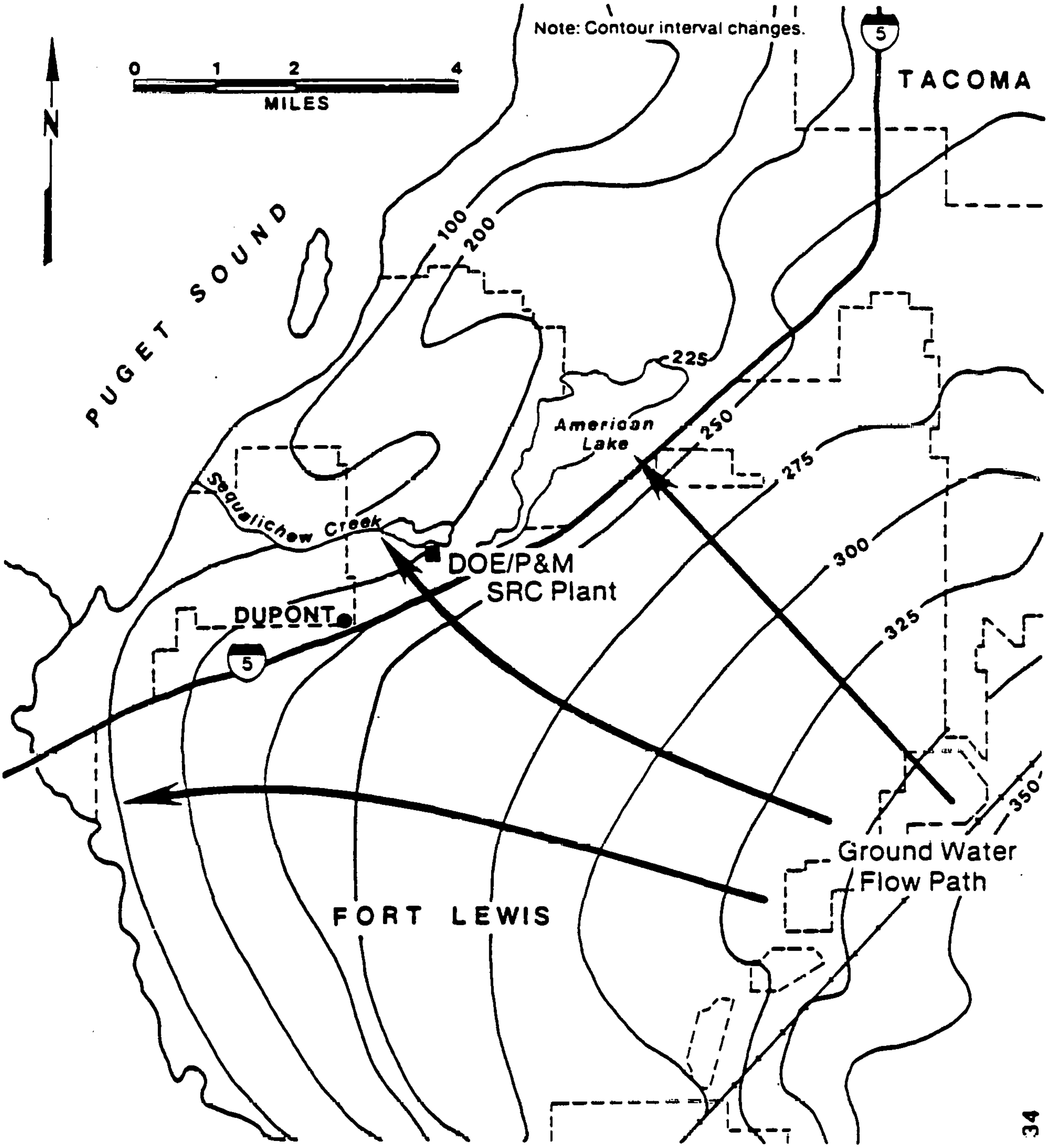


FIGURE 8-1. Regional Ground-Water Flow Pattern

8.2 Hydrology of Sequalitchew Springs and Sullivan Well

American Lake is apparently discharging both by contribution to ground water on the west side of the lake and by subsurface outflow at the southern end which emerges as springflow at Sequalitchew Lake. American Lake does not have a surface stream outlet. The flow of Sequalitchew Springs at the east end of Sequalitchew Lake is thus derived from American Lake (Griffin, et al., 1962), and the flow at Sullivan Well (which was a spring before being altered for water supply purposes) also is apparently derived from underflow from American Lake. The inferred flow paths for ground-water flow from American Lake to Sequalitchew Lake are shown in Figure 8-2. The elevation of American Lake is about 23 feet higher than that of Sequalitchew Lake; it is apparent that this hydraulic head is the driving force that causes the flow from American Lake to Sequalitchew Lake.

8.3 Local Hydraulic Gradient and Ground-Water Flow

Using piezometers installed by R-Z and Radian, depth-to-water measurements were made on all available wells on six different days: 18 March, 19 March, 27 March, 6 April, 14 April, and 1 May. Depths to water from established reference points were measured using electric water level tapes. All measurements were accomplished within 3 to 8 hours. Well pumpage and sampling activities were suspended three days before most measurement days, including 14 April and 1 May. Using surveyed elevations for the established reference points on each well, maps of the elevation of the water surface were prepared. Table 8-1 presents water level elevation data. Figures 8-3 and 8-4 present plan views of water level elevation data on 14 April and 1 May with elevation contours added. Horizontal control was achieved

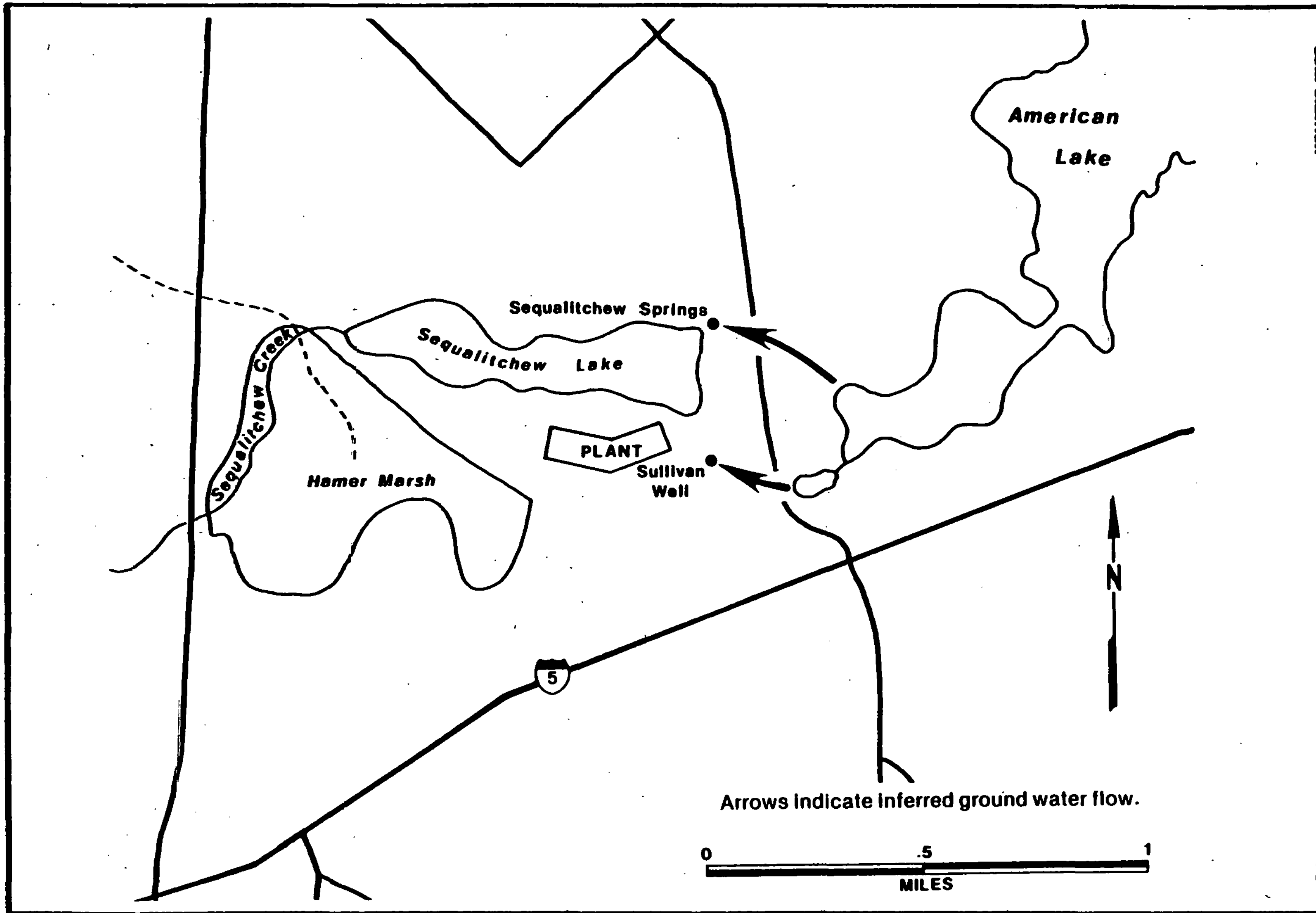
TABLE 8-1. WATER LEVEL ELEVATION DATA FROM PIEZOMETER WELLS

Well No.	18 March[1]	19 March	27 March	6 April	14 April	1 May
1	213.47	212.43	212.30	212.39	212.22	212.43
2	208.91	212.29	212.63	212.77	212.54	212.55
3	212.04	212.01	211.94	211.88	211.79	212.11
4	NA[2]	NA	NA	NA	NA	NA
5	NA	NA	NA	NA	NA	NA
6	210.77	212.42	213.34	213.19	213.11	213.24
7	212.02	212.16	212.25	212.31	212.19	212.34
8	212.48	212.27	212.44	212.47	212.37	212.49
9	213.09	212.93	212.98	212.97	212.89	212.89
10	212.01	212.04	211.78	211.77	211.74	211.97
11	NE[3]	NE	NE	211.52	211.58	211.96
12	NA	NA	NA	NA	NA	NA
13	NA	NA	NA	NA	NA	NA
14	NA	NA	NA	NA	NA	NA
15	NA	NA	NA	NA	NA	NA
16	NA	NA	NA	NA	NA	NA
17	NE	NE	NE	NE	212.99	213.25
18	NE	NE	NE	NE	213.04	213.13
19	NE	NE	NE	NE	211.83	212.02
20	NE	NE	NE	NE	212.38	212.54
21	NE	NE	NE	NE	212.43	212.57
22	NE	NE	NE	NE	212.42	212.54
23	NE	NE	NE	NE	212.40	212.54

[1] Wells had not equilibrated by sample cessation.

[2] NA-water level not available.

[3] NE-well did not exist.



Arrows indicate inferred ground water flow.

FIGURE 8-2. Inferred Ground-Water Flow from American Lake to Sequalitchew Springs and Sullivan Well.

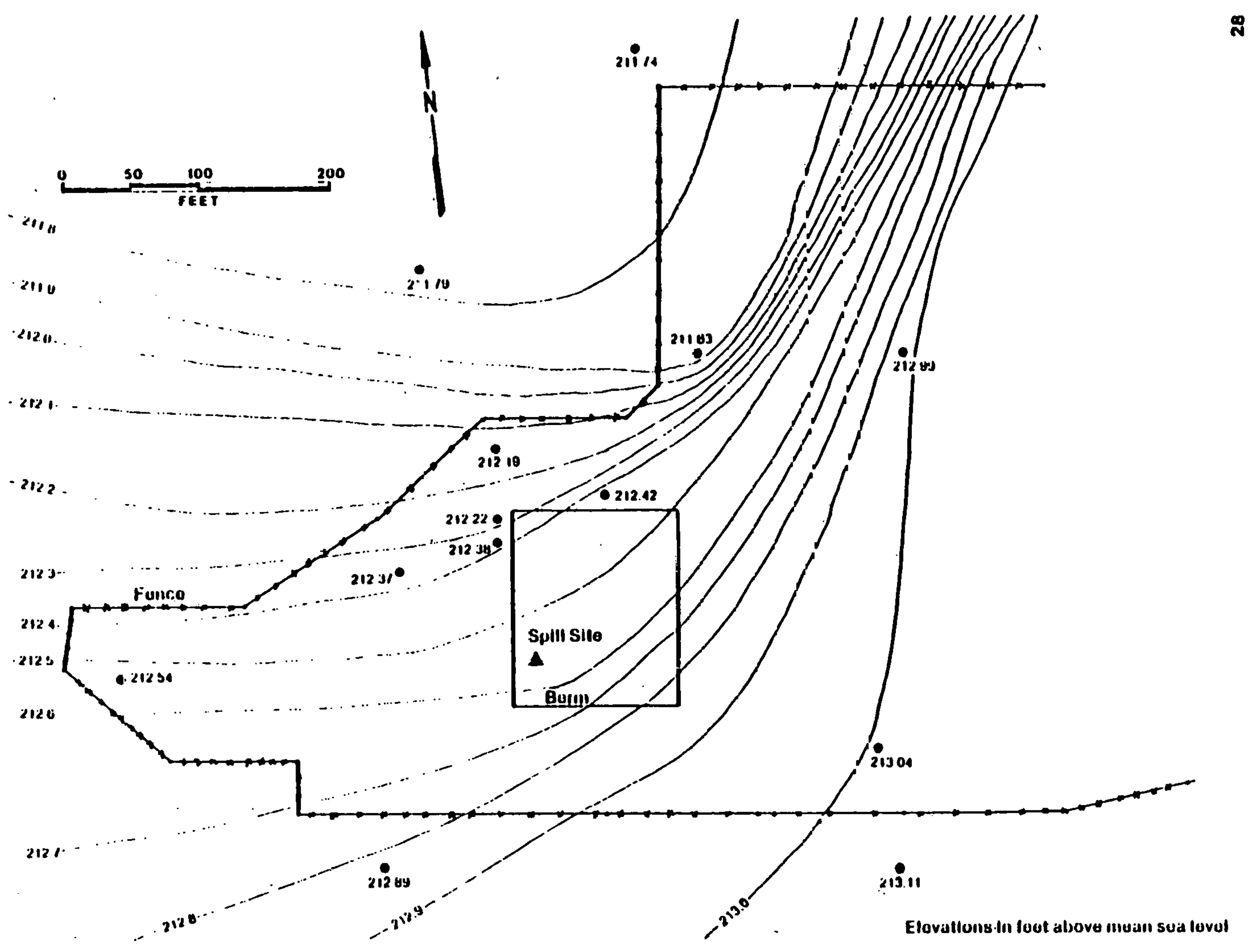


FIGURE 8-3. Contour Map of Water Table on 14 April 1980.

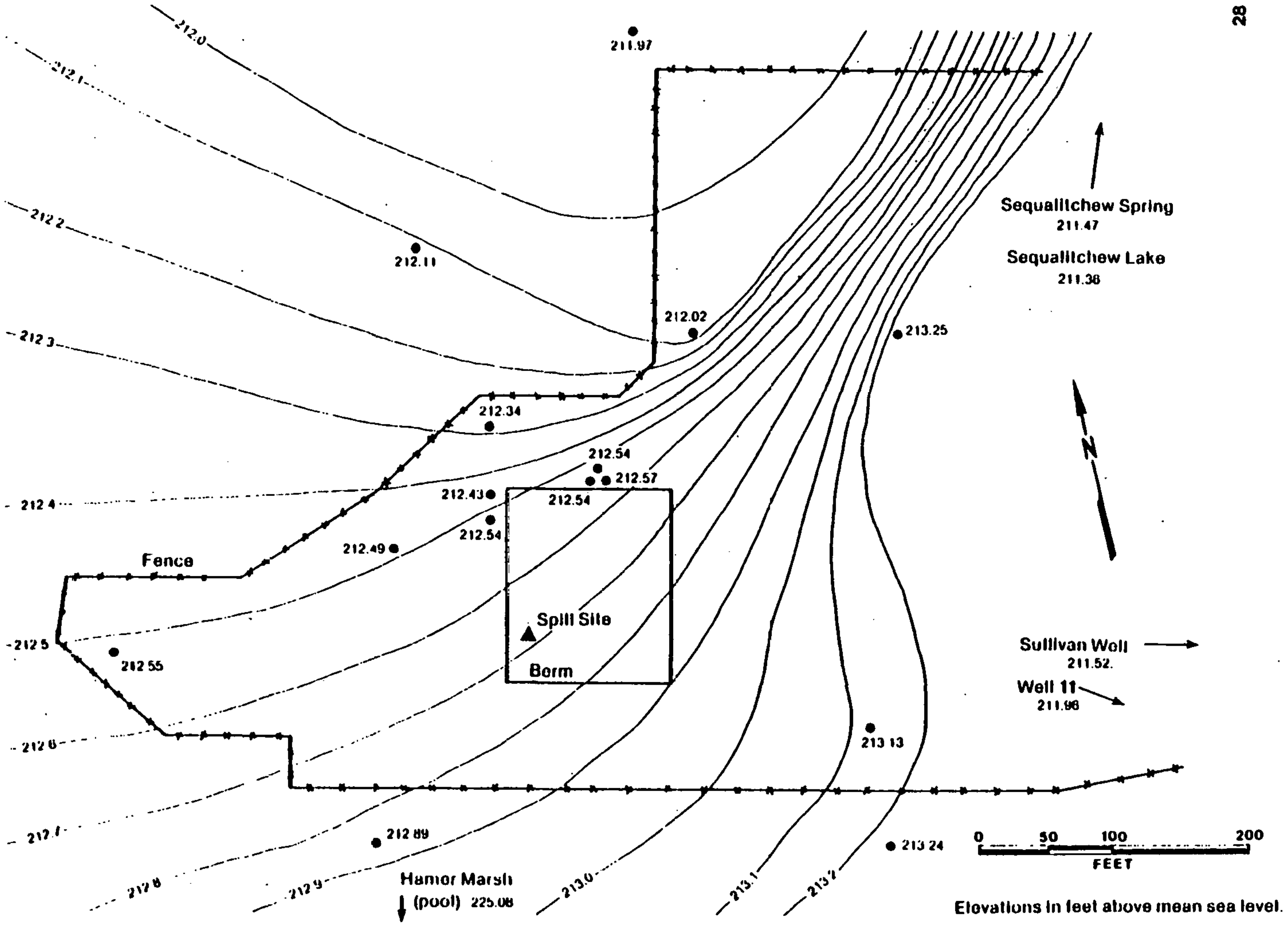


FIGURE 8-4. Contour Map of Water Table on 1 May 1980.

by plotting well locations on available plot plans; surveying for horizontal control was not necessary.

Water level elevations were also measured at other significant hydrologic points around the plant. Elevations (feet above MSL) on 1 May were:

Sequalitchew Springs - lake:	211.36
Hamer Marsh - effluent pool:	225.08
Sullivan Well - gallery under building:	211.52
Sequalitchew Springs - pool:	211.47 (pumps running)

The elevation drop of the water table along a flow line passing through the spill site from the highest contour to the lowest contour is about 1.2 feet. The hydraulic gradient along the same line was about 12.3 ft/mile (2.33×10^{-3} ft/ft) on 14 April and about 9.9 ft/mile (1.88×10^{-3} ft/ft) on 1 May.

The local hydraulic gradient on the west end of the SRC plant conforms to the regional pattern; a northward flow toward Sequalitchew Lake is clearly indicated on the basis of excellent control (14 water level data points). From the spill site, contaminants contained in ground water would be expected to migrate in a direction slightly west of due north, toward Well 20.

On 1 May, the elevation of Sequalitchew Lake was 211.36, which is about 0.6 feet below the elevation of ground water in the closest well to the lake (Well 10 at 211.97). The elevation of the pond in Hamer Marsh (225.08) indicates that the marsh is not an integral part of the ground-water flow system, but that a vadose zone of about 10 feet separates the marsh from the water table.

Well 11, which is near the east end of the SRC plant, has a lower water table elevation (211.96 on 1 May) than the wells around the spill site. The elevation in Well 11 is only about 0.44 feet above the elevation in Sullivan Well. Thus, there appears to be a ground-water divide at some point within the SRC plant between Well 11 and Wells 17 and 18. At present, there are insufficient water level data available to characterize ground-water flow patterns throughout the SRC plant.

8.4 Local Ground-Water Velocity

The ground-water velocity (V) at the spill site may be estimated using the data developed in preceding sections. The formation permeability (K) is estimated to be 4600 gpd/ft^2 (615 ft/da); the hydraulic gradient (I) across the site is 2 x 10^{-3}; and the porosity ($\emptyset$) of the most permeable zones in the aquifer is assessed to be 0.4. The fluid velocity is found by the following equation:

$$V = \frac{KI}{\emptyset} = \frac{615 \times 2 \times 10^{-3}}{0.4} = 3 \text{ ft/da}$$

Any soluble components of the SRC product fluid which have become entrained in the ground-water will move at nearly the ground-water flow rate.

9.0 WATER SUPPLY SOURCES IN THE FT. LEWIS REGION

Most of the water supply sources in the Ft. Lewis region are derived directly or indirectly from ground water. Several water wells have been drilled in the area around the SRC pilot plant. Ground water is used as a public water supply at the town of Dupont, and Ft. Lewis depends on ground water to fill most of its water needs. The SRC plant uses water purchased from Ft. Lewis. A map showing the locations of water wells and springs in the vicinity of the SRC pilot plant is shown in Figure 9-1, and the well characteristics are summarized in Table 9-1. Most of the wells in the area are drilled into deeper aquifers than the shallow water-table aquifer.

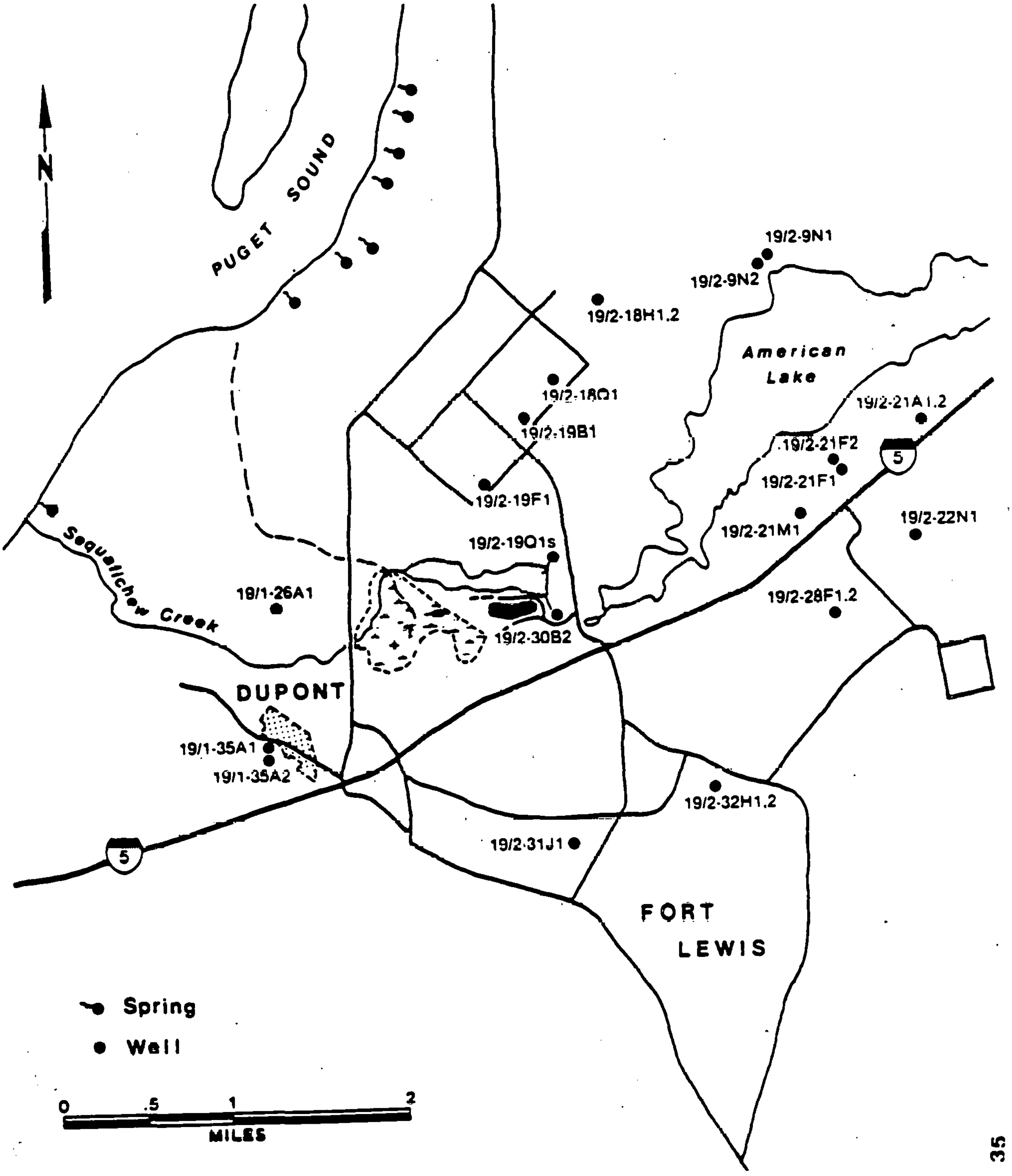


FIGURE 9-1. Ground-Water Supply Sources in the Vicinity of the SRC Plant.

TABLE 9-1. CHARACTERISTICS OF WELLS IN THE SRC PLANT AREA

	Well Characteristics						Water Level		Pump			
Well No.	Alt. (ft)	Type	Diam. (in)	Depth (ft)	Casing Depth (ft)	Character of Water Bearing Material	Below Land Surface (ft)	Date	Type	HP	Use of Water	Owner
19/1-26A1	220	Dr[1]	6	80	-	-	25-30	-	C[4]	1	Ind[8]	E.I. Dupont de Nemours
19/1-35A1	240	Dr	12	128	128	Sand	29.33	3-24-60	T[5]	15	PS[9]	City of Dupont, well 1
19/1-35A2	245	Dr	12,10	130	-	-	30	10-29-25	T	7.5	PS	City of Dupont, well 2
19/2-9N2	260	Dn[2]	6	-	-	-	17.1	2-23-60	-	3/4	N[10]	Individual
19/2-18H1	235	Dr	-	1450	-	-	114.3	6-04-53	N[6]	-	N	Ft. Lewis, well 4
19/2-18H2	233.4	Dr	20,16	1,112	1,112	-	138	1945	T	-	PS	Ft. Lewis, well 4A
19/2-18Q1	234	Dr	18	239	-	Sd & gvl	139	3-01-60	T	-	PS	Ft. Lewis, well 2
19/2-1981	234	Dr	18	224	220	Sand	140	3-01-60	-	-	PS	Ft. Lewis, well 1
19/2-19F1	235	Dr	18	229	229	Sd & gvl	138	3-01-60	-	-	PS	Ft. Lewis, well 3
19/2-19Q1s	210	-	-	-	-	-	-	-	T	-	PS	Ft. Lewis, Seq. Springs
19/2-21A1	280	Dg[3]	36	34	-	Gravel	25.15	4-10-40	N	-	N	Individual
19/2-21A2	279	Dr	8	59	-	-	33.70	9-03-41	-	1	PS,D[11]	Individual
19/2-21F1	265	Dr	6	53	53	Gravel	21.38	2-23-60	J[7]	1/2	D	Individual
19/2-21F2	261.6	Dg	36	28	28	Gravel	13.94	4-10-40	C	3/4	D	Individual
19/2-21M1	265	Dg	27	-	-	-	17.70	3-24-60	N	-	N	National Guard
19/2-22M1	279.6	Dr	38,26	2,261	1400	-	45	3-01-60	T	-	N	Ft. Lewis, well 7
19/2-28F1	280	Dr	24	43	43	Gravel	8.4	4-12-40	C	30	PS	National Guard
19/2-28F2	278	Dr	12	154	154	Gvl & sd	34.86	11-05-40	N	-	N	National Guard
19/2-30B2	210	Dg	14	12	-	Gvl & sd	-	-	T	200	PS	Ft. Lewis, Sullivan well
19/2-31H1	282	Dr	38,20	1000	990	-	187	3-01-60	-	-	PS	Ft. Lewis, well 5
19/2-32H1	293	Dr	-	1570	-	-	98	3-01-60	N	-	N	Ft. Lewis
19/2-32H2	291	Dr	20,18	1340	1340	-	129	4-19-43	T	250	PS	Ft. Lewis, well 6

Source: Walters and Kimmel, 1968

[1] Dr - Drilled
[2] Dn - Driven
[3] Dg - Dug
[4] C - Centrifugal
[5] T - Deep well turbine
[6] N - None
[7] J - Jet
[8] Ind Industrial
[9] PS - Public supply
[10] N - None
[11] D - Domestic

10.0 BACKGROUND WATER QUALITY

Data are available for regional ground-water quality and for surface-water quality in the immediate vicinity of the SRC plant. Prior to the 19 December spill, the only ground-water quality data collected were from Sullivan Well and Sequalitchew Springs.

10.1 Regional Ground-Water Quality

The ground water quality in the Tacoma upland is generally very good; most waters have a total dissolved solids content of less than 100 mg/ℓ. Table 10-1 shows representative ground-water analyses. Although the depths of the wells from which the samples were collected are highly variable (2 are very shallow, 3 are 200-250 feet, and 2 are 1000 feet or more), the chemical characteristics of the waters are remarkably uniform. For example, the TDS range is only 71 to 113 mg/ℓ.

10.2 Local Ground-Water Quality

Background water quality data for the vicinity of the SRC plant have been collected during the environmental monitoring program that is being conducted by Alsid, Snowden, & Associates. These data, which are for Sequalitchew Springs and Sullivan Well, are shown for 1979 in Table 10-2. The similarity of the water quality characteristics shown in this table indicate that the water may have a common source, most likely (as noted) American Lake. The quality of water in both of these sources is very good. Water quality variation does not appear to be seasonally related.

TABLE 10-1. REPRESENTATIVE GROUND WATER QUALITY ANALYSES[1]

Well / Parameter	Ft. Lewis Well 2 19/2-18Q1	Ft. Lewis Well 1 19/2-19B1	Ft. Lewis Well 3 19/2-19F1	Sequalitchew Springs 19/2-19Q1s	Sullivan Well 19/2-30B2	Ft. Lewis Well 5 19/2-31J1	Ft. Lewis Well 6 19/2-3-H2
Date Coll.	10-10-55	9-13-54	10-26-59	9-13-60	10-26-59	10-26-59	1-12-58
Analyst	GS[2]	GS	GS	GS	GS	GS	GS
Temp (°F)	53	53	52	54	54	54	53
Silicon	26	32	31	11	15	42	22
Aluminum	-	-	-	-	-	-	-
Iron	(T)[3]0.43	(T)8.1	0.45	0.03	0.08	(T)5.2	0.06
Calcium	11	12	12	11	14	6	17
Magnesium	4.7	6.3	5.7	4.0	4.2	3.0	8.4
Sodium	5.5	4.9	5.4	5.7	5.8	4.4	5.9
Potassium	1.7	2.3	1.7	0.9	1.3	2.4	1.5
Bicarbonate	67	64	72	57	59	42	96
Carbonate	0	0	0	0	0	0	0
Sulfate	3.5	13	3.3	6.4	11	3.3	6.0
Chloride	2.8	2.8	2.8	3.0	3.5	2.0	3.8
Fluoride	0.1	0.1	0	0.2	0.0	0.0	-
Nitrate	0.7	0.2	0.1	0.7	2.5	0.2	1.2
Phosphate	-	-	-	-	-	-	-
TDS	89	105	97	71	86	84	113
Hardness	47	56	54	44	52	28	77
Sp. Cond.	120	137	131	117	134	00	173
pH[4]	7.3	7.2	7.4	6.7	6.8	7.8	7.2
Color[5]	15	5	5	0	5	20	0

---

[1] Concentrations in mg/ℓ, on less otherwise notes.

