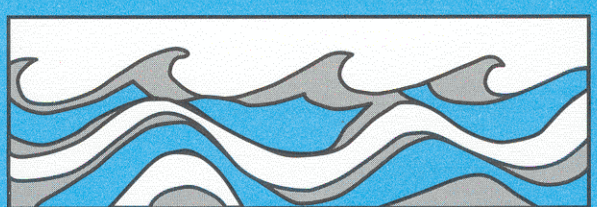
University of Washington
Department of Civil and Environmental Engineering

HAZARDOUS WASTE SITE CASE STUDIES: AN ANALYTICAL APPROACH FOR ENVIRONMENTAL MANAGERS

Michael S. Bowers
Dennis P. Lettenmaier



Water Resources Series
Technical Report No.129
August 1991

Seattle, Washington
98195

Department of Civil Engineering
University of Washington
Seattle, Washington 98195

HAZARDOUS WASTE SITE CASE STUDIES: AN ANALYTICAL APPROACH FOR ENVIRONMENTAL MANAGERS

Michael S. Bowers
Dennis P. Lettenmaier

Water Resources Series
Technical Report No. 129

August 1991

Hazardous Waste Site Case Studies: An Analytical Approach for Environmental Managers

By

Michael S. Bowers

and

Dennis P. Lettenmaier

Technical Report No. 129

September 1991

Department of Civil Engineering

University of Washington

Seattle, Washington 98195

Prepared for Pacific Northwest Laboratories

ABSTRACT

Over the past two decades, greatly increased emphasis has been placed on environmental management. This trend is evidenced by the passage of legislation and accompanying standards, procedures, and funding at the federal, state, and local levels to clean up thousands of hazardous waste sites across the country. However, since passage of the federal Superfund act in 1980, there is a general consensus that progress has been unsatisfactory, as only a handful of sites have been fully remediated.

This report is the outgrowth of a class taught at the University of Washington in Spring, 1991, as part of which the progress of cleanup at three diverse Superfund sites in the state of Washington was assessed. The three sites are a liquid waste evaporation facility on the Hanford Reservation in eastern Washington, a wood treatment facility on Bainbridge Island adjacent to Puget Sound, and a municipal landfill in the Tacoma area. For each case study, the site history, regulatory history, site characterization, and remediation approach were summarized. Where appropriate, site characterization data, including contaminant concentrations in soil and groundwater, and groundwater head observations, are summarized in appendices and on a computer disk. In addition to the site summary, for each site a set of questions were developed to encourage the reader to consider how the site could have been remediated more effectively.

Our hope is that these case studies will provide the basis for an assessment of the reasons for successes and failures in hazardous waste site remediation. Although all sites are in the state of Washington, the diversity of the sites should insure that the applicability of conclusions that might be reached is not regionally specific.

ACKNOWLEDGEMENTS

Much of the research conducted in support of this project was performed by Kevin Stover (Hanford Site 183-H Solar Basins), Kevin Vogelsang (Wyckoff/Eagle Harbor), and Charlie Eishen and Christopher Floro (Tacoma Landfill), all of whom were University of Washington Department of Civil Engineering Graduate Students. A variety of professionals in the hazardous waste/environmental remediation field also contributed to the project. We would like to acknowledge Mr. Robert Peterson of the Westinghouse Geosciences Group and Mr. Terry Likala of Battelle Pacific Northwest Laboratories for their assistance with the Hanford 183-H site; Ms. Ellen Hale, Mr. Renee Fuentes, and Ms. Lori Cohen of the U.S. Environmental Protection Agency Region 10 Superfund Branch for their assistance with the Wyckoff site, and Mr. Russ Darr of the State of Washington Department of Ecology for his assistance with the Tacoma Landfill site.

Ms. Kay Dewar of the University of Washington Department of Atmospheric Sciences provided graphics support to the project, and Ms. Kristin Mingus of the University of Washington Department of Civil Engineering provided typing and editing support. Funding for the project was provided in part by Pacific Northwest Laboratories under a curriculum enhancement grant to the University of Washington Department of Civil Engineering.

TABLE OF CONTENTS

TABLE OF CONTENTS, (CONT.)

TABLE OF CONTENTS, (CONT.)

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF TABLES

CHAPTER I: INTRODUCTION

A. BACKGROUND

In the Environmental Age of the 1990's, the federal government, as well as state and local agencies, have come under public pressure to clean up the thousands of identified hazardous waste sites across the country. Concerns raised by the highly publicized Love Canal site in Niagara Falls, NY in the late 1970's prompted Congress to pass the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) in 1980, which formed the basis for subsequent state and local legislation. Under CERCLA, a legislative fund (also known as the Superfund) was created to facilitate remediation of contamination for an estimated 1200 sites that were placed on a National Priority List (NPL) over the course of 5 years. However, in 1985, the U.S. General Accounting Office (GAO) estimated that an additional $40-60 billion would be required to remediate the 4000 sites it estimated would ultimately be added to the NPL. In addition, the GAO report estimated that an additional 38,000 hazardous waste sites, 600 hazardous waste storage/disposal sites, 52,000 landfills, 187,000 leaking underground storage tanks, 64,000 mining waste sites, and 470 Department of Defense (DOD) sites existed across the country which would require urgent attention in the immediate future.

Partly as a result of the GAO report, Congress passed the Superfund Amendments and Reauthorization Act of 1986 (SARA) which provided an addition $9 billion for remediation of NPL sites and leaking underground storage tanks. Despite these acts, in 1990, only 10 NPL sites were reported to have been remediated to Environmental Protection Agency (EPA) and/or state standards. Obvious questions have been raised as to why, after 10 years and the expenditure of over $10 billion of federal funds, so few sites have been remediated.

The answer to the above question, is that most of the funds were spent on remedial investigations (RI's) and Feasibility Studies (FS's) conducted by engineering firms. Furthermore, litigation between potentially responsible parties (PRP's), other private parties and the federal or state government at many hazardous waste sites has slowed progress toward remediation. Other factors contributing to the lack of progress in remediating hazardous waste sites include difficulties in identifying contaminant sources and/or the extent of contamination at known sites, lack of proven treatment technologies and/or experience in the use of evolving treatment technologies, and the lack of clear and achievable clean up standards at the federal and state levels.

In this report, we summarize the history of three hazardous waste sites in the state of Washington. These case studies have been prepared with the hope that improved training of engineers and other professionals involved in RI/FS and related remediation studies can result from a review of previous successes, failures, and lessons-learned.

B. OBJECTIVES

The goal of this report is to provide information about three hazardous waste sites in the State of Washington, including site histories and selected quantitative data, that will form the basis for specific assessments of the remediation process. Most engineering courses dealing with hazardous waste remediation focus on the technical aspects of groundwater modeling, multi-dimensional contaminant migration, soil chemistry, and treatment technology. The lack of progress toward remediating NPL sites suggests the need for improved curricula in the area of project management as well. The case study approach blends both the technical and management aspects of environmental engineering.

It is intended that these case studies be used in a graduate level course. The three case studies are all located in Washington State, primarily because this made the task of acquiring background data much easier. However, the three sites incorporate a diversity of physical data, contaminant sources and management histories which should be typical of hazardous waste sites nationally.

In developing this report, a candidate list of seven hazardous waste sites was reviewed by a team of five civil engineering graduate students. From the candidate list, three sites were selected for inclusion in this report: the Hanford Site 183-H Solar Evaporation Basins (183-H Basins), the Wyckoff/Eagle Harbor wood treatment facility, and the Tacoma Landfill. Figure I-1 shows the location of these sites. Over the course of three months (one academic quarter), each of these sites was thoroughly investigated by the project team. Interviews were conducted with the lead agency responsible for each site and other on-site officials, field visits were made to the sites, and site documents were reviewed at various information repositories including Region 10 EPA headquarters, the Washington Department of Ecology (WDOE), and public libraries. In compiling information from the sites, attention was focused on site history, investigations, maps, geologic profiles, chemical and physical data reports, contaminant migration modeling results, engineering evaluations, records of public hearings, court orders, feasibility studies, and records of decision. The information reviewed was

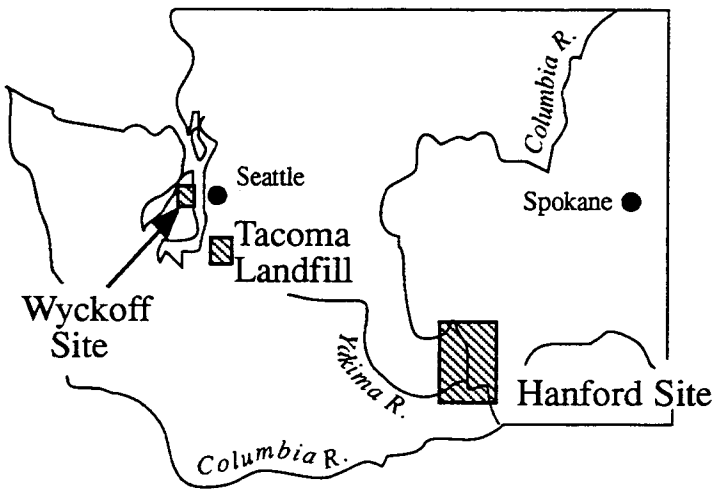


Fig. I-1 Case Study Site Locations

summarized into five categories for each case: Site History, Regulatory History, Site Characterization/Data Collection, Remediation and Evaluation/Critique. In addition, a data disk was created, which contains selected physical and chemical data for each of the sites.

