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Assessment of Ground Water and Surface Water Contamination at the Washington State University Chemical Dump Site
Pullman, Washington
March 13-15, 1990

by
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ABSTRACT

Ground water and surface water samples were collected March 13-15, 1990, from the Washington State University Chemical Dump Site in Pullman, Washington. Samples were analyzed for volatile and semivolatile organic compounds, priority pollutant metals, chlorinated pesticides, organophosphorus pesticides, herbicides, polychlorinated biphenyls (PCBs), cyanide, beta-radiation, and conventional water quality parameters. In general, contaminant concentrations at the site were low, confirming previous ground water sample results. Volatile and semivolatile organics, chlorinated pesticides and organophosphorus pesticides were detected primarily between the chemical waste cell and the manure disposal area. Herbicides picloram and dinoseb were detected at low concentrations in wells downgradient of the chemical waste cell. At least one priority pollutant metal was detected at low concentrations in most of the wells. PCBs were not detected in ground water or surface water samples. Cyanide was detected in wells downgradient of the manure disposal area and in surface water samples. Beta-radiation was below the detection limits for most of the wells sampled.

The hydrogeologic characterization of the facility is incomplete; areas where additional monitoring wells are needed to define the extent of contamination are identified. The construction of a number of wells is suspect for water quality sampling and should be evaluated to determine if the wells should be rehabilitated or decommissioned.

INTRODUCTION

Site Description

The Washington State University (WSU) Chemical Dump Site is located in Pullman, Washington, (Figure 1) on approximately 16 acres on the eastern edge of campus (T14N, R45E, Section 4). Between 1970 and 1980 manure, biological, low-level radioactive, and chemical waste generated at WSU were disposed of in a hazardous waste landfill, referred to as the Chemical Dump Site (see Figure 2). The landfill is located on a south-facing slope that is bordered by Airport Creek. Chemical and low-level nuclear wastes were inventoried and disposed of in separate unlined cells measuring about 12 feet deep, 2 feet wide, and 12 feet long. These cells were covered with approximately eight feet of loess obtained from on-site (Muniz, 1991). An inventory of the chemicals disposed of at the site is shown in Appendix A. Manure was disposed of west of the waste cells, in a gully which had been excavated to the fractured basalt. It was also covered with approximately eight feet of loess. After 1980, waste was no longer accepted at the site.

Previous Studies

In the spring of 1980, WSU installed nine on-site monitoring wells which were monitored monthly for pH, dissolved oxygen, and water levels. Ground water samples were collected from 1981 to 1983 and tested for conductivity, pH, sodium, chloride, nitrate, sulfate, total organic carbon, selected pesticides, chlorinated hydrocarbons, and metals.

Since that time, the chemical dump site has been the subject of two master theses. In 1985, 19 additional monitoring wells were installed as part of a ground water flow modeling thesis (Kuhlman, 1986). These well logs have been included as Appendix B. Also in 1988, samples were collected for selected parameters from several of the monitoring wells as part of another thesis to determine the hydrogeochemistry of the site (Martinez, 1989). Analytical results from Martinez (1989) are summarized in Table 1. Arsenic, lead, selenium, mercury, chromium, copper, and zinc were detected in several on-site wells. The highest concentrations of organic contaminants were detected in well 14A. None of the pesticides tested for were detected. Low levels of beta radiation were detected in most of the wells sampled.

Study Objectives

The Department of Ecology Eastern Regional Office (ERO) requested the Toxics Investigation and Ground Water Monitoring Section (TI&GWIS) to confirm the existence of previously detected ground water contamination at the WSU chemical dump site, determine if other contaminants listed in the chemical inventory were present, and to evaluate the adequacy of the existing monitoring network.

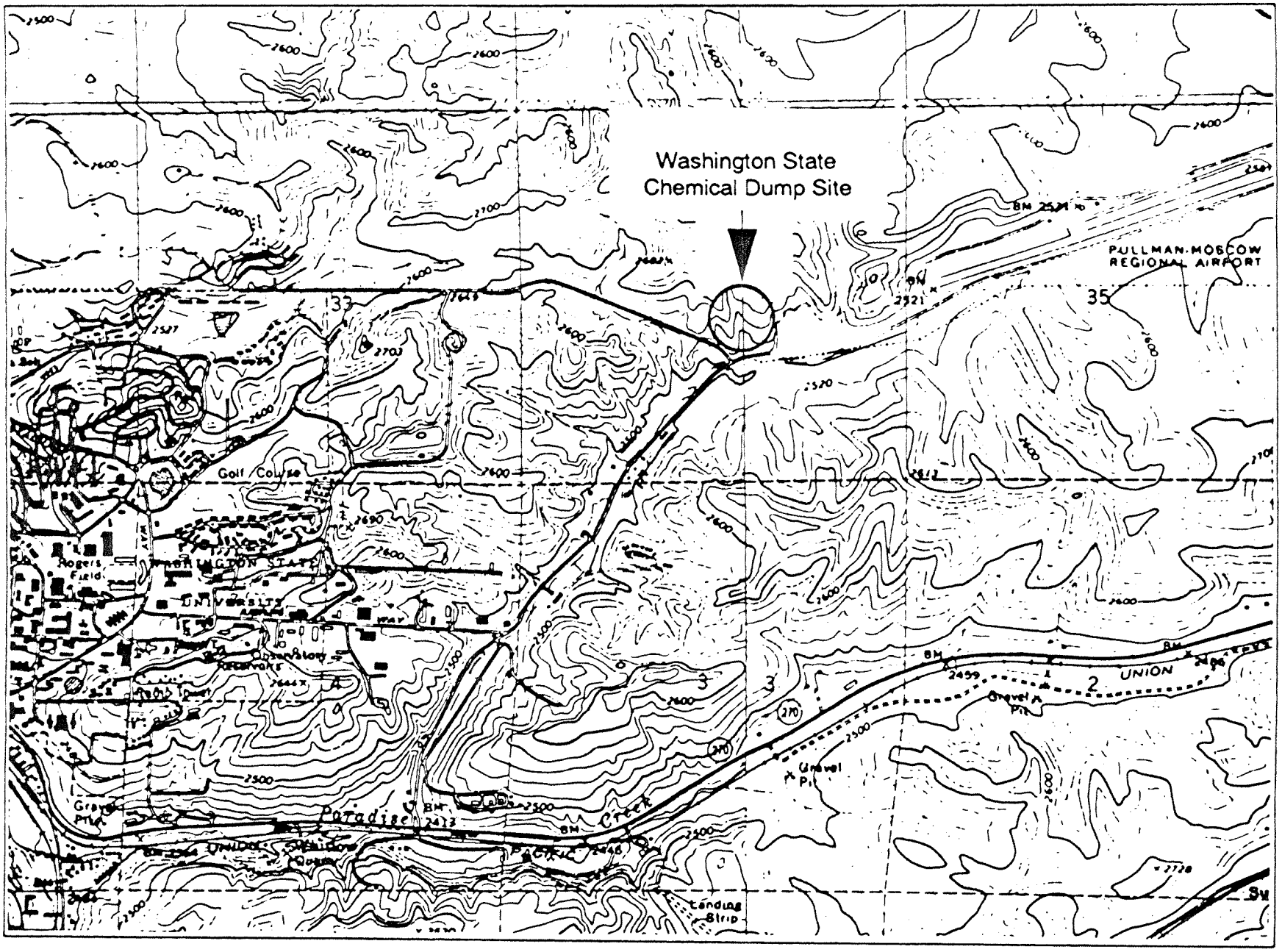

Figure 1: Washington State Chemical Dump Site - Location Map

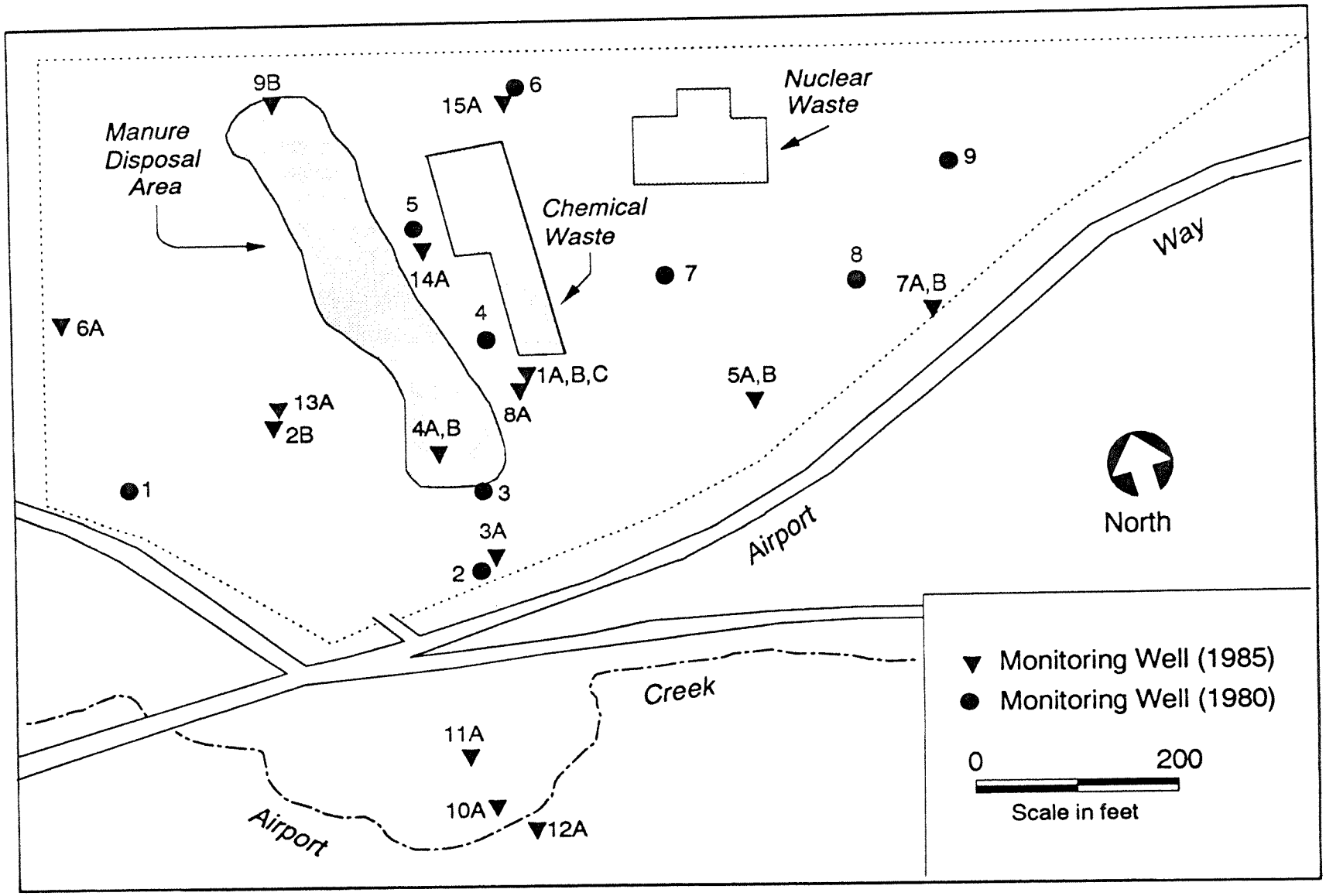

Figure 2: Washington State University Chemical Dump Site

Table 1: Summary of WSU results for monitoring wells at the Chemical Dump Site, April 2, 1988 (Martinez, 1989)