[2] GS = United States Geological Survey.

[3] T = total iron.

[4] Standard units.

[5] Pt Co units.

Source: Walters and Kimmel, 1968.

TABLE 10-2. 1979 WATER QUALITY DATA FOR SEQUALITCHEW SPRINGS AND SULLIVAN WELL

Parameter	Sequalitchew Springs 26 February	 9 April	 29 May	 23 August	 5 November	Sullivan Well 26 February	 9 April	 29 May	 23 August	 5 November
Temperature (°C)	11	13	15	14	13	10.5	12	13	16	13
Dissolved Oxygen (mg/ℓ)	7.5	7.2	8.5	6.4	6.7	7.9	8.5	6.6	6.6	6.8
Dissolved Oxygen (% Sat.)	58	56	-	-	-	65	66	-	-	-
Chemical Oxygen Demand (mg/ℓ)	N	5.4	0	1.0	2.1	N	6	0	30.7	25.2
Coliforms (no. per 100 ml)	0	0	0	0	0	0	0	0	0	0
Color (color units)	0	0	0	0	0	0	0	0	0	0
Specific Conductance (µmhos/cm) @ 25°C)	127	108	116	113	119	121	128	135	122	98
Total Dissolved Solids (mg/ℓ, derived from specific conductance)	82.55	70.2	75.4	73.45	77.35	78.65	83.2	87.75	79.3	63.7
pH	6.0	6.3	6.5	6.5	6.7	6.0	6.5	6.6	6.5	6.6
Sulfate (mg/ℓ)	9.3	8.4	5.7	8.5	8.4	9.5	9.3	8.5	7	6.5
Phosphate (mg/ℓ)	.07	.06	.03	.01	.04	.07	.07	.04	.01	.04
Nitrate (mg/ℓ)	.12	.10	.21	.52	.45	.13	.14	.3	.3	.3
Phenol (mg/ℓ)	<3	<3	5	5	5	<3	<3	5	5	5

10.3 Surface-Water Quality

As part of an ongoing environmental monitoring program at the SRC plant, surface-water quality is monitored at a number of locations. The major surface-water sampling points are shown in Figure 10-1. The annual average concentrations for several important parameters are shown in Table 10-3 for the years 1973, 1976, 1977, and 1978. Table 10-4 shows the results for samples taken in 1979. The quality of water from Sequalitchew Lake is generally better than the quality of Hamer Marsh Pond water, as would be expected when comparing a ground-water lake to a marsh. Although the dissolved solids content of the lake is higher than in the marsh, the marsh water is inferior in quality with respect to dissolved oxygen, chemical oxygen demand, coliforms, color, and phosphate.

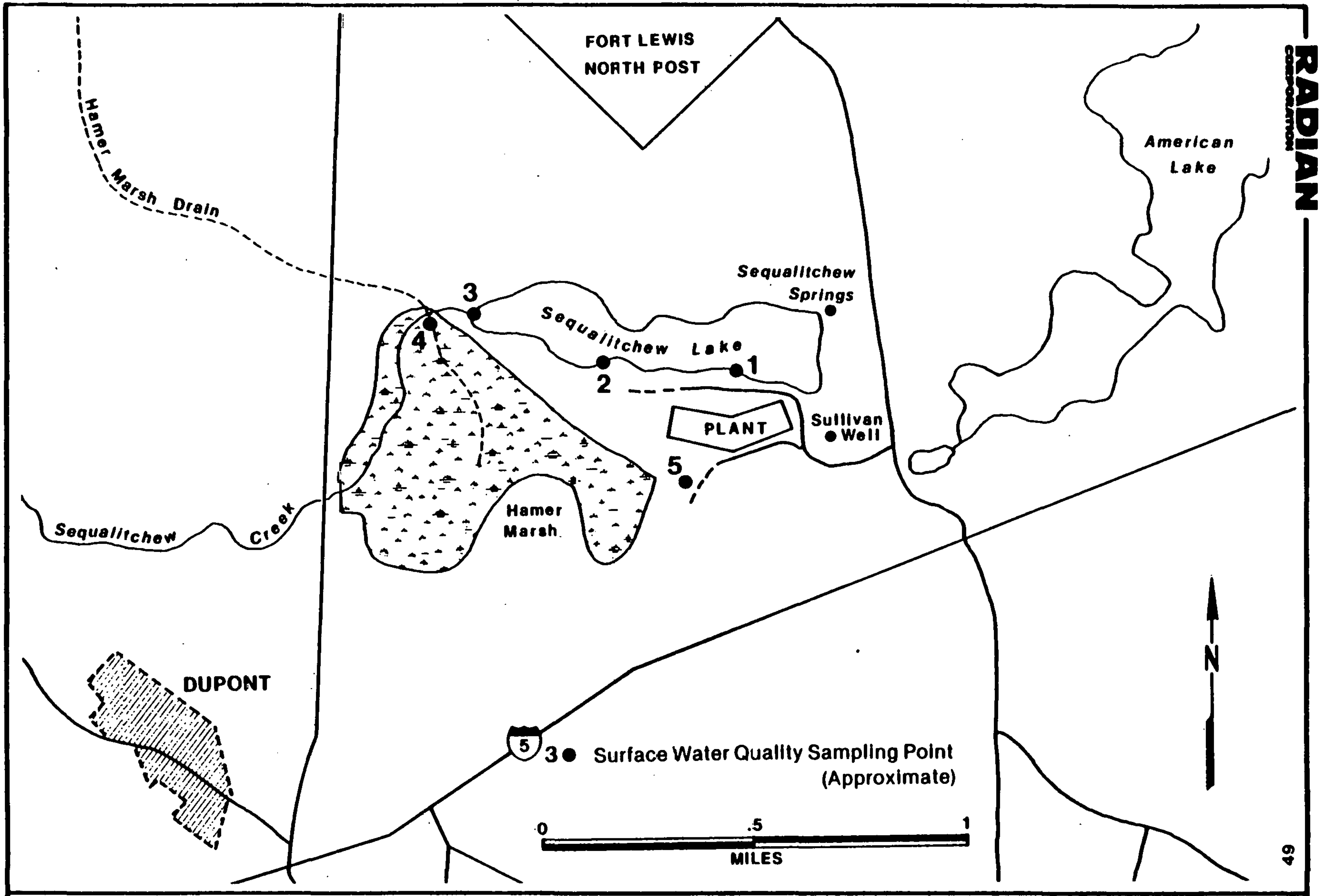


FIGURE 10-1. Surface Water Sampling Points in the SRC Plant Vicinity.

TABLE 10-3. SURFACE WATER QUALITY IN THE SRC PLANT VICINITY: AVERAGE ANNUAL VALUES FOR 1973, 1976, 1977 & 1978

Sample Point / Parameter	1 Sequalitchew Lake	2 Sequalitchew Lake	3 Sequalitchew Lake Outlet	4 Hamer Marsh Canal	5 Hamer Marsh Pond
Temperature (°C)					
1973	13	13.2	13	10.3	12.0
1976	19	20	20	13	15
1977	16	21.3	16.7	13.5	16
1978	13.5	13.8	13.2	12.0	11
Dissolved Oxygen (mg/ℓ)					
1973	11.7	11.7	11.3	7.0	6.4
1976	10.8	11	10	5	3.9
1977	11.3	11.6	7.3	3.5	5.2
1978	9.3	9.3	9.2	6.6	6.1
Dissolved Oxygen (% Sat.)					
1973	91	90	91	54	51
1976	83	83	80	39	31
1977	88	90	57	27	40
1978	72	72	71	51	47
Chemical Oxygen Demand (mg/ℓ)					
1973	3.1	3.1	1.3	2.6	5.8
1976	5	12	12	100	2.4
1977	4.5	6.0	30.4	5.4	17.9
1978	17	12.2	5.8	15.3	>27.8
Coliforms (no. per 100 ml)					
1973	2	1	<2	7	7
1976	10	7	9	46	54
1977	1	0	0	6	11
1978	<1	<1	<2	1	19
Color (color units)					
1973	4	5	6	3.0	56
1976	7	7	9	40	40
1977	8	18	>52	>74	65
1978	26	10	11	28	>56
Specific Conductance (µmhos/cm @250°C)					
1973	104	103	106	113	74.8
1976	132	125	125	166	142
1977	187	205	222	153	108
1978	145	153	147	165	103
Total Dissolved Solids (mg/ℓ, derived from specific conductance)					
1973	67.6	66.95	68.9	75	48.6
1976	85.8	81.25	81.25	108	92
1977	121.33	133.25	144.3	99	70
1978	94.25	99.45	95.55	107	67
pH					
1973	6.9	6.8	6.9	6.8	6.9
1976	7.6	8.1	8.3	6.6	6.2
1977	6.8	7.5	6.4	6.9	6.2
1978	6.7	6.8	6.9	6.3	5.9
Sulfate (mg/ℓ)					
1973	11	10	11	11	2
1976	10.2	10.4	11	13	10
1977	26.5	38	41	33	20
1978	19	21	19.9	22	12
Phosphate (mg/ℓ)					
1973	0.07	N	N	0.06	0.07
1976	0.00	0.01	0.01	0.32	0.07
1977	0.06	0.04	0.19	0.32	0.55
1978	0.18	0.05	0.12	0.19	0.10
Nitrate (mg/ℓ)					
1973	0.13	N	N	0.10	0.08
1976	0.11	0.13	0.12	0.12	0.13
1977	0.13	0.06	0.39	0.49	0.13
1978	0.10	0.16	0.09	0.27	0.08
Phenol (µg/ℓ)					
1973	<50	<50	<50	<50	N
1976	<50	<50	<50	<50	<50
1977	<5	<6	<5	<7	8
1978	<5	<5	<5	<5	<7

TABLE 10-4. SURFACE WATER QUALITY IN THE SRC PLANT VICINITY: RESULTS OF ANALYSES OF 1979 SAMPLES

Parameter \ Sample Point	Sequalitchew Lake	Sequalitchew Lake	[illegible]	Hamer Marsh Canal	Hamer Marsh Pond
Temperature (°C)					
26 February	8.5	9	8	7.5	8
9 April	11	11	11	10	7
29 May	16	17	16	13	15
23 August	18	18	18	14.8	15
5 November	11	11	11	12	12
Dissolved Oxygen (mg/ℓ)					
26 February	9.4	5.0	8.8	6.9	7.1
9 April	9.8	9.7	8.4	7.9	4.5
29 May	8.3	7.6	6.9	4.5	3.6
23 August	6.5	6.7	8.4	6.0	5.5
5 November	6.6	6.8	6.7	6.2	5.7
Dissolved Oxygen (% Sat.)					
26 February	73	70	68	53	55
9 April	76	75	65	61	35
29 May	-	-	-	-	-
23 August	-	-	-	-	-
5 November	-	-	-	-	-
Chemical Oxygen Demand (mg/ℓ)					
26 February	N	N	N	N	N
9 April	8.9	8.1	10	12.4	26
29 May	2.5	3.1	2.8	5.6	27.6
23 August	17.4	4.2	5.1	3.2	25
5 November	2.0	3.4	2.2	3.6	27.2
Coliforms (no. per 100 ml)					
29 February	0	0	0	6	0
9 April	0	1	2	8	63
29 May	151	8	2	6	50
23 August	5	5	10	TNTC	TNTC
5 November	4	TNC	1	5	18
Color (color units)					
29 February	20	10	10	20	30
9 April	10	20	20	30	80
29 May	30	10	10	30	100
23 August	30	30	20	80	30
5 November	10	10	10	20	30
Specific Conductance (µmhos/cm at 25°C)					
26 February	176	148	137	110	115
9 April	134	124	124	123	114
29 May	130	126	120	144	143
23 August	160	157	155	167	167
5 November	145	163	154	170	119
Total Dissolved Solids (mg/ℓ derived from Specific Conductance)					
26 February	114.4	96.2	89.05	71.5	74.75
9 April	87.1	80.6	80.6	79.95	74.2
29 May	84.5	81.9	78	93.6	92.95
23 August	104	102.05	100.75	108.55	108.55
5 November	94.25	105.95	100.1	110.5	77.35
pH					
26 February	6.4	6.8	7.1	6.5	6.0
9 April	7.0	6.8	6.6	6.5	6.1
29 May	8.4	8.1	7.5	6.6	6.3
23 August	7.2	7.4	9.1	6.4	6.2
5 November	6.9	7.0	6.9	7.1	6.7
Sulfate (mg/ℓ)					
26 February	20.5	19	18	13.9	13.8
9 April	13	14	13.3	16	3.6
29 May	12	10.5	10	12.3	9.6
23 August	22.3	24.1	35.5	40	39.5
5 November	19.8	24.6	26.7	31.9	36.7
Phosphate (mg/ℓ)					
26 February	0.08	0.03	0.03	0.01	0.06
9 April	0.06	0.02	0.02	0.02	0.05
29 May	0.19	0.09	0.08	0.21	0.12
23 August	0.01	0.05	0.04	0.03	0.02
5 November	0.09	0.11	0.13	0.20	0.15
Nitrate (mg/ℓ)					
26 February	0.28	0.5	0.14	0.08	.22
9 April	0.26	0.5	0.17	0.06	.23
29 May	0.12	0.16	0.12	0.24	.10
23 August	0.20	0.19	0.17	0.30	.32
5 November	0.21	0.23	0.19	0.27	.33
Phenol (µg/ℓ)					
26 February	<5	<5	<5	<5	4
9 April	<5	<5	<5	<5	<5
29 May	5	5	5	5	11.6
23 August	5	5	5	5	5
5 November	5	5	5	5	5

11.0 WATER QUALITY IMPACTS OF THE SRC SPILL

Because of concerns about the potential impact of the SRC fluid spill on the ground-water and surface-water resources in the area and possible ensuing human health or environmental effects, an intensive water quality monitoring program has been initiated. This section presents the results of this monitoring effort. The threshold values of the significant water quality parameters are first discussed, and the monitoring results are then presented and interpreted. Water quality monitoring results are reported for four general locations:

- vicinity of the spill site,
- east end of the SRC plant,
- Sullivan Well and Sequalitchew Springs, and
- surface-water bodies around the plant.

For each of these four locations, the most intensive monitoring has been for phenol, which is the most soluble component of the SRC fluid and is thus a good indicator for ground-water contamination. A bi-weekly sampling program for several polynuclear aromatic hydrocarbon compounds was also established for several sample points in and around the SRC plant. Inorganic analyses have been performed on samples from two points, Well 20 and Well 24, at the plant.

Laboratories of various organizations have conducted analyses of water samples as shown on Table 11-1. The analytical results of each laboratory are distinguished in the following discussion of the monitoring program.

TABLE 11-1. LABORATORIES PROVIDING ANALYTICAL SERVICES RELATED TO SRC FLUID SPILL

Organization	Parameters	Methods
The Pittsburg and Midway Coal Mining Company	Phenol in water	Hach® kit, prior to 6 Feb 80 *Standard Methods** thereafter
	Phenol in soils	Extraction by EPA Priority Pollutant Procedures**, analysis by *Standard Methods*.
Gulf Science and Technology Center	Analysis of SRC fluid	Gas chromatography-mass spectrometry (GC-MS) High Performance Liquid Chromatography (HPLC) Thin Layer Chromatography
	Polynuclear Aromatic Hydrocarbons in water	HPLC
Washington Department of Ecology	Phenol in water	*Standard Methods*
Alsid, Snowden and Associates	Phenol in water	*Standard Methods*, 5 cm cell
Radian Corporation	Analysis of SRC fluid	GC-MS
	Phenol in water	*Standard Methods*, 1 and 2½ cm cells
	Phenol in soils	Extraction by EPA Priority Pollutans Procedures, analysis *Standard Methods*
	Total metals in water	Inductively Coupled Argon Plasma Emission Spectrometer

**Standard Methods for the Examination of Water and Wastewater*, Fourteenth Edition, American Public Health Association, Water Pollution Control Federation, 1975.

The analyses for phenol were performed using standard methods 510A and 510B, involving a colorimetric determination using 4-aminoantipyrine (4-AAP) after extraction into chloroform.

**Interim Methods for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

11.1 Regulatory and Water Quality Criteria Background

As noted in Section 4.0 and Appendix I, the SRC fluid that was spilled on 19 December 1979 is a complex mixture of hydrocarbon compounds. A relatively small portion of the fluid, however, consists of hydrocarbons that contain elements other than hydrogen and carbon.

For purposes of estimating the relative degree of environmental hazard potentially posed by the SRC fluid, comparisons can be drawn with standards, criteria, and regulations that have been set forth by EPA pursuant to the Safe Drinking Water Act of 1974 (SDWA), the Resource Conservation and Recovery Act of 1976 (RCRA), and the Clean Water Act of 1977 (CWA). Comparisons can also be made with the EPA Multimedia Environmental Goals.

11.1.1 Safe Drinking Water Act Regulations

For the SDWA, EPA has established the National Interim Primary Drinking Water Regulations and the National Secondary Drinking Water Regulations. These regulations apply to the quality of water at the tap for public water supply systems. Maximum contaminant levels are set forth for 17 parameters for the NIPDWR and for 12 parameters for the NSDWR. The SRC fluid does not appear to contain any of the organic species regulated. The inorganic species addressed by these two regulations are shown in Table 11-2.

TABLE 11-2. PRIMARY AND SECONDARY DRINKING WATER REGULATION MAXIMUM CONTAMINANT LEVELS

Parameter	Maximum Contaminant Level
Arsenic	0.05 (P)
Barium	1.0 (P)
Cadmium	0.01 (P)
Chloride	250 (S)
Chromium	0.05 (P)
Copper	1 (S)
Fluoride	2.0 @ 60°F (P)
Iron	0.3 (S)
Lead	0.05 (P)
Manganese	0.05 (S)
Mercury	0.002 (P)
Selenium	0.01 (P)
Silver	0.05 (P)
Sulfate	250 (S)
Zinc	5 (S)
pH (pH units)	6.5-8.5 (S)
TDS	500 (S)

Values in body of table are in mg/ℓ, except as noted.

P = Primary
S = Secondary

11.1.2 Clean Water Act Regulations

The CWA contains a list of 65 toxic pollutants that was finalized by EPA into 129 Priority Pollutants by distinguishing specific organic compounds in some of the classes of compounds included in the toxic pollutant list. For the 65 toxic pollutants, EPA has proposed water quality criteria that should not be exceeded to protect human health and the environment. The Priority Pollutant compounds that were found in the SRC fluid by GC-MS analysis are as follows: naphthalene, acenaphthene, fluorene, fluoranthene, phenanthrene/anthracene, pyrene, chrysene/benzo(a)anthracene, benzo(b+k)fluoranthene, benzo(a+e)-pyrene, and phenol (see Appendix I). The mobility of these compounds in the environment depends upon several factors, such as solubility and affinity for soil particles. Criteria have been proposed for naphthalene, fluoranthene, acenaphthene, and phenol but not for the other compounds. The criteria for these four compounds are shown in Table 11-3.

Although chlorinated phenols apparently do not occur in the SRC fluid or in the ground water, the presence of phenol in both has caused concern about the water quality impact of chlorinating the water prior to public consumption. Chlorination of water containing phenolic compounds can result in the formation of chlorinated phenols. Table 11-4 shows the water quality criteria for the chlorinated phenol compounds.

11.1.3 Resource Conservation and Recovery Act Regulations

The RCRA defines solid waste very broadly and distinguishes two classes of waste -- hazardous and nonhazardous waste. Under RCRA regulations, hazardous waste is identified by examination of its characteristics and by listing sources of wastes

TABLE 11-3. WATER QUALITY CRITERIA FOR PRIORITY POLLUTANTS IN THE SRC FLUID

Constituent[1]	Freshwater Aquatic Life 24-Hour Average	Freshwater Aquatic Life Not to Exceed	Human Health
Naphthalene	ND[2]	ND[2]	143
Fluoranthene	250	560	200
Acenaphthene	110	240	20
Phenol	600	3400	3400

[1] Concentrations are in µg/ℓ.

[2] ND = Not derived because of insufficient data.

TABLE 11-4. WATER QUALITY CRITERIA FOR CHLORINATED PHENOL COMPOUNDS

Constituent[1]	Freshwater Aquatic Life		Human Health
	24-Hour Average	Not to Exceed	
2-Chlorophenol	60	180	0.3
3-Chlorophenol	ND[2]	ND	50
4-Chlorophenol	45	180	30
2,4-Dichlorophenol	0.4	110	0.5
2,5-Dichlorophenol	ND	ND	3
2,6-Dichlorophenol	ND	ND	3
2,4,5-Trichlorophenol	ND	ND	10
2,4,6-Trichlorophenol	52	150	100
2,3,4,6-Tetrachlorophenol	ND	ND	263
Pentachlorophenol	6.2	14	140

[1] Concentrations are in µg/ℓ.

[2] ND = Not derived because of insufficient data.

that are hazardous. Listing of hazardous wastes is also accomplished by listing specific compounds which render a waste hazardous if the waste contains the compounds. The SRC fluid contains compounds that are listed as hazardous under RCRA regulations. However, the fluid would not be considered hazardous by listing because it does not consist solely of any of the compounds listed in the regulations. Only if the fluid were to be tested according to criteria specified for toxicity, ignitability, corrosivity, and reactivity, and if it were to fail one of the tests, would it be considered hazardous. In any case, RCRA regulations do not become effective until 19 November 1980.

11.1.4 Multimedia Environmental Goal System

Another basis for comparison for the water quality effects of the SRC fluid is the Multimedia Environmental Goal (MEG) system developed for EPA. The MEG concentrations "are conservative emission goals which were developed using simplified models and available health/ecological effects data. . . . These goal concentrations are a useful research and development tool, indicating which potential pollutants and emission streams warrant further analytical effort, further health/ecological evaluation or control technology evaluation. For these R&D purposes, the MEG's are deliberately conservative. EPA is not currently considering the use of MEG's for regulatory purposes" (Henschel, 1980).

Multimedia Environmental Goals have been established for several of the polynuclear aromatic hydrocarbons (PNA's) in the SRC fluid as shown in Table 11-5. These compounds were chosen by the Gulf Science and Technology Center because they are the PNA's that are listed as priority pollutants.

TABLE 11-5. AMBIENT MULTIMEDIA ENVIRONMENTAL GOAL VALUES FOR POLYNUCLEAR AROMATIC HYDROCARBON COMPOUNDS IN THE SRC FLUID

Constituent	Criterion (mg/ℓ)	Source
Acenaphthene	None	--
Fluorene	None	--
Phenanthrene	280	Note 1
Anthracene	1995	Note 2
Fluoranthene	800	Note 1
Pyrene	8333	Note 2
Benz(a)anthracene	4	Note 1
Chrysene	79.4	Note 2
3,4 Benzofluoranthene*	31.5	Note 2
Benzo(k)fluoranthene	58	Note 2
Benz(a)pyrene	20	Note 1
DiBenz(a,h)anthracene	4	Note 1
Benzo(ghi)perylene	None	--
Indeno(1,2,3-cd)pyrene	58.5	Note 2

*Synonym for benzo(b)fluoranthene

Note 1. Toxicity Based Estimated Permissible Concentration (Based on Health Effects)

Note 2. Estimated Permissible Concentration for Zero Threshold Pollutants (Based on Health Effects)

11.2 Water Quality Monitoring Results in the Vicinity of the Spill

Monitoring for the impacts of the SRC fluid on ground-water quality in the vicinity of the spill site has been conducted using the smaller diameter (two-inch) wells, the pump well (Well 20), and the cluster of three wells for sampling three different depths in the aquifer (Wells 17, 18, and 19). Samples from the wells have been analyzed for phenols, polynuclear aromatic hydrocarbon compounds, and inorganic species.

11.2.1 Phenol Monitoring Results

Phenol monitoring has been done for all wells in the vicinity of the spill site.

11.2.1.1 Small Diameter Wells

Eight small-diameter (two-inch) wells were installed in early attempts to ascertain if the SRC fluid spill had an adverse impact on ground-water quality. Perforations were provided by cutting slots in the lower end of the two-inch galvanized iron pipe which serves as a well casing. Wells 1, 2, 3, 6, and 7 were slotted in the lower 10 feet, and Wells 8, 9, and 10 were slotted in the lower 20 feet. Figure 11-1 shows the zone of perforation relative to the upper aquifer. Most of the wells are perforated in all or part of the aquifer. Well 10 apparently taps only the upper part of the aquifer, and Well 2 is apparently perforated somewhat below the base of the aquifer. Water samples have been collected routinely on a daily or three-times-a-week schedule since about 26 January 1980. Most analyses were performed by P & M laboratories with spot checks by Alsid, Snowden and Associates and by WDOE.

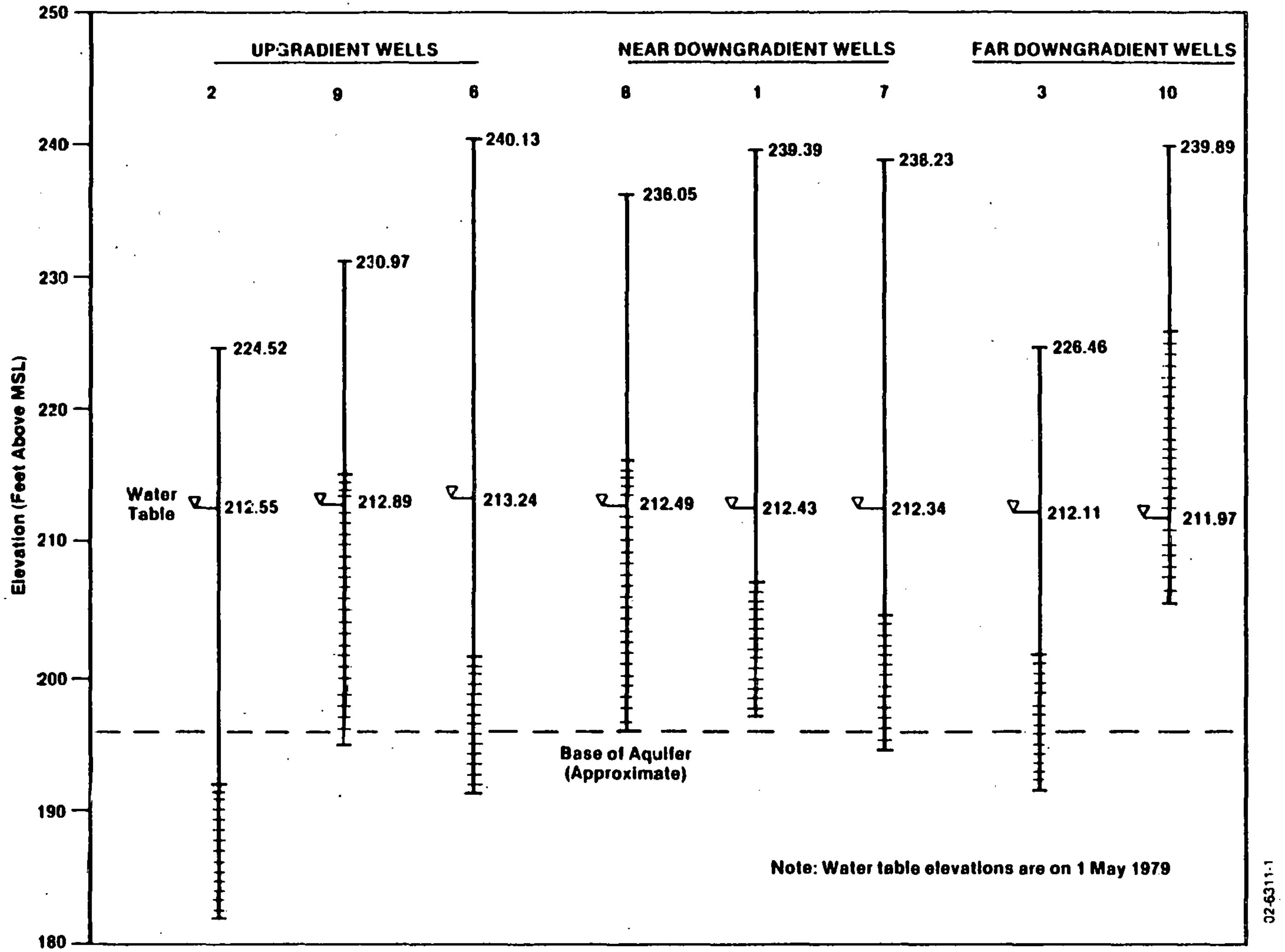


FIGURE 11-1. Sampling Depths for Small Diameter Wells

As noted in Table 11-1, P & M initiated phenol analyses with a Hach® kit, but later changed to standard methods. A series of six daily samples (1 through 6 February) were analyzed by both methods. The results of duplicate analyses agree remarkably well. Therefore, changing analytical methods should have no effect on the observations and conclusions drawn in the following sections.

The water quality monitoring results for the smaller diameter wells are discussed below in three categories--upgradient wells, near downgradient wells, and far downgradient wells. The upgradient wells should show minimal influence from the spill, whereas the near downgradient wells should reflect the greatest impact. The far downgradient wells should represent the quality of water after considerable dispersion of the contamination.

Upgradient Wells

The results of monitoring of the upgradient wells (Wells 2, 9, and 6) are shown in Figure 11-2. As shown in Figure 11-1, Well 2 may be completed somewhat below the base of the aquifer. Well 9 samples the entire depth of the aquifer, and Well 6 samples from the lower portion of the aquifer.

The phenol concentrations in all upgradient wells have been less than 1 mg/ℓ since monitoring began, so the proposed human health criterion for phenol of 3.4 mg/ℓ has not been exceeded. The 24-hour average value for freshwater aquatic life (0.6 mg/ℓ) was exceeded on two occasions in Well 2, but otherwise all analyses have been below the criterion. The concentration trends have been generally downward; concentrations began in the 0.01 to 0.1 mg/ℓ range with occasional excursions into the 0.1 to 1.0 mg/ℓ range. Most recently, the concentrations have been generally less than 0.01 mg/ℓ in Wells 2 and 9. In general, con-

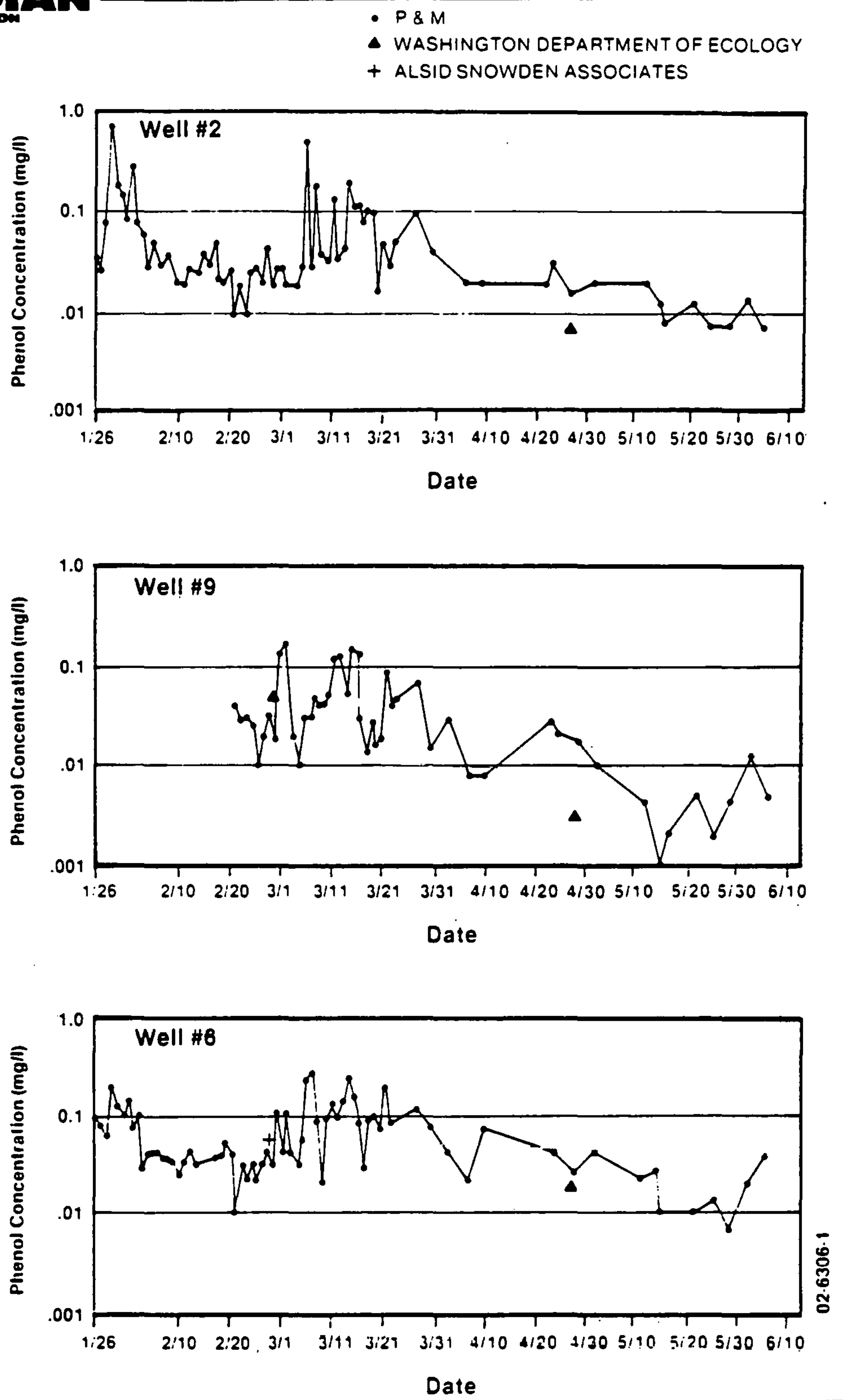


FIGURE 11-2. Phenol Concentrations in Upgradient Wells

centrations of 0.005 are at or below the detection limit for the method used. The depth of completion of the wells in the aquifer does not appear to have an influence on the phenol concentrations.