CHAPTER II - HANFORD SITE
183-H SOLAR EVAPORATION BASINS

A. INTRODUCTION

The Hanford Site is operated by the United States Department of Energy (DOE), and covers approximately 560 square miles in southeastern Washington. The Site was created in 1943 as a national defense-related plutonium production facility. In the mid - 1960's, a gradual transition was initiated by the U.S. Atomic Energy Commission (AEC), which then operated the site, to transform the Site into a research and development center for nuclear and other forms of energy. Plutonium production was halted in 1972, but resumed briefly in 1983 at one reactor. Figure II-1 shows the general layout of the Hanford Site.

In 1985, a major hazardous waste assessment effort began at Hanford. Over 1000 hazardous waste sites were identified, assessed, and consolidated to create several conglomerate sites for NPL designation. The subject of this case study, the 183-H Basins, is one part of the Hanford NPL site known as the 100 HR3 Operable Unit. The 183-H Basins are located in the 100-H area (see Figure II-1) at the north end of the Site adjacent to the Columbia River.

Chemical contaminants found in the groundwater and soils at the Hanford site include heavy metals, organics, inorganics, and radionuclides. Both groundwater and soil contamination have been noted beneath the 183-H Basins. The focus of this study is groundwater contamination.

B. SITE HISTORY

The 183-H Basins were initially constructed for water treatment at the 100-H plutonium reactor, which was in operation from October 1949 until April 1965. The basins were the flocculator/subsidence components of the water distribution system for the plant (see Figure II-2). The intake source was the Columbia River, approximately 600 feet away. Situated about 40 feet above the average water elevation (see Figure II-3), the 183-H Basins consist of 4 separate but contiguous concrete retaining structures forming the cells of a single facility measuring approximately 128 feet wide by 210 feet long and up to 16 feet deep (see Figure II-4). The concrete floor in the Basins is 6" thick in the deep section and 10" thick in the shallow section. Wall thickness varies from 2 feet at the base to 1 foot in the upper half of the basins.

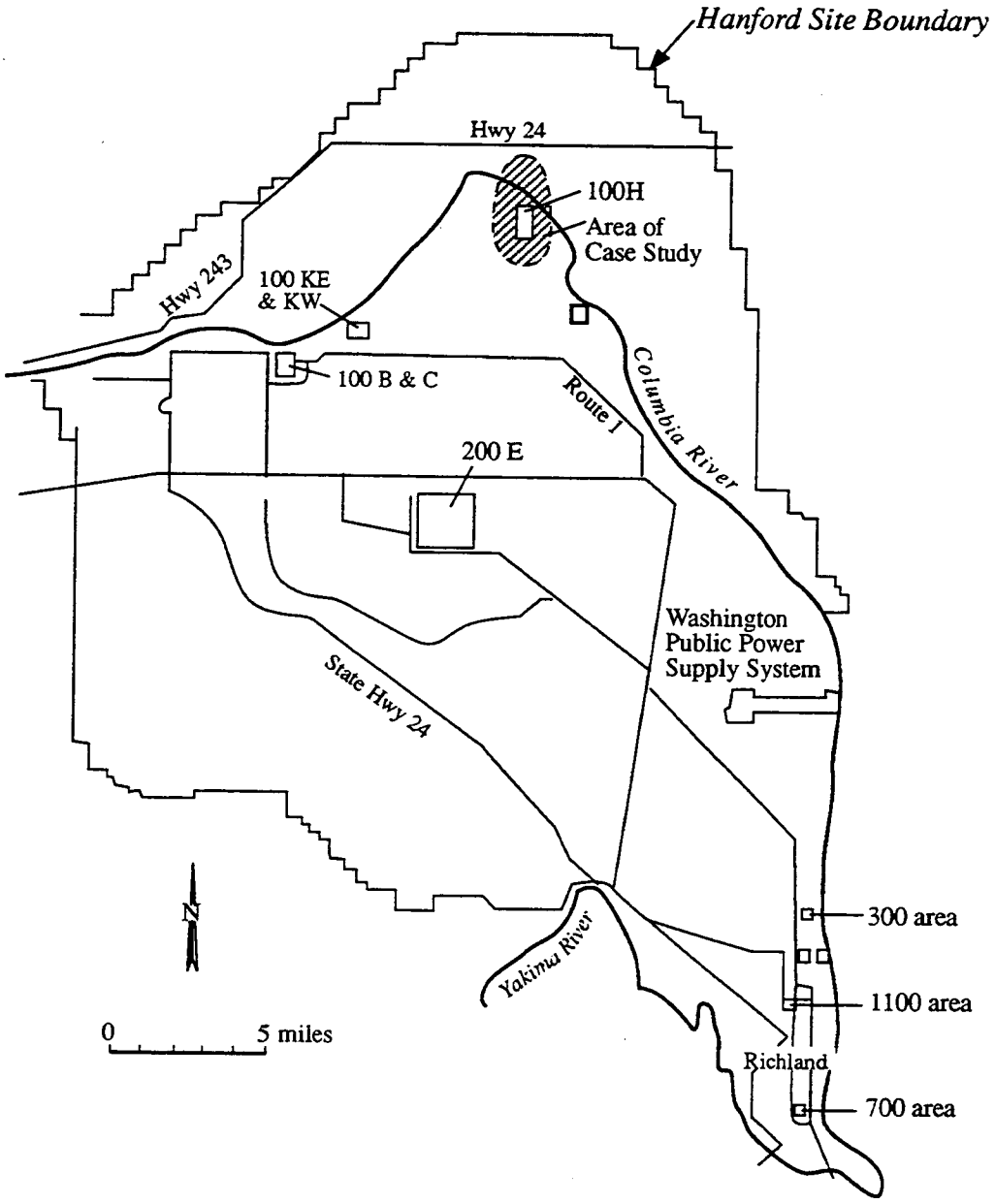


Fig. II-1 Hanford Site Map: Location of 183-H Solar Evaporation Basins (From Fig. IA-1: DOE, 1988a)

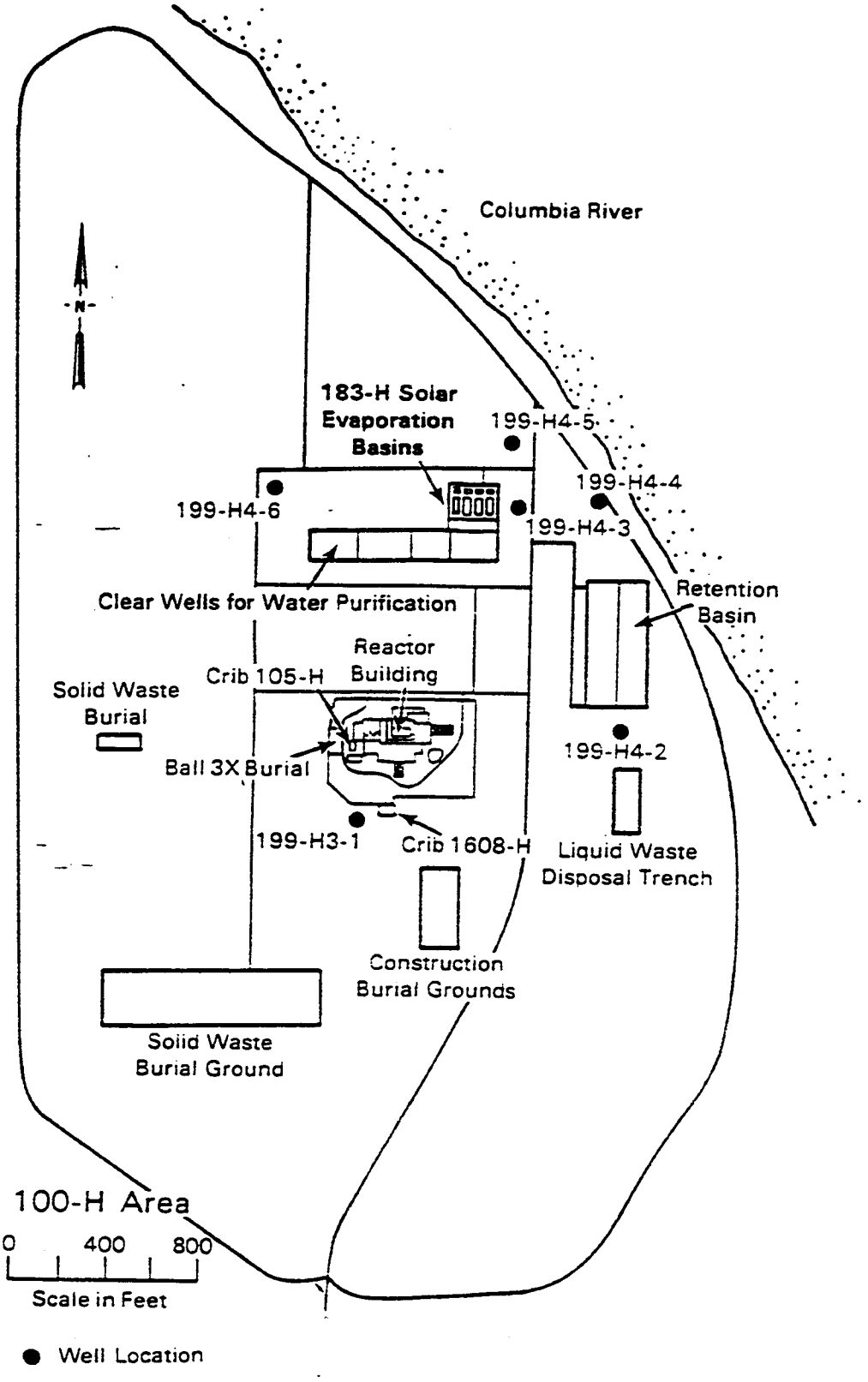


Fig. II-2 100-H Area Map (From Fig. 2: PNL, 1986)