	1A	2B	3A	4A	5A	6A	7A	9B	11A	14A	15A
Metals (Totals) (ug/L)											
Arsenic	11	24	49	33	9.6	9.6	9.6	8.2	63	35	55
Cadmium	3u	3u	3u	3u	3u	3u	3u	3u	3u	3u	3u
Lead	9.5	5u	6.4	4.5	5u	5u	5u	5u	5u	5u	5u
Selenium	4.7	12	39	23	5u	5.6	5u	5u	20	22	37
Mercury	1.0	2.5	1u	1u	1u	1u	1u	1u	1.1	1u	1u
Chromium	11	11	9.4	11	12	12	13	9.4	8.5	8.5	8.5
Copper	5u	7.7	7.0	5u	42	9.4	11	14	5u	18	5u
Nickel	–	–	–	–	–	–	–	–	–	–	–
Silver	10u	10u	10u	10u	10u	10u	10u	10u	10u	10u	10u
Zinc	41	36	28	37	53	45	53	58	32	36	5.2
Barium	400u	400u	400u	400u	400u	400u	400u	400u	400u	400u	400u
Boron	0.02u	0.02u	0.62	0.02u	0.02u	0.02u	0.02u	0.02u	0.03	0.44	0.02u
Organics (ug/L)											
chloroform	0.05u	0.05u	0.05u	0.05u	2.0	0.05u	0.05u	0.13	0.05u	860	0.07
benzene	1u	1u	5.8	16	1u	1u	1u	1u	1u	37	1u
carbon tetrachloride	0.05	0.05u	0.05u	0.05u	8.4	0.05u	0.05u	0.05u	0.05u	38	0.05u
trichloroethylene	0.05u	0.05u	0.05	1.5	0.20	0.05u	0.05u	0.05u	0.05u	60	0.05u
chlorobenzene	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u
dichlorobenzene	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u	0.05u
Pesticides (ug/L)											
2,4-D	40u	40u	40u	40u	40u	40u	40u	40u	40u	40u	40u
2,4,5-T	1.6u	1.6u	1.6u	1.6u	1.6u	1.6u	1.6u	1.6u	1.6u	1.6u	1.6u
Toxaphene	5u	5u	5u	5u	5u	5u	5u	5u	5u	5u	5u
Endrin	3u	3u	3u	3u	3u	3u	3u	3u	3u	3u	3u
Lindane	3u	3u	3u	3u	3u	3u	3u	3u	3u	3u	3u
Methoxychlor	1u	1u	1u	1u	1u	1u	1u	1u	1u	1u	1u
cyanide (mg/L)	0.26u	0.26u	0.26u	0.26u	0.26u	0.26u	0.26u	0.26u	0.26u	0.26u	0.26u
beta-radiation (pCi/L)	2.1	2.8	4.4	16	3	5.6	1.6	–	7.6	–	4.9

u = Not detected at detection limit shown – = Not analyzed = Detected values

GEOLOGY/HYDROGEOLOGY

Regional

The following is summarized from Martinez (1989). WSU is located in eastern Washington in the geologic province of the Columbia Plateau. The geology of the Pullman area consists of Pre-Tertiary crystalline basement rock overlain by Miocene to early Pliocene flood basalt flows and sedimentary interbeds, capped by Pleistocene loess deposits (Palouse Formation). The basement rocks of Pre-Tertiary age have an irregular surface and are probably a part of the Idaho batholith. The overlying basalts and associated sedimentary interbeds are part of the Wanupum and Grande Ronde formations of the Yakima Basalt Subgroup of the Columbia River Basalt Group. Loess, deposited as dunes, forms the present topography.

The upper and lower zones of individual basalt flows tend to be highly fractured and yield significant quantities of water. In general, the fine-grained interbeds restrict ground water flow. The nearly horizontal attitude of the basalts and interbeds results in a series of stacked, confined aquifers with limited vertical communication. Regional ground water flow in these units is west toward the Snake River. Ground water flow in the loess is unconfined and is controlled by local topography. Muniz (1991) noted some low permeability zones in the loess which were attributed to the presence of caliche or other low permeability materials.

Local

Based on the 1985 monitoring well logs (Kuhlman, 1986), site stratigraphy consists of loess (Palouse Formation) overlying fractured basalt (Columbia River Basalt). Thickness of the loess over the site ranges from 8 feet near Airport Creek to approximately 100 feet at the northern part of the site. The thickness of the fractured basalt ranges from about 3 to 10 feet, and overlays an undetermined thickness of unfractured basalt (Kuhlman, 1986).

Kuhlman modeled the local aquifer as a two layered flow system. The hydraulic conductivity of the loess, the upper layer, ranged from 0.015 to 0.029 feet per day based on falling head slug tests at on-site wells. No site-specific hydraulic conductivity data are available for the fractured basalt, the lower layer. Kuhlman estimated the hydraulic conductivity of the fractured basalt to range from 1.2 to 2.6 feet per day.

Kuhlman assumed ground water flow was solely to the south. However, at the time of Kuhlman's study, well 15A had not yet been installed. After the installation of this well, Martinez (1989) interpreted water level data to indicate an additional northward component of flow. Ecology's interpretation, based on water levels obtained during the March inspection, is that ground water flow is to the south and east (See Results section, Field Observations). Depth of the water table from the ground surface ranges from about 5.5 to 37.5 feet. Well water levels fluctuate seasonally one to ten feet in response to precipitation (Kuhlman, 1986).

METHODS

Sampling and Analysis

Sampling was conducted March 13-15, 1990, by Laura Chern and Jon Bennett of TI&GWIS, and Flora Goldstein of the ERO. Sample locations are shown in Figure 3. Samples were analyzed for total organic carbon (TOC), total dissolved solids (TDS), nonvolatile suspended solids, ammonia, nitrate/nitrite, total phosphorous, volatile and semivolatile organics, priority pollutant metals, chlorinated pesticides, organophosphorus pesticides, herbicides, PCBs, cyanide, and beta radiation. Analytes, test methods, and detection limits are listed in Table 2.

Sixteen on-site monitoring wells and piezometers were sampled, eleven of which were selected to replicate previous studies. Five additional wells were included in this investigation to help determine the lateral and vertical extent of contamination at the site. All wells were completed in the loess, with the exception of 1A, 3A, 4A, 5A, 6A, 7A, and 11A, which were completed at the loess/basalt interface. Wells range in depth from 10.5 to 38.5 feet. Wells 1A through 14A are constructed of a 2-inch PVC pipe with a perforated casing, a mesh polypropylene filter wrap and a 2-foot concrete surface seal. Well 15A is constructed of a 2-inch PVC pipe with a slotted screen, a sand pack, a bentonite seal and a cement seal.

During an initial site visit in the fall of 1989 water level measurements were obtained using an electronic water level indicator. Upon returning to the site in March 1990, water level measurements were obtained again at each well prior to purging. All monitoring wells were purged dry on March 12, 1990, using a teflon bailer. The bailer was cleaned between each well with deionized water. Purge water was stored on-site in plastic 5 gallon barrels provided by the university. Wells required 1-2 days to recharge before sampling could begin. Prior to sample collection water level measurements were recorded. Grab samples were collected and pH, temperature and specific conductance were measured. Samples were then collected using a decontaminated teflon bailer. Bailers were decontaminated using a Liquinox® wash and subsequent rinses of hot tap water, ten percent nitric acid, distilled/deionized water, pesticide-grade methylene chloride, pesticide-grade acetone, and distilled/deionized water, then air-dried and wrapped in aluminum foil until used.

Samples collected for dissolved metals (MW-5A and MW-7A) were filtered in the field using a 0.45μm polycarbonate membrane filter and an all teflon filtration system. Due to high turbidity, samples from the remaining wells were not filtered. For the two samples that were filtered in the field, all tubing used for filtering was dedicated with the exception of the silastic tubing in the pump head (approximately 12 inches). This tubing was flushed with 500 mL each of 10 percent nitric acid solution and deionized water prior to sampling.

Metals samples were preserved with 1 mL of nitric acid to a pH$<$2, while volatile organics were preserved with two drops of 1:1 hydrochloric acid. All samples were placed in priority pollutant cleaned containers supplied by I-Chem, Hayward, California, and stored on ice for transport to the Ecology/EPA Environmental Laboratory in Manchester, Washington. Chain-of-custody was maintained for all samples in accordance with Ecology procedures (Huntamer, 1986).