Near Downgradient Wells

The near downgradient wells (Wells 8, 1, and 7) are the closest to the spill site and would be expected to exhibit the greatest water quality impacts (Figure 11-3). All three wells have had phenol levels in excess of the 3.4 mg/ℓ level established as the human health and the not-to-exceed freshwater aquatic values in the proposed water quality criteria for phenols.

Well 1 had the highest phenol concentrations (almost 500 mg/ℓ) as well as the highest range (generally 10 to 100 mg/ℓ). However, the method of completion in combination with the location of the well has made these analytical results less than totally reliable. The well was not properly sealed with cement during completion and the casing used was PVC instead of steel. The well was sealed and destroyed in early May 1980. Wells 8 and 7 also show elevated phenol concentrations of 1 to 10 mg/ℓ. In the latter part of the record, these concentrations are reduced to the 0.1 to 1.0 mg/ℓ range in Well 8 and to the 0.01 to 0.1 mg/ℓ range in Well 7. For all three wells, depth does not appear to be a factor influencing the phenol concentrations.

Far Downgradient Wells

The far downgradient wells (Wells 3 and 10) appear to represent an intermediate case between the upgradient and the near downgradient wells, as would be expected (Figure 11-4). Both wells have exceeded the 0.6 mg/ℓ phenol concentration that is proposed as the 24-hour average for freshwater aquatic life.

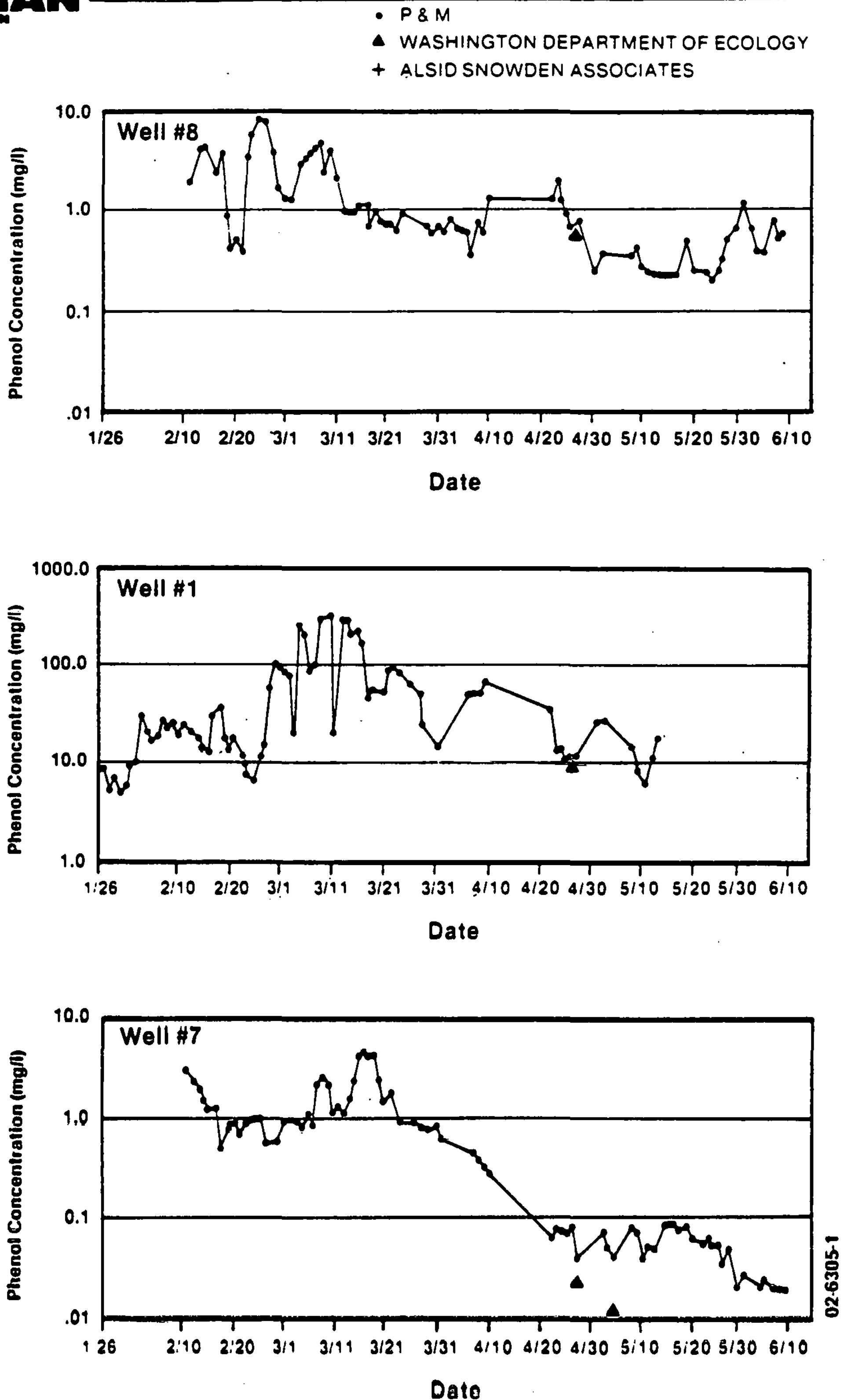


FIGURE 11-3. Phenol Concentrations in Near Downgradient Wells

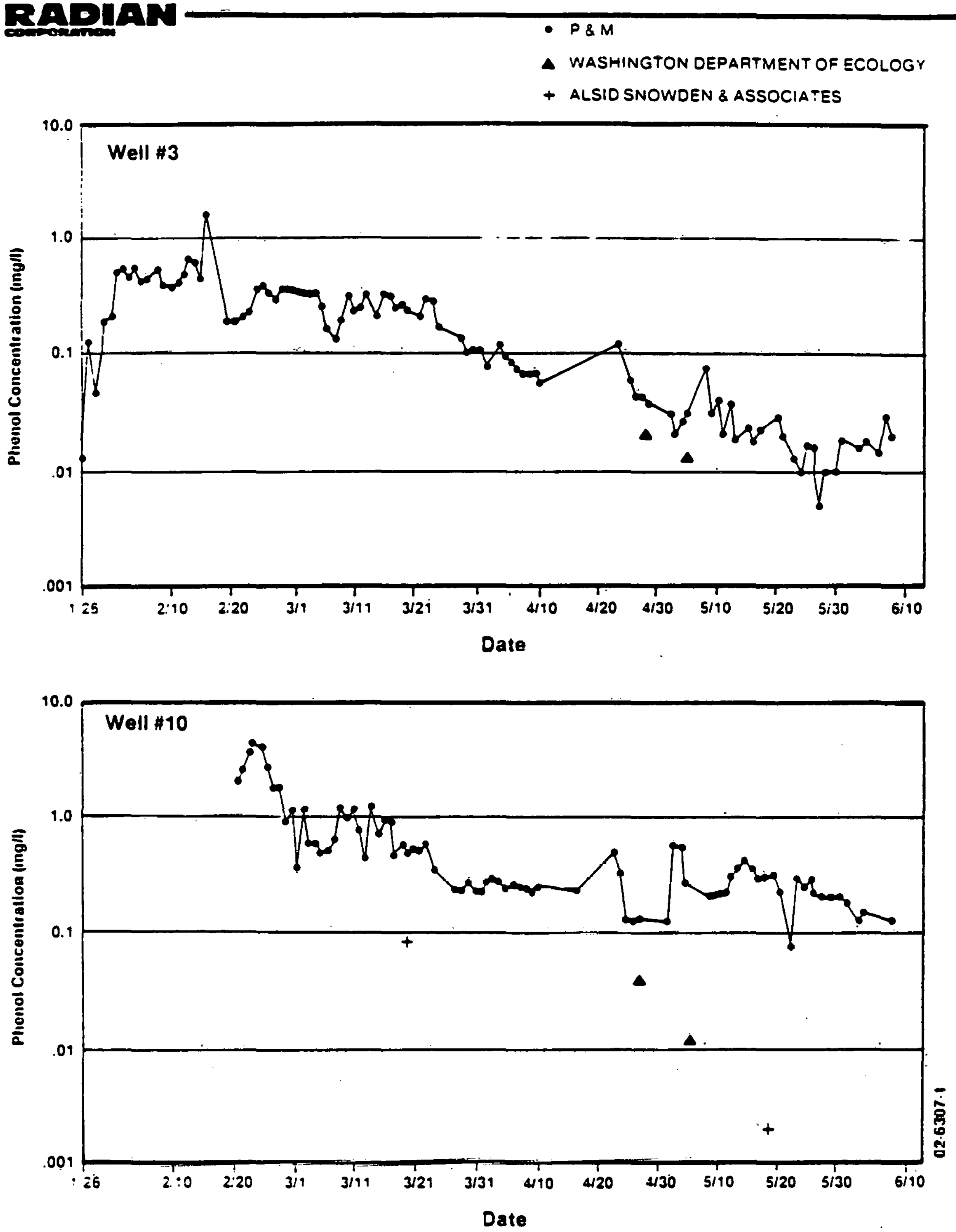


FIGURE 11-4. Phenol Concentrations in Far Downgradient Wells.

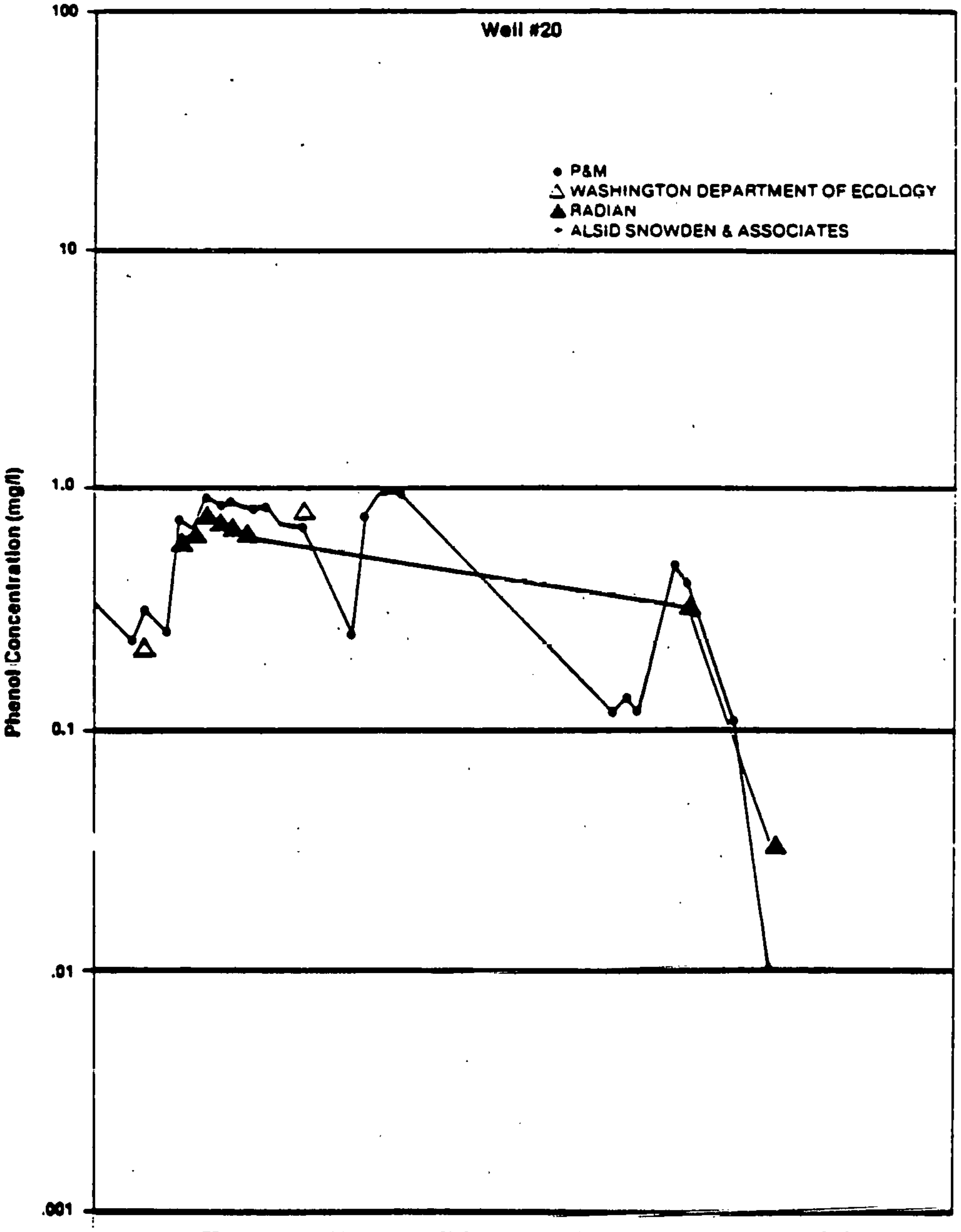
Well 10 has also exceeded the 3.4 mg/ℓ value proposed as the human health criterion.

The phenol concentrations in Well 3 are initially in the 0.1 to 1.0 mg/ℓ concentration range and trend downward to the 0.01 to 0.1 mg/ℓ concentration range. In Well 10, the concentrations were initially higher (1.0 to 10 mg/ℓ concentration range), and then trended downward to a 0.1 to 1.0 mg/ℓ range. Thus Well 10, which is further removed from the expected migration path of the spilled SRC fluid than Well 3, has a higher concentration of phenols. This unexpected difference may be due to the fact that Well 10 taps only the upper part of the aquifer (Figure 11-1), where any ground-water contamination that occurred would be expected to occur. Well 3, on the other hand, taps only the lower, less contaminated part of the aquifer.

11.2.1.2 Pump Well (Well 20)

An intensive sampling and analysis program was conducted for Well 20 during a pump test. Twenty-one samples were collected during a five-day period in early May. The analytical results are shown in Table 11-6. Initial phenol concentrations were in the 0.25 mg/ℓ range, but they increased rapidly to about 1.0 mg/ℓ and then stabilized.

In addition to the intensive water quality studies during pump testing of Well 20, a long-term monitoring program was instituted. The analytical results of this program are shown in Figure 11-5. Phenol concentrations, which were initially in the 0.5 to 1.0 mg/ℓ range, have reduced recently to the 0.01 to 0.05 mg/ℓ range. The phenol levels thus exceeded the 0.6 mg/ℓ 24-hour average value for freshwater aquatic life, but were within the 3.4 mg/ℓ value for human health.



02-6339-1

Figure 11-5. Phenol Concentrations in Well 20.

11.2.1.3 Depth Control Well Cluster

Wells 21, 22, and 23 (the "triad") were completed at three different depths at the same location to investigate the stratification of ground-water contamination in the aquifer. The completion depths of the wells are as follows:

Well 21: 43.5 to 45.0 ft.
Well 22: 37.0 to 38.5 ft.
Well 23: 31.5 to 33.0 ft.

TABLE 11-6. PHENOL CONCENTRATIONS DURING PUMP TEST OF WELL 20

Date	Time	Phenol (mg/ℓ)
May 2	2350	.25
May 3	1410	.29
	1440	.25
	2000	.78
May 4	0800	.89
	1200	.89
	1600	.91
	2000	1.01
	2200	.88
	2400	.94
May 5	0800	.96
	1200	1.05
	1600	1.05
	1900	1.25
	2000	1.23
	2200	1.13
	2400	.96
	0400	.99
May 6	0800	1.0
	1200	1.0
	1600	0.98 Alsid Snowden

Note: All analyses by P&M Coal, except as noted.

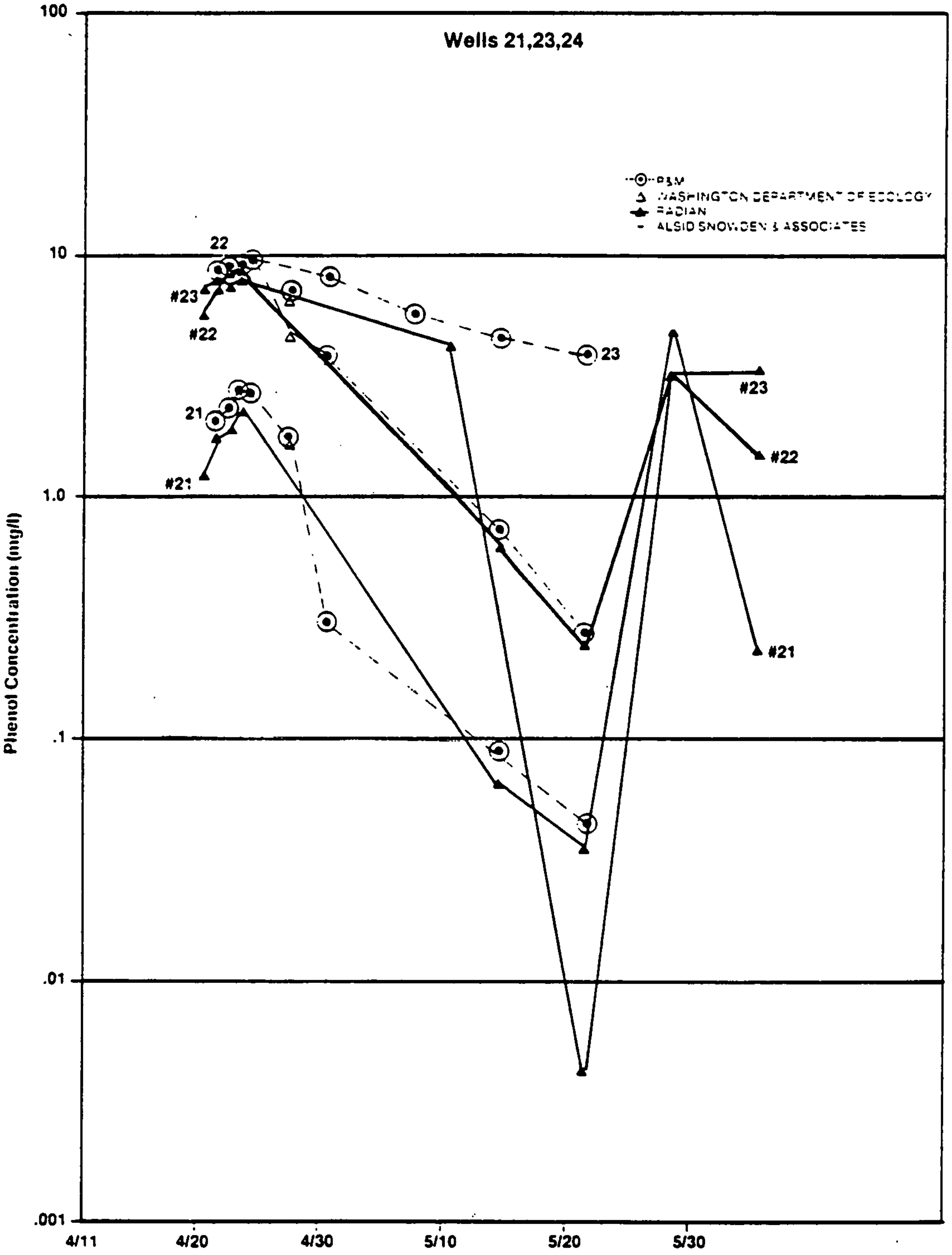
The available water level data at the time these wells were installed indicated that the location chosen was immediately downgradient of the spill. However, additional piezometers installed in the same time frame provided water level data that showed ground-water flow at about 40 to 50 degrees from the line extending from the spill site to the triad. Nevertheless, useful water quality data were obtained from the wells.

The analytical results from the triad are shown in Figure 11-6. The initial phenol concentrations in all three wells were in the 1.0 to 10.0 mg/ℓ concentration range. Overall, the concentrations decreased to the 0.5 to 5.0 mg/ℓ range in the latter part of the record. Both the 0.6 mg/ℓ and 3.4 mg/ℓ water quality criteria for phenol are exceeded in all three wells.

With respect to depth variation, the phenol concentrations initially showed expected trends. The deepest well (Well 21) had the lowest phenol concentrations, and the shallowest well (Well 23) had the highest concentration. The intermediate well showed intermediate phenol concentrations. This trend continued for the first 10 sampling events by different laboratories. Departures from this well-established trend in the latter part of the record by Wells 21 and 23 may reflect problems with sample preservation.

11.2.1.4 Summary of Phenol Analytical Results for the Spill Site Vicinity

The elevated concentrations of phenols in the vicinity of the spill site indicate that ground-water contamination has occurred in the area and that remedial measures are warranted. As noted, the phenol concentrations in the upgradient wells are all less than 1.0 mg/ℓ, but are generally greater than 1.0 mg/ℓ in the near downgradient wells. Concentrations fall below



02-6341-1

Figure 11-6. Phenol Concentrations in "Triad" Wells.

1.0 mg/ℓ in the far downgradient wells. Well 20, which yields the best samples and is located directly downgradient from the spill site, had phenol concentrations of about 1.0 mg/ℓ at the time of the pump test. The elevated concentrations at the triad (1 to 10 mg/ℓ initially), which is not located directly downgradient from the spill, indicates that other sources may be contributing contaminants to the shallow aquifer. Both the fresh water aquatic life criteria (0.6 mg/ℓ) and the human health criterion (3.4 mg/ℓ) are exceeded in wells downgradient from the spill site.

Almost all wells have showed a decreasing trend in phenol concentrations since sampling began. This may reflect the outward migration of the contamination plume from the vicinity of the spill site toward Sequalitchew Lake. Well 10, one of the far downgradient wells, has maintained a relatively constant phenol concentration in the last two-thirds of the monitoring period. Thus, a remedial measures pump well between the pump well near the spill site (Well 20) and the lake appears to be called for to intercept any contaminated water that may be nearing the lake.

11.2.2 Polynuclear Aromatic Hydrocarbon Monitoring Results

The results of PNA monitoring in wells in the vicinity of the spill are shown in Table 11-7. Wells 7, 8, 10 and 20 have been sampled for PNA content. For each observation, an ambient severity (AS) was calculated. The AS is the ratio of the observed concentration to the Multimedia Environmental Goal or the proposed water quality criterion for that constitutent. The AS provides a rapid means of comparing the observed (ambient) levels with the criteria. An AS less than 1 implies that the water poses no health or environmental threat, based on the given parameters.

TABLE 11-7 POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN VICINITY OF THE SPILL

Sample Date	Well 7		Well 8		Well 10		Well 20 or "Production Well"	
	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
Benzo (a) pyrene (20 μg/ℓ)*								
27 Feb 80**	0.03	1.5 (-3)***	0.01	5.0 (-4)				
11 Mar 80	0.01	5.0 (-4)	0.01	5.0 (-4)				
11 Apr 80							0.04	2.0 (-3)
17 Apr 80					<0.01	<5.0 (-4)	<0.01	<5.0 (-4)
12 May 80					<0.01	<5.0 (-4)		
29 May 80					<0.01	<5.0 (-4)	<0.01	<5.0 (-4)
Dibenz (a, h) anthracene (4 μg/ℓ)*								
11 Mar 80	0.01	2.5 (-3)			0.05	1.2 (-2)		
11 Apr 80							0.04	1.0 (-2)
17 Apr 80					0.05	1.2 (-2)	<0.01	<2.5 (-3)
12 May 80					<0.01	<2.5 (-3)		
29 May 80					0.01	2.5 (-3)	0.02	5.0 (-3)
Benzo (g, h, i) perylene (none)								
27 Feb 80**	0.06	none	0.02	none				
11 Mar 80	0.02	none	0.02	none	0.04	none		
11 Apr 80							0.02	none
17 Apr 80					<0.01	none	<0.01	none
12 May 80					<0.01	none		
29 May 80					<0.01	none	<0.01	none
Indeno (1, 2, 3 - cd) pyrene (58.5 μg/ℓ)*								
11 Mar 80	0.05	8.6 (-4)			0.03	5.1 (-4)		
11 Apr 80							0.01	1.7 (-4)
17 Apr 80					0.06	1.0 (-3)	<0.01	<1.7 (-4)
12 May 80					<0.01	<1.7 (-4)		
29 May 80					<0.01	<1.7 (-4)	<0.01	<1.7 (-4)

*Water Quality Criteria from Tables 11-3 and 11-5

**Analysis date

***a (-n) = a x 10^{-n}

TABLE 11-7. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN VICINITY OF THE SPILL (Continued)

Sample Date	Well 7 Concentration (µg/ℓ)	Well 7 Ambient Severity	Well 8 Concentration (µg/ℓ)	Well 8 Ambient Severity	Well 10 Concentration (µg/ℓ)	Well 10 Ambient Severity	Well 20 or "Production Well" Concentration (µg/ℓ)	Well 20 or "Production Well" Ambient Severity
Acenaphthene (20 µg/ℓ)*								
27 Feb 80**	16.8	0.84	9.2	0.46				
11 Mar 80	34.0	1.7	1.4	7.0 (-2,***	20.0	1.0		
11 Apr 80							0.03	1.5 (-3)
17 Apr 80					43.21	2.2	9.41	0.47
12 May 80					5.1	0.26		
29 May 80					0.20	1.0 (-2)	0.90	4.5 (-2)
Fluorene (none)								
27 Feb 80**			0.07	none				
11 Mar 80	64.0	none	3.0	none	3.5	none		
11 Apr 80							8.4	none
17 Apr 80					109.55	none	34.67	none
12 May 80					8.0	none		
29 May 80					0.30	none	1.30	none
Phenanthrene (280 µg/ℓ)*								
27 Feb 80**	0.33	1.2 (-3)	0.36	1.3 (-3)				
11 Mar 80	0.3	1.1 (-3)			0.1	3.6 (-4)		
11 Apr 80							0.01	3.6 (-5)
17 Apr 80					<0.01	<3.6 (-5)	1.78	6.4 (-3)
12 May 80					6.5	2.3 (-2)		
29 May 80					0.20	7.1 (-4)	1.31	4.7 (-3)
Anthracene (1995 µg/ℓ)*								
27 Feb 80**	0.14	7.0 (-5)	0.14	7.0 (-5)				
11 Mar 80	0.14	7.0 (-5)	2.9	1.45 (-3)	0.01	5.0 (-6)		
11 Apr 80							0.15	7.5 (-5)
17 Apr 80					0.18	9.0 (-5)	0.03	1.5 (-5)
12 May 80					0.08	4.0 (-5)		
29 May 80					< 0.01	< 5.0 (-6)	< 0.01	<5.0 (-6)
Fluoranthene (205 µg/ℓ)*								
27 Feb 80**	0.12	6.0 (-4)	0.02	1.0 (-4)				
11 Mar 80	0.08	4.0 (-4)	0.05	2.5 (-4)	1.0	5.0 (-3)		
11 Apr 80							0.01	5.0 (-5)
17 Apr 80					0.01	5.0 (-5)	0.01	5.0 (-5)
12 May 80					0.80	5.0 (-4)		
29 May 80					0.01	5.0 (-5)	0.01	5.0 (-5)

*Water Quality Criteria from Tables 11-3 and 11-5

**Analysis date

***a (-n) = a x 10^{-n}

TABLE 11-7 POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN VICINITY OF THE SPILL (Continued)

	Well 7		Well 8		Well 10		Well 20 or "Production Well"	
Sample Date	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
Pyrene (8333 μg/ℓ)*								
11 Mar 80	0.17	2.0 (-5)***	0.11	1.32 (-5)	0.05	6.0 (-6)		
11 Apr 80							0.34	4.1 (-5)
17 Apr 80					0.42	5.0 (-5)	0.47	5.6 (-5)
12 May 80					<0.01	<1.2 (-6)		
29 May 80					<0.01	<1.2 (-6)	0.01	1.2 (-6)
Benz (a) anthracene (4 μg/ℓ)*								
27 Feb 80**	0.007	1.8 (-3)						
11 Mar 80	0.01	2.5 (-3)	0.01	2.5 (-3)				
11 Apr 80							0.01	2.5 (-3)
17 Apr 80					<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
12 May 80					0.02	5.0 (-3)		
29 May 80					<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
Chrysene (79.4 μg/ℓ)*								
27 Feb 80**			0.51	6.4 (-3)				
11 Mar 80	0.18	2.3 (-3)	0.02	2.5 (-4)	0.20	2.5 (-3)		
11 Apr 80							0.13	1.6 (-3)
17 Apr 80					<0.01	<1.3 (-4)	0.38	4.8 (-3)
12 May 80					<0.01	<1.3 (-4)		
29 May 80					<0.01	<1.3 (-4)	<0.01	<1.3 (-4)
3, 4 Benzofluoranthene (31.5 μg/ℓ)*								
27 Feb 80**	0.0074	2.4 (-4)	0.0015	4.76 (-5)				
11 Mar 80	0.01	3.2 (-4)	0.03	9.5 (-4)	0.02	6.3 (-4)		
11 Apr 80							0.01	3.2 (-4)
17 Apr 80					0.42	1.3 (-2)	<0.01	<3.2 (-4)
12 May 80					0.03	9.5 (-4)		
29 May 80					0.08	2.5 (-3)	<0.01	<3.2 (-4)
Benzo (k) fluoranthene (58 μg/ℓ)*								
27 Feb 80**	0.0056	9.7 (-5)						
11 Mar 80	0.03	5.2 (-4)			0.03	5.2 (-4)		
11 Apr 80							0.01	1.7 (-4)
17 Apr 80					<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
12 May 80					0.02	3.4 (-4)		
29 May 80					<0.01	<1.7 (-4)	<0.01	<1.7 (-4)

*Water Quality Criteria from Tables 11-3 and 11-5

**[illegible]

***a (-n) = a x 10^{-n}

Table 11-7 shows that detectable quantities of each PNA were found from time to time. However, with the exception of acenaphthene, the AS is everywhere less than 0.1, implying no human health hazard exists from these PNA at the observed levels.