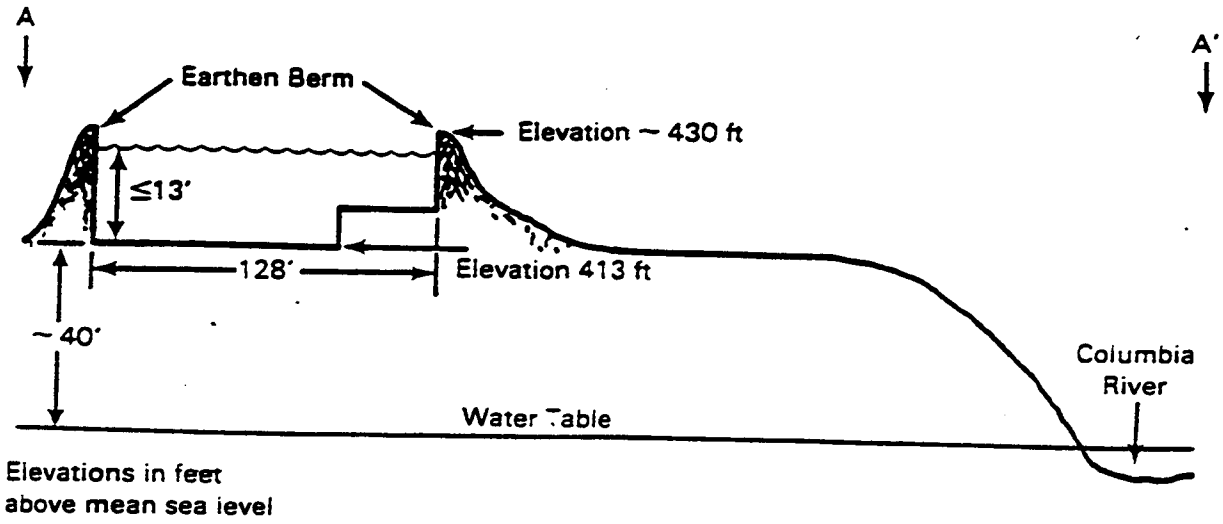


Fig. II-3 Schematic Cross-Section of 183-H Solar Evaporation Basins (From Fig. 3: DOE, 1986)

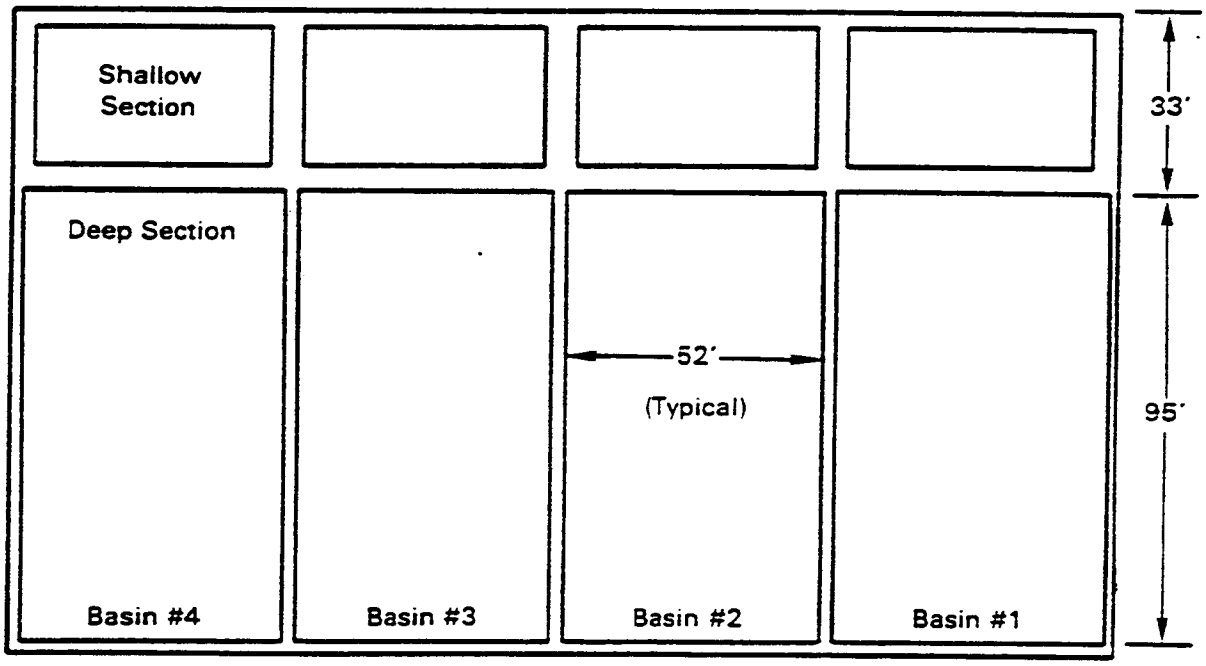


Fig. II-4 Plan View of 183-H Solar Evaporation Basins (From Fig. 4: PNL, 1986)

From 1965 until 1973, the basins were inactive, after which they were converted into a hazardous waste treatment, storage, and disposal (TSD) facility for storage and concentration of liquid chemical wastes by solar evaporation. The primary wastes discharged to the 183-H Basins were the neutralized mixed wastes routinely produced in the 300 Area during the fuel fabrication process. Nitrate, sulfate, and copper were present in high concentrations; other materials such as fluoride, hexavalent chromium, and enriched uranium were present in smaller amounts. Overall, it is estimated that 2,529,000 gallons of wastes were discharged to the 183-H Basins from 1973 on (Rokken, 1986). The following material types and quantities were discharged to the basins in 1985, the final year of operation:

Material	Pounds
Ammonium ion	520
Fluoride ion	27,000
Nitrate ion	550,000
Chromium	90
Copper	49,000
Manganese	200
Sulfate ion	97,000
Uranium	440

Before the TSD function was implemented for the basins, they were modified by permanently plugging the drains, inlets, and outlets; and then installing a new pipeline to fill the units. There is no mention in the documents reviewed as to whether the basins were checked for liquid tightness at this time.

Basin 1 was the first unit to receive waste. The waste was predominantly nitric acid solutions that were neutralized with sodium hydroxide, and it contained various metals and radioactive constituents. After two months of operation beginning in June 1973, use of the basin was postponed for over a year until operational problems in the 300 Area were resolved. Use of Basin 1 resumed in January 1975, but was discontinued again in August 1978 after nitrate was discovered in the groundwater at an adjacent well (199-H4-3), which had been previously installed by the AEC for monitoring purposes. All available records indicate that the nitrate contamination was attributable to the leakage/seepage of wastes from Basin 1 (no evidence of transportation spillage or waste handling problems could be found). At that time, Basin 1 was permanently removed from service, and the pumpable wastes were removed, leaving a sludge.

Concurrent with the Basin 1 shutdown, Basins 2 and 3 were prepared for service by coating the walls and floors with a urethane liner. In late 1982, Basin 4 was lined with butyl and Hypalon (a du Pont trademarked product), and then put into service.

The 183-H Basins were permanently removed from service in November 1985. The depth of the wastes in the three lined basins when remedial activity began in July, 1986, was approximately eight feet, with a total of 620,000 gallons of liquid and 36,000 cubic feet of sludge. Table II-1 shows the chemical makeup of five samples taken from the Basin 1 slurry before it was removed. Samples were taken at different locations within Basin 1 (near walls, at the bottom, at top, in the liquid, and in the solid/crystals) to represent the range of concentrations in the slurry.

C. REGULATORY HISTORY

The AEC originally operated the Hanford Site when its chief function was plutonium production. With the creation of DOE in 1974, all Federal nuclear facilities, including Hanford, came under DOE operational control. By the time DOE assumed operational control of the site, operation of Basin 1 at the 183-H site had been initiated and then halted due to the operational problems noted above.

Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976. Shortly thereafter, the 183-H Basins were designated a RCRA site since they were still operational in 1978 when groundwater contamination was detected.