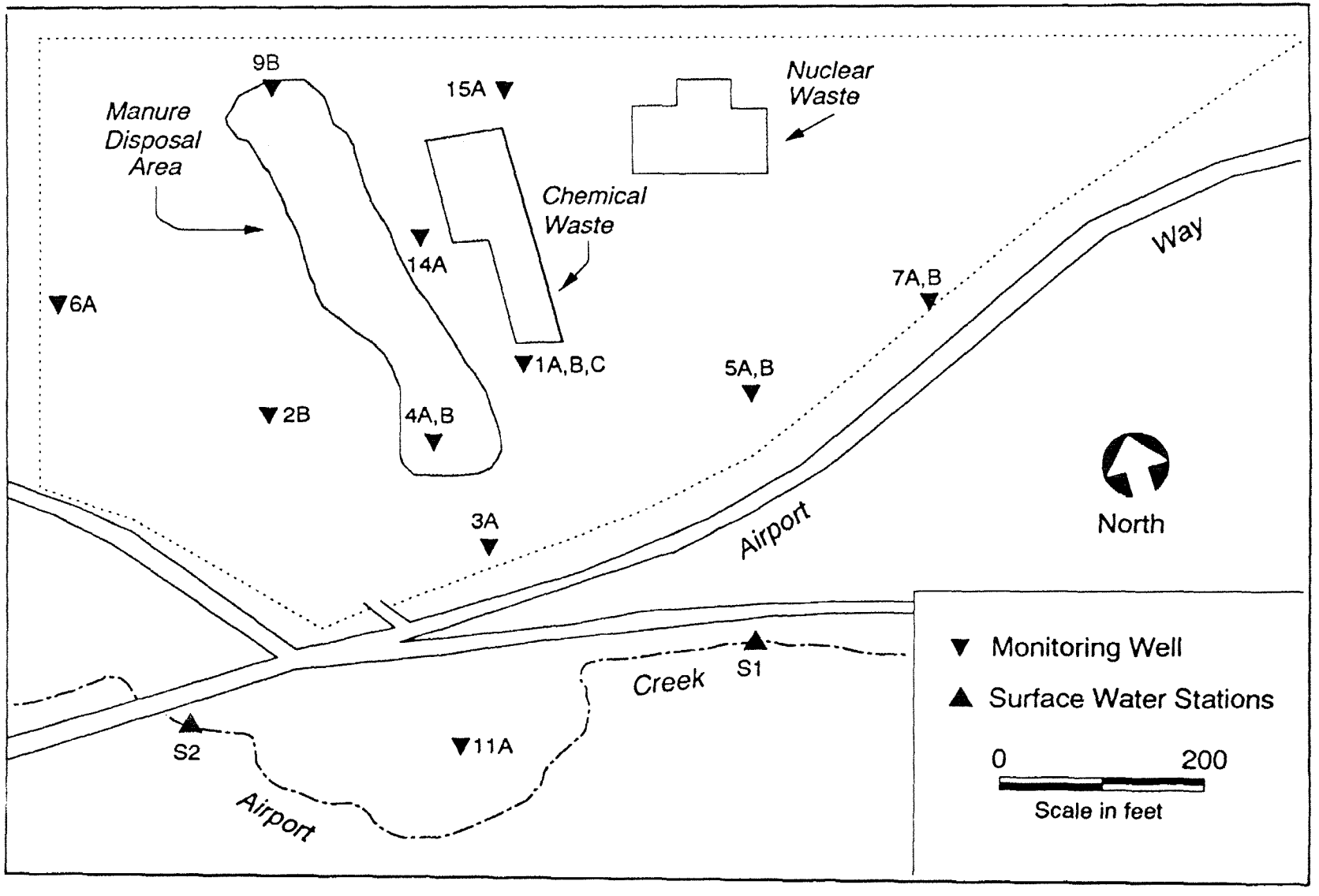

Figure 3: Washington State University Chemical Dump Site
Ecology Sample Stations

Table 2: Parameters, Analytical Methods and Detection Limits

Parameters	Analytical Method	Reference	Detection Limit
Field Parameters:			
Water Level	Slope Indicator Well Probe	NA	0.05 ft.
pH	Beckman pH Meter	NA	0.1 Std Units
Specific Conductance	Beckman RC-15C Conductivity Bridge	NA	10 μmhos/cm
Temperature	Precision Thermometer	NA	0.1°C
Conventionals:			
Total Dissolved Solids	#160.1	EPA 1983	10 mg/L
Ammonia-N	#350.1	EPA 1983	0.001 mg/L
Nitrate/Nitrite-N	#353.2	EPA 1983	0.01 mg/L
Total Phosphate	#365.3	EPA 1983	0.001 mg/L
Total Organic Carbon	#415.1	EPA 1983	0.1 mg/L
Metals (Total Recoverable):			
Arsenic	#206.2	EPA 1983	1.0 μg/L
Antimony	#204.2	EPA 1983	1.0 μg/L
Beryllium	#200.7	EPA 1983	1.0 μg/L
Cadmium	#213.2	EPA 1983	0.2 μg/L
Chromium	#200.7	EPA 1983	4.0 μg/L
Copper	#200.7	EPA 1983	2.0 μg/L
Lead	#239.2	EPA 1983	1.0 μg/L
Mercury	#245.1	EPA 1983	0.02 μg/L
Nickel	#200.7	EPA 1983	20 μg/L
Selenium	#270.2	EPA 1983	1.0 μg/L
Silver	#200.7	EPA 1983	2.0 μg/L
Thallium	#279.2	EPA 1983	2.0 μg/L
Zinc	#200.7	EPA 1983	5.0 μg/L
Cyanide	#335.3	EPA 1983	0.001 mg/L
Volatile Organics	#624	EPA 1983	1.0 μg/L
Semivolatiles	#625	EPA 1983	1.0 μg/L
Pesticides/PCBs	#608	EPA 1983	0.01 μg/L

NA = Not Applicable

U.S. EPA. Methods for the Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, March 1983.

Two surface water samples, one upstream and one downstream of the site, were collected from Airport Creek, and are designated S1 and S2, respectively. Grab samples were obtained by immersing the sample bottles in areas of free flowing water.

Quality Assurance/Quality Control Sampling

In addition to laboratory calibration standards and method blanks, field quality assurance samples consisted of a blind duplicate, transfer blanks, transport blanks, matrix spikes, and matrix spike duplicates.

Blind duplicate samples (labeled 14B) were collected for all parameters from well 14A. Transfer blanks were collected by pouring organic-free water through a decontaminated teflon bailer and tested for volatile and semivolatile organics, metals, pesticides, herbicides, PCB's, and cyanide. Transport blanks were carried throughout the investigation for the parameters listed above.

Methylene chloride (25 μg/L) and isophorone (0.2 μg/L) were detected in the transfer blank. Zinc (7.2 μg/L) was detected in the transport blank. All detected values for methylene chloride and zinc that were less than five times the blank levels have been qualified with a "B". Isophorone was not detected in any of the well samples.

Overall precision (sampling + laboratory) calculated from detected values in blind duplicate samples for ground water was good (the relative percent difference being $\pm$20%) for most conventional and metals analysis, but showed a wide range of variation for the organics. Parameters with low precision include; total phosphate (24%), total organic carbon (29%), ammonia (67%), zinc (32%), lead (52%), chromium (52%), 1,1,2-trichloroethane (127%), carbon tetrachloride (132%), trichloroethene (139%), 1,1,1-trichloroethane (146%), alpha-endosulfan (37%), dinoseb (26%), 2,4,5-TP (Silvex)(30%), and picloram (36%). Low precision also occurred in duplicate samples with concentrations at or near the detection limit. Poor precision for organics analyses was probably due to interference from particulate organic matter in the samples.

Matrix spike and spike duplicate recoveries were excellent for volatiles, semivolatiles, and metals (90-110%) and good (75-125%) for the pesticides. Several volatile organics were detected in one of the method blanks, but at levels below the detection limits. No qualification of the data was necessary. Zinc was detected in one method blank at an estimated concentration of 6.0 μg/L.

RESULTS

Field observations and results of analyses of ground water and surface water samples collected from the WSU Chemical Dump Site are summarized in Tables 3 through 7 and discussed below.

Field Observations

All sixteen wells were purged dry or nearly dry. A strong odor and dark organic material was observed in well 4B. Water level measurements, pH, temperature, and specific conductance readings and purge volumes are listed in Table 3.

A water-table contour map, using water level elevations obtained prior to purging the wells, is shown in Figure 4. Based on Figure 4, the direction of ground water flow is generally toward the south with an eastward component of flow beneath the northeast portion of the site. The horizontal hydraulic gradient is about 0.1 (feet/feet). Vertical hydraulic gradients can be calculated where nested wells exist (1A,1B,1C; 4A,4B; 5A,5B; and 7A,7B). Vertical downward gradients range from 0.02 to 0.2 (feet/feet).

Generally, pH ranged from 6.85 to 8.0, with the exception of well 15A which had a pH of 9.3. This elevated pH was confirmed using pH paper. Specific conductance ranged from 100 to greater than 1000 μmhos/cm, the maximum limit of the meter. Specific conductance exceeded 1000 μmhos/cm in wells 3A, 4A, 4B, and 15A.

Conventionals

Conventional parameter results are shown in Table 4. Concentrations for total dissolved solids (160-1540 mg/L), total organic carbon (2.8-136 mg/L), ammonia-N (0.01-60.4 mg/L), nitrite/nitrate-N (0.01-8.4 mg/L), and total phosphate (0.005-0.21 mg/L) varied widely. In general, higher concentrations for these parameters occurred in wells 3A, 4A and 4B, which are located downgradient of the manure disposal area.

Upstream (S1) and downstream (S2) results from Airport Creek were identical for total dissolved solids (279 mg/L) and ammonia-N (0.05 mg/L). However, total organic carbon increased from 14.2 to 16.4 mg/L, nitrite/nitrate-N increased from 3.9 to 8.7 mg/L, and total phosphate decreased from 0.09 to 0.06 mg/L from the upstream to the downstream samples.

Metals

All wells were tested for total metals (unfiltered) with the exception of wells 5A and 7A. Field sample filtration was discontinued because of high suspended sediments in the samples. Sample results are shown in Table 4. The metals detected and maximum observed concentrations are listed as follows: arsenic, 19.4 μg/L (11A); cadmium, 1.8J μg/L (1C); lead, 84 μg/L (1C); selenium, 5.2 μg/L (15A); mercury, 0.07J μg/L (14A); chromium, 38.7 μg/L (9B); copper, 37.2 μg/L (9B); nickel, 49J μg/L (3A); silver, 9.5J μg/L (9B); and zinc, 341 μg/L (11A). Arsenic, cadmium, lead, selenium, and copper were also detected in well 15A, the designated upgradient well. Dissolved metals concentrations were generally much lower than total metals concentrations and were commonly near the detection limit. Dissolved cadmium and copper

Table 3: Summary of Ecology results for indicator parameters from monitoring wells at the Washington State University Chemical Dump Site

Monitoring Well	Water Level+ (ft) 3/12/90	Water Level+ (ft) 3/13–15/90	pH (s.u.)	Temp. (C)	Specific Conductance (umhos/cm)	Purge Volume (gal)
1A	15.70	15.86	7.22	9.7	252	3.7
1B	14.95	15.15	7.41	9.2	167	2.5
1C	15.48	15.69	7.14	9.2	200	0.7
2B	15.53	15.59	7.99	9.7	370	2.2
3A	7.18	8.35	6.89	7.3	>1000	3.21
4A	10.98	10.82	7.05	9.4	>1000	3.0
4B	10.40	10.09	7.02	8.7	>1000	1.4
5A	17.81	17.93	7.04	9.7	290	3.3
5B	18.75	18.93	6.85	9.3	100	1.5
6A	13.97	14.27	7.9	8.7	270	4.0
7A	8.46	8.34	7.19	9.6	240	5.0
7B	8.75	8.81	6.88	5.4	215	0.3
9B	9.68	6.89	6.99	7.0	450	3.0
11A	5.49	5.65	8.0	7.3	800	1.5
14A	11.91	12.12	7.12	8.4	482	1.2
15A	37.45	42.3	9.29	9.4	>1000	3.5

+ = Water level depth measured from top of casing

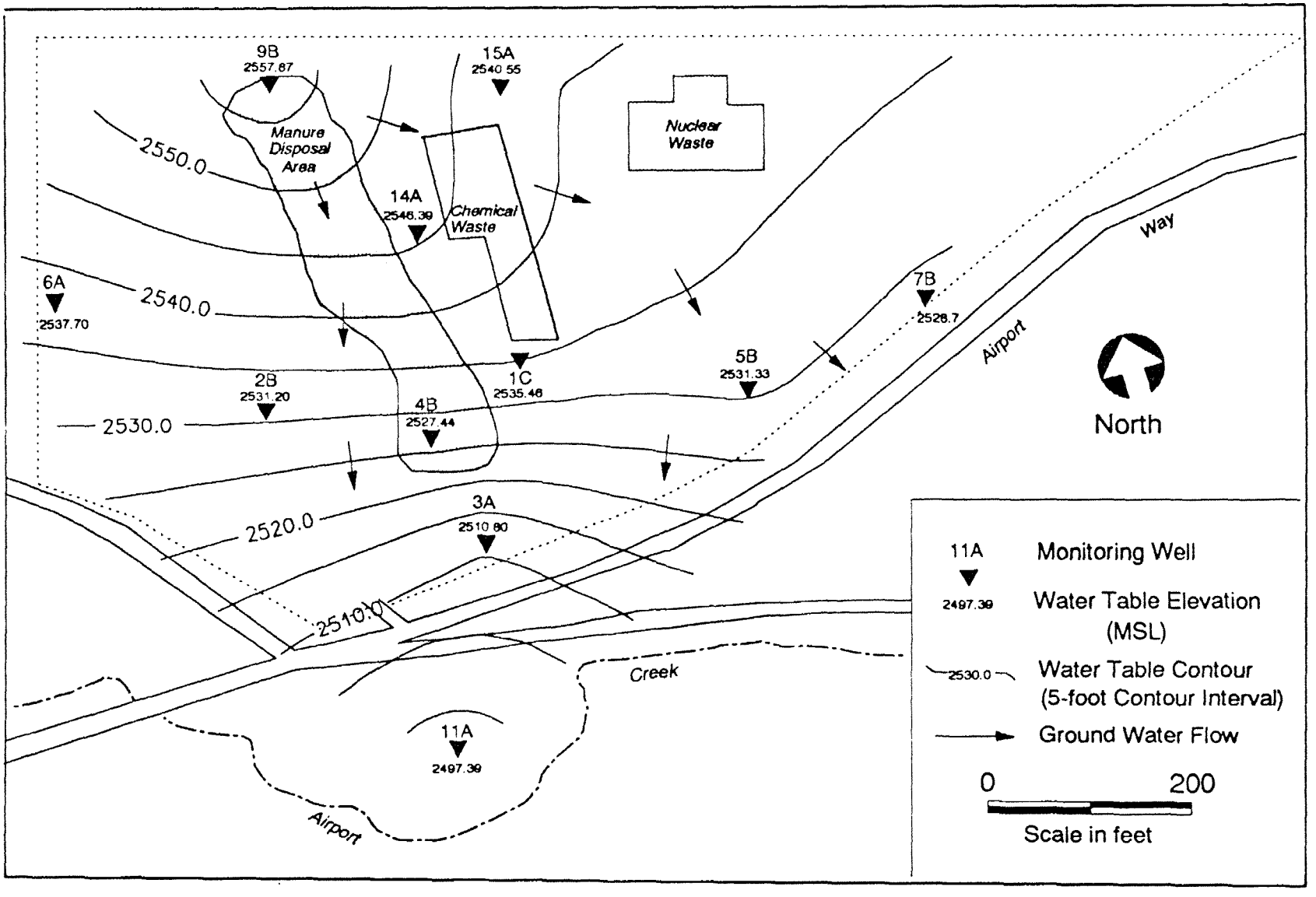

Figure 4: Washington State University Chemical Dump Site
Water Table Contour Map - March 12, 1990