Acenaphthene has been observed at levels above the proposed water qualtiy criterion of 20 μg/ℓ in Wells 7 and 10. The elevated observation in Well 7 coincides with the peak phenol concentration observed in that well. The occurrence of acenaphthene may thus be ascribable to the spill event, although other factors (such as reproducibility of the analytical procedure at these low concentrations and possible sample contamination) could explain the elevated concentration. The observed levels in Well 10, on the other hand, are probably not due to the spill. Well 10 is not along the most probable vector of contaminant movement, and elevated concentrations occur before contaminants from the spill could have arrived in the vicinity. Here again, instrument error or sample contamination may be responsible for the observed levels.

11.2.3 Results of Metals Analyses

Well 20 was sampled for metals on 5 June 1980. Results are shown on Table 11-8. These analyses were performed on Radian's Inductively-Coupled Argon Plasma Emission Spectrometer (ICAPES), a multi-channel analytical instrument capable of providing simultaneous analyses for up to 40 metals. At the time this sample was processed, the instrument was programmed for the elements shown, and all data obtained are presented. However, for purposes of this study, attention is focused on the metals regulated under the National Interim Primary and Secondary Drinking Water Regulations, which were shown on Table 11-2.

TABLE 11-8. CONCENTRATION OF SELECTED METALS IN WELL 20

Element	Concentration[1]	Detection Limit
Sb	.038*	.030
Cr	<.001	.001
Ag	<.002	.002
K	1.98	.040
Fe	.038*	.008
Ti	<.005	.005
Sr ✓	.128	.001
Bi	<.050	.050
Be	<.001	.001
Mn ✓	1.11	.001
Mg	7.26	.008
As	<.060	.060
Se	<.080	.080
Zn ✓	.133	.003
Mo	.007*	.003
Ca	21.0	.045
Pb	<.08	.080
Cd	<.008	.008
Co	<.006	.006
Sn	<.120	.120
In	<.055	.055
U	<.06	.060
Y	<.002	.002
Ba	.052	.001
Cu	<.001	.001
Ni	.017	.002
Si	11.6	.030
Na	9.2	.010
Pt	<.025	.025
B	<.009	.009
Il	.12*	.090
V	.011*	.003
Au	<.040	.040
Te	<.10	.100
Li	<.001	.001
Al	<.05	.050
P	<.18	.180

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[1] All concentrations as mg/ℓ.

*Indicates that element is present at concentration near its Detection Limit. Results should be interpreted accordingly.

Comparison of Table 11-8 with Table 11-2 shows that only manganese, Mn, exists at concentrations above the maximum contaminant level (mcl) specified. The ICAPES analytical detection limits for arsenic (As), lead (Pb), and selenium (Se) are all above their respective mcl, so no conclusions can be drawn. No analysis was performed for mercury, another primary drinking water metal, because of an inadequate ICAPES detection limit.

11.3 Water Quality Monitoring Results for the East End of the SRC Plant

Because of concern for the possible impact of the 19 December spill on the quality and usability of Sullivan Well, a major source of water supply for Ft. Lewis during the summer months, two wells (Wells 11 and 24) were emplaced at the east end of the SRC plant. Well 11 is a small-diameter (2") well installed by the hollow-stem auger method. The water level was found to be too deep for sampling by the vacuum method used at Wells 1 to 10. Sampling by airlift methods also proved unsuccessful, so a small bailer had to be used to obtain water samples. The analytical results from this well reflected the inadequacy of the sampling technique, so Well 11 was replaced by Well 24 as a sampling well. In anticipation of the need for a pump well that would provide an added remedial measure for protecting Sullivan Well from the effects of the 19 December spill, Well 24 was completed with a well screen and a sufficiently large diameter for a submersible pump.

11.3.1 Phenol Monitoring Results

The phenol analysis results for Wells 11 and 24 are shown in Figure 11-7. All phenol levels are below the 0.6 mg/ℓ criterion level for freshwater aquatic life. The phenol content

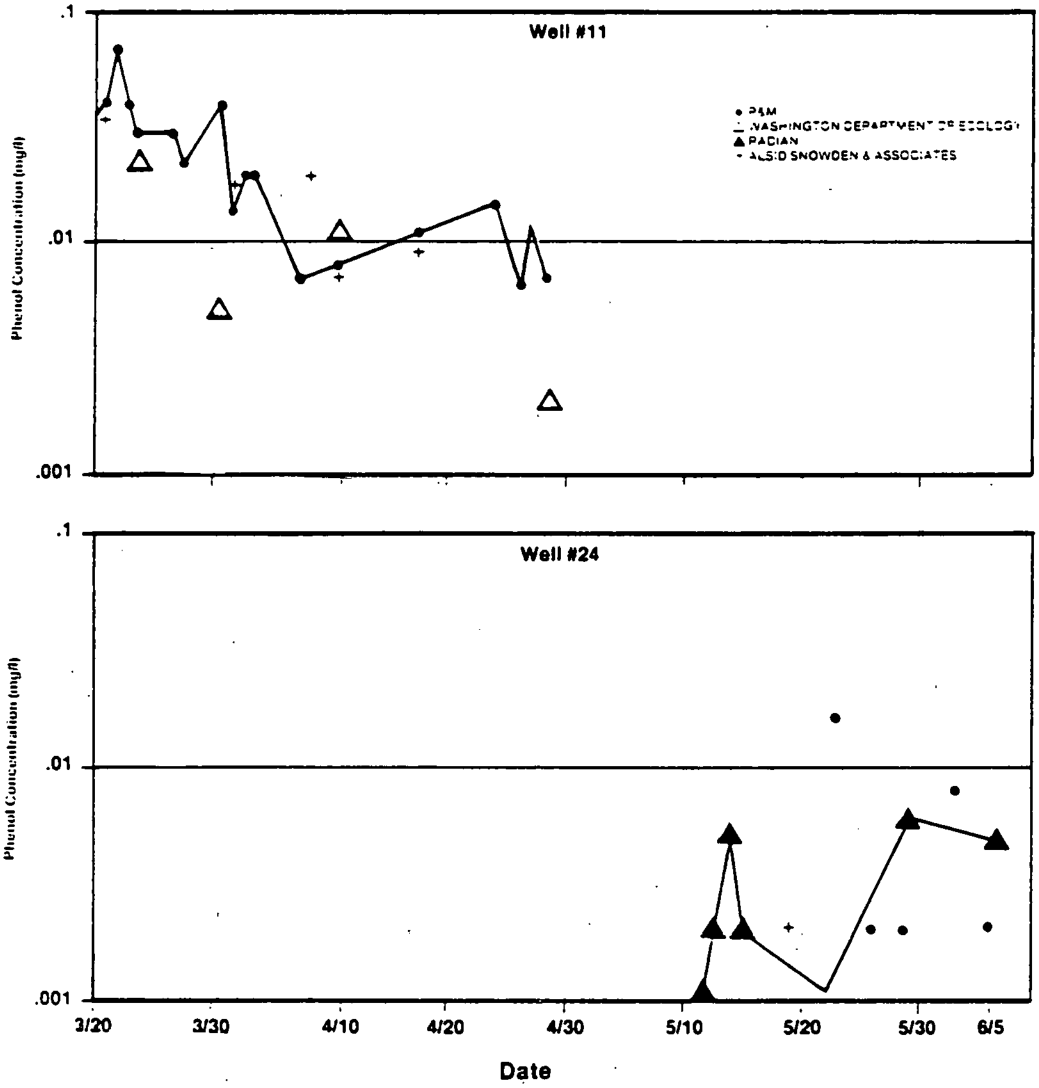

Figure 11-7. Phenol Concentrations in Well 11 and Well 24.

of water from Well 11 is in the 0.005 to 0.05 mg/ℓ range, whereas the concentration in Well 24 is in the 0.001 to 0.01 mg/ℓ range. The concentration in Well 24, which is properly constructed and reliably sampled, is considerably lower than in the more questionable Well 11. Most of the phenol concentrations in samples from Well 24 are near ar at the detection limit for the analytical method used.

11.3.2 Polynuclear Aromatic Hydrocarbon Monitoring Results

Wells 11 and 24 at the east end of the plant were sampled and analyzed for PNA content. The results of analyses are shown in Table 11-9. Ambient severities are all less than 0.1, indicating no hazard.

11.3.3 Results of Metals Analysis

Well 24 was sampled for metals on 5 June 1980. Results of analyses are shown in Table 11-10. Analyses were performed by ICAPES (see Section 11.2.3). All available determinations are below the mcl specified by the National Interim Primary and Secondary Drinking Water Regulations.

11.4 Water Quality Monitoring Results at Sullivan Well and Sequalitchew Springs

As noted in Section 10.0, Sullivan Well and Sequalitchew Springs have been routinely monitored during the course of the environmental monitoring program at the SRC plant. The sampling results for 1979 are presented in Table 10-2. These monitoring efforts were stepped up after the 19 December spill event because of concern for these two essential water supply sources for Ft. Lewis.

TABLE 11-9. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS AT EAST END OF THE SRC PLANT

	Well 11		Well 24	
Sample Date	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
Acenaphthene (20 μg/ℓ)*				
21 Mar 80	0.32	1.6 (-2)**		
2 Apr 80	<0.01	<5.0 (-4)		
17 Apr 80	0.75	3.8 (-2)		
12 May 80			2.0	0.1
28 May 80	1.8	9.0 (-2)		
Fluorene (none)*				
21 Mar 80	<0.01	none		
2 Apr 80	<0.01	none		
17 Apr 80	54.09	none		
12 May 80			6.0	none
29 May 80	4.3	none		
Phenanthrene (280 μg/ℓ)*				
21 Mar 80	<0.01	<3.6 (-5)		
2 Apr 80	<0.01	<3.6 (-5)		
17 Apr 80	2.53	9.0 (-3)		
12 May 80			<0.01	<3.6 (-5)
29 May 80	<0.01	<3.6 (-5)		
Anthracene (1995 μg/ℓ)*				
21 Mar 80	<0.01	<5.0 (-6)		
2 Apr 80	<0.01	<5.0 (-6)		
17 Apr 80	<0.01	<5.0 (-6)		
12 May 80			<0.01	<5.0 (-6)
29 May 80	0.04	2.0 (-5)		
Fluoranthene (200 μg/ℓ)*				
21 Mar 80	<0.01	<5.0 (-5)		
2 Apr 80	<0.01	<5.0 (-5)		
17 Apr 80	<0.01	<5.0 (-5)		
12 May 80			<0.01	<5.0 (-5)
29 May 80	<0.01	<5.0 (-5)		

*Water Quality Criteria from Tables 11-3 and 11-5
**a (-n) = a x 10^{-n}

TABLE 11-9. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS AT EAST END OF THE SRC PLANT (Continued)

	Well 11		Well 24	
Sample Date	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
Pyrene (8333 μg/ℓ)*				
21 Mar 80	<0.01	<1.2 (-6)**		
2 Apr 80	<0.01	<1.2 (-6)		
17 Apr 80	<0.01	<1.2 (-6)		
12 May 80			0.16	1.9 (-5)
29 May 80	0.01	1.2 (-6)		
Benz (a) anthracene (4 μg/ℓ)*				
21 May 80	<0.01	<2.5 (-3)		
2 Apr 80	0.02	5.0 (-3)		
17 Apr 80	0.07	1.8 (-2)		
12 May 80			<0.01	<2.5 (-3)
29 May 80	<0.01	<2.5 (-3)		
Chrysene (79.4 μg/ℓ)*				
21 Mar 80	<0.01	<1.3 (-4)		
2 Apr 80	<0.01	<1.3 (-4)		
17 Apr 80	<0.01	<1.3 (-4)		
12 May 80			0.02	2.5 (-4)
29 May 80	<0.01	<1.3 (-4)		
3, 4 Benzofluoranthene (31.5 μg/ℓ)*				
21 Mar 80	<0.01	<3.2 (-4)		
2 Apr 80	0.11	3.5 (-3)		
17 Apr 80	0.61	1.9 (-2)		
12 May 80			0.01	3.2 (-4)
29 May 80	<0.01	<3.2 (-4)		
Benzo (k) fluoranthene (58 μg/ℓ)*				
21 Mar 80	<0.01	<1.7 (-4)		
2 Apr 80	0.03	5.2 (-4)		
17 Apr 80	0.16	2.8 (-3)		
12 May 80			<0.01	<1.7 (-4)
29 May 80	0.01	1.7 (-4)		

*Water Quality Criteria from Tables 11-3 and 11-5

**a (-n) = a x 10^{-n}

TABLE 11-9. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS AT EAST END OF THE SRC PLANT (Continued)

	Well 11		Well 24	
Sample Date	Concentration (µg/ℓ)	Ambient Severity	Concentration (µg/ℓ)	Ambient Severity
Benzo (a) pyrene (20 µg/ℓ)*				
21 Mar 80	<0.01	<5.0 (-4)**		
2 Apr 80	<0.01	<5.0 (-4)		
17 Apr 80	0.07	3.5 (-3)		
12 May 80			<0.01	<5.0 (-4)
29 May 80	<0.01	<5.0 (-4)		
Dibenz (a. h) anthracene (4 µg/ℓ)*				
21 Mar 80	0.03	7.5 (-3)		
2 Apr 80	0.02	5.0 (-3)		
17 Apr 80	<0.01	<2.5 (-3)		
12 May 80			<0.01	<2.5 (-3)
29 May 80	<0.01	<2.5 (-3)		
Benzo (g, h, i)perylene (none)*				
21 Mar 80	0.01	none		
2 Apr 80	0.06	none		
17 Apr 80	0.04	none		
12 May 80			<0.01	none
29 May 80	<0.01	none		
Indeno (1, 2, 3 - cd) pyrene (58.5 µg/ℓ)*				
21 Mar 80	<0.01	<1.7 (-4)		
2 Apr 80	0.02	3.4 (-4)		
17 Apr 80	0.03	5.1 (-4)		
12 May 80			<0.01	<1.7 (-4)
29 May 80	<0.01	<1.7 (-4)		

*Water Quality Criteria from Tables 11-3 and 11-5

**a (-n) = a x 10^{-n}

TABLE 11-10. CONCENTRATION OF SELECTED METALS IN WELL 24

Element	Well 24[1]	Detection Limit
Sb	.055*	.030
Cr	<.001	.001
Ag	<.002	.002
K	1.61	.040
Fe	.066	.008
Ti	<.005	.005
Sr	.069	.001
Bi	<.050	.050
Be	<.001	.001
Mn	.017	.001
Mg	5.03	.008
As	<.06	.060
Se	<.08	.080
Zn	.635	.003
Mo	.005*	.003
Ca	14.2	.045
Pb	<.08	.080
Cd	<.008	.008
Co	<.006	.006
Sn	<.120	.120
In	<.055	.055
U	.12*	.060
Y	<.002	.002
Ba	.047	.001
Cu	<.001	.001
Ni	.017	.002
Si	14.9	.030
Na	7.8	.010
Pt	<.025	.025
B	<.009	.009
Cl	<.090	.090
V	.008*	.008
Au	<.040	.040
Te	.12*	.100
Li	<.001	.001
Al	<.05	.050
P	<.18	.180

[1] All concentrations are mg/ℓ.

*Indicates that element is present at concentrations near its detection limit. Results should be interpreted accordingly.

11.4.1 Phenol Monitoring Results

Because of the concern for Sullivan Well water quality, an intensive water sampling and analysis program was undertaken in May 1980. The results of this intense program are shown in Table 11-11. All analyses show that phenol concentrations are at or below the detection limit, which indicates that Sullivan Well has not been affected by the 19 December spill.

In addition to the intensive sampling program described above, monitoring for phenol levels in Sullivan Well has been ongoing at an increased pace during the entire period since the 19 December spill. The results of this monitoring program are shown in Table 11-12. These data all show concentrations at or near the analytical detection limit, revealing no phenol contamination. The variations observed may all be ascribed to analytical noise. All observations are below the 0.6 mg/ℓ criterion proposed for freshwater aquatic life.

11.4.2 Polynuclear Aromatic Hydrocarbon Monitoring Results

Both Sullivan Well and Sequalitchew Springs have been routinely sampled for PNA. Results of analyses are shown on Table 11-13, together with the AS for each observation. While detectable quantities of each PNA were found, the AS is, with the exception of acenaphthene, small everywhere. The largest AS calculated is 0.032 for benz(a)anthracene in Sequalitchew Springs on 17 April 1980. The AS for acenaphthene is less than 1.0 (non-hazardous), but are as large as 0.48 (Sullivan Well, 17 April 1980). This single observation is judged not be significant since preceding and subsequent observations are all

TABLE 11-11. PHENOL CONCENTRATIONS DURING PUMPAGE OF SULLIVAN WELL

Date	Time	Phenol (ppm)
12 May	1230	<.001
	1530	.002
	1830	.002
	2130	—
13 May	0030	<.001
	0630	.002
	1230	<.001
	1830	<.001
14 May	0030	<.001
	0630	<.001
	1200	<.001
	1800	<.001
15 May	0030	<.001
	0600	<.001
	1200	.002
16 May	0030	<.001
	1230	<.001
17 May	0030	.002
	1230	<.001
18 May	0030	<.001
	1230	<.001
19 May	0030	.001
	1230	.001

Note: All analyses by Alsid, Snowden, & Associates.

TABLE 11-12. PHENOL CONCENTRATIONS IN SULLIVAN WELL AND SEQUALITCHEW SPRINGS

Date 1980	Concentration[1] Sequalitchew Springs	Concentration[1] Sullivan Well
14 January	<.003	<.003
26 February	<.003	.003
7 March	<.003	<.003
11 March	<.003	<.003
17 March	<.003	<.003
24 March	.001	.001
31 March	.001	.001
2 April	.001	.001
	.004[2]	*.004*[2]
8 April	.001	.001
10 April	<.004	<.001
	.008[2]	*.001*[2]
14 April	.003	.003
15 April	<.001	<.001
	<.001[3]	*<.001*[3]
17 April	<.001	<.001
22 April	<.001	<.001
28 April	.003	<.001
	.001[3]	*.001*[3]
5 May	*.001*[3]	
12 May	.002	
13 May	<.001	
14 May	<.001	
15 May	.002	
16 May	<.001	<.001
17 May	<.001	
18 May	<.001	
19 May	<.001	
23 May	<.001	
5 June	<.001	.001
9 June	<.001	<.001
23 June	<.001	<.001
1 July	<.001	.001

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[1] Data generated by Alsid, Snowden & Associates (ASA) unless otherwise indicated.

[2] Radian Corporation data.

[3] Washington Department of Ecology data.

TABLE 11-13. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN SULLIVAN WELL AND SEQUALITCHEW SPRINGS

	Sullivan Well		Sequalitchew Springs	
Sample Date	Concentration (µg/ℓ)	Ambient Severity	Concentration (µg/ℓ)	Ambient Severity
Acenaphthene (20µg/ℓ)*				
27 Feb 80**	3.1	0.16	0.12	6.0 (-3)
21 Mar 80	< 0.01	< 5.0 (-4)***	2.1	0.10
2 Apr 80	< 0.01	< 5.0 (-4)	< 0.01	<5.0 (-4)
17 Apr 80	9.63	0.48	3.33	0.17
12 May 80	< 0.01	< 5.0 (-4)	< 0.01	<5.0 (-4)
29 May 80	1.8	9.0 (-2)	0.90	4.5 (-2)
Fluorene (none)*				
27 Feb 80**			6.56	none
21 Mar 80	< 0.01	none	< 0.01	none
2 Apr 80	< 0.01	none	< 0.01	none
17 Apr 80	< 0.01	none	39.13	none
12 May 80	< 0.01	none	< 0.01	none
29 May 80	2.8	none	1.4	none
Phenanthrene (280µg/ℓ)*				
27 Feb 80**	0.52	1.9 (-3)	0.20	7.1 (-4)
21 Mar 80	< 0.01	< 3.6 (-5)	< 0.01	<3.6 (-5)
2 Apr 80	0.26	9.3 (-4)	< 0.01	<3.6 (-5)
17 Apr 80	0.41	1.5 (-3)	< 0.01	<3.6 (-5)
12 May 80	0.10	3.6 (-4)	< 0.01	<3.6 (-5)
29 May 80	0.7	2.5 (-3)	< 0.01	<3.6 (-5)
Anthracene (1995µg/ℓ)*				
27 Feb 80**	0.03	1.5 (-5)	0.04	2.0 (-5)
21 Mar 80	0.11	5.5 (-5)	< 0.01	<5.0 (-6)
2 Apr 80	< 0.01	< 5.0 (-6)	< 0.01	<5.0 (-6)
17 Apr 80	0.37	1.8 (-4)	0.01	5.0 (-6)
12 May 80	< 0.01	< 5.0 (-6)	< 0.01	<5.0 (-6)
29 May 80	0.04	2.0 (-5)	0.01	5.0 (-6)

*Water Quality Criteria from Tables 11-3 and 11-5

**Analysis date

***$a\ (-n) = a \times 10^{-n}$

TABLE 11-13. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN SULLIVAN WELL AND SEQUALITCHEW SPRINGS (Continued)

	Sullivan Well		Sequalitchew Springs	
Sample Date	Concentration (µg/ℓ)	Ambient Severity	Concentration (µg/ℓ)	Ambient Severity
Fluoranthene (200 µg/ℓ)*				
21 Mar 80	<0.01	<5.0 (-5)***	0.06	3.0 (-4)
2 Apr 80	0.02	1.0 (-4)	0.01	5.0 (-5)
17 Apr 80	0.08	4.0 (-4)	0.37	1.8 (-3)
12 May 80	<0.01	<5.0 (-5)	0.10	5.0 (-4)
29 May 80	<0.01	<5.0 (-5)	0.02	1.0 (-4)
Pyrene (8333 µg/ℓ)*				
27 Feb 80	0.02	2.4 (-6)		
21 Mar 80	<0.01	<1.2 (-6)	<0.01	<1.2 (-6)
2 Apr 80	0.01	1.2 (-6)	<0.01	<1.2 (-6)
17 Apr 80	0.46	5.5 (-5)	<0.01	<1.2 (-6)
12 May 80	<0.01	<1.2 (-6)	<0.01	<1.2 (-6)
29 May 80	<0.01	<1.2 (-6)	<0.01	<1.2 (-6)
Benz (a) anthracene (4 µg/ℓ)*				
27 Feb 80**	0.006	1.5 (-3)	0.006	1.5 (-3)
21 Mar 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
2 Apr 80	<0.01	<2.5 (-3)	0.01	2.5 (-3)
17 Apr 80	0.01	2.5 (-3)	0.13	3.2 (-2)
12 May 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
29 May 80	<0.01	<2.5 (-3)	0.02	5.0 (-3)
Chrysene (79.4 µg/ℓ)*				
27 Feb 80**			0.04	5.0 (-4)
21 Mar 80	<0.01	<1.3 (-4)	0.07	8.8 (-4)
2 Apr 80	0.03	3.8 (-4)	0.03	3.8 (-4)
17 Apr 80	0.29	3.6 (-3)	0.30	3.8 (-3)
12 May 80	0.02	2.5 (-4)	0.07	8.8 (-4)
29 May 80	<0.01	<1.3 (-4)	<0.01	<1.3 (-4)

*Water Quality Criteria from Tables 11-3 and 11-5
**Analysis date
***a (-n) = a x 10^{-n}

TABLE 11-13. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN SULLIVAN WELL AND SEQUALITCHEW SPRINGS (Continued)

	Sullivan Well		Sequalitchew Springs	
Sample Date	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
3, 4 Benzofluoranthene (31.5 μg/ℓ)*				
27 Feb 80**	0.11	3.5 (-3)***	0.01	3.2 (-4)
21 Mar 80	<0.01	<3.2 (-4)	<0.01	<3.2 (-4)
2 Apr 80	<0.01	<3.2 (-4)	0.02	6.3 (-4)
17 Apr 80	0.44	1.4 (-2)	0.05	1.6 (-3)
12 May 80	<0.01	<3.2 (-4)	<0.01	<3.2 (-4)
29 May 80	<0.01	<3.2 (-4)	<0.01	<3.2 (-4)
Benzo (k) fluoranthene (58 μg/ℓ)*				
27 Feb 80**			0.05	8.6 (-4)
21 Mar 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
2 Apr 80	0.02	3.4 (-4)	0.03	5.2 (-4)
17 Apr 80	0.03	5.2 (-4)	<0.01	<1.7 (-4)
12 May 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
29 May 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
Benzo (a) pyrene (20 μg/ℓ)*				
27 Feb 80**	0.009	4.5 (-4)		
21 Mar 80	0.08	4.0 (-3)	<0.01	<5.0 (-4)
2 Apr 80	0.09	4.5 (-3)	0.01	5.0 (-4)
17 Apr 80	0.04	2.0 (-3)	0.16	8.0 (-3)
12 May 80	<0.01	<5.0 (-4)	0.05	2.5 (-3)
29 May 80	<0.01	<5.0 (-4)	0.01	5.0 (-4)
Dibenz (a, h) anthracene (4 μg/ℓ)*				
27 Feb 80**	0.01	2.5 (-3)		
21 Mar 80	0.01	2.5 (-3)	<0.01	<2.5 (-3)
2 Apr 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
17 Apr 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
12 May 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
29 May 80	0.03	7.5 (-3)	<0.01	<2.5 (-3)

*Water Quality Criteria from Tables 11-3 and 11-5

**Analysis date

***a (-n) = a x 10^{-n}

TABLE 11-13. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN SULLIVAN WELL AND SEQUALITCHEW SPRINGS (Continued)

	Sullivan Well		Sequalitchew Springs	
Sample Date	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
Benzo (g, h, i) perylene (none)*				
27 Feb 80**	0.05	none		
21 Mar 80	0.01	none	<0.01	none
2 Apr 80	<0.01	none	<0.01	none
17 Apr 80	0.06	none	<0.01	none
12 May 80	<0.01	none	<0.01	none
29 May 80	0.05	none	<0.01	none
Indeno (1, 2, 3 - cd) pyrene (58.5 μg/ℓ)*				
21 Mar 80	0.22	3.8 (-3)***	<0.01	<1.7 (-4)
2 Apr 80	0.01	1.7 (-4)	0.06	1.0 (-3)
17 Apr 80	0.08	1.4 (-3)	0.20	3.4 (-3)
12 May 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
29 May 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)

*Water Quality Criteria from Tables 11-3 and 11-5

**Analysis date

***a (-n) = a x 10^{-n}

low. Both of these important water sources are non-hazardous with respect to PNA contamination.

11.5 Surface-Water Quality Monitoring Results

Routine water quality sampling and analysis was underway for Sequalitchew Lake (3 locations), and Hamer Marsh (2 points) before the 19 December spill as part of the environmental monitoring program. The results of this program are reported in Tables 10-3 and 10-4. Since 19 December, the monitoring program has been intensified.

11.5.1 Phenol Monitoring Results

The phenol monitoring results for surface water bodies are shown in Table 11-14. These data nearly all show concentrations at or near the analytical detection limit. It can be concluded that these surface water bodies display no phenol contamination. The variations observed may all be ascribed to analytical noise. All observations are below the 0.6 mg/ℓ criterion proposed for freshwater aquatic life.

11.5.2 Polynuclear Aromatic Hydrocarbon Monitoring Results

The surface water bodies of American Lake and Lake Sequalitchew have also been sampled for PNA. Results of analysis are shown in Table 11-15. A single analysis (acenaphthene in American Lake on 17 April 1980) has a calculated ambient severity of 0.72. Inasmuch as the balance of the acenaphthene observations are low, the 17 April observation should be considered an outlier and disregarded. Other AS calculated are all low. These surface water bodies may be considered uncontaminated.

TABLE 11-14. PHENOL MONITORING RESULTS FOR SURFACE WATER BODIES

	Concentration[1] Sequalitchew Lake Stations			American Lake
Date	1	2	3	
14 Jan	<0.003	<0.003	<0.003	
	0.011[2]	<0.003[3]		
26 Feb	<0.003	0.003		
7 Mar	<0.003			<0.003
11 Mar	0.004			<0.003
17 Mar	0.004	≤0.003	≤0.003	<0.003
24 Mar	0.004			0.001
31 Mar	0.004			0.001
2 Apr	0.001			0.001
	0.009[4]			*0.006*[4]
8 Apr	0.001			0.001
10 Apr	<0.001			<0.001
	0.011			*<0.001*[4]
14 Apr	0.003	0.003		
	0.011[2]	0.003[3]		
15 Apr	0.005			<0.001
	0.012[5]			*<0.001*[5]
17 Apr	0.003			<0.001
22 Apr	<0.001			<0.001
28 Apr	<0.001[2]	0.003[2]	0.003	
	0.003[5]	*0.001*[5]	*<0.001*[5]	
19 May	0.002			<0.001
5 June	0.002			<0.001
9 June	0.001	<0.001	<0.001	<0.001
23 June	0.003			<0.001
1 July	0.001			<0.001

Notes:

[1] Data generated by Alsid, Snowden & Associates (ASA) unless otherwise indicated.