In 1983, DOE identified six wells in the vicinity of the 183-H Site (see Figure II-5) that were to be used to monitor possible groundwater contamination resulting from leakage of the basins. Three of these wells were new and three were pre-existing as part of the Hanford Groundwater Monitoring Project, whose purpose was to characterize local geology and hydrogeology, and to monitor the large scale dynamics of groundwater and contaminant movement throughout the Hanford Site.

In 1985, the RCRA Compliance Groundwater Monitoring Project for the 183-H Basins was implemented. This project was intended to augment the Hanford Groundwater Monitoring Project with site-specific data required under RCRA for sites, such as the 183-H Basins, where contamination is known to exist. The compliance monitoring was designed to facilitate movement of the 183-H Basins from a detection level to an assessment level program. The RCRA Compliance Groundwater Monitoring Project activity for this facility was the Revised Groundwater Monitoring Compliance Plan for the 183-HSolar Evaporation Basins. Under RCRA, an assessment level program is mandated when groundwater contamination has already

Table II-1 Characterization Results for Basin 1 Slurry/Solid Waste (From Table 9: PNL Characterization Reports, PNL, 1987)

		SAMPLE IDENTIFICATION				
COMPONENT/UNITS		I-2	I-5	I-12	I-13	I-15
Na	%	23.5	20.3	18.8	19.5	17.7
F^-	%	5.4	6.2	6.1	6.4	6.1
NO_3^-	%	10.4	9.6	7.4	6.9	6.1
SO_4^{2-}	%	19.8	23.5	20.3	19.7	17.7
Cr	ppm	930	1380	1450	1280	1380
Cu	%	12.6	12.8	12.7	11.2	10.0
Fe	%	0.2	0.23	0.28	0.29	0.3
Mn	ppm	1540	2130	2360	2190	2380
Mo	ppm	189	338	364	396	419
Ni	ppm	64	169	183	163	169
S	%	10.38	9.67	7.86	8.42	7.46
Sn	ppm	516	780	902	925	943
U	ppm	375	579	678	685	647
Zr	%	1.90	3.43	3.55	3.32	3.85
^{60}Co	pCi/g	1.56	24.5	28.2	12.1	22.1
^{137}Cs	pCi/g	<3.0	5.62	<3.3	<2.3	<2.8
^{54}Mn	pCi/g	<2.5	7.45	<2.7	<1.7	<2.5
^{99}Tc	pCi/g	<439	<39	<116	<90	<93
^{234}U	pCi/g	6960	2920	9030	5470	5900
^{235}U	pCi/g	454	216	602	409	401
^{238}U	pCi/g	4940	2130	6390	3980	4170

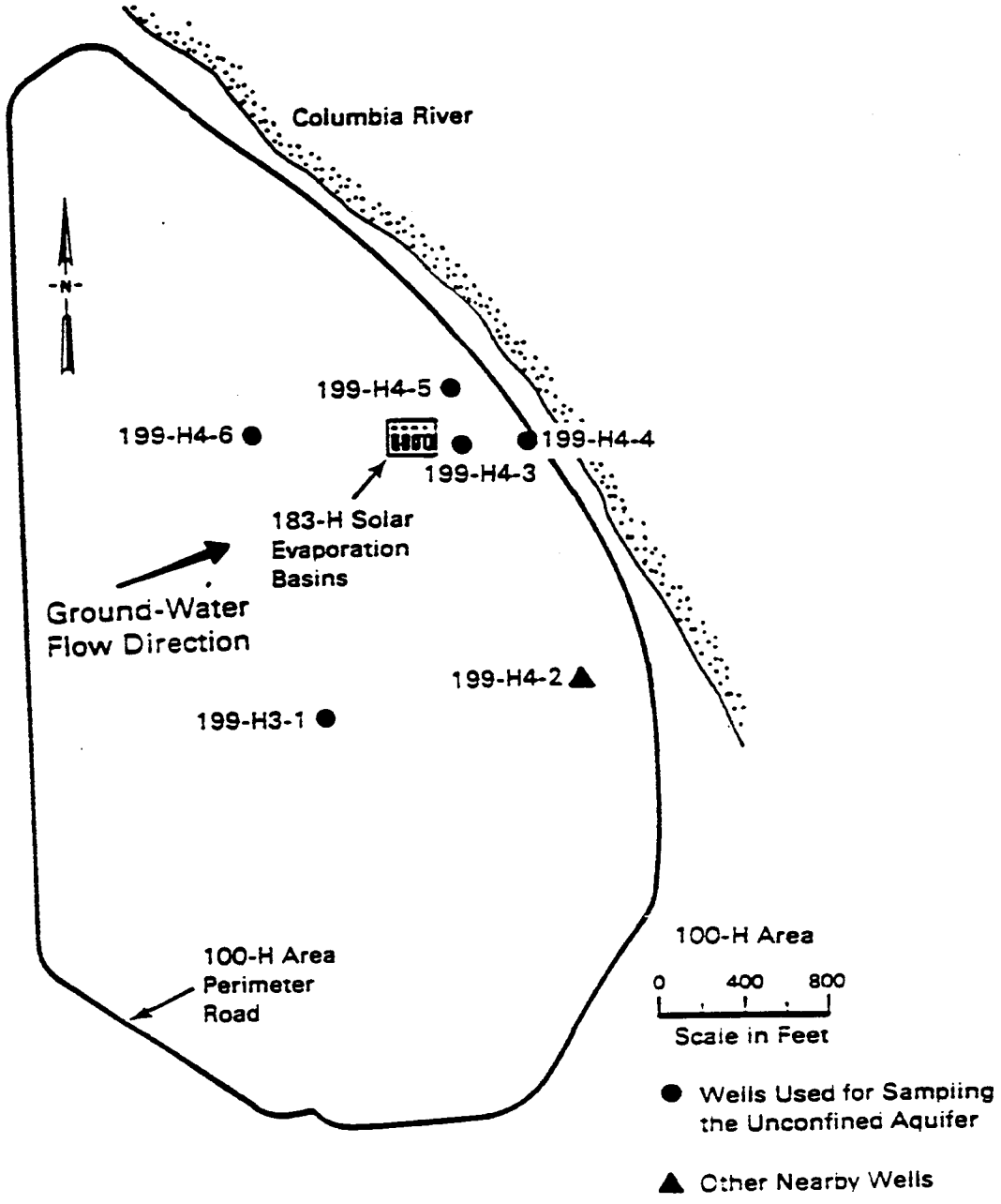


Fig. II-5 100-H Area Well Location Map (From Fig. 12: DOE, 1986)

been detected. Assessment level programs include site characterization and other activities similar to the RI/FS process under CERCLA.

The 183-H project was labeled, as were most other Hanford cleanup projects at the time, as "interim" projects until a final applicable project designation and lead agency could be assigned. The EPA assumed the lead agency role initially in 1985 until an overall Hanford agreement could be reached between EPA, DOE and the WDOE. On October 1, 1986, a "Consent Agreement and Compliance Order" was signed by EPA, DOE, and WDOE. This order provided for the construction of 16 additional monitoring wells near the 183-H Basins by a milestone date of November 1986. This deadline was subsequently met by DOE.

In 1989, in part due to mounting public pressure, the Hanford Federal Facility Agreement and Consent Order, also known as the Action Plan, was executed between the EPA, DOE, and WDOE. The Action Plan provided a blueprint for managing cleanup of all designated CERCLA and RCRA facilities and sites at Hanford. Also, as provided under the Action Plan, EPA and WDOE are charged with a shared lead agency responsibility for most of the Hanford sites, including the 183-H Basins. The DOE remains the liable and responsible party for all Hanford hazardous waste sites, but now is fully subject to regulatory compliance under EPA and WDOE.

D. SITE CHARACTERIZATION/DATA COLLECTION

Site Geography

The 560 square mile Hanford site is located in the lower Columbia Basin in south central Washington, within the Pasco Basin. The climate in this basin is typical of lower elevations in Eastern Washington. Maximum temperatures in the summer reach 100 to 115 degrees Fahrenheit, while winter temperatures can fall below zero degrees Fahrenheit. The area is arid with an annual precipitation less than 10 inches per year. The Columbia River flows through the Hanford Site, while the Yakima River borders the southern edge of the site just before its confluence with the Columbia River. All Hanford Site operational activity is south and west of the Columbia River (see Figure II-1).

The 183-H Basins are located on an alluvial bench adjacent to the Columbia River. Priest Rapids Dam is located approximately 6 miles upstream of the facility. Variable releases from the dam for electric power generation, both seasonally and diurnally, cause substantial fluctuations in the level of the river as well as in wells adjacent to the river.

Land use in the region surrounding the Hanford Site is primarily irrigated agriculture and range land. The Tri-Cities of Richland, Kennewick and Pasco, form the main population center. These cities are located to the southeast of the Hanford Site and have a combined population of over 120,000.