Table 4: Summary of Ecology results for conventionals and metals from sampling stations at the Washington State University Chemical Dump Site

Monitoring Well	1A	1B	1C	2B	3A	4A	4B	5A	5B	6A	7A	7B	9B	11A	14A	14B*	15A	S1	S2
Sample No. 11-	8240	8239	8238	8241	8237	8244	8243	8232	8233	8236	8230	8231	8234	8242	8245	8246	8235	8250	8249
Sample Type	T	T	T	T	T	T	T	D	T	T	D	T	T	T	T	T	T	T	T
Conventionals (mg/L)																			
TDS	209	160	236	273	1040	1120	1540	206	179	201	187	–	446	571	411	399	617	279	279
NH3-N	ND	ND	0.006	ND	0.16	33	60	ND	0.014	ND	ND	–	0.23	0.1	0.097	0.048	0.007	0.056	0.05
NO2/NO3-N	4.4	2	1.5	0.68	0.026	ND	0.01	5.7	0.41	0.48	0.8	–	8.4	0.061	0.28	0.32	0.76	3.9	8.7
Total P	0.006	0.06	0.023	0.13	0.03	0.06	0.21	0.12	0.067	0.093	0.13	–	0.094	0.14	0.024	0.019	0.005	0.094	0.057
TOC	7.1	8.1	7.1	14	82	136	134	4.5	2.8	16	6.3	–	12	39	9.6	13	5.6	14	16
Cyanide	ND	ND	–	ND	0.002	0.012	0.017	ND	–	ND	ND	–	ND	ND	0.002	0.006	–	0.004	ND
Metals (ug/L)																			
Arsenic	1.0u	1.0u	2.1J	1.0u	2.9J	3.5J	8.6	1.0u	4.2J	2.2J	2.0J	–	9.5	19	3.9J	3.2J	1.1J	1.4J	1.0u
Cadmium	0.20u	0.79J	1.8J	0.21J	1.2J	0.48J	0.20u	0.31J	1.2J	0.20J	0.30J	–	0.83J	0.33J	1.2J	1.2J	0.90J	0.20u	0.20u
Lead	2.7J	7.0	84	11	6.9	2.5J	2.2J	1.0u	12	1.0J	1.0u	–	17	5.2	12	7.2	7.4	2.5J	1.8J
Selenium	1.2J	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.5J	1.0u	1.3J	–	1.0u	1.0u	1.0u	1.8J	5.2	1.4J	1.0u
Mercury	0.02u	0.02u	0.02u	0.02u	0.02u	0.02u	0.02u	0.02u	0.02u	0.02u	0.02u	–	0.02u	0.02u	0.07J	0.02u	0.02u	0.02u	0.02u
Chromium	6.1J	4.0u	9.3J	5.2J	4.0u	4.0u	4.0u	4.0u	24	6.1J	6.6J	–	39	4.0u	13J	7.6J	4.0u	4.0u	4.0u
Copper	2.0u	3.2J	12	3.6J	13	6.5J	5.0J	2.7J	24	4.5J	2.0u	–	37	7.7J	18	15	10	6.7J	5.9J
Nickel	20u	20u	20u	20u	49J	20u	35J	20u	27J	20u	20u	–	48J	20u	20u	26J	20u	20u	20u
Silver	2.0u	2.0u	2.0u	2.0u	2.0u	2.4J	7.0J	2.0u	5.9J	2.0u	2.0u	–	9.5J	4.4J	3.4J	3.0J	2.0u	2.1J	2.0u
Zinc	5.0u	7.2JB	31JB	5.9JB	28JB	11JB	6.2JB	11JB	77	8.4JB	19JB	–	96	341	53	38	30JB	24JB	15JB

T = Whole water-unfiltered

D = Dissolved fraction-filtered thru 0.45um polycarbonate filter

ND = Not detected at unspecified detection limit

J = Estimated concentration

B = Detected in blank

u = Not detected at detection limit shown

* = Duplicate

– = Not analyzed

were found in well 5A (0.31J μg/L and 2.7J μg/L), while arsenic (2.0J μg/L), cadmium (0.30J μg/L), selenium (1.3J μg/L), and chromium (6.6J μg/L) were detected in 7A. Cyanide was detected in wells 3A, 4A, 4B, and 14A with a maximum concentration of 0.017 mg/L in well 4B.

Metals results in Airport Creek samples were low or near the detection limit. Generally, concentrations were higher upstream than downstream. Metals detected include arsenic, lead, selenium, copper, and silver. Cyanide was also detected in the upstream sample at a concentration of 0.004 mg/L.

Organics

Several volatile organic compounds were detected in the wells. The results are listed in Table 5. Most of the detections occurred in one well, 14A, which is located adjacent to the chemical waste cell. Contaminants and the maximum observed concentrations include: carbon tetrachloride, 300 μg/L (14A); acetone, 1200 μg/L (15A); chloroform, 2900 μg/L (14A); 1,1,1-trichloroethane, 77 μg/L (14A); methylene chloride 290 μg/L (15A); trichloroethene, 45 μg/L (14A); and 1,2-dichloroethane 2500 μg/L (14A). Tentatively identified volatile organics include: cyclohexane in well 11A, tetrahydrofuran in well 4B, and 1,2-diethoxyethane in well 14A.

Semivolatile organic results are shown in Table 5. Di-n-butylphthalate, N-nitrosodiphenylamine, 1,2-dichlorobenzene, 1,4-dichlorobenzene, bis(2-ethylhexyl)phthalate, and 1,2,4-trichlorobenzene were detected at or near the detection limit in wells 11A, 14A, and 15A. Several semivolatile organics were tentatively identified in well 14A and it's duplicate sample 14B. These constituents and concentrations are listed in Appendix C.

Several pesticides, shown in Table 6, were detected in well 14A. Pesticides which occurred above the level of detection at concentrations of concern are heptachlor epoxide (1.3J μg/L), alachlor (6.1J μg/L), and dinoseb (126 μg/L). Picloram, which occurred in half of the wells sampled, was the most frequently observed pesticide. Concentrations ranged from 0.16 to 234 μg/L. Picloram was present at a concentration of 0.16 μg/L in 11A, which is located downgradient of the chemical waste cell and adjacent to Airport Creek.

None of the priority pollutant volatile or semivolatile organic compounds analyzed for were present above the detection limits in the two surface water samples. However, two tentatively identified semivolatile compounds, 2-cyclohexen-1-one (1.0 μg/L) and atrazine (1.4 μg/L), were detected in both samples with the higher concentrations occurring in the upstream sample. Atrazine was also detected in both surface water samples using the pesticide test method (EPA #608) at 0.75 and 0.64 μg/L.

Radionuclides

Samples from wells 1A, 1B, 3A, 4A, 4B, 5A, 7A, and 9B were analyzed by gamma spectroscopy for tritium (H-3), carbon-14 (C-14) and potassium-40 (K-40). Results are shown in Table 7. Radionuclide results are derived by subtracting a background value from the

Table 5: Summary of Ecology results for volatile and semivolatile organic compounds from sample stations at the Washington State University Chemical Dump Site (units are ug/L)

Monitoring Well	1A	1B	1C	2B	3A	4A	4B	5A	5B	6A	7A	7B	9B	11A	14A	14B*	15A	S1	S2
Sample No. 11-	8240	8239	8238	8241	8237	8244	8243	8232	8233	8236	8230	8231	8234	8242	8245	8246	8235	8250	8249
Volatile Organics																			
Carbon Tetrachloride	1.0u	1.0u	0.6J	1.0u	1.0u	1.0u	1.0u	19	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	300	61	1.0u	1.0u	1.0u
Acetone	3.0u	5.0u	6	31	33	130J	1.0u	1.0u	1.0u	120J	1.0u	1.0u	6.0u	1.0u	4.0u	2.0u	1200J	1.0u	1.0u
Chloroform	0.8J	1.0u	19	1.0u	1.0u	1.0u	1.0u	15	1.0u	1.0u	0.4J	3	1.0u	1.0u	2900	2800	1.0u	1.0u	1.0u
Benzene	1.0u	1.0u	1.0u	1.0u	1.0u	1	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	2.0u	1.0u	1.0u	1.0u
1,1,1-Trichloroethane	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	77	12	1.0u	1.0u	1.0u
Methylene Chloride	3.0u	1.0u	1.0u	1.0u	1.0u	18B	1.0u	1.0u	4.0u	2.0u	1.0u	1.0u	2.0u	1.0u	5B	3B	290J	1.0u	1.0u
Bromoform	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	3	2.0u	1.0u	1.0u	1.0u
1,1-Dichloroethane	1.0u	1.0u	1.0u	1.0u	1.0u	2	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	10	1J	1.0u	1.0u	1.0u
1,1-Dichloroethene	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	4	0.7J	1.0u	1.0u	1.0u
1,1,2-Trichloroethane	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	9	2	1.0u	1.0u	1.0u
Trichloroethene	1.0u	1.0u	1.0u	1.0u	1.0u	2	1.0u	0.2J	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	45	8	1.0u	1.0u	1.0u
1,1,2,2-Tetrachloroethane	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	2	0.4J	1.0u	1.0u	1.0u
1,2-Dichlorobenzene	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1	2.0u	1.0u	1.0u	1.0u
1,2,4-Trimethylbenzene	1.0u	1.0u	1.0u	1.0u	1.0u	0.2J	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	2.0u	1.0u	1.0u	1.0u
1,2-Dibromoethane (EDB)	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	4	0.7J	1.0u	1.0u	1.0u
1,2-Dichloroethane	1.0u	1.0u	10	1.0u	13	210	19	0.7J	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	2500	2400	1.0u	1.0u	1.0u
Tetrachloroethene	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	0.3J	2.0u	1.0u	1.0u	1.0u
Cis-1,2-Dichloroethene	1.0u	1.0u	1.0u	1.0u	4	5	0.4J	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	2.0u	1.0u	1.0u	1.0u
Semivolatile Organics																			
Di-n-Butylphthalate	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	2.0u	0.9u	0.8u	1.0u	1.0u	0.8u	0.09J	0.8u	0.8u	1.0u	0.8u	0.8u
N-Nitrosodiphenylamine	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	2.0u	0.9u	0.8u	1.0u	1.0u	0.8u	0.8u	0.8u	0.8u	1J	0.8u	0.8u
1,2-Dichlorobenzene	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	2.0u	0.9u	0.8u	1.0u	1.0u	0.8u	0.8u	0.6J	0.7J	1.0u	0.8u	0.8u
1,4-Dichlorobenzene	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	2.0u	0.9u	0.8u	1.0u	1.0u	0.8u	0.8u	0.2J	0.2J	1.0u	0.8u	0.8u
bis(2-ethylhexyl)phthalate	0.8u	0.8u	2.0u	0.8u	1.0u	4.0u	3.0u	2.0u	0.9u	0.8u	1.0u	1.0u	0.8u	0.8u	0.8u	0.8u	2	0.8u	0.8u
1,2,4-Trichlorobenzene	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	0.8u	2.0u	0.9u	0.8u	1.0u	1.0u	0.8u	0.8u	0.8u	0.1J	1.0u	0.8u	0.8u