[2] ASA station 3b nearby

[3] ASA station 4b nearby

[4] Radian Corporation data

[5] Washington Department of Ecology data

TABLE 11-15. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN SURFACE WATER BODIES

	American Lake		Lake Sequalitchew	
Sample Date	Concentration (µg/ℓ)	Ambient Severity	Concentration (µg/ℓ)	Ambient Severity
Acenaphthene (20 µg/ℓ)*				
27 Feb 80**	2.8	0.14	1.05	5.2 (-2)
21 Mar 80	<0.01	< 5.0 (-4)***	< 0.01	< 5.0 (04)
2 Apr 80	<0.01	< 5.0 (-4)	< 0.01	< 5.0 (-4)
17 Apr 80	14.27	0.71	0.52	2.6 (-2)
12 May 80	<0.01	< 5.0 (-4)	< 0.01	< 5.0 (-4)
29 May 80	<0.01	< 5.0 (-4)	< 0.01	< 5.0 (-4)
Fluorene (none)*				
27 Feb 80**	10.8	none	7.36	none
21 Mar 80	<0.01	none	< 0.01	none
2 Apr 80	<0.01	none	< 0.01	none
17 Apr 80	<0.01	none	31.22	none
12 May 80	<0.01	none	5.3	none
29 May 80	<0.01	none	< 0.01	none
Phenanthrene (280 µg/ℓ)*				
21 Mar 80	<0.01	< 3.6 (-5)	0.5	1.8 (-3)
2 Apr 80	<0.01	< 3.6 (-5)	< 0.01	< 3.6 (-5)
17 Apr 80	<0.01	< 3.6 (-5)	< 0.01	< 3.6 (-5)
12 May 80	<0.01	< 3.6 (-5)	0.13	4.6 (-4)
29 May 80	<0.01	< 3.6 (-5)	< 0.01	< 3.6 (-5)
Anthracene (1995µg/ℓ)*				
27 Feb 80**	0.09	4.5 (-5)		
21 Mar 80	<0.01	<5.0 (-6)	<0.01	<5.0 (-6)
2 Apr 80	<0.01	<5.0 (-6)	<0.01	<5.0 (-6)
17 Apr 80	0.29	1.4 (-4)	<0.01	<5.0 (-6)
12 May 80	<0.01	<5.0 (-6)	<0.01	<5.0 (-6)
29 May 80	<0.01	<5.0 (-6)	<0.01	<5.0 (-6)
Fluoranthene (200 µg/ℓ)*				
21 Mar 80	<0.01	<5.0 (-5)	<0.01	<5.0 (-5)
2 Apr 80	<0.01	<5.0 (-5)	0.06	3.0 (-4)
17 Apr 80	<0.01	<5.0 (-5)	2.98	1.5 (-2)
12 May 80	<0.01	<5.0 (-5)	0.02	1.0 (-4)
29 May 80	<0.01	<5.0 (-5)	0.19	9.5 (-4)

*Water Quality Criteria from Tables 11-3 and 11-5

**Analysis date

***$a\ (-n) = a \times 10^{-n}$

TABLE 11-15. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN SURFACE WATER BODIES (Continued)

	American Lake		Lake Sequalitchew	
Sample Date	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
Pyrene (8333 μg/ℓ)*				
27 Feb 80**			0.08	9.6 (-6)***
21 Mar 80	<0.01	<1.2 (-6)	0.06	7.2 (-6)
2 Apr 80	<0.01	<1.2 (-6)	0.09	1.1 (-5)
17 Apr 80	0.31	3.7 (-5)	<0.01	<1.2 (-6)
12 May 80	<0.01	<1.2 (-6)	0.14	1.7 (-5)
29 May 80	0.11	1.3 (-5)	<0.01	<1.2 (-6)
Benz (a) anthracene (4 μg/ℓ)*				
21 Mar 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
2 Apr 80	<0.01	<2.5 (-3)	0.04	1.0 (-2)
17 Apr 80	<0.01	<2.5 (-3)	0.05	1.2 (-2)
12 May 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
29 May 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
Chrysene (79.4 μg/ℓ)*				
27 Feb 80**			0.15	1.9 (-3)
21 Mar 80	<0.01	<1.3 (-4)	<0.01	<1.3 (-4)
2 Apr 80	<0.01	<1.3 (-4)	<0.01	<1.3 (-4)
17 Apr 80	0.11	1.4 (-3)	0.43	5.4 (-3)
12 May 80	<0.01	<1.3 (-4)	0.10	1.3 (-3)
29 May 80	<0.01	<1.3 (-4)	0.12	1.5 (-3)
3, 4 Benzofluoranthene (31.5 μg/ℓ)*				
21 Mar 80	<0.01	<3.2 (-4)	0.05	1.6 (-3)
2 Apr 80	0.02	6.3 (-4)	<0.01	<3.2 (-4)
17 Apr 80	<0.01	<3.2 (-4)	0.17	5.4 (-3)
12 May 80	0.06	1.9 (-3)	<0.01	<3.2 (-4)
29 May 80	<0.01	<3.2 (-4)	<0.01	<3.2 (-4)
Benzo (k) fluoranthene (58 μg/ℓ)*				
27 Feb 80**			0.06	1.0 (-3)
21 Mar 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
2 Apr 80	0.01	1.7 (-4)	<0.01	<1.7 (-4)
17 Apr 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
12 May 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
29 May 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)

*Water Quality Criteria from Tables 11-3 and 11-5

**Analysis date

***a (-n) = a x 10^{-n}

TABLE 11-15. POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS IN SURFACE WATER BODIES (Continued)

	American Lake		Lake Sequalitchew	
Sample Date	Concentration (μg/ℓ)	Ambient Severity	Concentration (μg/ℓ)	Ambient Severity
Benzo (a) pyrene (20 μg/ℓ)*				
21 Mar 80	<0.01	<5.0 (-4)***	<0.01	<5.0 (-4)
2 Apr 80	<0.01	<5.0 (-4)	0.01	5.0 (-4)
17 Apr 80	<0.01	<5.0 (-4)	<0.01	<5.0 (-4)
12 May 80	<0.01	<5.0 (-4)	<0.01	<5.0 (-4)
29 May 80	<0.01	<5.0 (-4)	<0.01	<5.0 (-4)
Dibenz (a, h) anthracene (4 μg/ℓ)*				
27 Feb 80**			0.03	7.5 (-3)
21 Mar 80	0.02	5.0 (-3)	0.09	2.2 (-2)
2 Apr 80	<0.01	<2.5 (-3)	0.01	2.5 (-3)
17 Apr 80	0.03	7.5 (-3)	<0.01	<2.5 (-3)
12 May 80	0.03	7.5 (-3)	<0.01	<2.5 (-3)
29 May 80	<0.01	<2.5 (-3)	<0.01	<2.5 (-3)
Benzo (g, h, i) perylene (none)*				
21 Mar 80	0.04	none	<0.01	none
2 Apr 80	<0.01	none	<0.01	none
17 Apr 80	0.02	none	<0.01	none
12 May 80	0.03	none	<0.01	none
29 May 80	0.03	none	<0.01	none
Indeno (1, 2, 3 - cd) pyrene (58.5 μ/ℓ)*				
21 Mar 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)
2 Apr 80	0.02	3.4 (-4)	0.15	2.6 (-3)
17 Apr 80	0.10	1.7 (-3)	0.30	5.1 (-3)
12 May 80	0.04	6.8 (-4)	<0.01	<1.7 (-4)
29 May 80	<0.01	<1.7 (-4)	<0.01	<1.7 (-4)

*Water Quality Criteria from Tables 11-3 and 11-5
**Analysis date
***a (-n) = $a \times 10^{-n}$

11.6 Evaluation of Ground-Water Contamination

The SRC fluid spilled on 19 December contains numerous organic compounds and inorganic species, some of which are on the primary and secondary drinking water regulations and the list of priority pollutants. It is not known if the fluid or the soil contaminated by the fluid would be considered hazardous waste according to RCRA regulations. Multimedia Environmental Goals have been established for several of the polynuclear aromatic hydrocarbon compounds in the fluid.

Phenol, the most soluble and mobile component of the SRC fluid, is used as an indicator compound for ground-water contamination that has occurred. Based on the phenol analytical results, ground-water contamination has occurred in the vicinity of the tank farm. Much of the contamination is probably from the 19 December spill, but contamination from other sources is also indicated. Additional study is underway to evaluate ground-water contamination at the SRC plant. It is not possible at this time to distinguish the contamination plume from the 19 December spill from plumes from other sources at and around the tank farm.

The contamination problem indicated by the phenol is alleviated somewhat by the low solubility of other components of the SRC fluid. For example, the same wells that indicate ground-water contamination on the basis of phenol levels generally have safe levels of PNA compounds. Very few ground-water samples (from Wells 7 and 10) had PNA values with an Ambient Severity greater than one. With respect to inorganic species, there is some indication of elevated concentrations of manganese in the vicinity of the spill site, but it is doubtful that this is the results from the SRC fluid spill.

All water quality data obtained for this program show ground-water contamination only in the vicinity of the tank farm. Both routine and occasional intensive sampling at the east end of the SRC plant, in Sullivan Well and Sequalitchew Springs, and at American Lake, Sequalitchew Lake and other nearby surface-water bodies have shown little or no contamination outside the local area around the tank farm. The quality of ground water elsewhere in the SRC plant and northward toward Lake Sequalitchew from the plant is unknown.

12.0 HUMAN HEALTH AND ENVIRONMENTAL IMPLICATIONS

Ground-water contamination resulting from spills can have adverse effects on human health where a water supply for human consumption is affected and the impact is not detected. If contaminated ground water emerges at the surface, as at springs, or discharges to water bodies such as lakes or streams, then aquatic life can be adversely affected.

12.1 Potential Human Health Effects

As noted in Section 9.0, ground water is used extensively in the region around the SRC pilot plant for public and private water supply. The nearest documented public water supply sources are Sullivan Well and Sequalitchew Springs, which are used to supply water to Fort Lewis (Figure 8-3, #19/2-30B2 and 19/2-Q1s). Sequalitchew Springs is used continuously, and Sullivan Well is used to meet high water demand during the summer months. As noted in Section 11.0, it appears that the 19 December spill does not pose a water quality hazard to either of these water sources; the regional ground-water flow pattern indicates flow at the spill site to be away from rather than toward the well and the springs. The regional flow pattern is confirmed by detailed mapping of the water-table surface in the vicinity of the spill site, which indicates that flow is northward and northwestward and not toward the well and springs. Sequalitchew Springs and Sullivan Well probably derive their flow from underflow from American Lake to Sequalitchew Lake, as described in Section 8.0. American Lake does not have a surface outlet, but apparently discharges flow to Sequalitchew Springs and to ground water on the western side of the lake bottom. Sullivan Well was a spring analogous to Sequalitchew Springs prior to man-made alternation to its present configuration as a well. Spring flow can still be observed in a ditch leading from Sullivan Well to Sequalitchew Lake. Because they derive their flow from American Lake, Sullivan Well and Sequalitchew Springs are apparently not in danger of contamination from the 19 December spill event.

The community of DuPont apparently has two water wells (Figure 8-3, #19/1-35A1 and A2) about 1.5 miles southwest of the SRC pilot plant. These wells are not endangered by the 19 December spill event because they tap deeper aquifers (130 foot well depth) and because they are not downgradient from the spill site. Further protection is provided by the relatively long distance from the spill site. An industrial well owned by E. I. DuPont de Nemours (Figure 8-3, #19/1-26A1) is also not endangered by the spill for the same reasons.

Fort Lewis has four wells in the North Post area (Figure 8-3, #19/2-19F1, 19/2-19B1, 19/2-18Q1, and 19/2-18H1,2). Well 19/2-19F1 (Fort Lewis Well #3) is the closest to the spill site and thus is potentially the most likely to be adversely affected. Although these wells are downgradient from the spill site, they are not endangered by the spill because of two factors--the protective influence of Sequalitchew Lake and the depths of the wells. As described below, any ground-water contaminants from the spill will be intercepted by the lake, since ground water flowing northward through the SRC plant will pass through Sequalitchew Lake before continuing northward toward the wells on the North Post. The lake thus acts as a protective buffer for these wells; only if the lake were to become extremely contaminated would there be concern for the wells. The fact that the wells are quite deep (220 feet or more) indicates that they tap deeper aquifers than the aquifer affected by the spill, which further alleviates concern about the impact at the spill.

It thus appears that the 19 December spill does not pose a hazard to any existing water supply source. It is unlikely however, that any new water supply wells for human consumption would be advisable between the spill site and Sequalitchew Lake for the foreseeable future. The Remedial Measures Plan recommended in Section 2.0 provides that remedial measures cease when the phenol concentrations in all water quality monitor wells falls below one-tenth of the proposed EPA water quality criterion of 0.6 mg/ℓ, the 24-hour average allowed for protection of freshwater aquatic life.

12.2 Potential Environmental Effects

Aside from the contamination of ground water as an environmental impact in and of itself, the largest environmental concern is for the secondary impact on Sequalitchew Lake. The berm of the tank farm prevented any direct contamination of surface water by the spilled fluid.

Sequalitchew Lake has been used for raising Coho salmon to a large enough size for release to Puget Sound. About 2.9 million salmon were released in May 1980, and the size of the population is expected to increase in coming years. The protection of the lake assumes greater importance in this context, inasmuch as many of the salmon released are destined ultimately for human consumption.

As noted in earlier sections, the ground-water flow is from the spill site toward Sequalitchew Lake. However, analysis of lake water samples to date have indicated no rise in phenol concentrations, as shown in Section 11.0. The Remedial Measures

Plan of Section 2.0 has as a principal aim the prevention of the flow of phenol-contaminated ground water into the lake. Once the pump wells are commissioned, the flow of contaminated water toward the lake will be reversed. Pumpage will be continued until phenol concentration falls to within acceptable limits at all monitor wells.

As noted in Section 3.0, the Radian analysis of the SRC fluid spilled indicates a phenol content of about 4,500 mg/kg and a total phenolic compound content of about 110,000 mg/kg (determined after extraction but before GC-MS analysis). A "worst-case" scenario of impacts on Sequalitchew Lake can be constructed by assuming that all of the phenols or phenolic compounds flow into the lake instantaneously. Calculations and assumptions for this scenario are shown in Figure 12-1. This analysis shows that if all of the phenol spilled reached the lake, the expected rise in phenol concentrations would be about 50 $\mu g/\ell$. The expected rise in total phenolic compounds would be about 1,240 $\mu g/\ell$.

The foregoing analysis does not, of course, take into account the dilution of phenols in ground water prior to their arrival in the lake or the flushing of the lake by inflow from Sequalitchew Springs and outflow to Sequalitchew Creek during the long timeframe (1 to 5 years) of the ingress of phenol-contaminated ground water. These factors together could possibly be sufficient to preserve the phenol and total phenolic compound concentrations below a threshold value of 600 $\mu g/\ell$, even without implementation of the Remedial Measures Plan.

ASSUMPTIONS:

Volume of Spilled Materials: 2,300 gal
Phenol Content: 4,500 mg/kg
Total Phenol Compound Content: 110,000 mg/kg
Phenol Density: 1.0

VOLUME OF SEQUALITCHEW LAKE:

Area: 94 acres = 4.1×10^6 ft^2
Depth (Conservative): 10 ft
Lake Volume: 3.06×10^8 gal
(1.16×10^9 ℓ)

VOLUME OF PHENOL SPILLED:

Safety Factor: 1.5
Volume of Phenol (2,300)(0.0045)(1.5): 15.5 gal
Weight of Phenol (15.5)(8.34 lb/gal): 129 lb (58.7 kg)

Volume of Total Phenolic Compounds (2,300)(0.11)(1.5): 380 gal
Weight of Total Phenolic Compounds (380)(8.34 lb/gal): 3,165 lbs (1,436 kg)

CONCENTRATION OF PHENOL:

$$\frac{58.7\ \text{kg}}{1.16 \times 10^9\ \ell} \times 10^9\ \mu\text{g/kg} \doteq 50\ \mu\text{g}/\ell$$

CONCENTRATION OF TOTAL PHENOLIC COMPOUNDS:

$$\frac{1436\ \text{kg}}{1.16 \times 10^9\ \ell} \times 10^9\ \mu\text{g/kg} \doteq 1240\ \mu\text{g}/\ell$$

Figure 12-1. Determination of Approximate "Worst-Case" Concentration of Phenol and Total Phenolic Compounds in Sequalitchew Lake.

13.0 REMEDIAL MEASURES PLAN DEVELOPMENT

When a contaminant is spilled to the land, steps should be taken to minimize or prevent any adverse environmental or human health effects. These remedial measures consist of removal, containment (isolation), in-situ treatment, control of contaminant or ground-water movement, or a combination of these measures. When a liquid contaminant is spilled at the land surface, it will move downward to ground water by gravity and by infiltrating precipitation. Remedial measures may be applied in the vadose zone above the water table and in the underlying aquifer. In the vadose zone, contaminated soil may be physically removed for off-site treatment or disposal, or the contaminating fluid may be immobilized or treated in place (chemical immobilization or biological degradation). In the aquifer, the movement of contaminants may be controlled by ground-water control measures (passive barriers), plume management measures (pumping or injecting water to control the direction and rate of plume migration) or in-situ treatment.

The hydrogeologic setting of the SRC plant is such that the spill location is somewhat susceptible to contamination of ground-water by contaminants at the surface. The factors which contribute to the higher-than-normal sensitivity include: 1) high porosity and permeability of the unsaturated zone, particularly in the gravel fill; 2) shallow water table; 3) high ground-water velocities; and 4) relatively low content of clay, which would serve to attenuate any contamination plume generated. This section contains interpretations and discussion of the data presented in earlier sections and provides the basis for the recommended Remedial Measures Plan of Section 2.0.

Remedial measures for the SRC product fluid spill were developed by considering available measures in the context of those directed by regulatory authorities as well as those undertaken during the investigation of the spill. The principal elements of the Remedial Measures Plan to be presented are as follows:

- Excavate soil contaminated by the spill. Backfill with clean material. South of tank 010, the depth of soil to be removed is 11 feet; north of tank 010, at the original spill site, soil is to be removed to a depth of 20 feet.
- Seal the land surface at the spill site, along with the whole tank farm floor, to prevent further infiltration of precipitation.
- Pump Well 20 to control the ground-water transport of contaminants away from the spill site.
- Install and place in service a new well 500 feet downgradient of the spill to control such contaminants as may have migrated beyond the zone of influence of Well 20.

- Relocate one of the surface water sampling points in Lake Sequalitchew to coincide with the most probable exit point of the plume.

- Institute a long-term monitoring program consisting of monthly sampling of Wells 20, 21, 22, 24, and the new pump well.

The following sections present a survey of available remedial measures and a discussion of each element in the recommended plan.

13.1 Remedial Measures Available

As noted, remedial measures can be applied in the vadose zone and the saturated zone below.

13.1.1 Measures To Be Applied in the Vadose Zone

Gravity drainage of the SRC product fluid was essentially complete a few days after the spill event. Subsequent movement is with infiltrating precipitation, either by immiscible displacement or by dissolution and solute transport. In the coarse-grained substrate at the spill site, solute transport dominates. The insoluble fraction of the SRC fluid will adhere to the soil and remain in place. Further downward migration of the contaminants can then be stopped by preventing infiltration at the land surface. An impermeable surface seal with runoff collection would accomplish this. To be effective, the seal should extend substantially beyond the spill area to minimize lateral movement of infiltrating precipitation. For long-term effectiveness, the integrity of the surface seal must be maintained through continued inspection and maintenance.

Alternatively, the contaminated soil may be removed for off-site treatment or disposal. Sufficient material should be removed to insure that the remaining contaminant poses no health or environmental hazard. Partial excavation may be combined with a surface seal to provide an effective long-term remedial measure.

13.1.2 Measures To Be Applied In The Aquifer

Several types of remedial measures have been successfully applied in mitigation of ground-water pollution plumes similar to the one produced by the SRC process fluid spill. These measures may be divided into ground-water control measures, plume management measures, and in-situ treatment measures.

13.1.2.1 Ground-Water Control Measures

Ground-water control consists of a passive physical barrier constructed so that ground-water flow is reduced or diverted away from a particular site. This technique, under ideal conditions, has the effect of hydraulically isolating the site from the surrounding ground-water flow system. Used in combination with top-sealing barriers to prevent downward percolation of surface water over the site, ground-water flow barriers may prevent additional input of pollutants into the ground water. Several types of physical barriers have been successfully used for ground-water control, including slurry-trench cutoff walls, grout curtains, and sheet piling cutoff walls.

Slurry-Trench Cutoff Walls

The slurry-trench cutoff wall is constructed by digging a trench, filling the trench with a bentonite slurry as excavation work proceeds, and backfilling the completed trench with the excavated material. This method has the advantage of providing a low permeability barrier with relatively simple construction techniques. In addition, ground-water levels away from the site are not affected by this maintenance-free barrier.

However, in soils with high permeability this method may be ineffective due to excessive migration of the slurry during construction. Also, rocks or boulders may require over-excavation of the trench. For these reasons, a bentonite slurry-trench cutoff wall would not be an effective remedial measure for containment of ground waters in the highly permeable glacial outwash aquifer underlying the P&M plant.

Grout Curtain

Grout curtains are constructed by injecting cement or grout solutions under pressure into the ground to form an impermeable barrier. The type of grout must be carefully selected on the basis of soil conditions at the site. Due to the highly variable soil conditions at the P&M plant, with a large percentage of coarse-grained material, emplacement of a grout curtain cutoff wall would require a detailed soil exploration program. Also, other corrective measures are generally applied with grout curtains to insure successful control of ground-water flow.

Sheet Piling Cutoff Walls

Sheet piling walls are constructed by driving lengths of interlocking steel sheets into the ground. Because the sheet piling is generally not completely water-tight and may be damaged during driving through rocky soils, this method would probably not be successful at the P&M site.

13.1.2.2 Plume Management Measures

Plume management techniques are designed to mitigate adverse effects of pollution by manipulating the flow of ground water at the site. These techniques generally involve either the withdrawal of ground water to form a cone of depression that entraps and partially removes a contaminant plume or the injection of water to create an active barrier to control the direction of plume migration.

Ground-Water Withdrawal

Two kinds of pumping systems are possible for pollution plume management. Well point systems are used to lower the water table a few feet and/or to collect affected ground water. Because water is pumped from a series of well points by suction left from a central pump, this method does not produce a large radius of influence or large drawdowns. Deep well systems involve only a few deep wells, each with a pump, that are capable of producing significant drawdowns and have relatively broad cones of depression. These methods have the advantage of actually removing polluted water for treatment with a relatively simple installation of materials. However, because this type of remedial action involves an active process, continued maintenance and supervision is required. Site conditions at the P&M plant are favorable for this type of remedial measure.

Ground-Water Injection

Injection of water into the ground down the hydraulic gradient from a contaminated zone provides an active barrier to divert the pollution plume. Creation of a ground-water mound may be by either shallow or deep well injection. An important consideration in the design of an injection well system is the prediction of an alternative direction of travel for the plume. Both injection and pumping wells can be coordinated to effectively manipulate the flow direction and reduce the size of the pollution plume.

13.1.2.3 In-Situ Treatment Measures

Contaminants in ground water may be neutralized in place by injecting chemicals to destroy or tie up a specific pollutant. Generally, any one chemical will only react with one or two types of pollutants. This process is potentially expensive and risks accidental pollution of an aquifer due to migration of the injected chemicals. In-situ chemical immobilization is currently a developing technique and most ground-water pollution problems are more easily managed by one of the previously described techniques.

A potentially effective variation on this method is injection of air and nutrients to stimulate biological activity and hasten the breakdown of organic pollutants. Such measures have been successfully employed to clean up gasoline spilled from a pipeline rupture.

13.2 Excavation of Contaminated Soil and Sealing of the Spill Site

After the spill, the SRC product fluid seeped into the underlying earth materials. The majority of the immiscible fraction of the fluid is held in the unsaturated zone beneath the spill site by capillary forces. During the coring of the spill site, the upper part of the vadose zone contained visual "oil" stain or free oil, but the lower part did not. There was no observed lens of immiscible fluid at the water table. Had there been gravity flow throughout the vadose zone, staining would have been observed, and an immiscible lens would have formed where the product encountered the water table. The fraction which is soluble in water, notably phenols, has been partially washed downward into the ground water below by infiltrating rainfall. A significant portion remains within the unsaturated zone, however. Shortly after the spill occurred, the floor of the tank farm at the spill was covered with an impermeable plastic sheet to prevent further infiltration and washdown of the miscible fraction.

The Washington Department of Ecology (WDOE) has ordered that the soil contaminated by the spill be removed. P&M Coal and DOE verbally agreed on 24 March to excavate soil at the spill site as a remedial measure, and P&M confirmed this intention (contingent on DOE approval) on 3 April in the response to the Notice of Violation. Radian proposed a methodology for defining the body of contaminated soil to be excavated, and the excavation of contaminated soil is a key part of the Remedial Measures Plan presented in this report.

The spill site has been cored, and phenol concentrations were determined in the soil samples recovered. The fraction of phenol present which would be leached if the soil were left in place was determined by performing the RCRA Extraction Procedure. A conservative ten-fold dilution in ground water was assumed. The recommended threshold for excavation is the depth at which the phenol concentration is less than 133 μg/g. Recommended depths of excavation range from 11 feet (south of tank 010) to 20 feet (north of tank 010, at the original site of the spill, Figure 13-1). A detailed presentation of the methodology for determining the contaminated soil volume is presented in Appendix IV.

The depth of excavation is defined on the basis of concentrations of the indicator parameter, phenol. To insure the effectiveness of excavating a volume defined by phenol concentrations, the first soil sample from each core below the excavation interface has been submitted for a 96-hour static toxicity bioassay. This bioassay measures the aggregate toxicity of the contaminated soil. Since this WDOE standard test shows no toxicity, the excavation depth defined by the Radian methodology is considered adequate. The bioassay procedure was undertaken in lieu of the EP and priority pollutant analysis proposed in Appendix IV.

The recommended area of the excavation (1,770 square feet) was determined by extending the edge of the observed spill surface pool by three to five feet. However, because of the difficulty of driving sheet piling in an irregular line, P&M has elected to excavate a rectangular area of 36 feet (east-west) by 50 feet (north-south). This area encompasses all of the spill site.

Adequate disposition must be made of the material removed. It may be conveyed to an approved hazardous waste disposal facility or treated to remove the SRC product fluid. If treatment is the method of choice, then the method of treatment and demonstration of its adequacy must be approved by the Washington Department of Ecology.

The excavation is to be backfilled with clean material and the site restored to its current use. The land surface at

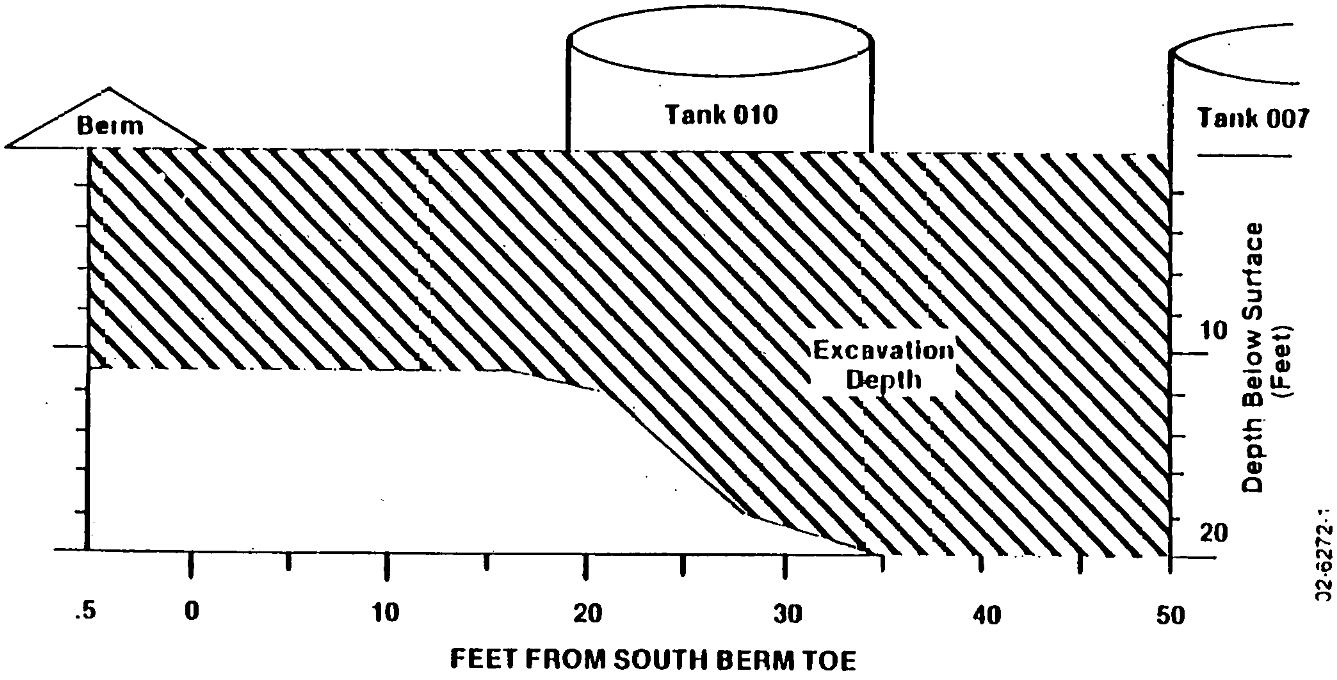

Figure 13-1. Cross Sectional View of Recommended Excavation Depth.

the spill site, along with the whole tank form floor, is to be sealed to prevent future infiltration of precipitation. Planning for the excavation and awarding of contracts for the work are being carried forward by P & M.

13.3 Ground-Water Flow Control Wells

During the course of the field investigations, an aquifer test well (Well 20) was drilled downgradient of the spill site. This well was also to serve as an interim remedial measure to intercept the flow of such contaminants as might have already been entrained in the ground-water flow if the need to do so were indicated. This need, which was based on a judgement of the possibility of imminent hazard to human health or the environment, did not arise during the conduct of the program.

13.3.1 Well 20 As a Plume Management Measure

Well 20 should be placed in service as a part of this Remedial Measures Plan. The ground-water flow system will be distorted by the cone of depression of the pumping well, and flows in the vicinity of the spill will be diverted to the well. All flow beneath the spill site will go to the well. Additionally, the normal northward flow of ground water will be reversed, and flow from as far downgradient as the vicinity of Well 3 will go to Well 20. The projected water table contours after 30 days of pumping are shown in Figure 13-2. These contours were drawn by superimposing a cone of depression on the water table contour map of May 1, 1980. The pre-pumping water table is reflective of a dynamic equilibrium between the regional northward ground-water flow (between Hamer Marsh and Lake Sequalitchew) and local recharge. The effect of pumping Well 20 is superimposed on this dynamic system, and its cone of depression will also vary over time. During extended periods of low rainfall, the cone will

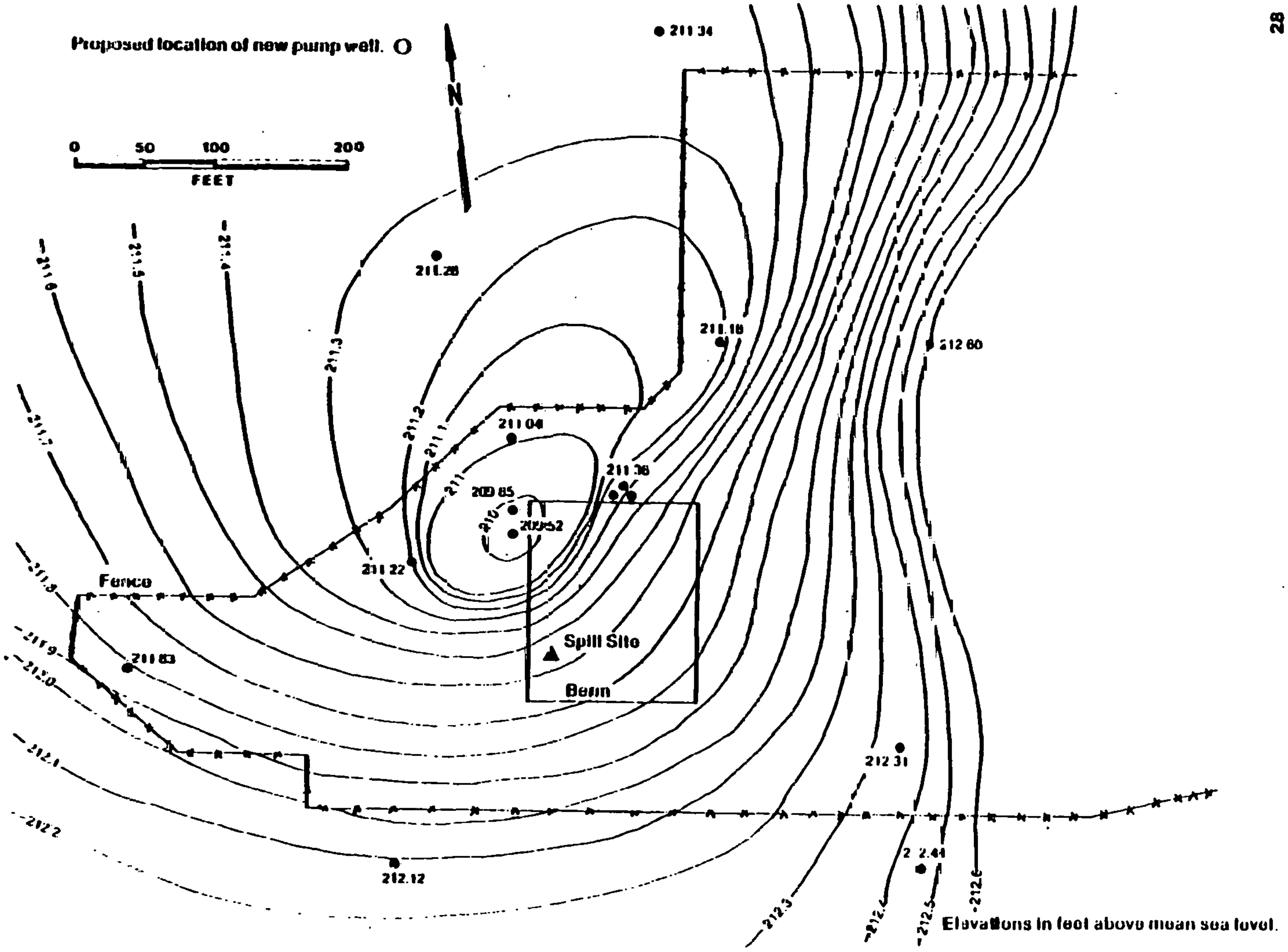

Figure 13-2. Ground-Water Contours With Pumping of Well 20.

grow slowly, eventually intersecting the shore of Lake Sequalitchew. Rainfall and subsequent recharge events will limit both the size and rate of growth of the cone. The configuration shown on Figure 13-2 may be taken as a useful approximation of typical conditions.