Geology/Hydrogeology

Three distinct geologic formations have been identified underlying the 100-H Area at Hanford. In ascending order, they are the Saddle Mountains Basalt Formation, the Ringold Formation, and the Hanford Formation (see Figures II-6 and II-7). Of primary significance for the 183-H Basins is the Hanford formation, which contains an unconfined near-surface aquifer over much of the site. The Hanford formation consists primarily of unconsolidated alluvial sands and gravels with high groundwater transmissivity. The underlying Ringold Formation contains clays, silts, and sands, and becomes more cemented and impermeable with depth, and provides a confining layer for the deeper artesian aquifer contained within the Saddle Mountains Basalt Formation. The upper part of the Ringold formation has a low percentage of clay, contributing to its greater transmissivity. Figures II-8 and II-9 show measured hydraulic conductivity values for the Hanford and Ringold formations in feet per day. These values were calculated at various wells near the 183-H Basins. Table II-2 shows the general characteristics of the geologic formations beneath the 100-H Area.

Recharge of the Hanford formation occurs primarily from precipitation, particularly from occasional winter snow on the Rattlesnake Hills to the west. However, of particular note is the unconfined aquifer's interface with the surface water of the Columbia River at the 100-H Area. Intermittent direct recharge from the river at high stages, usually resulting from dam releases upstream, results in flow gradient reversals. There are no groundwater withdrawals for potable use in the vicinity of the 183-H Basins.

Groundwater Monitoring Wells

The 100-H Area groundwater had been monitored for many years before implementation of the RCRA Compliance Ground-Water Monitoring Project in 1985. A total of six wells predated the RCRA project (wells 199-H3-1, H4-2, H4-3, H4-4, H4-5, and H4-6; note that all wells formally have the 199- prefix which is dropped here for convenience). All except H4-2 are completed in the unconfined aquifer in the vicinity of the 183-H basins. Monitoring well H4-2 was drilled into the basalt for the study of the confined aquifer's piezometric surface. Sampling of well H4-3 began in

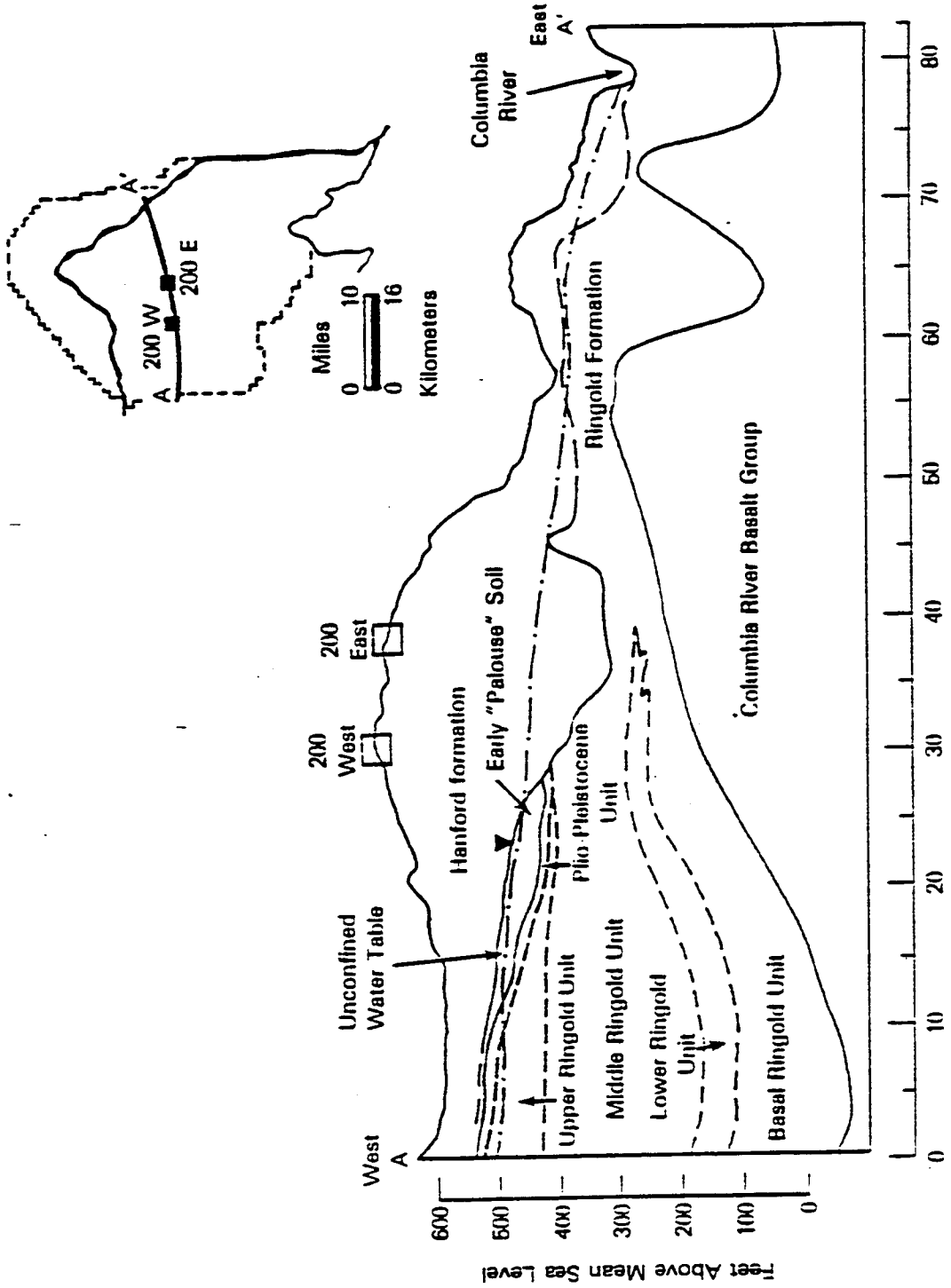


Fig. II-6 Geologic Cross-Section of the Hanford Site (From Fig. 3: PNL, 1987)

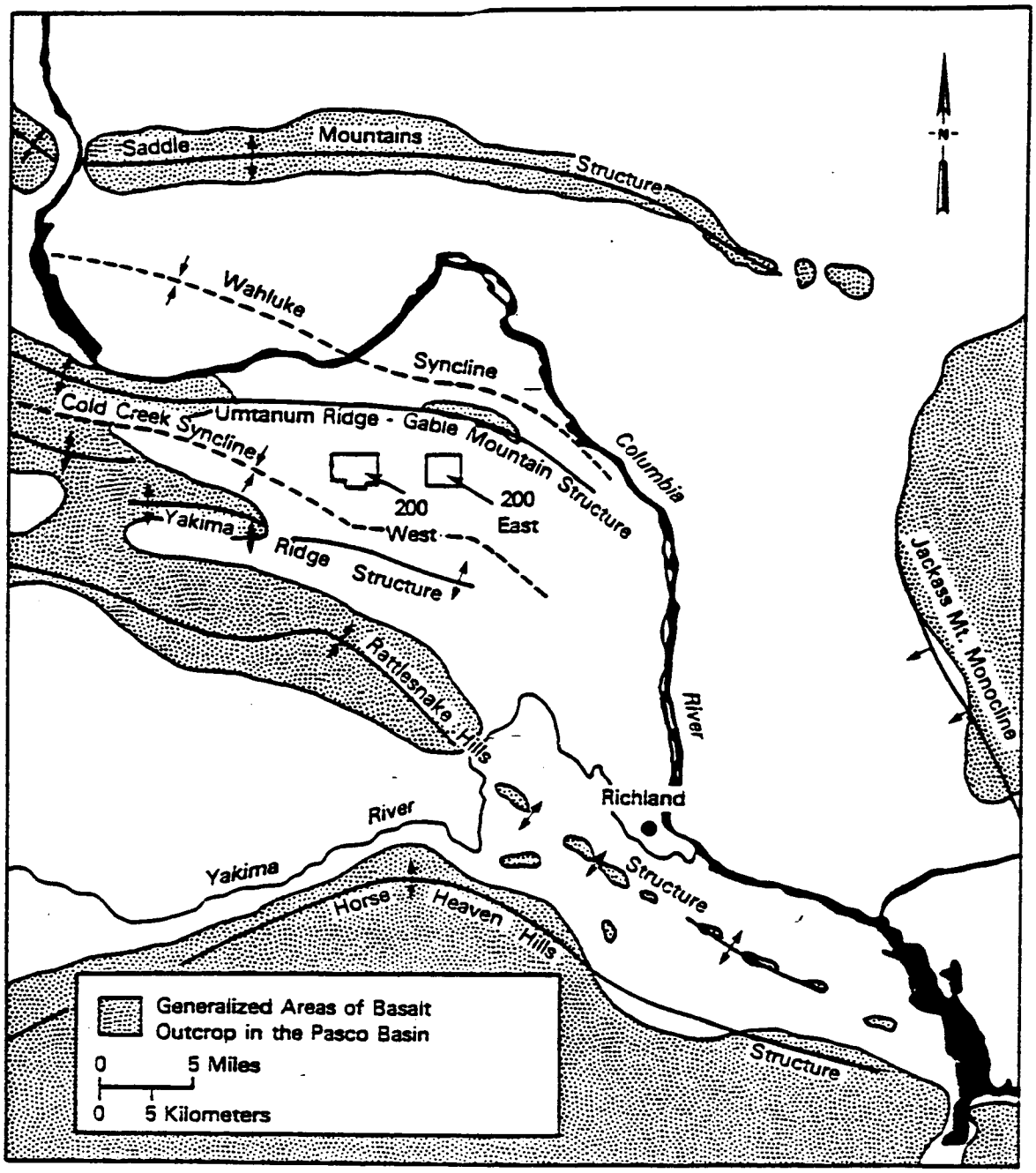


Fig. II-7 Structural Geology of the Pasco Basin (From Fig. 2: PNL, 1987)