* = Duplicate u = Not detected at detection limit shown J = Estimated concentration B = Detected in blank

Table 6: Summary of Ecology result for pesticides/herbicides from sample stations at the Washington State University Chemical Dump Site

Monitoring Wells:	1A	1B	1C	2B	3A	4A	4B	5A	5B	6A	7A	7B	9B	11A	14A	14B	15A	S1	S2
Sample No. 11–	8240	8239	8238	8241	8237	8244	8243	8232	8233	8236	8230	8231	8234	8242	8245	8246	8235	8250	8249
Pesticides (ug/L)																			
4,4'–DDT	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.12N	0.020u	0.013u	0.042	0.014u	0.85J	0.057NJ	0.022u	0.013u	0.013u
Endrin	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.065u	0.065NJ	0.022u	0.013u	0.013u
Methoxychlor	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.013u	0.020u	0.013u	0.014u	0.014u	0.92J	0.095J	0.22u	0.013u	0.013u
p.p' DDD	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.56J	0.076J	0.022u	0.013u	0.013u
4,4'–DDE	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.065u	1.7J	0.022u	0.013u	0.013u
Heptachlor	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.065u	0.065NJ	0.022u	0.013u	0.013u
alpha–Endosulfan	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.29J	0.42J	0.022u	0.013u	0.013u
Heptachlorepoxide	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	1.3J	0.081J	0.022u	0.013u	0.013u
Endosulfansulfate	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.72J	0.065NJ	0.022u	0.013u	0.013u
Atrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.75	0.64
Endrinaldehyde	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.065u	0.065NJ	0.022u	0.013u	0.013u
Alachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.5J	6.1J	ND	ND	ND
beta–Endosulfan	0.013u	0.013u	0.012u	0.013u	0.013u	0.013u	0.013u	0.013u	0.014u	0.13u	0.020u	0.013u	0.014u	0.014u	0.47J	0.051NJ	0.022u	0.013u	0.013u
Toxaphene	0.39u	0.39u	0.36u	0.39u	0.39u	0.39u	0.39u	0.40	0.43u	0.39u	0.56u	0.39u	0.41u	0.42u	1.95u	1.95u	0.65u	0.39u	0.39u
Pesticides Organophosphorous (ug/L)																			
Dimethoate	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.013u	0.01u	0.01u	0.01u	1.4	1.5	0.015u	0.01u	0.01u
Dichlorvos (DDVP)	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.013u	0.01u	0.01u	0.01u	0.03N	0.03N	0.015u	0.01u	0.01u
Fensulfothion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.6	4.3	ND	ND	ND
Monocrotophos	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.013u	0.01u	0.01u	0.01u	2.9	2.7	0.015u	0.01u	0.01u
Mevinphos	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.01u	0.013u	0.01u	0.01u	0.01u	0.52	0.51	0.015u	0.01u	0.01u
Fenamiphos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.11	0.08	ND	ND	ND
Herbicide (ug/L)																			
Trichlorobenzoic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	270J	260J	ND	ND	ND
2,3,6–Trichloro benzeneacetic acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	150J	150J	ND	ND	ND
Dinoseb	0.010u	0.010u	0.010u	0.010u	0.10N	1.7	1u	0.010u	0.010u	0.010u	0.010u	0.010u	0.010u	0.010u	97	126	0.010u	0.020u	0.010u
2,4,5–TP (Silvex)	0.010u	0.010u	0.010u	0.010u	0.10u	0.5u	1u	0.010u	0.010u	0.010u	0.010u	0.010u	0.010u	0.010u	5.7	7.7	0.010u	0.020u	0.010u
Picloram	0.35	0.010u	0.20	0.010u	5.0	16	15	0.010u	0.010u	0.010u	0.010u	0.010u	0.010u	0.16	163	234	0.010u	0.020u	0.010u

* = Duplicate or replicate

ND = Not detected at unspecified detection limit

N = Presumptive evidence of material

u = Not detected at detection limit shown

J = Estimated concentration

Table 7: Summary of Ecology results for radiation from monitoring wells at the Washington State University Chemical Dump Site (units are pCi/L)

Monitoring Well	H-3		C-14		K-40	
	Result	Error	Result	Error	Result	Error
1A	-4.30E+01	1.74E+02	1.03E+02	9.90E+01		
1B	-8.90E+01	1.73E+02	6.50E+01	9.90E+01	3.31E+02	2.78E+02
3A	-2.70E+01	1.74E+02	2.20E+01	9.80E+01	1.77E+02	2.70E+02
4A	1.55E+02	1.73E+02	8.90E+01	9.90E+01	2.00E+02	1.00E+02
4B	8.90E+01	1.77E+02	-2.80E+01	9.80E+01	2.63E+02	2.42E+02
5A	-1.12E+02	1.72E+02	6.30E+01	9.90E+01	3.06E+02	2.19E+02
7A	-2.90E+01	1.70E+02	-7.00E+00	9.80E+01	3.90E+02	3.20E+02
9B	-2.02E+02	1.71E+02	1.90E+01	9.80E+01	1.38E+02	3.07E+02
Lower Level of Detection	3.50E+02		1.65E+02		5.00E+01	

analytical result, consequently some values are reported below the detection level and as negatives. Results for tritium and carbon-14 were all below the level of detection. Potassium-40 concentrations were detected at or near the detection limit. K-40 is a naturally occurring isotope found in soils and living organisms. The concentrations observed in these samples are below the level of concern (Brennan, 1991).

DISCUSSION

Conventional parameters, metals, organics and pesticide concentrations are elevated in ground water at the WSU Chemical Dump Site. Analytical data from the March 1990 investigation suggests that contaminants have migrated to the ground water from both the manure disposal area and the chemical waste cell. However, the extent of contamination cannot be defined due to deficiencies in the ground water monitoring network. These deficiencies are discussed below.

Past interpretations of water level data concluded that ground water flow was primarily to the south with a possible northward component of flow near well 15A. However, Figure 4, the water-table contour map based on water levels obtained March 12, 1990, shows an eastward component of flow near the chemical and nuclear waste cells. As a result, no wells exist immediately downgradient of the chemical and nuclear disposal areas. Also from Figure 4, well 15A the designated upgradient well, appears to be downgradient of the manure disposal area. Elevated concentrations of TDS, ammonia, and TOC supports this concern.

The uppermost aquifer system at the site consists of two hydraulically connected layers, loess overlying fractured basalt. All wells are completed in the loess, with the exception of 1A, 3A, 4A, 5A, 6A, 7A, and 11A, which were completed at the loess/basalt interface. Both layers require characterization and monitoring. Estimates of the saturated hydraulic conductivity of the fractured basalt layer range from 1.2 to 2.6 feet per day, about 85 times higher than the overlying loess. The fractured basalt is a significant potential migration pathway for contaminants. Additional characterization of the fractured basalt is necessary and should include *in situ* hydraulic testing at a sufficient number of locations to provide spatial variability of hydraulic conductivity.

The well construction for wells 1A through 14A, installed in 1985 to obtain water level data, are suspect for water quality sampling. Mesh polypropylene filter wraps were installed over the sampling interval to reduce migration of particulates from the formation. Filter wraps may be adsorbing contaminants and thus biasing water quality results. Ground water samples from most of the wells were highly turbid, which may also affect water quality results. Filtered samples from wells 5A and 7A, showed lower metals concentrations than unfiltered samples. High turbidity is largely a function of well construction and sampling procedures.

Elevated concentrations of TDS, ammonia, and TOC in wells 3A, 4A, and 4B strongly suggest that the manure disposal area is affecting ground water quality (Table 4). A maximum TDS concentration of 1540 mg/L was observed at well 4B. Ammonia and TOC concentrations were elevated in monitoring wells 3A (0.16 mg/L and 82 mg/L), 4A (33 mg/L and 136 mg/L) and 4B (60 mg/L and 134 mg/L), respectively. Well 3A is immediately downgradient of the manure

disposal area (Figure 4) and is screened at the loess/basalt interface. Wells 4A and 4B were installed in the south end of the manure pit, with 4A screened at the loess/basalt interface and 4B screened in the manure.

Contaminants that exceeded ground water quality criteria and/or EPA's Maximum Contaminant Levels (MCL) at the WSU site are listed in Table 8 and include: total dissolved solids; lead; carbon tetrachloride; chloroform; methylene chloride; 1,1-dichloroethane; 1,1,2-trichloroethane; trichloroethene; 1,2-dibromoethane (EDB); 1,2-dichloroethane; heptachlor epoxide; alachlor; and dinoseb. Another contaminant of concern for which there are no established ground water quality criteria is acetone which was detected in several wells, with a maximum concentration of 1200 μg/L in well 15A. Acetone was used in the decontamination of the teflon bailers, but was not detected in any of the procedural blanks.

Table 8. WSU Chemical Dump Site Summary of Contaminants, Maximum Contaminant Levels, and Ground Quality Criteria.

Analyte	Range of Concentrations Detected in this Study	Maximum Contaminant Level (MCL) (1)	Ground Water Quality Criteria (2)
Conventionals (mg/L)			
Total Dissolved Solids	160 - 1540		500
Metals (μg/L)			
Lead	1.0 - 84.0	5*	50
Organics (μg/L)			
Carbon Tetrachloride	1.0 - 300	5	0.3
Chloroform	1.0 - 2900		7
Methylene Chloride	1.0 - 290J		5
1,1-Dichloroethane	1.0 - 10		1
1,1,2-Trichloroethane	1.0 - 9	5	
Trichloroethene	1.0 - 45	5	3
1,2-Dibromoethane (EDB)	1.0 - 4		0.001
1,2-Dichloroethane	1.0 - 2500	5	0.5
Pesticides (μg/L)			
Heptachloro epoxide	0.012 - 1.29J	0.2	0.009
Alachlor	5.5J - 6.1J	2	
Dinoseb	0.01 - 126	7	

* = Under Review

(1) U.S. Environmental Protection Agency. Drinking Water Regulations and Health Advisories. November 1990.

(2) Washington State Department of Ecology. Water Quality Standards for Ground Waters of the State of Washington, Chapter 173-200 WAC.

TDS concentrations exceeded ground water quality criteria (500 mg/L) in wells 3A, 4A, 4B, 11A and 15A. A maximum TDS concentration of 1540 mg/L was observed at well 4B.

At least one priority pollutant metal was found above the detection limit in each of the wells sampled, however, no consistent pattern of contamination was evident in metals concentrations across the site. Lead, detected in well 1C at 84 μg/L, was the only metal to exceed the ground water quality criteria of 50 μg/L.

Elevated concentrations of chlorinated hydrocarbons were found primarily in samples from well 4A and 14A. Well 4A is located at the southern end of the manure disposal area and well 14A is directly west of the chemical waste cell (Figure 4). Contaminants which exceeded ground water quality criteria include: carbon tetrachloride; chloroform; 1,1-dichloroethane; 1,1,2-trichloroethane; trichloroethene; 1,2-dibromoethane (EDB); and 1,2-dichloroethane. Estimated concentrations of acetone (1200 μg/L) and methylene chloride (290 μg/L) were detected in well 15A. Although wells 1A, B, and C are located directly south of the chemical waste cell, few contaminants were detected in samples from these wells. The potential exists that contaminants are migrating through the fractured basalt beneath the existing monitoring network.