13.3.2 Additional Well for Plume Management

Such contaminants as may have already spread north (downgradient) of Well 3 will not normally be contained within the cone of depression of Well 20, although their rate of flow will be reduced to nearly zero. Therefore, an additional pump well will be required between the spill site and Lake Sequalitchew. This well will control the spread of contaminants that are outside the zone of influence of Well 20.

The new pump well will be emplaced in the same manner as was Well 20. The well will have an 8-inch diameter, and the bottom of the hole will be at the top of the till layer. However, the well is to have a PVC casing to allow it to be part of the long-term monitoring program discussed below. An appropriate submersible pump will be procured after the well is drilled, cased, developed, and pump-tested.

The proposed location of the new pump well is shown on Figure 13-2. It is along the vector of most probable contaminent travel, at a radial distance of 500 to 600 feet from the spill site, which is approximately the maximum extent of the spread of contaminants from the spill. Inasmuch as the proposed location is in a heavily wooded area, the well will be drilled at a location of convenience determined by onsite inspection by a Radian hydrogeologist. The site selection will have to be approved by Fort Lewis Facilities Engineer.

The combined effect of pumping Well 20 and the new pump well will be creation of an elongate trough in the water table. The exact size and shape depends on the aquifer performance characteristics in the vicinity of the new well. However, the trough should extend from the spill site to the south shore of Lake Sequalitchew.

The primary effect of these plume control measures is to stop the further spread of contaminants in the ground-water system. They will also remove a certain proportion of the contaminants from the system, reducing the level of aquifer contamination caused by the spill.

13.3.3 Options for Disposal of Pump Well Discharges

The discharge from Well 20 is 120 gallons per minute (gpm). The discharge from the proposed new pump well is unknown, but can be expected to be of a similar magnitude. These discharges will contain phenol at a maximum level of a few mg/ℓ. Adequate provision must be made for disposal of this water. Available options include:

- direct use as industrial process water.
- discharge to sanitary sewer,
- discharge to industrial waste treatment plant, and
- separate treatment and discharge to Hamer Marsh.

The long-term option recommended is direct use as industrial process water. This option reduces fresh water use and avoids costs of separate treatment and/or disposal. However, the SRC pilot plant currently is served with a single water distribution system, with water being taken for industrial and potable use throughout the system. The system would have to be modified to accommodate non-potable process water. The P&M staff is currently evaluating this option. Any portion of the pump well discharges which may be put to beneficial use in the plant should be so used.

The second long-term option recommendation is discharge to the sanitary sewer system serving the North Fort Lewis sewage treatment plant (STP). This plant, a 7.5 MGD high-rate trickling filter facility, can adequately accept and treat the proposed flows with the phenol concentrations expected. However, concerns have been raised over possible biocidal constituents (other than phenol) in the well discharge and over heavy metals in the discharge accumulating in the STP sludge. Also, at times (typically during January and February), the normal flow to the STP may approach its rated capacity of 7.5 MGD. The Fort Lewis Facilities Engineer may ask that the discharge be temporarily directed out of the sanitary sewer. At such times an alternate means of treatment and disposal must be available.

The short-term option recommended is treatment in existing activated charcoal filters followed by direct discharge to Hamer Marsh. This option provides a means of bringing the wells into service as rapidly as possible and continuing operation while difficulties with the long-term options are resolved. The water produced by the well/filter system may be tested for biocidal properites and heavy metal concentrations. The direct use option may be further explored. The filters may also be maintained as a standby system for periods when direct use or discharge to the sanitary sewer is infeasible.

Discharge to the industrial waste treatment plant is judged infeasible, inasmuch as it is often operating at capacity. Any further discharge would overload the system and possibly lead to permit violations.

13.4 Pump Well for Protection of Sullivan Well

During the time that the effects of the spill were being investigated, the Washington Department of Ecology (WDOE) began reporting detectable quantities of phenol in Sullivan Well, a major water supply source for Fort Lewis. At the same time, a two-inch diameter piezometer (Well 11) was installed at the east end of the plant property, between the SRC pilot plant operation and Sullivan Well. Phenol analyses of water bailed from Well 11 showed erratic results. Occasionally, concentrations as high as 0.04 mg/ℓ were observed. These observations, coupled with uncertainty over the configuration of the ground-water flow system between the SRC plant and Sullivan Well, led the Fort Lewis Facilities Engineer to suspect that plant activities and/or the SRC product spill were contaminating the well.

To guard against this possibility, and to obtain a more representative ground-water sample, a production well (Well 24) was drilled at the east end of the plant property (Figure 6-1), directly between the plant operations area and Sullivan Well. Pumping this well would create a cone of depression which would act as a barrier to migration of contaminants from the plant to Sullivan Well.

Samples from Well 24 revealed no evidence of contamination, so the well has not been placed in service as a remedial measure. However, the well remains in place, and could be brought on line, if necessary. Well 24 thus provides an added measure of protection for Sullivan Well.

13.5 Long-Term Ground-Water Monitoring Plan

The remedial measures described above, combined with the natural processes of biological degradation and contaminant attenuation, are expected to control and reduce the phenol concentrations in the ground water. Eventually, the concentrations should be lowered to environmentally acceptable levels. Radian recommends that a long-term monitoring program be undertaken, both to document the effectiveness of the remedial measures and to determine when the ground-water flow control wells can be taken out of service.

One additional ground-water sampling well will be required for a complete program for the spill event. This well is to be located approximately 100 feet south of the shore of Lake Sequalitchew and north of the proposed new pump well, the exact location to be selected by a Radian hydrogeologist. Its construction will be similar to that of Well 23, i.e., six-inch casing, screened just below the water table. The purpose of this well is to monitor ground-water quality immediately adjacent to Lake Sequalitchew, which is the nearest surface water body which might be impacted by the spill event. The elevation of the water table at this site will be a measure of the effectiveness of the ground-water flow control wells. That is, if the water level in the new monitor well is lower than the lake level, then no ground water is moving northward into the lake, but rather, the pumping is inducing flow from the lake into the ground-water system.

The long-term monitoring program will consist of monthly samples collected from the wells shown below:

Well 20	Well 24
Well 21	New pump well
Well 22	

The samples are to be analyzed for phenol, the most appropriate indicator parameter. In addition, quarterly samples from the new pump well should be analyzed for the inorganic constituents shown in Table 13-1. Since this well will have a PVC casing, samples for trace metals analysis should be drawn from it, rather than from wells with galvanized iron or steel casing.

TABLE 13-1. INORGANIC CONSTITUENTS RECOMMENDED FOR ANALYSIS

As	Cu	Zn
Pb	Fe	TDS
Se	Hg	NH_3-N
Ag	K	NO_3-N
Al	Mg	Cl
Ba	Mn	SO_4
Be	Na	S
Ca	Ni	F
Cd	Sb	
Cr	V	

Results of phenol analyses may be used to signal the end of the need for active water table control measures. At such time as the phenol concentration in all monitor wells drops below 0.060 mg/ℓ, and remains below that level for 3 months, there would be no further need for pumping to control ground-water flow. The level of 0.060 mg/ℓ phenol represents one tenth the 1979 proposed water quality criteria for protection of aquatic life (see Section 11). Ground-water concentrations at or below this level should pose no environmental hazard.

The long-term monitoring program should be made a permanent part of the plant operations, with sampling and analysis carried out at a reduced frequency (quarterly or semi-annually for phenol and annually for inorganic species).

13.6 Integration with Other Sources at the SRC Plant

The Remedial Measures Plan developed herein must be integrated with the investigation of other potential contaminant sources at the SRC plant. Any remedial measures to be adopted for other contamination must be consonant with those measures adopted for the spill. The long-term monitoring program will also be used to provide data for assessing other contaminant sources.

14.0 SUMMARY AND CONCLUSIONS

Although ground-water contamination apparently has occurred as a result of the 19 December spill, the contamination plume is localized to the vicinity of the SRC plant and Lake Sequalitchew. A contamination plume apparently is presently moving toward Lake Sequalitchew, but the two pump wells included in the Remedial Measures Plan will arrest this movement. These wells will be pumped until phenol concentrations in the groundwater fall to acceptable levels. The source of contamination at the spill is being cut off by excavation of the contaminated soil and sealing of the floor of the tank farm.

Even without the pump wells, it is unlikely that Lake Sequalitchew would be significantly adversely affected by the spill. The contaminants are diluted by dispersion in the upper aquifer. In addition, the flushing of the lake by ground-water inflow and outflow, by inflow from Sequalitchew Springs, and by outflow through Sequalitchew Creek would tend to prevent buildup of significant phenol concentrations.

No public water supplies are appreciably endangered by the 19 December spill. Most public wells are upgradient from the spill and are thus in no danger. The downgradient wells are protected by the fact that they tap deeper aquifers than the upper aquifer at the SRC plant site and by the buffering effect of Lake Sequalitchew. The upper aquifer in the vicinity of the spill site probably should not be considered for use as a public or private water supply for the foreseeable future.

A long-term ground-water monitoring plan is being implemented to ensure early discovery of any unanticipated impacts of the spill. If further water quality problems are disclosed, additional remedial measures will be undertaken as necessary.

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APPENDIX I
ANALYSES OF SRC FLUID

APPENDIX I

Part 1

ANALYSIS OF SRC FLUID BY RADIAN

DCN 80-214-029-02

Technical Memorandum 214-029-02

ANALYSIS OF SRC-II COAL FUEL OIL MIDDLE DISTILLATE

Prepared by:
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Submitted to:
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29 April 1980

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1.0 INTRODUCTION

The Pittsburg and Midway Coal Company has commissioned Radian to perform a gas chromatography - mass spectrometry (GC-MS) analysis of Solvent Refined Coal product fluid. The SRC-II fluid analyzed is of the same type as was spilled on 19 December 1979 at the SRC pilot plant, Fort Lewis, Washington. The fluid analyzed is described as follows:

> Fuel Oil Blend, 2.9:1 Middle Distillate: Heavy Distillate, Lot 4/2 - 5/79 from Tank 92011, Lab retain.

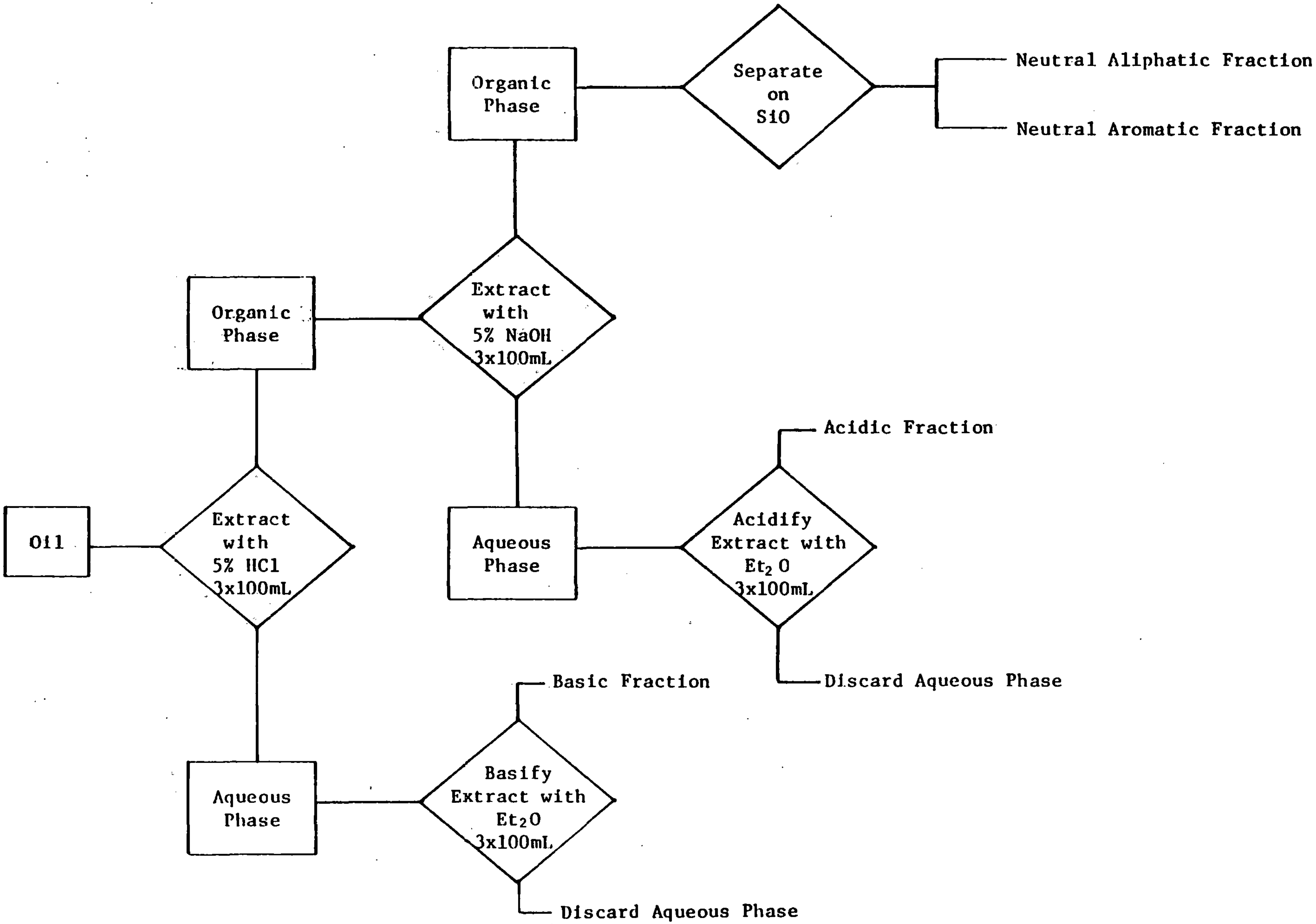
This technical memorandum presents the results of the GC-MS analysis of the SRC-II fluid.

2.0 SAMPLE PREPARATION

The SRC oil was separated into neutral aliphatic, neutral aromatic, acidic and basic fractions according to the scheme outlined in Figure 1 and described below.

The scheme utilizes a series of liquid-liquid partitions and pH adjustments to separate the oil into neutral, acidic, and basic fractions. The neutral fraction is then further separated by column chromatography on silica gel.

Figure 1. Flow Diagram for Separation of SRC-II Fluid



3.0 EXPERIMENTAL APPROACH

100 g of oil was successively extracted with three 100-mL portions of five percent hydrochloric acid. The aqueous acidic phase containing the basic species was basified with sodium hydroxide and extracted with three 100-mL portions of diethyl ether. The organic layer was then extracted with three 100-mL portions of five percent sodium hydroxide. The combined aqueous phase was acidified and extracted with three 100-mL portions of diethyl ether to isolate the acidic species.

A 1-mL aliquot of the neutral fraction was loaded onto a 1 cm ID chromatography column containing 50 g of fully activated E. Merck Grade 60 silica gel (70-230 mesh). The aliphatic and aromatic fractions were collected by elution with hexane and 1:1 hexane:methylene chloride, respectively. Five void volumes (approximately 300 mL of each solvent was used for elution.

All fractions were concentrated by Kuderna-Danish evaporation to a volume suitable for analysis.

4.0 GC-MS ANALYSES

Each of the four fractions generated in the sample workup of the SRC-II middle distillate fraction were analyzed using gas chromatography-mass spectrometry (GC-MS) techniques. The neutral and basic fractions were each analyzed on a 6-foot SP-2250 DB analytical column, while the acidic phenol fraction was analyzed on a 6-foot SP-1240 DA analytical column.

The identifications of sample components were all made based on manual interpretation of mass spectral data.

Each sample fraction was spiked prior to analysis with an internal standard (d_{10}-anthracene) for quantification of sample components. Quantification was performed by determination of areas under selected ion current plots of characteristic ions for each identified sample component. These area measurements were normalized to the m/e 188 ion current sample plot for d_{10}-anthracene. The concentration of each identified sample component was determined using the following equation.

$$C_c = \frac{A_c \times C_{IS}}{A_{IS} \times RF_c}$$

Where:

C_c is component concentration

A_c is the area of the characteristic ion for compound (c)

A_{IS} is area of m/e 188 for d_{10}-anthracene

C_{IS} is concentration of d_{10}-anthracene in sample

RF_c is the relative response factor for compound (c).

Response factors for this study were either known from prior work or were estimated based on knowledge of similar compounds.

The concentrated neutral and basic extracts were analyzed by GC-MS on a 3% SP-2250 DB glass packed column. After holding the column temperature initially at 50°C for 4 minutes, the column was then programmed to 270°C at 8°C/minute according the EPA Priority Pollutants Protocol. The basic and neutral compounds eluting from the SP 2250 DB column were detected using a computer-controlled 5895 Hewlett-Packard quadrapole mass spectrometer operated in the electron impact mode at 70 electron volts.

The phenolic fraction was chromatographed on a 6-foot glass column packed with 1% 1240 DA on 80/100 mesh Supelcoport. The GC oven was programmed from 70°C to 200°C at 10°C/minute. The phenols were detected using a Hewlett-Packard 5985 computer-controlled mass spectrometer operated in the electron impact mode at 70 electron volts.

5.0 RESULTS

The results of the GC-MS analysis of the SRC-II fluid are presented on the following pages. The analytical results are presented for the four fractions:

- aromatic hydrocarbons,
- aliphatic hydrocarbons,
- phenolic compounds, and
- basic compounds.

The total organics identified represent 60 percent of the total sample weight. A large portion of the compounds was identified only as alkyl substitute aromatics of various types. Therefore, these quantitative results are approximate and are based on estimated response factors for the various analytes. Table 1 shows a comparison of GC-MS weight percent data for the various fractions with the weight percent data obtained after separation but before GC-MS analysis.

TABLE 1. SUMMARY OF SAMPLE RESULTS OF SRC-II

Fraction Type	% Found By GC-MS	% Found After Extraction
Aromatic and aliphatic compounds	52	82
Phenolic compounds	5.4	11
Basic compounds	2.3	6.9

The differences observed in the acid and basic fraction are probably due in part to neutral carryover into these fractions.

Major differences in each fraction can, however, also, be attributed to the estimated response factors used for many of the analytes. Finally, a portion (probably small) of the difference can be attributed to unresolved organics that were not identified by GC-MS analysis.

ORGANIC ANALYSIS OF SRC II COAL FUEL OIL MIDDLE DISTILLATE BY GC-MS

Compound	Concentration (mg/100 g Sample)
Aromatic Hydrocarbons	
C_3-Alkyl benzene	480
Indane	150
C_3-Alkyl benzene	1100
Methyl indane	130
C_5-Alkyl benzene (Isomer 1)	300
Methyl indane/tetralin	750
C_5-Alkyl benzene (Isomer 2)	1780
C_6-Alkyl benzene	170
C_2-Alkyl indane/tetralin (Isomer 1)	300
C_2-Alkyl indane/tetralin (Isomer 2)	600
Naphthalene	3850
C_2-Alkyl indane/tetralin (Isomer 3)	1100
C_2-Alkyl indane/tetralin (Isomer 4)	300
C_7-Alkyl benzene	170
Methyl naphthalene	11000
C_8-Alkyl benzene	100
C_9-Alkyl benzene	64
C_3-Alkyl indane/tetralin (Isomer 1)	34
C_3-Alkyl indane/tetralin (Isomer 2)	76
C_3-Alkyl indane/tetralin (Isomer 3)	48
C_3-Alkyl indane/tetralin (Isomer 4)	26
C_3-Alkyl indane/tetralin (Isomer 5)	94
C_2-Alkyl naphthalene	11000
C_4-Alkyl indane/tetralin	1100
Biphenyl	1200
Biphenyl ether	1400
C_3-Alkyl naphthalene	2800
Indole	100
Methylbiphenyl	346
Acenaphthene	100
Methylindole (Isomer 1)	140

Continued

Compound	Concentration (mg/100 g Sample)
Dibenzofuran	320
Methylindole (Isomer 2)	240
C_4-Alkyl naphthalene	840
C_2-Alkyl biphenyl	110
Methyl acenaphthene (Isomer 1)	900
Fluorene	430
9-Methylfluorene (Isomer 1)	90
Methylacenaphthene (Isomer 2)	300
Methyldibenzofuran (Isomer 1)	80
Methyldibenzofuran (Isomer 2)	210
Methylfluorene (Isomer 2)	300
Methyldibenzofuran (Isomer 3)	160
Methylfluorene (Isomer 3)	300
Methyldibenzofuran (Isomer 3)	90
Dibenzothiophene	120
Phenanthrene/Anthracene	1600
Methyldibenzothiophene (Isomer 1)	50
Methyldibenzothiophene (Isomer 2)	90
Methylphenanthrene	1000
9H-Cylcopenta[d,e,f]phenanthrene	60
2-Phenylnaphthalene	100
Carbazole	250
C_2-Alkyl phenanthrene	550
C_3-Alkyl phenanthrene (Isomer 1)	50
Methylcarbazole (Isomer 1)	40
C_3-Alkyl phenanthrene (Isomer 2)	110
Methylcarbazole (Isomer 2)	140
Methylphenylnaphthalene (Isomer 1)	110
Fluoranthene	150
Methylphenylnaphthalene (Isomer 2)	40
1-Phenylnaphthalene	90
Pyrene	690
Benzofluorene or Methyl fluoranthene/pyrene	34
Benzofluorene or Methyl fluoranthene/pyrene	34

Continued

Compound	Concentration (mg/100 g Sample)
Methylphenylnaphthalene (Isomer 3)	90
Benzofluorene or Methyl fluoranthene/pyrene	240
Benzofluorene or Methyl fluoranthene/pyrene	70
C_2-Alkyl fluoranthene/pyrene (Isomer 1)	90
C_2-Alkyl fluoranthene/pyrene (Isomer 2)	90
Chyrsene/Benz(a)anthracene	170
Methyl chrysene/Benzanthracene	90
C_2-Alkyl chrysene/Benzanthracene	100
Benzo(b & k)fluoranthenes	30
Benzo(a & e)pyrene	27
Methylbenzopyrene	3.8
Aliphatic Hydrocarbons	
n-Tridecane	120
n-Tetradecane	150
n-Pentadecane	180
n-Hexadecane	390
n-Heptadecane	110
n-Octadecane	66
n-Nonadecane	47
n-Eicosane	39
n-Uncosane	32
n-Docosane	24
n-Tricosane	19
n-Tetracosane	14
n-Pentacosane	11
n-Hexacosane	9.4

Continued

Compound	Concentration (mg/100 g Sample)
Phenolic Compounds	
Dimethylphenol	33
Phenol	450
o-Cresol	620
o-Ethylphenol	37
m/p-Cresols	95
Dimethylphenol	420
C_3-Alkyl phenol (Isomer 1)	48
2,3-Xylenol and m/p-Ethylphenol	960
C_3-Alkyl phenol (Isomer 2)	110
3,5-Xylenol	370
C_3-Alkyl phenol (Isomer 3)	170
C_4-Alkyl phenol (Isomer 1)	13
3,4-Xylenol	91
C_3-Alkyl phenol (Isomer 4)	730
C_4-Alkyl phenol (Isomer 2)	8.8
C_3-Alkyl phenol (Isomer 5)	37
C_4-Alkyl phenol (Isomer 3)	22
C_4-Alkyl phenol (Isomer 4)	130
Methyl indanol (Isomer 1)	24
4-Indanol	400
Methyl indanol (Isomer 2)	55
C_4-Alkyl phenol (Isomer 5)	26
Methyl indanol (Isomer 3)	70
5-Indanol	40
Methyl indanol (Isomer 4)	240
Methyl indanol (Isomer 5)	47
o-Phenylphenol	23
1-Naphthol	6.4
2-Naphthol	19
Methyl naphthalene (Isomer 1)	7.2
Methyl naphthalene (Isomer 2)	5.1

Continued

Compound	Concentration (mg/100 g Sample)
Methyl naphthol (Isomer 3)	5.2
m or p-Phenylphenol	7.6
m or p-Phenylphenol	11
Hydroxyfluorene	3.5
Basic Compounds	
Methyl pyridine	8.6
C_3-Alkyl pyridine (Isomer 1)	1.3
C_2-Alkyl pyridine (Isomer 1)	5.5
C_2-Alkyl pyridine (Isomer 2)	25
C_3-Alkyl pyridine (Isomer 2)	10
Aniline	97
C_3-Alkyl pyridine (Isomer 3)	8
C_4-Alkyl pyridine (Isomer 1)	5.4
Methyl aniline (Isomer 1)	68
Methyl aniline (Isomer 2)	110
Methyl tetrahydroquinoline	2.2
C_4-Alkyl pyridine (Isomer 2)	2.3
Tetrahydroquinoline (Isomer 1)	7.4
C_2-Alkyl aniline	160
C_5-Alkyl pyridine	1.3
Methyl tetrahydroquinoline (Isomer 1)	2.1
Tetrahydroquinoline (Isomer 2)	39
C_5-Alkyl pyridine (Isomer 2)	2.9
C_3-Alkyl aniline	74
C_2-Alkyl tetrahydroquinoline (Isomer 2)	2.2
Quinoline	130
Methyl tetrahydroquinoline (Isomer 2)	16
C_2-Alkyl tetrahydroquinoline (Isomer 2)	8.6
C_4-Alkyl aniline	32
Methyl quinoline	74
Tetrahydroquinoline (Isomer 3)	26
C_2-Alkyl quinoline	6.3

Continued

Compound	Concentration (mg/100 g Sample)
Isoquinoline	19
Pyridobenzene (Isomer 1)	1.7
C_5-Alkyl aniline	32
Tetrahydroquinoline (Isomer 4)	37
Methyl tetrahydroquinoline (Isomer 3)	4.4
Methyl quinoline	43
Methyl tetrahydroquinoline (Isomer 4)	4.9
C_2-Alkyl quinoline (Isomer 2)	24
Pyridobenzene (Isomer 2)	2.3
C_2-Alkyl tetrahydroquinoline (Isomer 3)	15
Pyridobenzene (Isomer 3)	1.1
Diphenylamine	3.0
α-Naphthylamine	1.7
β-Naphthylamine	2.4
Methyl naphthylamine	6.3
Acridine	1.7
Methyl acridine	2.1

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INTERNAL CORRESPONDENCE
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FROM R. T. Sebulsky AT Harmarville DATE April 21, 1980

TO Mr. J. K. Ward AT Tacoma REFERENCE 5-535TF00
Attn.: Mr. Russell Perrussell

SUBJECT

DETAILED ANALYSIS OF SRC MIDDLE DISTILLATES

SUMMARY

A coal liquid was submitted from the Solvent-Refined Coal Pilot Plant of the Pittsburg and Midway Coal Mining Company for a comprehensive hydrocarbon characterization by Mr. Russell Perrussell. A spill involving this coal liquid occurred in Fort Lewis, Washington which necessitated the characterization of the liquid involved.

The hydrocarbon characterization was accomplished in the following manner. A sample of the coal liquid was analyzed as is for priority pollutants by thin layer and liquid chromatography. Then because of analytical requirements the coal liquid was separated by distillation into two boiling range fractions.

Each fraction was subjected to an acid/base extraction to separate the phenolic, nitrogen-containing, and neutral-oil fractions. Following this a liquid chromatographic separation was performed on the neutral oil fraction to obtain the aromatic and saturate cuts. All the resulting fractions were analyzed by gas chromatography and/or mass spectrometry. This report documents the results of these analyses.

DISCUSSION

TOTAL SAMPLE ANALYSIS

To get a more accurate description of the total coal liquid, a simulated distillation was run by gas chromatography. This gives information on the initial boiling point of the sample, and the percentage of the sample boiling at each increasing temperature value up to and including the samples final boiling point.

The priority pollutant PNA's were also determined on the total coal liquid sample using both thin layer chromatography and liquid chromatography.

APR 23 1980
P & M
FT. LEWIS

EXTRACTION AND SEPARATION

The hydrocarbon characterization was accomplished by first separating the sample into two boiling fractions, one boiling below 450°F and the other boiling above 450°F.

Distillation into two(2) fractions was necessary to eliminate the danger of the loss of lighter components during HPLC analysis and to allow better separation during the subsequent extractions.

Following the distillation separation each boiling range sample was separated into five fractions using caustic and acid extractions. An emulsion formed during the caustic extraction of the high boiling fraction which necessitated the addition of toluene to the sample to break the emulsion and allow successful extraction of the phenolics.

The acidic fraction contains the basic nitrogen compounds which were detected by mass spectrometry and confirmed by elemental nitrogen analyses.

The neutral oil fraction of each boiling range sample was analyzed for elemental nitrogen present as neutral nitrogen compounds. Then each neutral oil fraction was separated into saturate and aromatic cuts by liquid chromatography. The saturate and aromatic components were identified and quantified by gas chromatography and mass spectrometry.

The analytical flow scheme used for the extraction and separation is shown in Figure 1. Beside each fraction is a test number which indicates the analytical test performed on that fraction. These tests are further described in Table 1.

TABULATION OF DATA

All the data collected from the gas chromatographic, liquid chromatographic, and mass spectrometric analysis are presented in Tables 1-9. The concentrations reported are calculated as the component concentration in the original Ft. Lewis coal liquid. These tables contain the following information:

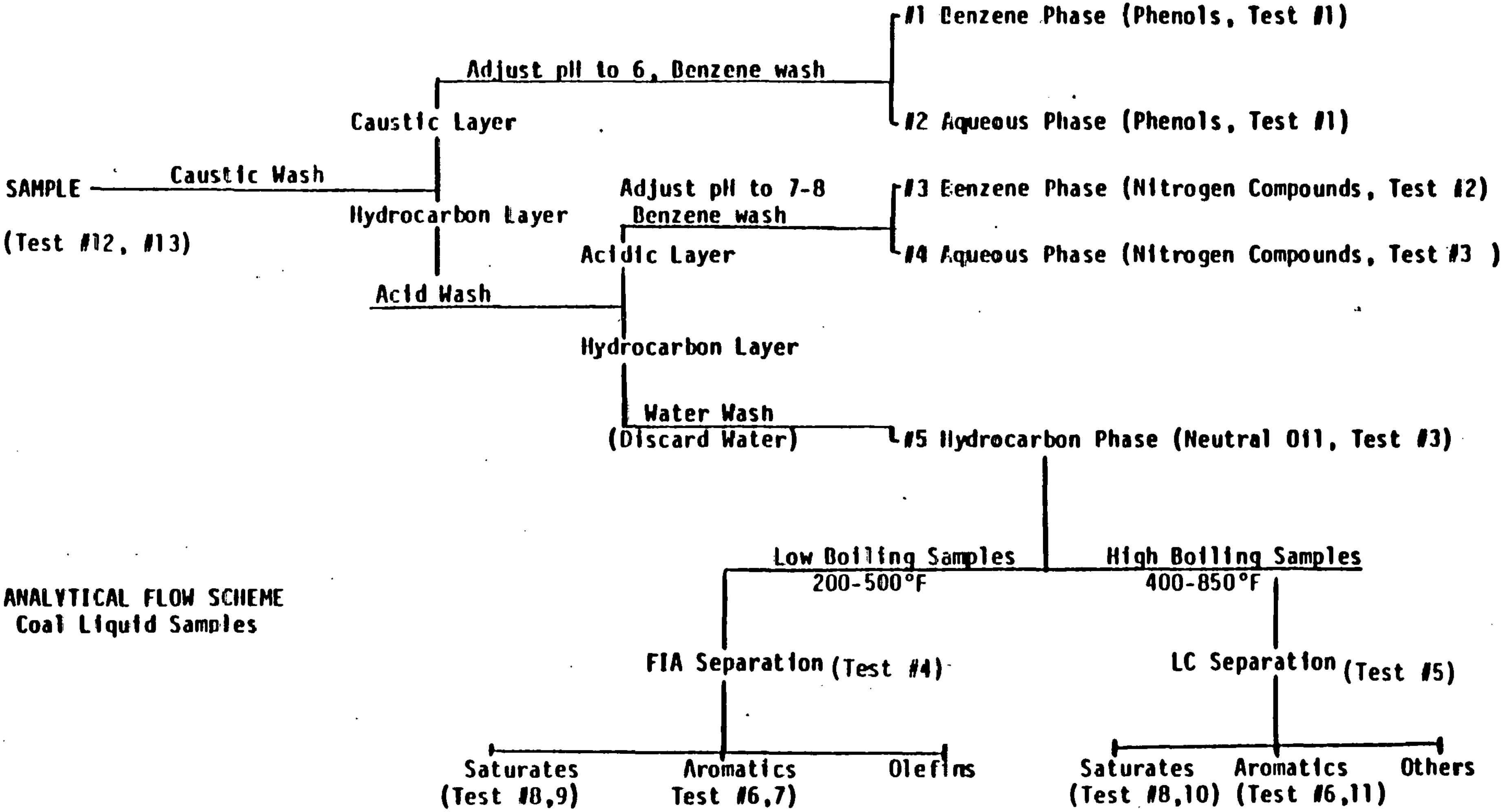
TABLE 1	Analytical Tests Run on Separated Fractions.
TABLE 2	Extractions of Ft. Lewis Coal liquid.
TABLE 3	Gas Chromatographic Simulated Distillation of Ft. Lewis Coal liquid.
TABLE 4	Liquid Chromatographic analysis of NaOH extract (Fraction #1 and #2).
TABLE 5	Basic Nitrogen Compounds in Fort Lewis Coal liquid Mass Spectrometric Group Type Analysis of HCl extract (Fraction #3).
TABLE 6	Saturate Group Type Analysis - Mass Spectrometry (Fraction #5).
	Normal Paraffins Boiling Below 450°F (Fraction #5
TABLE 7	Gas Chromatographic Analysis of the Aromatic fraction (Fraction #5).
TABLE 8	Aromatic Group Type Analysis - Mass Spectrometry (Fraction #5).
TABLE 9	Analysis of Priority Pollutants - PNA's.