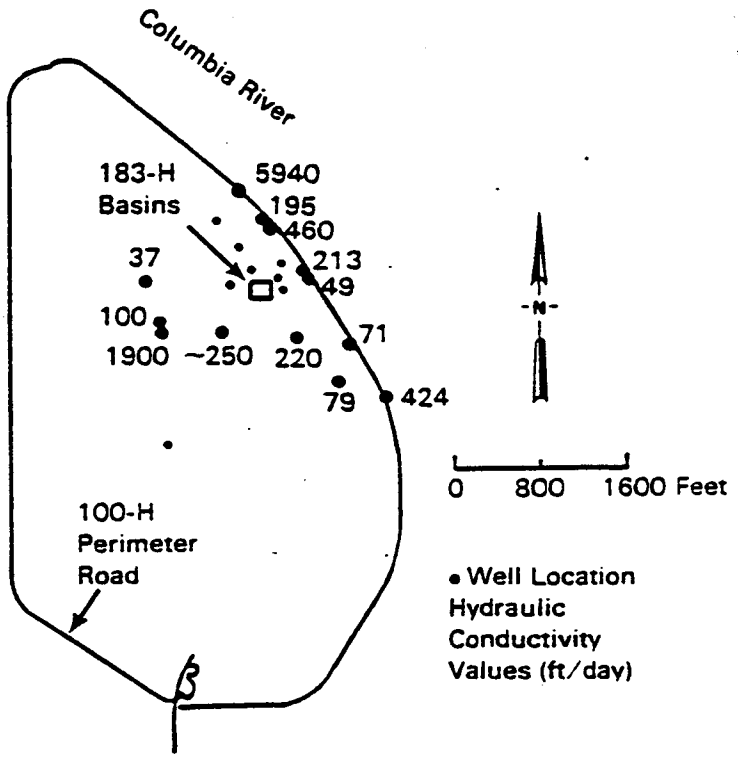


Fig. II-8 Hydraulic Conductivity Values for the Ringold Formation Silty Sand and Gravelly Silty Sand Units (From Fig. 34: Likala et al., 1988)

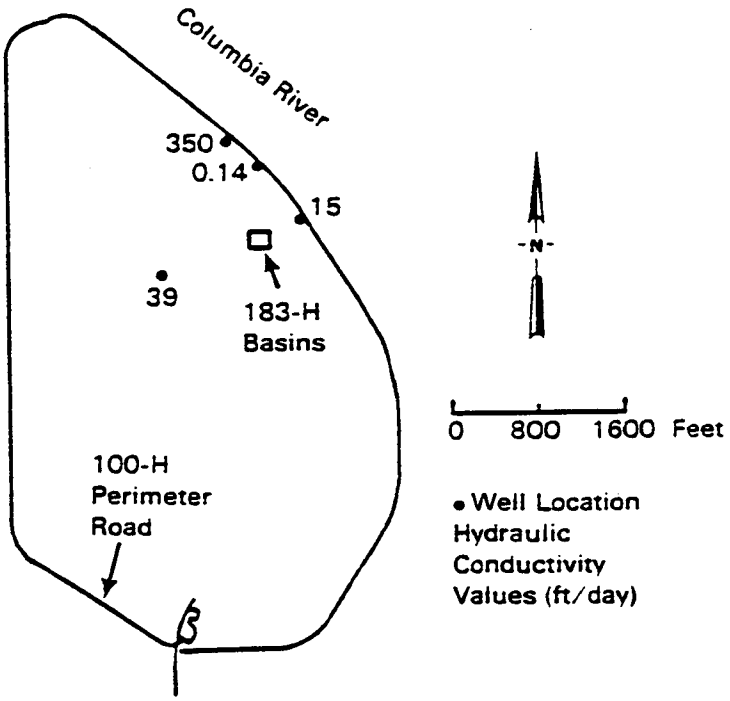


Fig. II-9 Hydraulic Conductivity Values for the Unconfined Aquifer (From Fig. 35: Likala et al., 1988b)

Table II-2. General Characteristics of the Geologic Formations Beneath the 100-H Area (From Table 3: PNL, 1987)

Formation	Unit/Member	Texture	Sorting	Mineralogy	Color	HCL Reaction	Consolidation
Hanford Formation	Silty Sandy Gravel	50% Gravel 40% Sand 1% Silt	Poor	Basaltic, Quartz-Rich, and Metamorphic	Gray, Black, and Brown	None to Strong	Unconsolidated
Ringold Formation	Gravelly Silty Sand	5% Gravel 70% Sand 20% Siltpo 5% Clay	Poor	Quartz-Rich and Basaltic with Caliche	Reddish Brown	Strong	Unconsolidated to Slightly Consolidated
	Silty Sand	75% Sand 15% Silt 10% Clay	Well	Quartz-Rich and Basaltic with Caliche	Reddish Brown, Yellowish Brown, and Brown	Slight to Strong	Slightly Consolidated to Consolidated
	Silty Claycy Sand to Sandy Silty Clay	50% Sand 25% Silt 25% Clay	Well	Quartz-Rich with Caliche	Yellow, Green, Blue, Brown, and Black	Slight to Strong	Consolidated to Well Consolidated
Saddle Mountains Basalt	Elephant Mountain	80% Basalt 20% Clay		Basaltic	Dark Grey, Black, and Very Dark Brown		Dense
	Interflow Zone	Ash, Gravel, Sand, Silt and Clay					
	Elephant Mountain	Basalt					

1974 shortly after its completion: at this well, nitrate contamination was discovered in August 1978. Wells H4-4, H4-5, and H4-6 were specifically drilled in 1983 to monitor the basins as part of the Hanford Groundwater Monitoring Project prior to RCRA enforcement action at the 183-H Basins.

In conjunction with the October 1986 Consent Agreement and Compliance Order, new wells were planned to collect hydrogeologic information, to determine the extent of contamination originating from the 183-H Basins, and to determine the rate of movement of contaminants. The monitoring well network was expanded from the six Phase I wells with the addition of 16 Phase II wells following the 1986 agreement. Phase III subsequently followed in early 1987 which added three more wells. With the addition of the Phase III wells, samples could be collected from all three stratigraphic layers in the vicinity of the 183-H Basins. All Phase II and III wells were constructed to RCRA standards, which recommend the use of stainless steel casing and screens. Table II-3 summarizes the well completion data indicating depth, locations, and water table elevations. Figures II-10 thru II-14 show the complete monitoring network in map form as well as the planned construction profiles for typical wells (actual construction varied somewhat from the plan; see PNL (1987) and Likala et al., 1988) for details).

Sampling

Groundwater samples are collected at all but two of the 25 wells in the 100-H Area. One of the two remaining wells is used exclusively for hydraulic head measurements, while the other well penetrates the confined artesian aquifer in the Columbia River Basalt. This well has been capped to prevent it from flowing. The "point of compliance" well, 199-H4-3, is located approximately 75 feet downgradient of the facility and has shown the highest concentrations of contaminants attributable to the 183-H Basins. Routine reviews of data collected at this well since 1974 show that nitrate and chromium levels were increasing until they peaked in 1978. Levels of chromium and nitrate declined sharply after corrective measures were taken at Basin 1.

Two constituents were chosen as the focus of this case study: nitrate and gross beta. Nitrate was chosen because it is the primary contaminant in the wastes that were discharged into the 183-H Basins. Gross beta, which originated from several radioactive constituents used in the 300 Area fuel fabrication process, has also persisted over a long enough period of time to allow the identification of a plume in the unconfined aquifer. The concentrations of these two constituents appear to have clear declining trends as shown in Figures II-15 and 16.