Elevated concentrations of pesticides were found primarily in samples from well 14A. Contaminants which exceeded established standards include heptachlor epoxide (1.3 μg/L), alachlor (6.1 μg/L), and dinoseb (126 μg/L). Although picloram with a maximum concentration of 234 μg/L did not exceed the EPA MCL of 500 μg/L, it was found in half of the wells sampled, and was the most frequently observed pesticide. Picloram was present in 11A, the farthest downgradient well.

Contaminated ground water beneath the facility may be affecting the water quality of Airport Creek. As seen in Figure 4, the Water-Table Contour Map, ground water generally flows to the south, with an eastward component of flow near the chemical and nuclear waste cells. It appears that both surface water stations are downgradient of the facility. Of the contaminants detected in Airport Creek, concentrations were generally higher in samples collected from the upstream station, S1. Arsenic, lead, selenium, copper, and silver were detected in both surface water samples. These metals were also detected in wells 5A, 5B, and 7A (see Figure 4). Although the results are not conclusive, ground water may be contributing to metal concentrations found in the surface water samples.

Although not detected in any of the monitoring wells, two tentatively identified semivolatile compounds, 2-cyclohexen-1-one (1.0 μg/L) and atrazine (1.4 μg/L), were detected in both surface water samples. These occurrences suggest possible off-site sources of contaminants. Atrazine was also detected in both surface water samples using a pesticide test method at 0.75 and 0.64 μg/L. Picloram, the most frequently detected pesticide in the ground water samples was not detected in the surface water.

CONCLUSIONS

1. Ground water is contaminated beneath the WSU Chemical Dump Site with conventional pollutants, metals, organics, and pesticides. Elevated concentrations of TDS, ammonia, and TOC strongly suggest that the manure disposal area is affecting ground water quality. Elevated concentrations of organics and pesticides also suggests that the chemical waste disposal area is affecting ground water quality.

2. Based on water levels obtained March 12, 1990, ground water appears to flow south with an eastward component of flow near the chemical and nuclear waste cells.

3. The existing monitoring network is not adequate to characterize ground water flow and the extent of contamination. These deficiencies include:

    a. a lack of wells downgradient of the disposal areas;
    b. a designated upgradient well that may be affected by leakage from the facility;
    c. an insufficient number of wells completed in the fractured basalt, a potential ground water pathway; and
    d. monitoring well construction that may be adversely affecting water quality results.

RECOMMENDATIONS

1. Additional downgradient and upgradient wells are needed in the following areas to complete the characterization of the facility:

    a. north of wells 9B and 15A. Well 15A, originally designated the upgradient well, may be downgradient of the manure disposal area;
    b. east of the chemical waste disposal cell;
    c. south and east of the nuclear waste cell; and
    d. south of the waste cells in the fractured basalt. The monitoring network must be capable of detecting contamination in the saturated portions of both the loess and the fractured basalt. Site-specific hydraulic conductivity testing of the fractured basalt should be conducted.

2. Identify wells to be replaced and/or decommissioned.

    a. Filter wrap materials should be evaluated to determine their contaminant adsorption potential. If the potential is high then the wells should not be used for ground water sampling. New wells should be installed for sampling. Wells not being used should be decommissioned.
    b. Ground water samples collected during this round of sampling were very turbid. If the existing wells are determined to be adequate for sampling purposes the wells with turbid samples should be redeveloped until discharge is sediment free or identified as no longer useful and decommissioned and/or replaced.

c. Monitoring wells should be constructed and decommissioned in accordance with the Minimum Standards for Construction and Maintenance of Wells, Chapter 173-160 WAC.

4. Once a new monitoring network has been established the following should be conducted:

   a. the ground water flow pattern at the facility should be verified using water levels obtained from the new monitoring network;
   b. ground water samples should be collected and analyzed for conventional parameters, priority pollutant metals, volatile and semivolatile organic compounds, pesticides, PCBs, and beta-radiation;
   c. an additional sample station should be located along Airport Creek far enough upstream to be unaffected by ground water discharge from the chemical dump site;
   d. samples should be collected from Airport Creek during seasonal low flow to verify previous results; and
   e. Airport Creek sediments should be analyzed for metals, pesticides, organophosphorus pesticides, and semivolatile organic compounds.

5. The vertical and lateral extent of the waste cells should be characterized in detail. At some locations the waste was likely placed below the water table.

6. Source control measures to reduce further ground water contamination should be identified, evaluated and implemented, if feasible. For example, removal of the manure from beneath the water table would likely reduce the loading to ground water.

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APPENDIX A

WSU Chemical Inventory

Known Quantities of Selected Metals at the Site.

Antimony	kg	lit	adj. kg.
Antimony	0.005		0.005
Antimony chloride	0.03		0.02
Antimony pentachloride	0.28		0.11
Antimony sulfide	0.10		0.04
Antimony trichloride	2.15		1.15
Total	2.57		1.33

Arsenic			
Ammonium arsenate	2.38		0.92
Arsenate	13.61		7.34
Arsenic	5.45	5.91	5.45
Arsenic acid	18.09	0.1	9.55
Arsenical soap	1.81		
Arsenic trioxide	3.85		2.35
Arsenious acid	4.54		2.70
Calcium arsenate	2.72		1.02
Copper arsenate	0.48		0.51
Copper acetic arsenate	0.01		
Dimethyl arsenate	0.026		
Lead arsenate	1.77		0.40
Potassium arsenate	5.45		1.59
Sodium arsenate	2.19	0.5	1.12
Sodium arsenic soil		408.82	
Sodium arsenite	1.36		0.95
Zinc arsenide	0.03		
Total	63.77	409.42	33.90

Barium			
Barium acetate	0.56		0.30
Barium azide	0.57		0.35
Barium carbonate	4.65		3.24
Barium chloride	1.20	1.45	0.79
Barium chromate	0.23		0.12
Barium dioxide	0.45		0.36
Barium hydroxide	13.25	0.275	10.62
Barium nitrate	4.54		2.39
Barium sulfate	4.08		2.40
Barium sulfide	11.79		9.56
Total	41.32	1.73	30.13

	kg	lit	adj. kg.
Boron			
Boric acid	13.72	3.79	2.40
Boron tribromide		5.79	
Boron trifluoride		0.95	
Boron trifluoridimethyl		3.79	
Total	13.72	10.53	2.40
Bromides			
Acetyl bromide	0.5		0.32
Ammonium bromide	0.45		0.37
Bromide cyanide		37.85	
Bromine	1.67		1.67
Bromoform	0.45		0.28
Bromo-nitro-cresol	0.2		
Bromo phenol	0.01		0.005
Bromo propane	0.12		0.078
Cyanogen bromide		3.79	
Ethylene bromide		0.47	
Hydrobromic acid	2.82	4.26	2.79
Mercuric bromide	0.45		0.20
Methyl bromide		456.14	
Methyl Mg. bromide	0.45		0.302
Phenyl Mg. bromide		0.8	
Phosphorous tribromide	0.5	11.36	0.443
Total	12.27	516.16	10.05
Cadmium			
Cadmium	2.51		2.51
Cadmium chloride	0.91		0.56
Cadmium nitrate	0.91		0.43
Total	4.33		3.50

Chromium	kg.	lit.	adj. kg.
Ammonium chromate	0.68		0.23
Ammonium dichromate	0.91		0.38
Barium chromate	0.23		0.05
Calcium dichromate	11.34		5.67
Calcium bichromate	0.45		0.22
Chrom acetic acid	0.23		
Chromate solvents	8.16		
Chromerage		142.00	
Chromium dioxide		0.94	
Chromium fluoride	0.45		0.40
Chromium potassium	0.04		
Chromium trioxide	25.05	142.09	17.13
Copper trichromate	0.03		
Dichromate	0.025	467.73	
Dichromate acid mix		160.88	
Dichromate cleaning solution	0.91		
Potassium bichromate	1.13	0.15	0.40
Potassium chromate	3.84		1.03
Potassium chromium-sulfate	4.54		0.47
Potassium dichromate	19.96	310.46	7.05
Sodium bichromate	0.11		0.02
Sodium chromate		0.4	
Sodium dichromate	22.36		7.80
Sulfuric chromium trioxide		0.24	
Zinc chromate	331.12		119.34
	233.60 (liq)		
Total	665.17	1224.16	160.19

Copper			
Copper	45.36		45.36
Copper acetic arsenate	0.01		
Copper arsenate	0.48		0.22
Copper sulfate	68.49		27.28
Copper trichromate	0.03		
Total	114.37		72.86

Cyanide	kg	lit	adj. kg
Acetic cyanide		1.89	
Alkyl cyanide	0.91		
Ammonium thiocyanate	3.51		1.20
Benzyl isocyanate	0.005		
Bromide cyanide		37.85	
Calcium cyanide	2.27		1.28
Cyanamide	0.11		0.07
Cyanate	9.07		9.07
Cyanic acid		3.79	
Cyanide	75.93	34.69	75.93
Cyanogas	2.72		2.72
Cyanogen bromide	0.225	3.79	0.06
Ethyl thiocyanate		0.47	
Isocyanate		18.93	
Mercuric oxycyanate	0.2		
Mercuric thiocyanate	0.45		0.07
Mercury cyanide	0.1		0.02
Methyl thiocyanate	0.1	0.47	0.04
Phenyl thiocyanate	0.11		0.02
Potassium cyanide	7.38	6.79	2.95
Potassium ferricyanide	5.70	3.00	2.70
Potassium thiocyanate	6.39	0.1	1.71
Rhodomine-B-isothiocyanate		1.00	
Sodium cyanide	13.08	0.11	6.94
Thiocyanate	4.54	0.5	2.00
Zinc cyanide	0.91		0.40
Total	133.72	113.38	107.18

Heavy Metals	1.81	4.29	
Lead			
Lead	46.26	4.12	46.26
Lead acetate	12.63	5.44	6.00
Lead arsenate	1.77		0.41-1.06
Lead carbonate	0.45		0.35
Lead citrate	0.53		0.31
Lead monoxide	2.27		2.11
Lead nitrate	6.24	1.30	3.90
Lead oxide	3.75	0.38	3.48
Lead sulfate	0.45		0.31
Lead tetra-acetate	0.5		
Total	74.85	11.24	63.13-63.78

Mercury	kg	lit	adj. kg
Calomel	0.33		0.31
Ceresan	1.36		
Diphenyl mercury	0.08		0.05
Mercuric acetate	0.56		0.35
Mercuric acid	0.01		
Mercuric bichloride	0.06	8.17	0.04
Mercuric bromide	0.45		0.25
Mercuric chloroanilate	0.01		
Mercuric chloride	3.97	9.93	2.93
Mercuric iodide	2.32		1.42
Mercuric nitrate	1.43	1.05	0.86
Mercuric oxide	2.36	3.94	2.19
Mercuric oxycyanate	0.20		0.09
Mercuric perchlorate		0.95	
Mercuric thiocyanate	0.45		0.28
Mercurous sulfate	0.10		0.08
Mercury	23.17	240.10	23.17
Mercury acetate solution		5.68	
Mercury acid solution		18.93	
Mercury cyanide	0.10		0.08
Mercury sulfide		18.93	
Methyl mercury		20.43	
Phenol mercuric nitrate	0.06		
Phenyl mercuric acid		0.10	
Total	37.79	328.21	32.10

Nickel			
Nickel	1.70		1.70
Nickel chloride	0.11		0.05
Nickel electropolish	0.03		
Nickel nitrate		1.00	
Nickel oxide		0.025	
Nickel pickle		3.79	
Nickel sulfate	0.34	0.65	0.13
Niclelous chloride	0.45		0.20
Total	2.63	5.47	2.08

Silver			
Silver iodate	0.11		0.40
Silver nitrate	1.12	15.35	0.71
Silver picrate	0.01		
Total	1.24	15.35	0.75

Thallium	kg	lit.	adj. kg.
Thallium chloride		0.80	
Uranium			
Uranium acetate	5.55		3.13
Uranium oxide	0.03		0.03
Uranyl acetate	0.002		0.001
Uranyl nitrate	0.45		0.21
	---		---
Total	5.58		3.37
Zinc			
Zinc		0.1	
Zinc arsenide	0.03		0.02
Zinc chromate	331.12		119.34
	233.60 (liq)		
Zinc-mercury waste	4.54		
	---	---	---
Total	569.29	0.1	119.36

APPENDIX B

1985

Well Logs

DRILLING RECORD

DATE 9/13/85

PROJECT

HOLE NO. 1A

HOLE USE Piezometer/Monitor Well

ELEVATION 2550.67

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

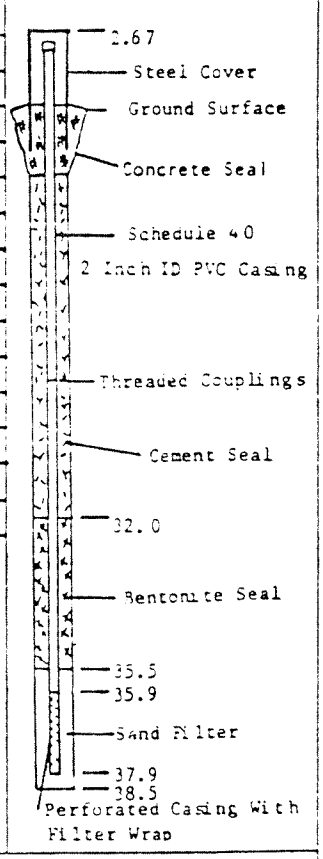
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	38.5	38.5	
Basalt, weathered chips	38.5			

TOTAL DEPTH 38.5 feet

STATIC WATER LEVEL

REMARKS: No water at time of completion.