R. T. Sebulsky

By

Attachment
cc w/a: Mr. J. Smith - Tacoma
Mr. W. Hubis - Denver

FIGURE 1



ANALYTICAL FLOW SCHEME
Coal Liquid Samples

TABLE 1

ANALYTICAL TESTS RUN ON SEPARATED FRACTIONS

TEST NO.	DESCRIPTION
1	Analyses of Phenolics by Liquid Chromatography
2	Analysis of Nitrogen Compounds by Mass Spectrometry -- Nitrogen Group Type 5398
3	Analysis of Nitrogen Test No. 2594
4	FIA Separation of Neutral Oil Fraction -- Test 5100
5	Preparative Separation of Neutral Oil Fraction by Liquid Chromatography -- Test No. 5479
6	Analysis of Aromatic Cut of Neutral Oil Fraction by gas Chromatography -- Poly Phenylether Capillary Column
7	Analyses of Aromatic Cut of Neutral Oil Fraction by Mass Spectrometry -- Test No. 5374
8	Normal Paraffin Analysis of Saturate Cut of Neutral Oil Fraction by Gas Chromatography -- Test No. 5299
9	Analysis of Saturate Cut of Neutral Oil Fraction by Mass Spectrometry -- Test No. 5380
10	Analysis of Saturate Cut of Neutral Oil Fraction by Mass Spectrometry (High Boiling Range) -- Test No. 5378
11	Analysis of Aromatic Cut of neutral Oil Fraction by Mass Spectrometry (High Boiling Range) -- Test No. 5375
12	Analysis of Priority Pollutants
13	G.C. Simulated Distillation -- Test No. 5210

TABLE 2

EXTRACTIONS OF FORT LEWIS COAL LIQUID

		Weight Percent
MATERIALS EXTRACTED WITH NaOH		34.3%
Identified Phenols	4.9%	
Unidentified phenolic type compounds	15.9%	
Unidentified NaOH extracted material	13.5%	
MATERIALS EXTRACTED WITH HCL		9.6%
Basic Nitrogen Compounds	8.3%	
Unidentified HCl Extracted Material	1.3%	
NEUTRAL OIL FRACTION		56.1%
Saturate	6.7%	
Aromatic	49.4%	
	TOTAL	100%

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CSF:kdl
4/16/80

TABLE 3
GAS CHROMATOGRAPHIC SIMULATED DISTILLATION OF FT. LEWIS COAL LIQUID

CORRESPONDING TO PERCENT DISTILLED AT	DEGREES F
Initial Boiling Point	291
5%	351
10%	378
15%	394
25%	412
40%	446
50%	470
60%	485
70%	511
80%	549
90%	627
Final Boiling Point	843

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CSF:kdl
4/17/80

TABLE 4
LIQUID CHROMATOGRAPHIC ANALYSIS OF NAOH EXTRACT

COMPOUND	WEIGHT PERCENT
Resorcinol	0.01%
Phenol	0.42%
1,5-Naphthalenediol) 2,7-Naphthalenediol) --	0.01%
m,p-Cresol	2.55%
o-Cresol	0.56%
o-Chlorophenol	0.01%
o-Nitrophenol) 1,4-Naphthalenediol) --	0.01%
3,4-Dimethylphenol	0.31%
2,6-Dimethylphenol	0.92%
2-Naphthol) 4-tert-butyl Pyrocatechol) --	0.08%
p-Phenylphenol	0.01%
p-tert-butyl phenol	0.01%
Total Identified Phenols	4.9%
Total Unidentified Phenol Type Compounds	15.9%

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CSF:kdl
4/16/80

TABLE 5
BASIC NITROGEN COMPOUNDS IN FT. LEWIS COAL LIQUID
MASS SPECTROMETRIC GROUP TYPE ANALYSIS OF HCL EXTRACT

COMPOUND	WEIGHT PERCENT
Pyridene, Aniline	2.3%
Phenylquinoline	0.1%
Tetrahydroquinoline	2.6%
Pyridobenzonaphthene	0.1%
Dihydroquinoline/indole	0.3%
Pyridophenanthrene	0.1%
Quinoline	1.7%
Pyridylbenzene	0.7%
Carbazole	0.1%
Acridine	0.3%
Total Nitrogen Compound Concentration	8.3%

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4/17/80

TABLE 6

SATURATE GROUP TYPE ANALYSIS - MASS SPECTROMETRY

	WEIGHT PERCENT	
PARAFFINS	1.7%	
CONDENSED CYCLOPARAFFINS	0.7%	
NONCONDENSED CYCLOPARAFFINS	1.4%	
CONDENSED TRICYCLOPARAFFINS	0.2%	
ALKYLBENZENES	0.1%	
UNKNOWN SATURATES BOILING ABOVE 450°F (includes paraffins & cycloparaffins)	2.6%	
TOTAL SATURATES		6.7%

NORMAL PARAFFINS BOILING BELOW 450°F

NORMAL PARAFFINS	WEIGHT PERCENT
C7	--
C8	--
C9	0.03%
C10	0.1%
C11	0.2%
C12	0.2%
C13	0.2%
C14	0.1%
C15	0.1%
C16	0.03%
C17	Trace
C18	Trace

TOTAL NORMAL PARAFFINS = 0.9%

GS&TC - ATD
Harmarville
CSF:kdl
4/17/80

TABLE 7

GAS CHROMATOGRAPHIC ANALYSIS OF AROMATIC FRACTION

COMPOUND	WEIGHT PERCENT
Benzene	0.1%
Ethylbenzene	0.1%
P-Xylene) M-Xylene) --	0.2%
O-Xylene	0.2%
n-Propylbenzene	0.1%
1-Methyl-4-ethylbenzene) 1-Methyl-3-ethylbenzene) --	0.2%
tert-Butylbenzene	0.1%
1-Methyl-3-isopropylbenzene) 1,2,4-Trimethylbenzene) 1-Methyl-2-ethylbenzene) 1-Methyl-2-isopropylbenzene) --	0.3%
1,2,3-Trimethylbenzene) 1,3-Diethylbenzene) 1-Methyl-3-n-propylbenzene) 1-Methyl-4-isopropylbenzene) --	0.1%
1-Methyl-4-n-propylbenzene) n-Butylbenzene) --	0.1%
1,4-Diethylbenzene) 1-Ethylpropylbenzene) --	0.1%
1,2-Diethylbenzene) 1-Methyl-2-n-propylbenzene) --	0.6%
Indane	0.1%
Indene	0.6%
Methyldiisopropylbenzene	0.1%
1,Methyl-2-tetrabutylbenzene	0.1%
1,2,3,5-tetra-Methylbenzene	0.1%
1,2,3,4-Tetrahydronaphthalene	1.7%
Naphthalene	3.3%
1-Methylnapthalene	8.3%
Biphenyl	3.8%
Unknowns	29.1%
Total Aromatic	49.4%

TABLE 8

AROMATIC GROUP TYPE ANALYSIS - MASS SPECTROMETRY

COMPOUND	WEIGHT PERCENT
Decahydrobenzochrysene	0.3%
Octahydrobenzochrysene	0.3%
Hexahydrobenzochrysene	0.1%
Tetrahydrobenzochrysene	0.1%
Benzochrysene	0.1%
Decahydrobenzpyrene	0.3%
Octohydrobenzpyrene	0.5%
Hexahydrobenzpyrene	0.5%
Tetrahydrobenzpyrene	0.2%
Dihydrobenzpyrene	0.2%
Benzopyrene	0.4%
Dodecahydrochrysene	0.3%
Octahydrochyrysene	0.3%
Chrysene	0.3%
Decahydropyrene	1.0%
Hexahydropyrene	2.3%
Tetrahydrofluoranthene	0.5%
Pyrene-fluoranthene	1.5%
Dihydropyrene-tetrahydro-chrysene	2.0%
Octahydrophenanthrene	1.2%
Hexahydrophenanthrene	0.7%
Tetrahydrophenanthrene	5.9%
Phenanthrene	2.1%
Fluorene-dihydrophenanthrene	1.4%
Acenaphthene-biphenyl	1.8%
Tetralins	10.2%
Tetrahydroacenaphthene	1.7%
Naphthalenes	9.0%
Benzenes	2.2%
Octahydrochrysene	0.5%
Hexahydrochrysene	0.2%
Unknowns	1.3%
Total Aromatic	49.4%

TABLE 9

ANALYSIS OF PRIORITY POLLUTANTS - PNA's

	Parts Per Million
Benzo(e)pyrene	0.5
Benzo(b)fluoranthene	1.7
Benzo(a)pyrene	1.5
Dibenz(a,h)anthracene	5.7
Benzo(ghi)perylene	3.8
Indeno(1,2,3-cd)pyrene	1.8
Benzo(k)fluoranthene	2.8
*Fluorene	6783
*Acenaphthene	4429
*Fluoranthene	26
*Phenanthrene	56
*Anthracene	29
Pyrene	1.2
Chrysene	2.9

*Determined by HPLC

GS&TC - ATD
Harmarville
CSF:kdl
4/22/80

OUTGOING TELEGRAM

MAY 6, 1980 -CONFIRMATION COPY-

TO: JOHN K. WARD (FORT LEWIS)

COPY BY WIRE: MR. WALT HUBIS - DENVER

SUBJECT: <u>ANALYSIS OF SRC MIDDLE DISTILLATE</u>

REFERENCE: MEMO OF APRIL 21, 1980 R. T. SEBULSKY TO MR. J. K. WARD

THE FOLLOWING IS CORRECTED PRIORITY POLLUTANT POLYNUCLEAR AROMATICS DATA AND ADDITIONAL PHENOLICS DATA:

HPLC/TLC ANALYSIS OF POLYNUCLEAR AROMATICS PRIORITY POLLUTANTS

(Replaces Table 9)

	PARTS PER MILLION
NAPHTHALENE	1780
ACENAPHTHENE	1190
PHENANTHRENE	498
ANTHRACENE	145
FLUORANTHENE	130
FLUORENE	560
PYRENE	12
BENZ(a)ANTHRACENE	38
CHRYSENE	85
BENZ(e)PYRENE	5
BENZO(b)FLUORANTHENE	17
BENZO(k)FLUORANTHENE	28
BENZO(a)PYRENE	15
DIBENZ(a,h)ANTHRACENE	57
BENZO(ghi)PERYLENE	[illegible]
INDENO(1,2,3-cd)PYRENE	[illegible]

GC/MS ANALYSIS OF NAOH EXTRACTABLES *(Weight Percent)*

(Supplements Table 4)

ORTHO-ETHYLPHENOL	[illegible]
2,3 DIMETHYLPHENOL	[illegible]
2,5 DIMETHYLPHENOL	0.34
TRIMETHYLPHENOL (1 ISOMER)	0.27
ETHYLPHENOLS (2 ISOMERS)	1.85
3,5 DIMETHYLPHENOL	.81
TRIMETHYL-OR METHYLETHYLPHENOLS (8 ISOMERS)	1.67
TETRAMETHYL AND/OR DIETHYL AND/OR METHYLPROPYLPHENOL	0.06
PROPYLPHENOLS (2 ISOMERS)	2.70
BUTYLPHENOL (1 ISOMER)	0.20

COPY [illegible]
[illegible]
[illegible]
JAS
REP
[illegible]

END OF PAGE ONE

PAGE TWO CONTINUED

GC/MS ANALYSIS OF NAOH EXTRACTABLES (Continued)

OTHER C_3 AND C_4 ALKYLPHENOLS (7 ISOMERS)	0.72
METHYL-ALLYLPHENOLS AND/OR C_4 ALKYLPHENOLS (3 ISOMERS)	2.03
ALLYLPHENOLS AND/OR C_4 ALKYLPHENOLS (2 ISOMERS)	2.28
PARA-CRESYL ACETATE	0.30
C_4 AND C_5 ALLYL AND ALKYLPHENOLS (20 ISOMERS)	4.45
TOTAL	18.3
TOTAL PREVIOUSLY IDENTIFIED	4.9
TOTAL IDENTIFIED PHENOLS	23.2
UNACCOUNTED FOR MATERIAL + UNIDENTIFIED NAOH EXTRACTABLES	11.1
TOTAL NAOH EXTRACTABLES	34.3

PLEASE CORRECT THE REFERENCED REPORT. IF ADDITIONAL INFORMATION IS REQUIRED PLEASE CONTACT W. C. BRANT OR G. P. FEULMER.

mcB R. T. SEBULSKY/M. C. BRYSON/WCB
kdl

CC: RTS-AMH
MCB
WRL
FHJ
WAPM
WCB
GPF
CSF

APPENDIX I

Part 2

ANALYSIS OF SRC FLUID BY GULF SCIENCE AND TECHNOLOGY CENTER AT HARMARVILLE, PENNSYLVANIA

APPENDIX II
LOGS OF WELLS AND CORES

APPENDIX II
Part 1
LOGS OF TANK FARM CORES

PAGES II-3 to II-4

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LOGS OF TANK FARM CORES

Sample No.	Depth	Blows	Texture	Contamination	
				Visual	Odor
Hole 12:					
C-1-1	3-4 1/2	30/10/8	Sandy gravel	Wet, stained	Strong
C-1-2	5-6 1/2	24/15/8	Sandy gravel	Wet, oily, stain	Strong
C-1-3	7 1/2-9	9/10/11	Sandy gravel	Wet, oily, stain	Strong
C-1-4	10-11 1/2	16/16/14	Sandy gravel	Damp, mod stain	Strong
C-1-5	12 1/2-14	14/18/13	Gravelly sand	Damp, mod stain	Strong
C-1-6	14-15 1/2	12/11/14	Sand	Damp, no stain	Mod strong
C-1-7	15 1/2-17	16/16/24	Gravelly sand	Damp, no stain	Moderate
C-1-8	17-18 1/2	30/41/42	Gravelly sand	Damp, no stain	Moderate
C-1-9	18 1/2-20	27/35/27	Gravelly sand	Mod dry, no stain	Moderate
C-1-10	20-21 1/2	30/27/42	Gravelly sand	Mod dry, no stain	Moderate/light
C-1-11	21 1/2-23	14/19/26	Gravelly sand	Mod dry, no stain	Light
C-1-12	23-24 1/2	20/25/38	Gravelly sand	Mod dry, no stain	Light
C-1-13	24 1/2-26	50/50/30	Gravelly sand	Dry, no stain	Light
C-1-14	26-27 1/2	16/20/20	Gravelly sand	Mod dry, no stain	Light/mod
C-1-15	27 1/2-29	20/22/26	Gravelly sand	Mod dry, no stain	Light
C-1-16	29-30 1/2	21/29/38	Gravelly sand	Wet, no stain, w.t. abt 30	Light

(Continued)

(Continued)

Sample No.	Depth	Blows	Texture	Contamination Visual	 Odor
Hole 13:					
C-2-1	3-4 1/2	35/34/30	Sandy gravel	Wet, stained	Strong
C-2-2	5-6 1/2	15/25/30	Sandy gravel	Wet, stained	Strong
C-2-3	7 1/2-9	16/12/16	Gravelly sand	Wet, stained	Very strong
C-2-4	10-11 1/2	8/7/7	Sandy gravel	Wet, slight stain	Strong
C-2-5	12 1/2-14	5/5/9	Sandy gravel	Wet, slight stain	Moderate
C-2-6	15-16 1/2	5/7/7	Sandy gravel	Mod wet, no stain	Moderate
C-2-7	16 1/2-18	7/14/23	Sandy gravel	Mod wet, no stain	Moderate
C-2-8	18-19 1/2	21/18/25	Sandy silt ≈6" Med sand below	Wet, no stain Mod wet, no stain	Strong Mod/strong
C-2-9	19 1/2-21	7/16/32	Fine/med sand	Wet, stain	Strong
C-2-10	21-22 1/2	19/21/18	Gravelly sand	Wet, no stain	Moderate
C-2-11	22 1/2-24	50/33/17	Gravelly sand	Mod wet, no stain	Moderate
C-2-12	24-25 1/2	12/12/14	Gravelly sand	Mod wet, no stain	Moderate
C-2-13	25 1/2-27	4/6/8	Sandy gravel	Mod wet, no stain	Moderate
C-2-14	27-28 1/2	18/20/19	Sandy gravel	Mod wet, no stain	Mod/light
C-2-15	28 1/2-30	11/21/24	Med sand, pebbles	Mod wet, no stain	Mod/light
C-2-16	30-31 1/2	12/14/12	Med sand, pebbles	Wet(w.t.), no stain	Light
C-2-17	31 1/2-33	10/14/14	Med sand, pebbles	Wet(w.t.), no stain	Light
C-2-18	33-34 1/2	Lost count	Med sand, pebbles	Wet(w.t.), no stain w.t. approx. 30'	Light

(Continued)

(Continued)

Sample No.	Depth	Blows	Texture	Contamination	
				Visual	Odor
Hole 14:					
C-3-1	3-4 1/2	10/12/22	Sandy gravel (berm mtl)	Moist, no stain	Light/none
C-3-2	5-6 1/2	21/22/23	Sandy gravel	Mod dry, no stain	Light/none
C-3-3	7 1/2-9	20/23/30	Sandy gravel	Mod dry, no stain	Light/none
C-3-4	10-11 1/2	12/16/23	Sandy gravel	Dry, no stain	None
C-3-5	12 1/2-15	8/12/13	Sandy gravel	Mod dry, no stain	Light
C-3-6	15-16 1/2	Lost count	Sandy gravel	Mod dry, no stain	Light
C-3-7	16 1/2-18	3/5/6	Med sand	Dry, no stain	Light/mod
C-3-8	18-19 1/2	9/10/15	Med sand	Dry, no stain	Light/mod
C-3-9	19 1/2-21	16/11/18	Med sand	Dry, no stain	Light/mod
C-3-10	21-22 1/2	11/16/22	Med sand/small peb.	Dry, no stain	Light/mod
C-3-11	22 1/2-24	16/22/18	Gravel/sand	Dry, no stain	Light
C-3-12	24-25 1/2	16/17/23	Gravel/sand	Dry, no stain	Light
C-3-13	25 1/2-27	19/18/17	Gravel/sand	Dry, no stain	Light
C-3-14	27-28 1/2	17/25/31	Gravel/sand	Dry, no stain	Light
C-3-15	28 1/2-30	21/32/32	Gravel/sand	Dry, no stain	Light
C-3-16	30-31 1/2	21/33/40	Gravel/sand	Wet(w.t.), no stain	None
C-3-17	31 1/2-33	17/30/24	Gravel/sand	Wet(w.t.), no stain w.t. approx. 31'	Light/none

(Continued)

(Continued)

Sample No.	Depth	Blows	Texture	Contamination	
				Visual	Odor
Hole 15:					
C-4-1	3-4 1/2	25/15/21	Gravel/sand	Moist/stain	Strong
C-4-2	5-6 1/2	11/16/9	Gravel/sand	Moist/stain	Strong
C-4-3	7 1/2-9	9/11/15	Gravel/sand	Moist, stain, free oil	Strong
C-4-4	10-11 1/2	11/19/18	Gravel/sand	Moist, stain, free oil	Strong
C-4-5	12 1/2-14	7/9/10	Gravel/sand	Moist, slight stain	Strong
C-4-6	15-16 1/2	6/10/11	Gravel/sand	Moist, slight stain	Strong/mod
C-4-7	16 1/2-18	5/11/16	Gravel/sand	Moist, no stain	Moderate
C-4-8	18-19 1/2	17/23/21	Gravel/sand	Moist, no stain	Moderate
C-4-9	19 1/2-21	8/15/17	Gravel/sand	Moist, no stain	Moderate
C-4-10	21-22 1/2	12/17/22	Gravel/sand	Moist, no stain	Mod/light
C-4-11	22 1/2-24	14/18/26	Gravel/sand	Moist, no stain	Light
C-4-12	24-25 1/2	14/19/33	Sand w/gravel	Moist, light stain	Moderate
C-4-13	25 1/2-27	32/29/31	Sand w/gravel	Moist, light stain	Moderate
C-4-14	27-28 1/2	30/27/26	Sand w/gravel	Moist, no stain	Moderate
C-4-15	28 1/2-30	21/24/26	Sand w/fine gravel	Moist, no stain	Moderate
C-4-16	30-31 1/2	8/33/21	Sand w/fine gravel	Wet(w.t.), no stain	Light
C-4-17	31 1/2-33	8/14/21	Sand w/fine gravel	Wet, no stain	None
C-4-18	33-34 1/2	5/8/15	Sand w/fine gravel	Wet, no stain	None

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(Continued)

Sample No.	Depth	Blows	Texture	Contamination	
				Visual	Odor
Hole 16:					
C-5-1	3-4 1/2	12/20/30	Sandy gravel, fines	Wet, stained, free oil	Strong
C-5-2	5-6 1/2	17/20/25	Sandy gravel, fines	Wet, stained, free oil	Strong
C-5-3	7 1/2-9	9/35/40	Sandy gravel, fines	Wet, stained, free oil	Strong
C-5-4	10-11 1/2	12/14/14	Sandy gravel, fines	Wet, stained, free oil	Strong
C-5-5	12 1/2-14	5/8/11	Sandy gravel, fines	Wet, stained, free oil	Strong
C-5-6	15-16 1/2	15/18/14	Sandy gravel, fines	Wet, stained, free oil	Strong
C-5-7	17 1/2-19	15/25/23	Sand/gravel	Wet, stained, some free oil on top	Strong
C-5-8	19-20 1/2	17/24/29	Sand/gravel	Moist, no stain, no oil	Strong
C-5-9	20 1/2-22	19/20/23	Sand/gravel	Moist, no stain	Moderate
C-5-10	22-23 1/2	19/30/18	Med sand, pebbles	Moist, no stain	Moderate
C-5-11	23 1/2-25	10/8/9	Sand/gravel	Moist, no stain	Light
C-5-12	25-26 1/2	9/14/21	Sand/gravel, little clay	Moist, no stain	Light
C-5-13	26 1/2-28	15/20/21	Sand/gravel, little clay	Moist, no stain	Light/mod

(Continued)

(Continued)

Sample No.	Depth	Blows	Texture	Contamination Visual	 Odor
Hole 16 (Continued)					
C-5-14	28-29 1/2	14/15/8	Sand/gravel, little clay	Wet(w.t.), no stain	Light/mod
C-5-15	29 1/2-31	8/10/10	Sand/gravel, little clay (clean gravel at base)	Wet(w.t.), no stain	Light/mod
No sample	31-32 1/2	8/9/6	No recovery	-	-
C-5-16	32 1/2-34	4/7/8	Fine sand above, clean fine gravel below	Wet, no stain, w.t. at abt 29'	Light/mod

PAGES II-11 to II-12

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LOGS OF PIEZOMETERS

Sample No.	Depth (feet)	Blows	Description and Comments
Well 19:			
B-12-1	3-4.5	11/9/8	Gravel, trace sand
B-12-2	5.5-7	11/19/14	Sand, trace gravel
B-12-3	8-9.5	14/11/10	Sand
B-12-4	10.5-12	6/10/14	1-3 inch gravel, sand below
B-12-5	13-14.5	18/20/27	Gravelly sand
B-12-6	15.5-17	12/17/13	Sand and gravel
B-12-7	18-19.5	11/21/26	Sand and gravel
B-12-8	20.5-22	60 for 6"	Gravelly sand
B-12-9	23-24.5	12/14/22	Sandy gravel
B-12-10	25.5-27	5/5/7	Gravel, poor recovery
B-12-11	28-29.5	15/26/23	Sand and gravel
B-12-12	30.5-32	8/5/5	Sandy gravel
B-12-13	33-34.5	10/30/25	Sandy gravel
B-12-14	35.5-37	12/17/13	Gravel, hit water
B-12-15	38-39.5	7/12/11	?
B-12-16	40.5-42	?	Sand and gravel
Well 17:			
B-13-1	3-4.5	40/38/30	Sandy gravel
B-13-2	5.5-7	5/5/10	Sand and gravel
B-13-3	8-9.5	7/15/25	Sand and gravel
B-13-4	10.5-12	18/25/27	Sand and gravel
B-13-5	13-14.5	14/14/17	Sand and gravel
B-13-6	15.5-17	21/22/30	Sand and gravel
B-13-7	18-19.5	70/50 for 3"	Sand and gravel
B-13-8	20.5-22	21/53 for 6"	Sand and gravel, trace clay
B-13-9	23-24.5	14/19/26	Clayey sand and gravel
B-13-10	25.5-27	36/50 for 4"	Gravelly sand
B-13-11	28-29.5	23/17/18	Sand, trace gravel

(Continued)

(Continued)

Sample No.	Depth (feet)	Blows	Description and Comments
B-13-12	30.5-32	25/21/18	Medium and coarse sand
B-13-13	33-34.5	10/15/17	Medium and coarse sand, hit water
B-13-14	35.5-37	10/16/16	Medium and coarse sand
B-13-15	38-39.5	?	Medium and coarse sand
Well 18:			
B-14-1	3-4.5	32/29/30	Sandy gravel
B-14-2	5.5-7	7/13/10	Wet sand and gravel
B-14-3	8-9.5	2/2/10	Wet sandy gravel
B-14-4	10.5-12	17/37/38	Wet sandy gravel
B-14-5	13-14.5	9/20/39	Wet gravelly sand, trace silt and clay
B-14-6	15.5-17	17/18/25	Gravelly, clayey sand
B-14-7	18-19.5	24/26/28	?
B-14-8	20.5-22	15/15/21	Sand; gravelly sand
B-14-9	23-24.5	9/12/12	?
B-14-10	25.5-27	?	Gravel
B-14-11	28-29.5	6/7/7	Sandy gravel
B-14-12	30.5-32	4/4/6	Sand; gravel
B-14-13	33-34.5	17/21/54	Sand; gravel

APPENDIX II
Part 2
LOGS OF PIEZOMETERS

APPENDIX II

Part 3

LOGS OF "TRIAD" WELLS

LOGS OF "TRIAD" WELLS

Depth (feet)	Description and Comments
	<u>Well 21 (deep well)</u>
0-18	fill: gravel; sand and gravel
18-28	sand and gravel
28-29	sandy gravel; strong "fuel oil" smell
29-37	sand and gravel; sandy gravel at 35 feet; hit water at 35 feet; strong fuel oil smell; traces of silt and clay at 35 feet
38	silty, clayey sand and gravel
45	silty, clayey sand and gravel; fines increasing
46	silty, clayey sand and gravel; fines increasing
	<u>Well 22 (middle depth well)</u>
0-19	fill: sand and gravel
19-27	sandy gravels and gravelly sands
27-34	sand and gravel; traces of silt and clay
34-35	sandy gravel; hit water; fuel oil smell; trace silt and clay
35-39	sand and gravel; fines increasing
39	silty, clayey sand and gravel
39.5	caving sand filling annulus
	<u>Well 23 (shallow well)</u>
0-15	fill: sand and gravel
15-31	sandy gravels; sand and gravel
32	hit water after waiting
32-34	sand and gravel
34-35	sand and gravel; traces of silt and clay

APPENDIX II
Part 4
LOG OF WELL 24

PAGES II-19 to II-20

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LOG OF WELL 24

Depth (Feet)	Description
0-3	Gravelly sand, slightly silty
3-5	Gravelly sand, slightly silty
5-10	Gravelly sand, slightly silty
10-15	Gravelly sand, slightly silty, easy drill 10-12
15-20	Gravelly sand, slightly silty
20-25	Gravel; slightly sandy
25-30	Silty gravelly sand
30-35	Silty gravelly sand
35-40	Gravelly sand; slightly silty
40-45	Silty sand; slightly gravelly and clayey
45-50	Silty sandy gravel; hard drill at 48
50-55	Clayey silty sand; 51-53 gravel
55-59	Clayey silty sand

APPENDIX III
AQUIFER TEST DATA

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AQUIFER TEST DATA

Pacific Daylight Time	Elapsed Time min/sec	Depth to Water	Depth to Water	Drawdown (feet)	Discharge (gpm)	Notes
WELL #20 (PW-1) - PUMPED WELL						
May 3						
11 52 00		25'-1 3/4"				
13 52		25'-1½"				
13 52		1½"				Tape reading
-13 55 00						Pump on
	00/37	13¼"		.98		
	08/10	17¼"		1.31		
	10/30				118	55 gal./28 sec.
	11/54	17 3/4"		1.35		
	23/00				122	27 seconds
	29/50	19 5/8"		1.51		
	42/00				122	
	45/34	20¼"		1.56		
	62/50	20 3/4"		1.60		
	64/00				122	
15 15 30	80/30					
	83/05	20 1/8"		1.64		
	89/00				118	28 seconds
15 58 00	123/00				122	
16 03 15	128/15	21 5/8"		1.68		
16 54 35	179/35	22 1/8"		1.72		
16 57	182/00				118	
18 19 00	264/00				122	
18 24 50	267.50	22 5/8"		1.76		
22 47 15	532/15	23 5/8"		1.84		
22 51 00	536/00				122	
May 4						
11 24 10	1289/10	23¼"		1.81		
11 32 00	1297/00				122	

AQUIFER TEST DATA (Continued)

Pacific Daylight Time	Elapsed Time min/sec	Depth to Water	Depth to Water	Drawdown (feet)	Discharge (gpm)	Notes
May 4 (continued)						
20 48 00	1853/00	23½"		1.83		
20 51 00	1856/00				122	
May 5						
12 59 45	2824/45	23 3/4"		1.85		
13 05 00	2830/00				122	
May 6						
15 52 00	4437/00				122	
15 55 55	4440/55	25"		1.96		
16 02 00	4447/00					Pump off
20 18 33	256/33	3"		1.83		Recovery
May 7						
11 15 00	1153/00	2 1/8"		1.91		

WELL #1 - OBSERVATION WELL

Pacific Daylight Time	Elapsed Time min/sec	Depth to Water	Depth to Water	Drawdown (feet)	Discharge (gpm)	Notes
May 3						
11 44 00		27'-½"				
13 49 00		26'-11½"				
13 49 00		23¼"	23.25	0		Tape reading
	0002/15	27 3/8"		.34		
	03/25	28 1/8"		.41		
	04/10	28½"		.44		
	05/00	28 3/4"		.46		
	05/45	29"		.48		
	06/30	29¼"		.50		

AQUIFER TEST DATA (Continued)

Pacific Daylight Time	Elapsed Time min/sec	Depth to Water	Depth to Water	Drawdown (feet)	Discharge (gpm)	Notes
May 3 (continued)						
	13/10	30 3/4"		.63		
	15/35	31 1/8"		.66		
	20/00	31½"		.69		
	25/20	31 7/8"		.72		
	28/30	32-0"		.73		
	31/15	32 1/8"		.74		
	40/15	32 1/8"		.74		
	47/45	32 7/8"		.80		
	60/55	33¼"		.83		
	67/45	33¼"		.83		
15 12 40	77/40	33 3/4"		.88		
15 15 30	80/30					
	85/00	33 3/4"		.88		
15 52 45	117/45	34"		.90		
16 52 05	177/05	34 7/8"		.97		
18 27 50	272/50	35½"		1.02		
18 58 13	303/13	35¼"		1.00		
22 44 40	529/40	36"		1.06		
May 4						
11 27 50	1292/50	36¼"		1.08		
20 45 40	1850/40	36¼"		1.08		
May 5						
13 02 20	2827/20	36 3/8"		1.09		
22 44 10	3409/10	36 1/8"		1.07		
May 6						
15 57 45	4442/45	36¼"		1.08		
16 02 00	4447/00					Pump off
16 02 16	00/16	36"		.02		Recovery

AQUIFER TEST DATA (Continued)

Pacific Daylight Time	Elapsed Time min/sec	Depth to Water	Depth to Water	Drawdown (feet)	Discharge (gpm)	Notes
May 6 (continued)						
16 03 03	1/03	33 3/4"		.20		
16 03 38	1/38	33¼"		.25		
16 04 09	2/09	33"		.27		
16 04 30	2/30	32 3/8"		.32		
16 04 55	2/55	32 1/8"		.34		
16 05 47	3/47	31 5/8"		.38		
16 06 17	4/17	31¼"		.41		
16 06 52	4/52	31 1/8"		.42		
16 07 28	5/28	31"		.43		
16 08 20	6/20	30 5/8"		.47		
16 09 10	7/10	30¼"		.50		
16 10 04	8/04	30 1/8"		.51		
16 11 16	9/16	29 3/4"		.54		
16 12 47	10/47	29 3/8"		.57		
16 14 22	12/22	28 7/8"		.61		
16 15 52	13/53	28 5/8"		.63		
16 17 30	15/30	28½"		.64		
16 19 50	17/50	28¼"		.66		
16 22 55	20/55	28¼"		.66		
16 27 08	25/08	27 3/4"		.71		
16 31 30	29/30	27 5/8"		.72		
16 37 03	35/03	27½"		.73		
16 44 08	42/08	27"		.77		
16 51 45	49/45	26 7/8"		.78		
17 02 10	60/02	26 5/8"		.80		
17 30 24	88/24	26¼"		.83		
20 16 16	254/16	25 3/8"		.91		
May 7						
11 17 00	1155/00	24 7/8"		.95		
17 37 00	1535/00	24 3/8"		.99		

APPENDIX IV

TECHNICAL MEMORANDUM

DEFINITION OF ZONE OF SOIL CONTAMINATION AT THE SRC PILOT PLANT FORT LEWIS, WASHINGTON

DCN 80-214-029-12

TECHNICAL MEMORANDUM 214-029-03

DEFINITION OF ZONE OF SOIL CONTAMINATION AT THE SRC PILOT PLANT FORT LEWIS, WASHINGTON

by
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Submitted to
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4 June 1980

PAGES IV-3 to IV-4

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1.0 INTRODUCTION

The objective of this memorandum is to report the delineation of the lateral and vertical extent of soil contaminated by a spill of SRC-II product on December 19, 1979. This information is to be used by the Pittsburg and Midway Coal Mining Company in the excavation of contaminated soil which represents a potential hazard to ground and surface waters. The methodology used and the results obtained are given herein.