Table II-3 Completion Data for the 100-H Area Wells (From Likala, et al., 1988)

Well No.	Completion Date	Construction Materials		Depth (ft)[a]			Hydrostratigraphic Unit[b]
		Casing	Screen	to Bottom[a]	to Water	of Screened Interval	
Original Monitoring Wells							
199 113 1	09-00-60	Carbon Steel	Perforated	75	45	29 - 74	Unc Aq
199-114-3	05-00-74	Carbon Steel	Perforated	55	39	34 - 55	Unc Aq
199-114-4	06-00-83	Carbon Steel	Stainless	50	36	33 - 43	Unc Aq
199-114-5	05-00-83	Carbon Steel	Stainless	60	36	32 - 42	Unc Aq
199-114-5	05-00-83	Carbon Steel	Stainless	54	41	39 - 49	Unc Aq
Phase II Wells							
199-113-2A	11-04-86	Stainless	Stainless	51	41	36 - 51	Unc Aq
199-113-2B	11-14-86	Stainless	Stainless	55	40.5	50 - 55	Unc Aq
199-113-2C	10-15-86	Stainless	Stainless	110	41	100 - 110	SS&GSS
199-114-7	09-22-86	Stainless	Stainless	53	43	38 - 53	Unc Aq
199-114-8	09-11-86	Stainless	Stainless	48	44	38 - 48	Unc Aq
199-114-9	09-24-86	Stainless	Stainless	46	43	36 - 46	Unc Aq
199-114-10	09-22-86	Stainless	Stainless	38	29	23 - 38	Unc Aq
199-114-11	10-10-86	Stainless	Stainless	53	43	38 - 53	Unc Aq
199-114-12A	11-04-86	Stainless	Stainless	48	38	33 - 48	Unc Aq
199-114-12B	11-11-86	Stainless	Stainless	50	37	45 - 50	Unc Aq
199-144-12C	10-03-86	Stainless	Stainless	82	36	72 - 82	SS&GSS
199-114-13	11-20-86	Stainless	Stainless	52	42	37 - 52	Unc Aq
199-114-14	12-05-86	Stainless	Stainless	53	43	38 - 53	Unc Aq
199-114-15A	11-11-86	Stainless	Stainless	42	32	27 - 42	Unc Aq
199-114-15B	11-19-86	Stainless	Stainless	42	30	37 - 42	Unc Aq
199-114-15C(P)[c]	10-29-86	Stainless	Stainless	327	Flowing	325 - 327	Low Con Aq
199-114-15C(Q)[c]	10-29-86	Stainless	Stainless	297	0.25	295 - 297	Upp Con Aq
199-114-15C(R)[c]	10-29-86	Stainless	Stainless	196	27.5	194 - 196	SS&GSS
199-114-15C(S)[c]	10-29-86	Stainless	Stainless	80	30.5	78 - 80	SS&GSS
Phase III Wells							
199-114-16	04-30-87	Stainless	Stainless	57.5	48.5	42.5 - 57.5	Unc Aq
199-114-17	05-08-87	Stainless	Stainless	45	41.5	35 - 45	Unc Aq
199-114-18	05-26-87	Stainless	Stainless	51	45	40 - 50	Unc Aq

(a) All depths are given in feet relative to land surface.
(b) Unc Aq = Unconfined Aquifer; SS&GSS = Silty Sand & Gravelly Silty Sand; Upp Con Aq = Upper Confined Aquifer Low Con Aq = Lower Confined Aquifer.
(c) Piezometers.

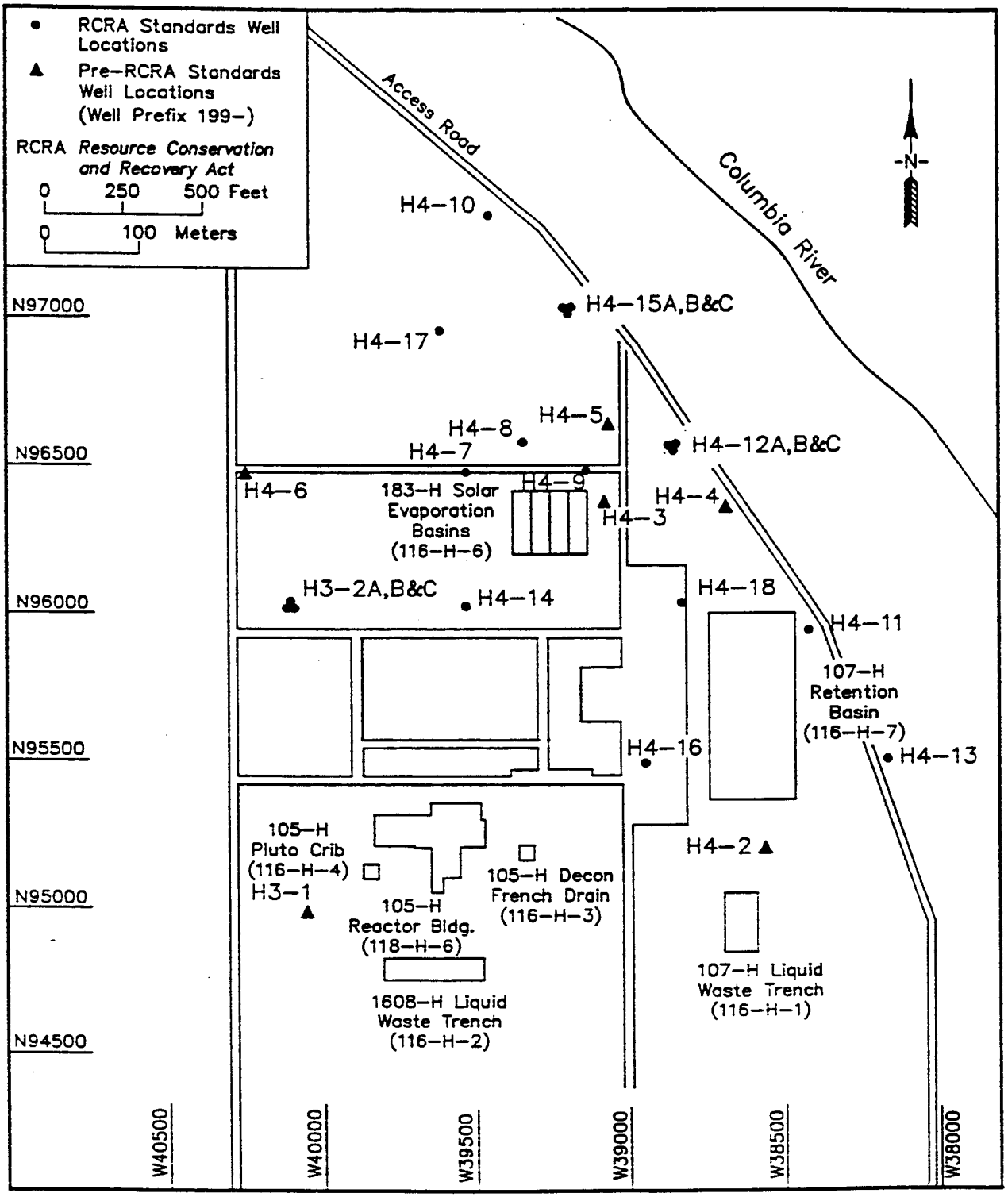


Fig. II-10 Monitoring Well Locations for the 183-H Solar Evaporation Basins (From Fig. 2-1: DOE, 1991)

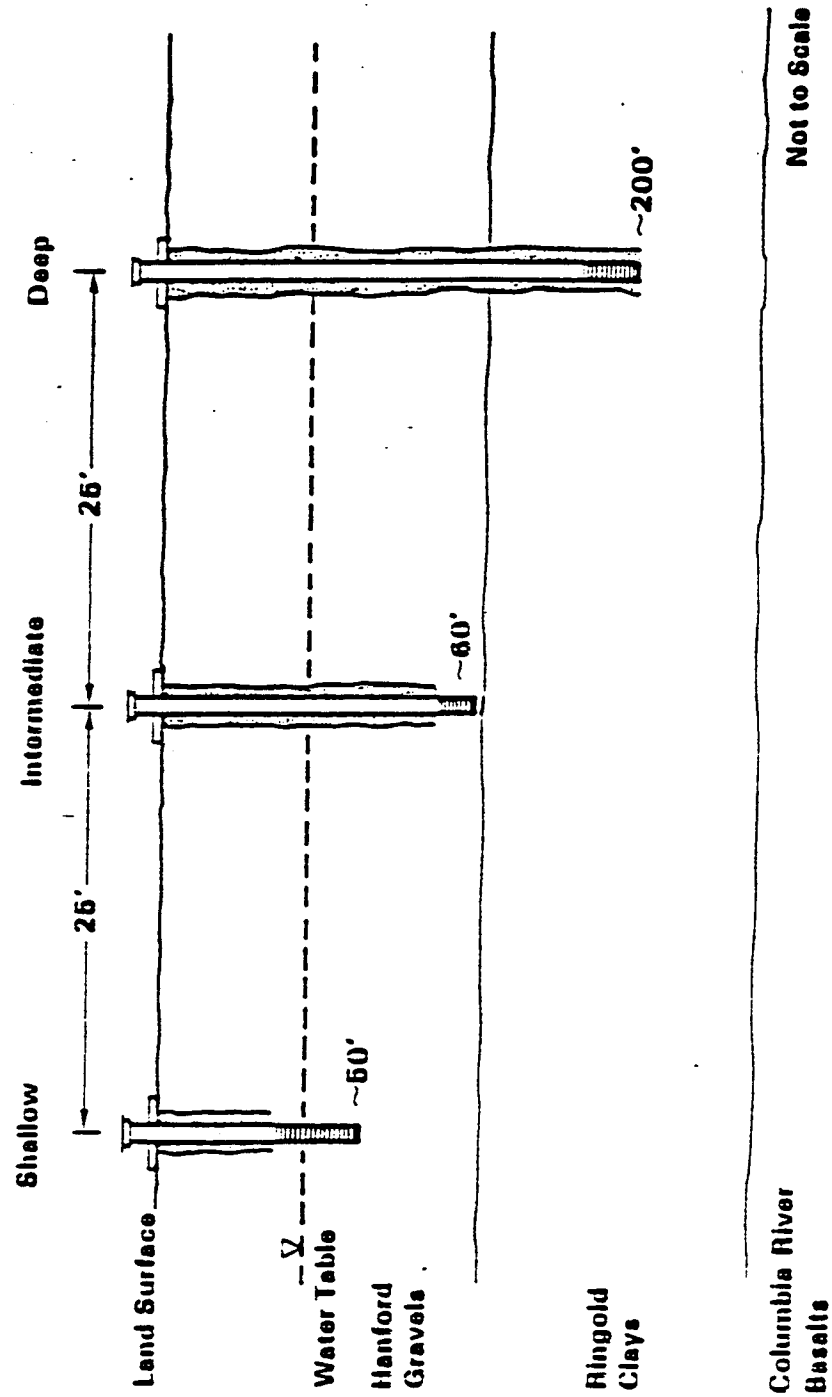


Fig. II-11 Cross-Sectional View of Well Cluster Completion (From PNL, 1987)