BOREHOLE COMPLETION SKETCH



DRILLED BY J. Kuhlman, T. Weber, D. Jenkins

LOGGED BY J. Kuhlman

GEOLOGICAL ENGINEERING SECTION

WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 9/19/85

PROJECT

HOLE NO. 1B

HOLE USE Piezometer/Monitor Well

ELEVATION 2550.77

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

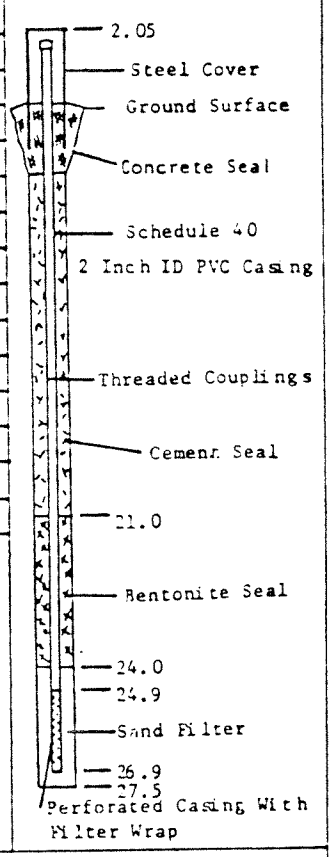
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	27.5		

TOTAL DEPTH 27.5 feet

STATIC WATER LEVEL

REMARKS: No water at time of completion.

BOREHOLE COMPLETION SKETCH



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WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 9/20/85

PROJECT

HOLE NO. 1C

HOLE USE Piezometer/Monitor Well

ELEVATION 2550.94

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

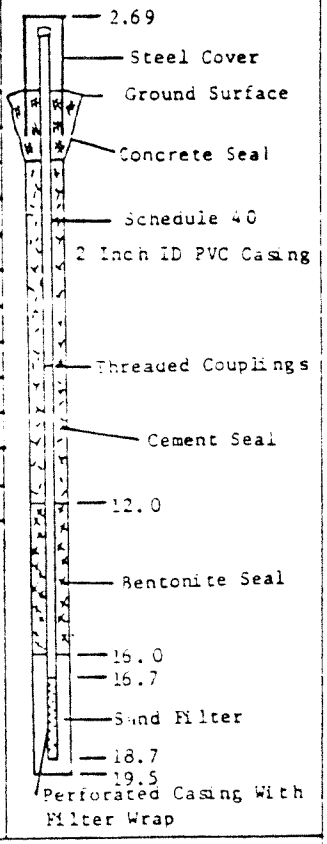
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	19.5		

TOTAL DEPTH 19.5 feet

STATIC WATER LEVEL

REMARKS: No water at time of completion.

BOREHOLE COMPLETION SKETCH



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WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 9/24/85

PROJECT

HOLE NO. 2B

HOLE USE Piezometer/Monitor Well

ELEVATION 2546.73

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

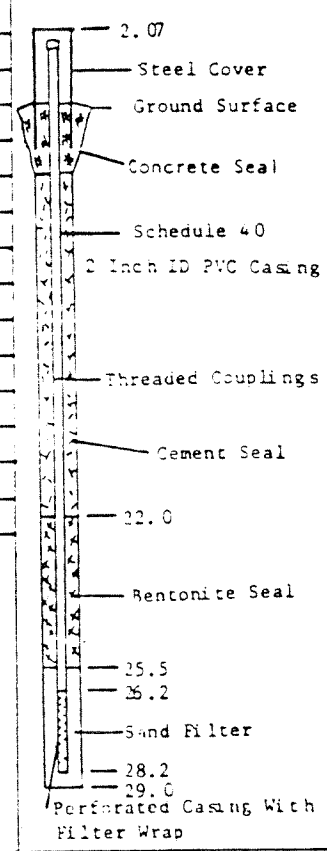
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	29		

TOTAL DEPTH 29 feet

STATIC WATER LEVEL

REMARKS: Hole partially caved but recovered. Water not measurable.

BOREHOLE COMPLETION SKETCH



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DRILLING RECORD

DATE 9/25/85

PROJECT

HOLE NO. 3A

HOLE USE Piezometer/Monitor Well

ELEVATION 2517.98

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

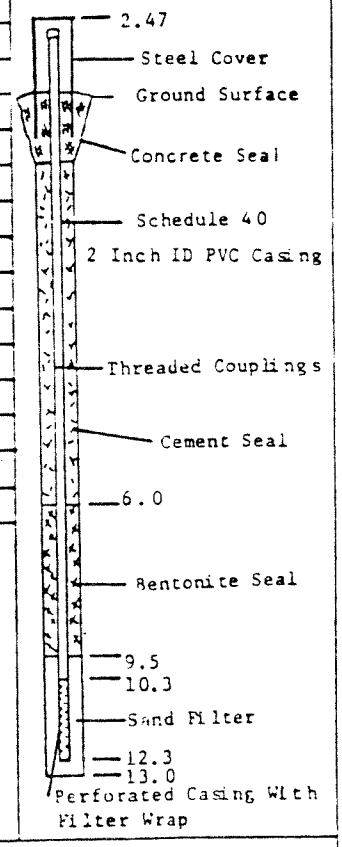
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Dark brown clayey silt	0	12	12	
Weathered broken basalt and dense gray clay	12	13		

TOTAL DEPTH 13 feet

STATIC WATER LEVEL 10 feet below surface

REMARKS:

BOREHOLE COMPLETION SKETCH



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GEOLOGICAL ENGINEERING SECTION

WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 9/25/85 **PROJECT** _____

HOLE NO. 4A **HOLE USE** Piezometer/Monitor Well

ELEVATION 2537.94 **ELAPSED TIME** _____

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

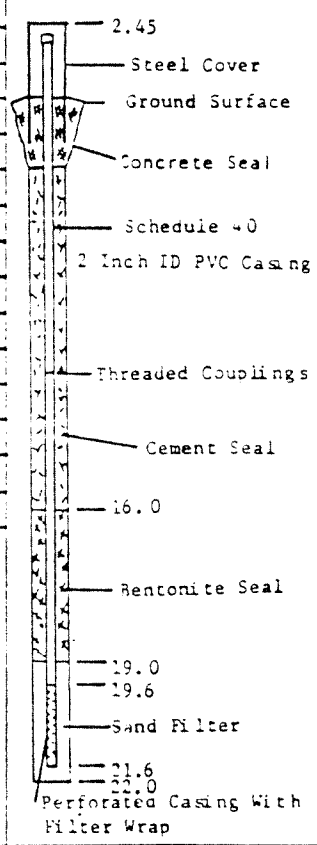
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS
Tan clayey silt	0	5	5
Buried manure, gray fiberous	5	21	16
Light tan clayey silt	21	23.5	1.5
Dense gray clay, basalt chips	23.5	24	

TOTAL DEPTH 24 feet

STATIC WATER LEVEL _____

REMARKS: Bottom of hole lost.

BOREHOLE COMPLETION SKETCH



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WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 10/1/85

PROJECT

HOLE NO. 4B

HOLE USE Piezometer/Monitor Well

ELEVATION 2537.84

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

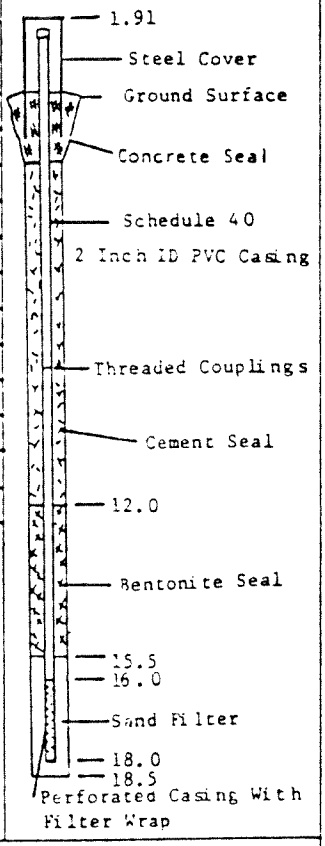
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	5	5	
Buried manure, gray fiberous	5	18.5		

TOTAL DEPTH 18.5 feet

STATIC WATER LEVEL

REMARKS:

BOREHOLE COMPLETION SKETCH



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GEOLOGICAL ENGINEERING SECTION

WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 9/30/85

PROJECT

HOLE NO. 5A

HOLE USE Piezometer/Monitor Well

ELEVATION 2550.09

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

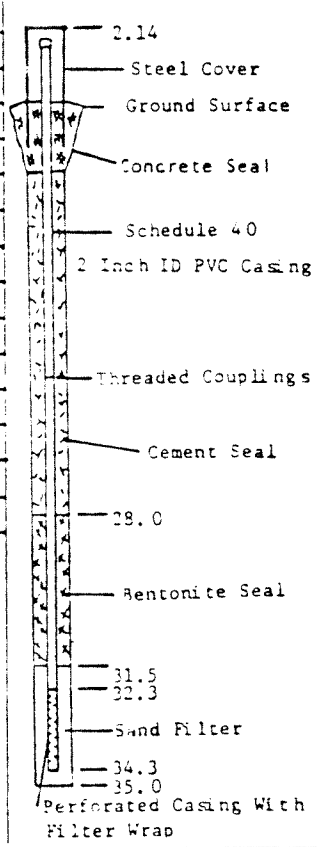
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	37.5	37.5	
Weathered basalt	37.5	38		

TOTAL DEPTH 38 feet

STATIC WATER LEVEL

REMARKS: Lost bottom 3 feet of hole to caving.