2.0 BACKGROUND

The soil beneath the spill acted essentially as a natural chromatographic medium witin the hydrologically unsaturated zone. Solute transport was mainly vertical in this zone, with the less mobile chemical species being retarded and concentrated toward the surface, and the more mobile species being advected and dispersed lower. Variable, episodic dissolution and flushing caused by rainfall tended to cause a concentration gradient of the species, decreasing with depth.

The real concern, of course, is the potential impact of the spill on the local ground water. Accordingly, that soil which is contaminated to an extent that it represents a hazard to ground-water supplies should be removed. It is also recognized that even though some soil may contain species of interest at levels above "background," certain levels do not constitute hazards to ground or surface waters; no benefit is to be gained by the costly removal of such soil. A definition of what concentration level in the solid phase constitutes a potential hazard was necessary.

3.0 APPROACH

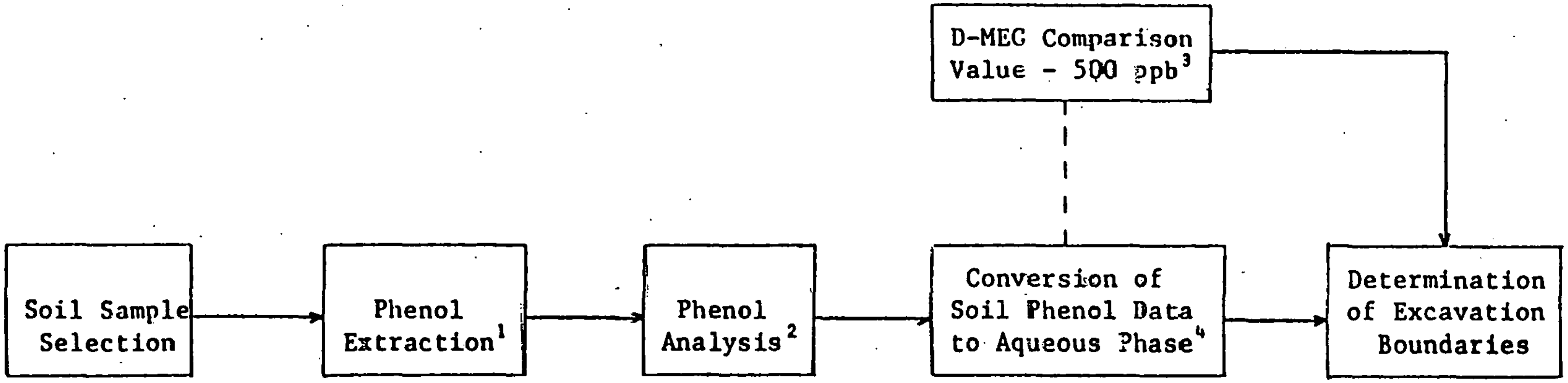
The approach used by Radian to determine the excavation boundaries is shown schematically in Figure 3-1. Approximately 85 samples of the substrate underlying the spill site were collected from four cores within and one core outside the spill area. These samples were collected in late March, approximately three months after the spill. Since that time, the spill area has been covered to prevent penetration of rainfall through the soil beneath the spill and subsequent transport of contaminants through the soil structure.

The extent of lateral and vertical contamination due to the spill was determined by chemical analysis of core samples for phenol. Since phenols were initially in high concentrations in the spilled material and were, most likely, the most mobile organic compound present, the selection of phenols to define the extent of contamination is appropriate.

Next, the potential degree of contamination to the ground and surface waters due to natural, rain-induced leaching of the spill area was determined using the EPA Extraction Procedure. The extraction study allowed conversion of solid-phase, phenol concentrations to aqueous-phase concentrations.

Finally, the aqueous-phase concentration of each core sample was compared, under the provisions of the Resource Conservation and Reclamation Act, with the D-MEG value representing the maximum level recommended by the EPA for waste effluents to ground or surface waters. If a particular area of contaminated soil contributed aqueous phenol concentrations above that deemed hazardous to ground or surface waters, that area was marked for excavation.

FIGURE 3-1. METHODOLOGY FOR DEFINING ZONE OF SOIL CONTAMINATION



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[1] Interim Methods for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

[2] Standard Methods for the Examination of Water and Wastewater, 14th Edition American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1975.

[3] Multimedia Environmental Goals for Environmental Assessment, Volume IV, MEG Charts and Background Information Summaries (Categories 13-26), U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Reserach Triangle Park, N.C., EPA-600/7-79-176b, August, 1979.

[4] Comparison of RCRA Extraction Procedure Results to Soil Phenol Analysis Results.

3.1 Analysis for Total Phenol

Core samples were preserved and prepared for phenol analysis in accordance with EPA priority pollutant analysis requirement for sediments.[1] Samples were kept frozen prior to analysis to inhibit biological degradation. A 5 g portion of the finer soil material was used as received for the analyses to identify a worst-case (highest) phenol content of the samples. The solid was mixed with deionized water and the pH lowered to 4.0 with dilute phosphoric acid. The soil slurry was then transferred to a distillation flask for analysis.

The slurry was distilled until 500 ml of distillate was collected according to Standard Methods[2] 510A. The Chloroform Extraction Method (510B) was used for quantitative analysis of steam-distillable phenols. Phenol was reacted with 4-aminoantipyrine at a pH of 10 in the presence of potassium ferricyanide to form a colored antipyrine dye. The dye was extracted from aqueous solution with chloroform and the absorbance was measured at 460 nm. The concentration of phenolic compounds was expressed in µg/g soil on an as-received basis.

3.2 Phenol D-MEG for Water Ecology

The approach to define the potential hazard level consists of use of the Multimedia Environmental Goals (MEG's) con-

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[1] Interim Methods for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

[2] Standards Methods for the Examination of Water and Wastewater, 14th Edition American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1975.

cept of EPA's Industrial Environmental Research Laboratory.[1] D-MEG's (Discharge MEG's, formerly Minimum Acute Toxicity Effluents, or MATE's) have been established for avoiding health and ecological effects in air, water, and land resources. These values represent maximum recommended values for waste effluents to a stream or lake (either surface discharge or subsurface inflow) that will avoid toxic aquatic effects.

Currently, DMEG's for phenol are being revised to make them less stringent, on the basis of the data base analysis and subsequent proposal by EPA of water quality criteria (44 Federal Register, 43688, July 25, 1979). However, Radian has conservatively adopted for use in this application the older D-MEG's, published by EPA in August, 1979.[2] The phenol D-MEG for water-ecology is taken to be 500 μg/ℓ (ppb). In comparison the proposed water quality criteria, ambient concentration recommendations, are 600 μg/ℓ for aquatic life and 3,400 μg/ℓ for human health. (Individual chlorinated phenols have ambient numerical criteria ranging from several tens to several hundred ppb to avoid organoleptic (taste and odor-producing) vis-a-vis toxic properties; a D-MEG of 500 μg/ℓ for individual chlorinated phenols is approximately appropriate for these criteria as well).

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[1] Multimedia Environmental Goals for Environmental Assessment, Volume 1, U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory. Research Triangle Park, North Carolina, EPA-600/7-77-136a, November 1977.

[2] Multimedia Environmental Goals for Environmental Assessment; Volume IV, MEG Charts and Background Information Summaries (Categories 13-26), U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, N.C., EPA-600/7-79-176b, August, 1979.

It should be noted that standard analyses conducted for "phenols" are actually analyses for many (but not all) individual phenolic compounds. Because D-MEG's for phenols are based on criteria for simple phenols in a strict sense, this use is a conservative feature of the methodology.

In summary, the approach recommended here proposes to use a value of 500 μg/ℓ phenol in an aqueous solution that would be tributary to a receiving water body containing aquatic life (e.g., ground water to a lake) as the conservative threshold for water quality protection.

3.3 RCRA Extraction Procedure (EP)

Since the D-MEG is a tributary aqueous concentration, it can not be compared directly with the soil analytical values for phenol. The method of correlating solid and liquid phase phenol concentrations is the EPA Extraction Procedure (EP).[1] A subset of six soil samples ranging from low to high phenol concentration were extracted to define the aqueous extract concentration as a function of soil concentration.

In principal the EP test extracts a mass of solid waste with a volume of water equivalent to twenty times the waste mass. The test is conducted to simulate acidic (pH = 5) conditions, however, a maximum acetic acid addition of 4 mls of 1N acid per gram of waste is set to simulate realistic conditions for alkaline wastes. A ten-fold dilution of extract results is used for direct comparison with aqueous D-MEGs. This approach is consistent with EPA applications in its RCRA regulations and its MEGs programs.

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[1] Federal Register, 44, December 18, 1978.

4.0 RESULTS

This section presents the results of chemical analyses. Included are the analyses of core samples for total phenols and extractable phenol. A definition is made of this level of phenol in the soil which constitutes a hazard.

4.1 Total Phenol in Soil Samples

Sixty-eight soil samples from five cores have been analyzed for total phenol by P&M Coal Company with analyses of 24 sample splits by Radian. The results are presented in Table 4-1. The results between the two labs for 21 common samples indicate agreement to within 13 ppm phenol for all but one sample.

4.2 Extractable Phenol

Six core samples were extracted using this EP to define the correlation between solid and aqueous phase phenol. The results are presented in Table 4-2. Figure 4-1 presents the correlation between solid and aqueous phase phenol which was established to evaluate the solid phase concentration which will result in contamination above the D-MEG value. The .500 μg/ml phenol aqueous D-MEG value is equivalent to 133 μg/g phenol solid concentration. Solid concentrations in excess of this value are recommended for excavation.

4.3 Definition of Excavation Depth

The ratio of the solid phase phenol concentration in the soil with the D-MEG equivalent solid phase concentration provides an index of the degree of severity of phenol contamination. When the degree of severity exceeds 1.0 (DS>1.0) the potential for ground-water contamination is high. In other

TABLE 4-1. PHENOL CONCENTRATION AS A FUNCTION OF CORE SAMPLE DEPTH

Depth (feet)	Well #12 Core (C-1)		#13 (C-2)		#14 (C-3)		#15 (C-4)		#16 (C-5)	
0										
2										
4	1		1	(232)	1	3.9	1		1	
6	2		2		2	1.7	2		2	48.3
8	3	9	3		3	2.0(<1)	3	(806)	3	193.1
10	4	14.6	4		4	5.5	4	98.7	4	
12										
14	5	5.7(6)	5	9.4	5	22.0	5	39.6	5	125.2
	6	25.3								
16	7	23.0(25)	6	21.0(24)	6	99.6	6	42.6	6	493.1
18	8	9.5	7	31.9	7	71.0(78)	7	7.7		
20	9	10.8	8	(209)	8		8	9.8	7	57.3(76)
22	10	8.5(11)	9	81.5	9	29.1(25)	9	1.2(2)	8	46.2
	11	6.0	10	47.2	10		10		9	37.2(50)
24	12	1.9(2)	11	71.0(80)	11	2.7(4)	11	4.1	10	33.2
26	13	1.1	12	40.6	12	4.0	12	13.7	11	19.3
28	14	4.0(1)	13	37.4	13	1.9	13	42.7(54)	12	14.1
	15	4.4	14	47.2	14	2.1	14	56.6	13	4.4(11)
30	16	16.9(19)	15	25.3	15	1.7(<1)	15	49.2(42)	14	15.1
32			16	57.2	16		16	27.2	15	26.0(20)
			17	17.8	17	5.5	16	22.4	16	17.7
34			18				18	7.6(7)	17	

Phenol concentration as ppm (μg/g) on a wet weight basis.

Explanation:

x y(z)

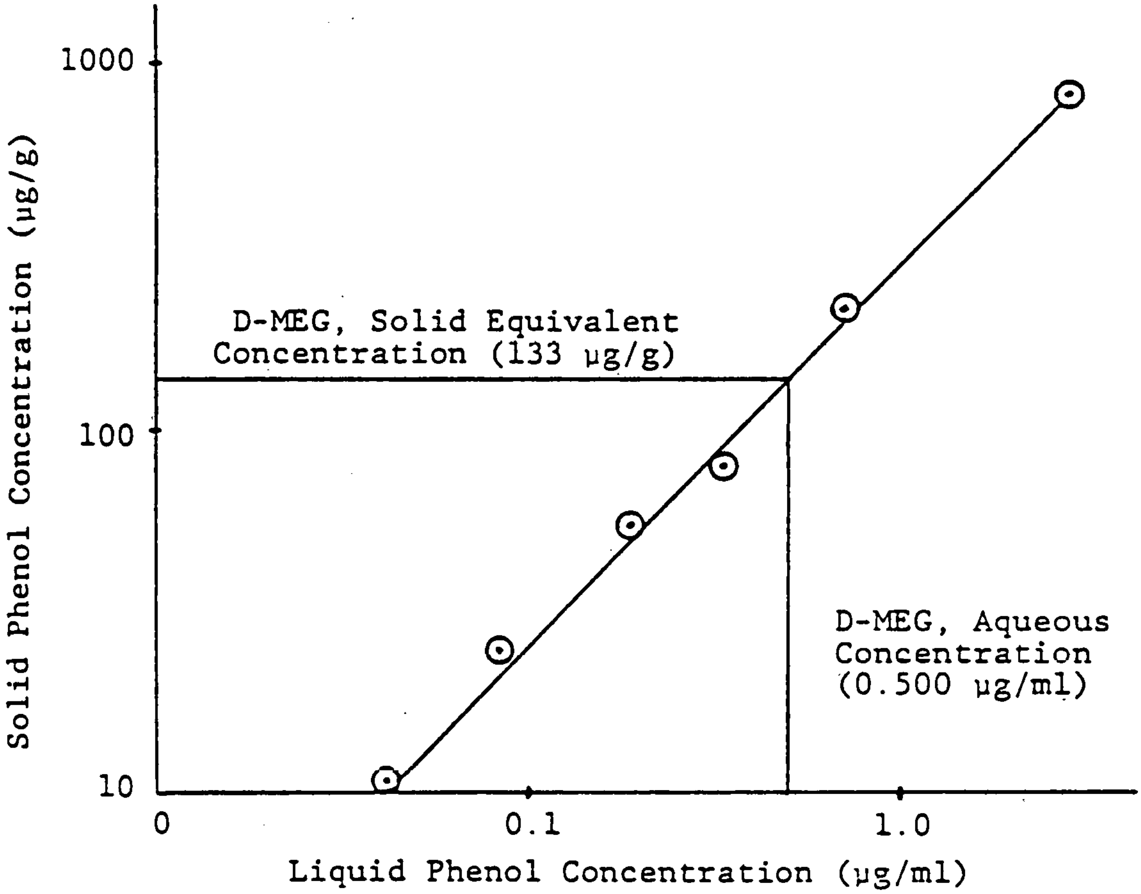
x = Sample number
y = P&M results
z = Radian results

TABLE 4-2. ANALYSIS OF EXTRACTABLE PHENOLS

Sample	Phenol Solid Concentration (μg/g)	Phenol Extractable Concentration[1] (μg/ml)
C-1-10	11	0.042
C-1-7	25	0.084
C-4-13	54	0.189
C-3-7	78	0.339
C-2-8	209	0.704
C-4-3	806	2.81

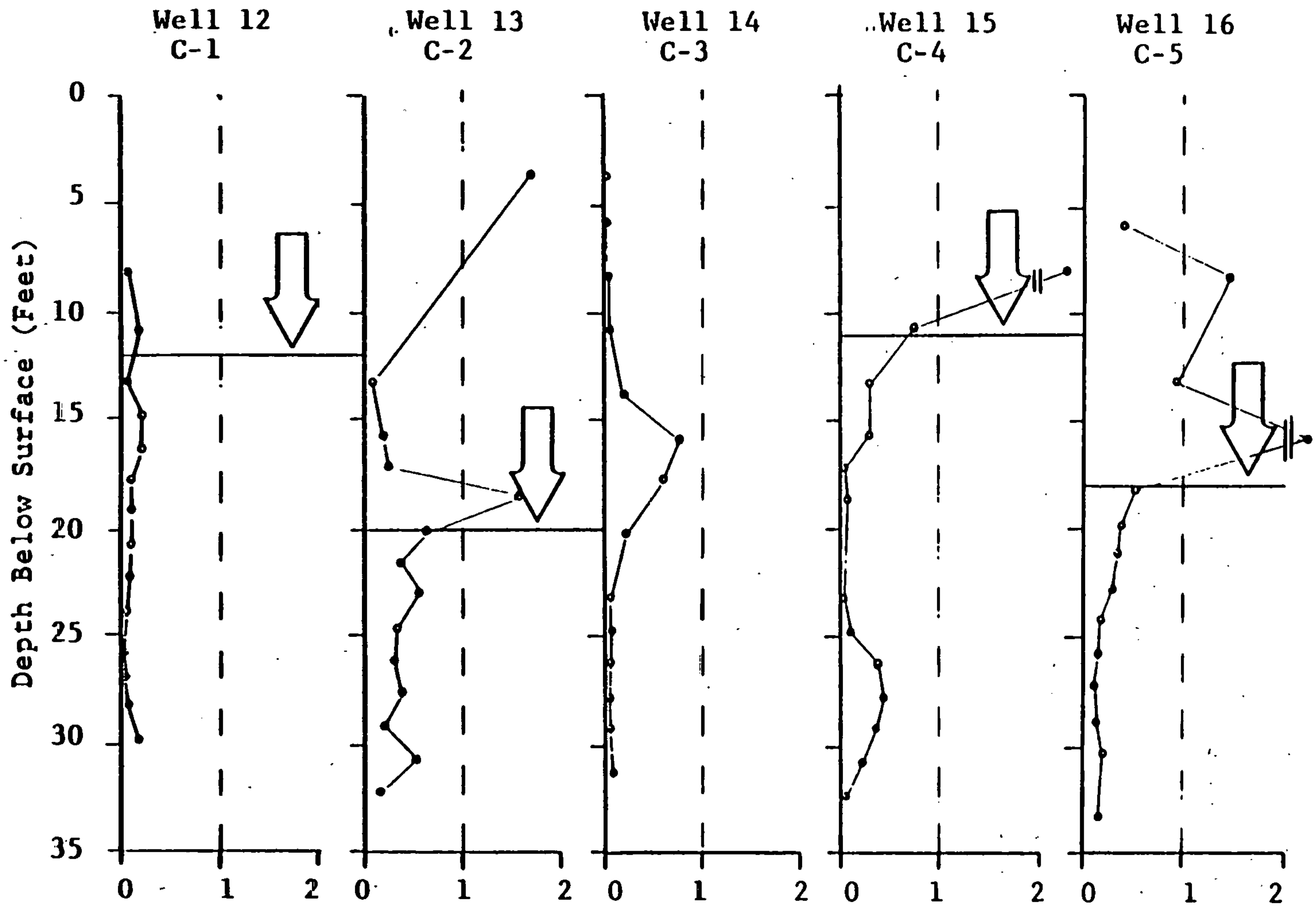
[1] Includes a ten-fold dilution for comparison with D-MEG value.

FIGURE 4-1. SOLID VS LIQUID PHENOL CONCENTRATION



words, the D-MEG value of .500 μg/ml will be exceeded. Figure 4-2 presents plots of this degree of severity of phenol contamination as a function of depth for the five cores. Arrows have been drawn to indicate the depth of excavation necessary to remove contaminated soil (i.e., DS>1). The depth of well 12 is indicative of convenience in removal in relation to depths on either side. No removal is necessary for well 14 although lateral migration of phenol from the spill site is hinted at the 15-20 foot depth.

FIGURE 4-2. DEGREE OF SEVERITY OF PHENOL CONTAMINATION AS A FUNCTION OF DEPTH



Degree of Severity = $\frac{\text{Solid Concentration}}{\text{D-MEG}}$

5.0 CONCLUSIONS

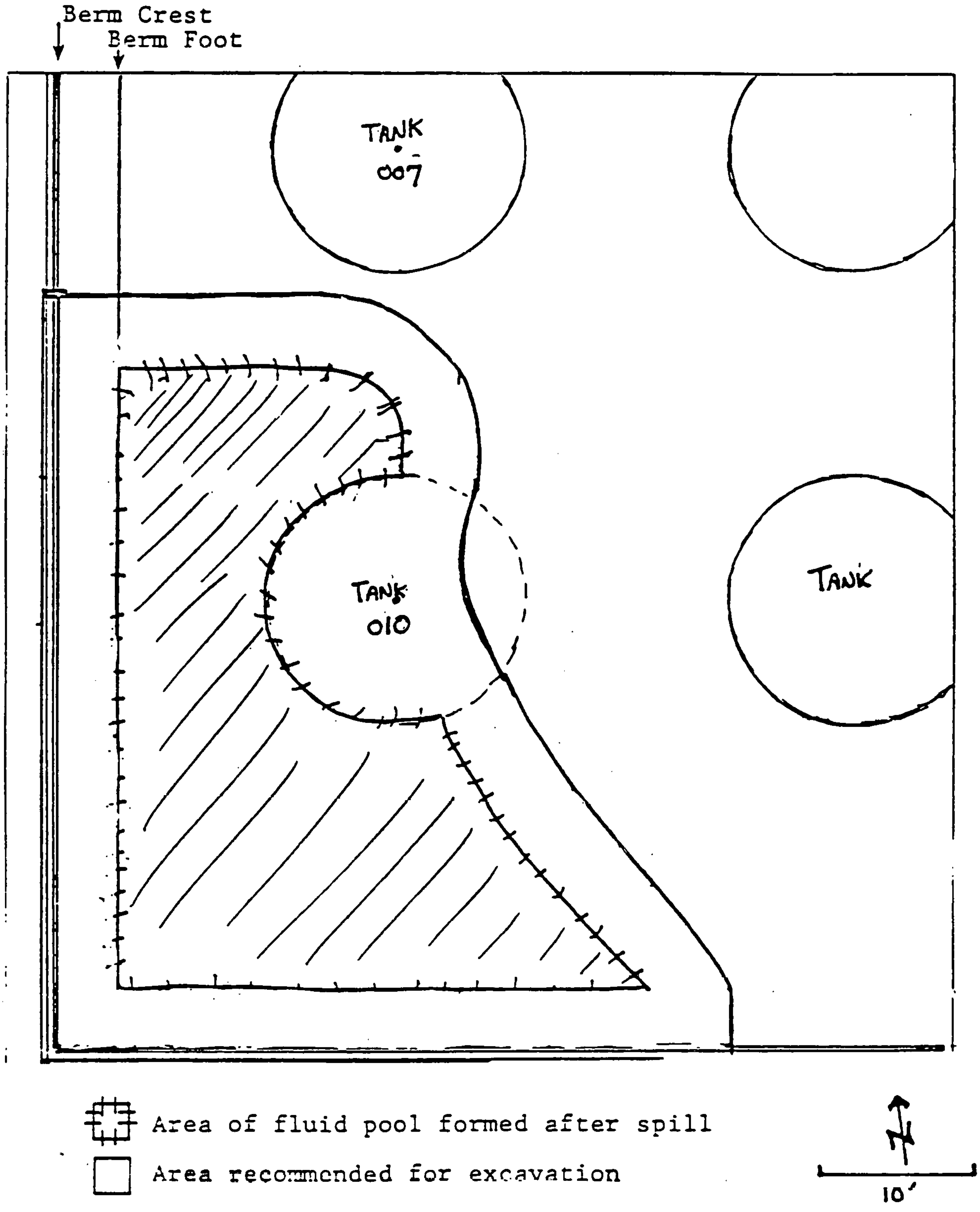
The volume of contaminated soil to be excavated is estimated to be 90 cubic yards. It was established from the depth information in Figure 4-2 and the cross-sectional area of the fluid pool formed after the spill. This area is presented in Figure 5-1. The excavation depth is 11 feet below (south of tank 010) and drops to 20 feet in the area of the spill north of that tank.

The recommended cross-sectional area of approximately 1770 square feet was established by extending the edge of the observed fluid pool by five feet. Although the concrete pad for tank 010 has probably limited the amount of phenol transported beneath it, evcavation is planned beneath the pad to facilitate simplicity in excavation.

Figure 5-2 presents a depth profile looking across the tank from east to west.

This action is recommended to remove the majority of the SRC product as well as the more mobile species such as phenol. To insure the effectiveness of this action, the first soil sample from each core within the spill area below the excavation interface will be extracted using the EP methodology and then subjected to GC-MS scan for priority pollutants. If concentrations of other contaminants are below their appropriate D-MEG based threshold value the remedial action is considered completed. If not the interface will be redefined at lower elevations as necessary.

FIGURE 5-1. AREA OF SPILL AND RECOMMENDED EXCAVATION AT SRC TANK FARM



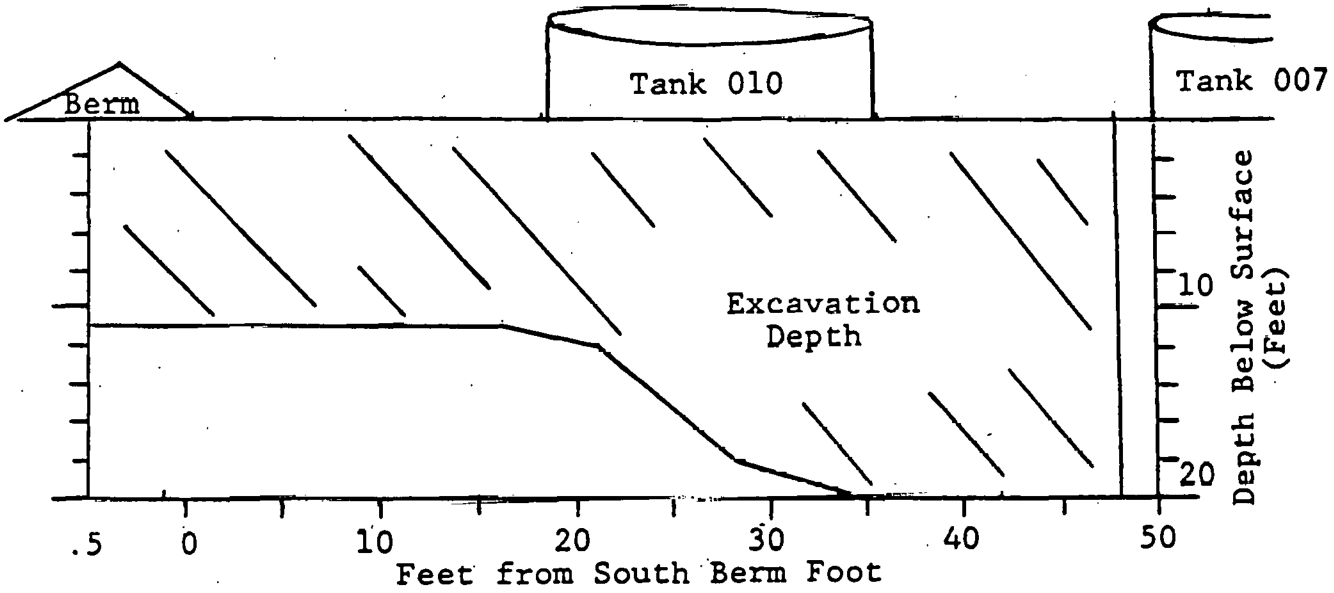


FIGURE 5-2. VIEW OF EXCAVATION DEPTH

☆U.S. GOVERNMENT PRINTING OFFICE: 1980-740-145/1005