BOREHOLE COMPLETION SKETCH



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GEOLOGICAL ENGINEERING SECTION

WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 4/9/86

PROJECT

HOLE NO. 5B

HOLE USE Piezometer/Monitor Well

ELEVATION 2550.08

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

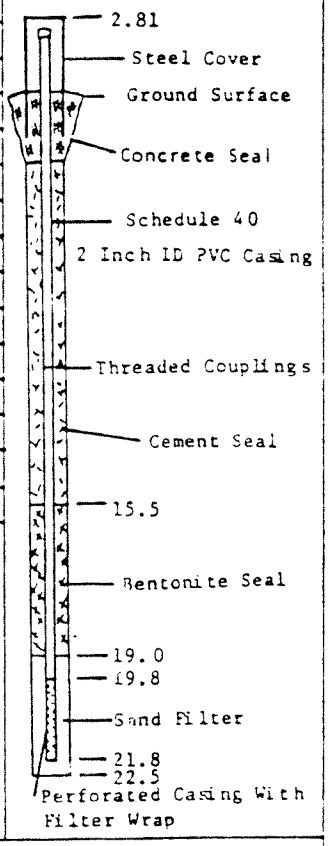
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	22.5		

TOTAL DEPTH 22.5 feet

STATIC WATER LEVEL

REMARKS:

BOREHOLE COMPLETION SKETCH



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GEOLOGICAL ENGINEERING SECTION

WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 10/16/85 **PROJECT** _____

HOLE NO. 6A **HOLE USE** Piezometer/Monitor Well

ELEVATION 2551.67 **ELAPSED TIME** _____

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

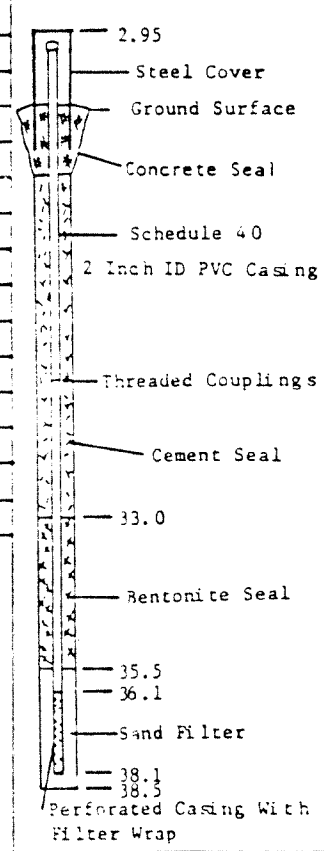
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	38.5		
Weathered broken basalt	38.5			

TOTAL DEPTH 38.5 feet

STATIC WATER LEVEL _____

REMARKS:

BOREHOLE COMPLETION SKETCH



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GEOLOGICAL ENGINEERING SECTION

WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 1/14/86

PROJECT

HOLE NO. 7A

HOLE USE Piezometer/Monitor Well

ELEVATION 2537.26

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

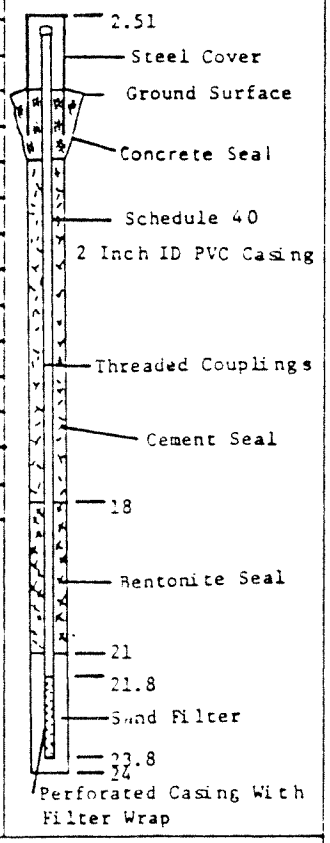
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan silt	0	0.5	0.5	
Dark brown clayey silt	0.5	6	5.5	
Tan clayey silt	6	26	20	
Weathered basalt	26			

TOTAL DEPTH 26 feet

STATIC WATER LEVEL

REMARKS: Bottom two feet of hole lost.

BOREHOLE COMPLETION SKETCH



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WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 4/9/86 PROJECT

HOLE NO. 7B HOLE USE Piezometer/Monitor Well

ELEVATION 2537.47 ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

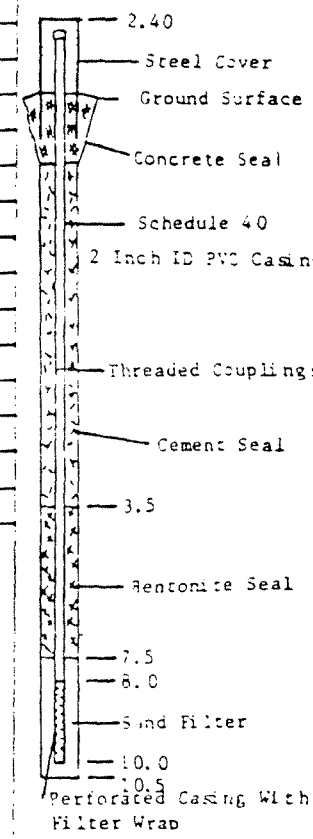
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS
Tan silt	0	1	1
Dark brown clayey	1	6	5
Tan clayey silt	6	10.5	

TOTAL DEPTH 10.5 feet

STATIC WATER LEVEL

REMARKS:

BOREHOLE COMPLETION SKETCH



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GEOLOGICAL ENGINEERING SECTION

WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 4/9/86

PROJECT

HOLE NO. 9B

HOLE USE Piezometer/Monitor Well

ELEVATION 2567.55

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

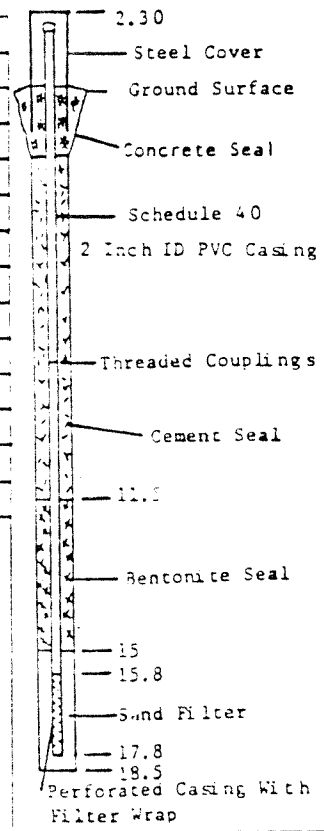
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	5	5	
Buried manure w/ tan silt	5	10	5	
Tan clayey silt	10	18.5		

TOTAL DEPTH 18.5 feet

STATIC WATER LEVEL

REMARKS:

BOREHOLE COMPLETION SKETCH



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DRILLING RECORD

DATE 4/11/86 PROJECT

HOLE NO. 11A HOLE USE Piezometer/Monitor Well

ELEVATION 2502.88 ELAPSED TIME

LOCATION South of WSU Hazardous Waste Site

BOREHOLE RECORD

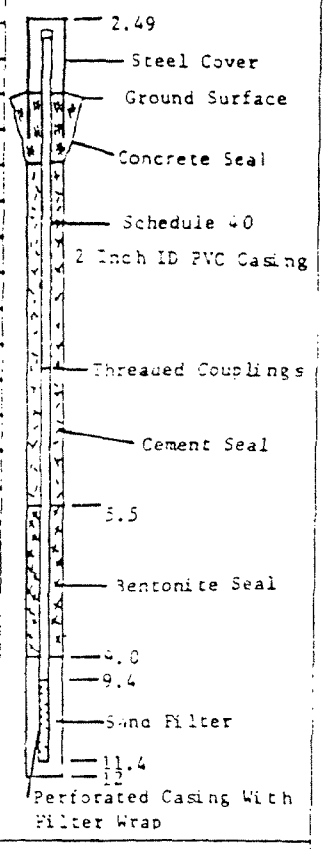
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Black silt	0	2	2	
Tan clayey silt	2	4	2	
Dark gray clayey silt	4	12	8	
Weathered basalt	12			

TOTAL DEPTH 12 feet

STATIC WATER LEVEL

REMARKS:

BOREHOLE COMPLETION SKETCH



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WASHINGTON STATE UNIVERSITY

DRILLING RECORD

DATE 5/8/86

PROJECT

HOLE NO. 14A

HOLE USE Piezometer/Monitor Well

ELEVATION 2558.30

ELAPSED TIME

LOCATION WSU Hazardous Waste Site

BOREHOLE RECORD

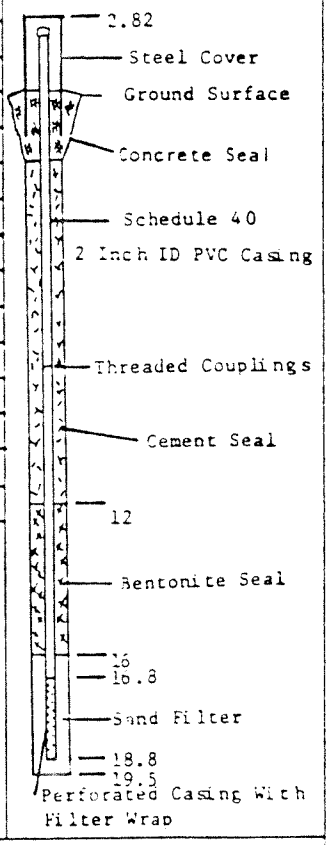
FORMATION DESCRIPTION	DEPTH TO TOP	DEPTH TO BOTTOM	THICKNESS	
Tan clayey silt	0	19.5		

TOTAL DEPTH 19.5 feet

STATIC WATER LEVEL

REMARKS:

BOREHOLE COMPLETION SKETCH



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APPENDIX C

Ecology - March 13-15, 1991
Tentatively Identified Compounds

Volatile and semivolatile organic compounds tentatively identified from samples collected by Ecology March 13-15, 1990 from monitoring wells from the chemical dump site at the Washington State University (units are ug/l)

Monitoring Well	1A	1B	1C	2B	3A	4A	4B	5A	5B	6A	7A	7B	9B	11A	14A	14B*	15A	S1	S2
Sample No. 11-	8240	8239	8238	8241	8237	8244	8243	8232	8233	8236	8230	8231	8234	8242	8245	8246	8235	8250	8249
Volatile Organics																			
Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9NJ	ND	ND	ND	ND	ND
Tetrahydrofuran	ND	ND	ND	ND	ND	ND	1.1NJ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Diethoxyethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.99NJ	ND	ND	ND	ND
Semivolatile Organics																			
Hexanoic Acid 2-Ethyl	ND	ND	0.86NJ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl) ester hexanedioic acid	3.5NJ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Camphor (ACN)	ND	ND	ND	ND	ND	ND	1.3NJ	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.6NJ	1.9NJ	ND	ND	ND
Trichlorobenzoic Acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.7NJ	ND	ND	ND
2,3,6-Trichloro benzeneacetic acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.9NJ	920NJ	ND	ND	ND
Dinoseb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	46NJ	68NJ	ND	ND	ND
1-Chloro-4-methylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4NJ	100NJ	ND	ND	ND
Dicyclopropyl methanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9NJ	1.9NJ	ND	ND	ND
1-Methyethyl ester carbamic acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.0NJ	9.2NJ	ND	ND	ND
3,4-Dichlorobenzyl N-methylcarbamate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11NJ	11NJ	ND	ND	ND
O,O,S-Trimethyl phosphorodithioic acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.79NJ	0.79NJ	ND	ND	ND
4,7-Methanoisobenzofur+	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.61NJ	ND	ND	ND
Alachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.1NJ	4.3NJ	ND	ND	ND
2-Methyl-2H-benzotriazole	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.8NJ	3.1NJ	ND	ND	ND
Fenamiphos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	50NJ	3.6NJ	ND	ND	ND
2-Cyclohexen-1-one	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0NJ	0.97NJ
Atrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4NJ	0.98NJ

* = Duplicate

u = Not detected at detection limit shown

J = Estimated concentration

N = Presumptive evidence of material

ND = Not detected at unspecified detection limit