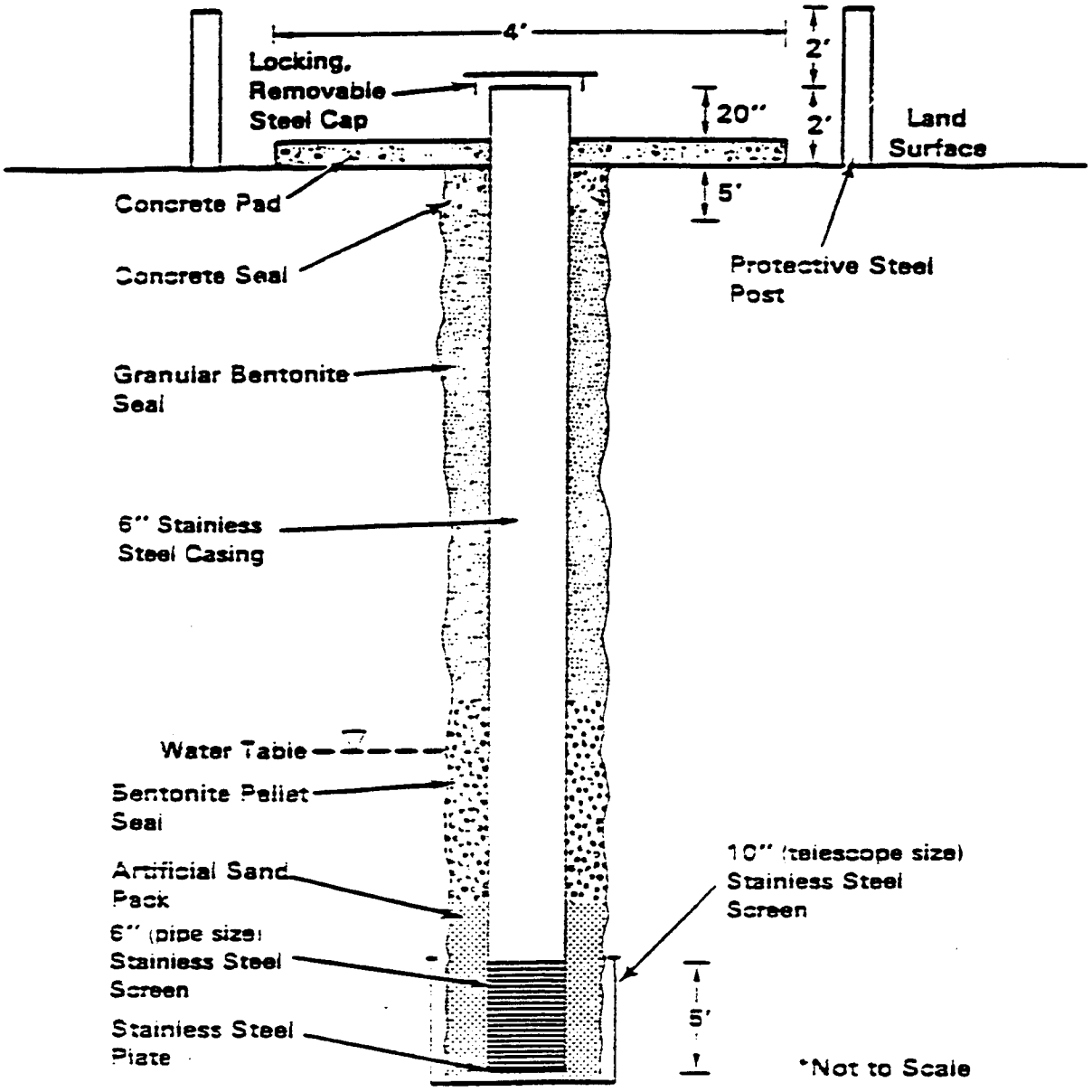


Fig. II-12 Completion Detail for Intermediate Wells Completed at the Bottom of the Unconfined Aquifer (From PNL, 1987)

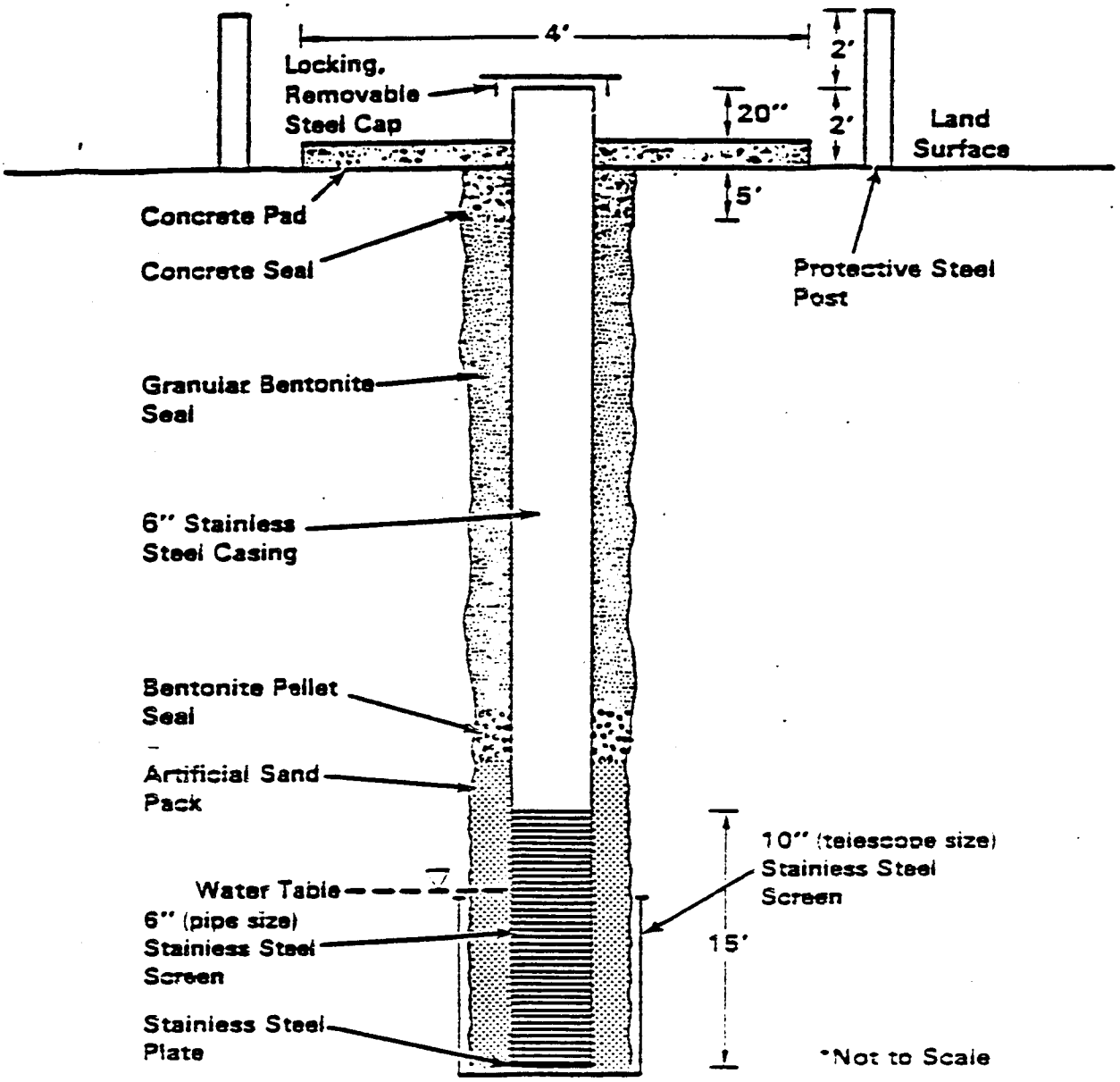


Fig. II-13 Completion Detail for Single Shallow Wells in Hanford Gravels (From PNL, 1987)

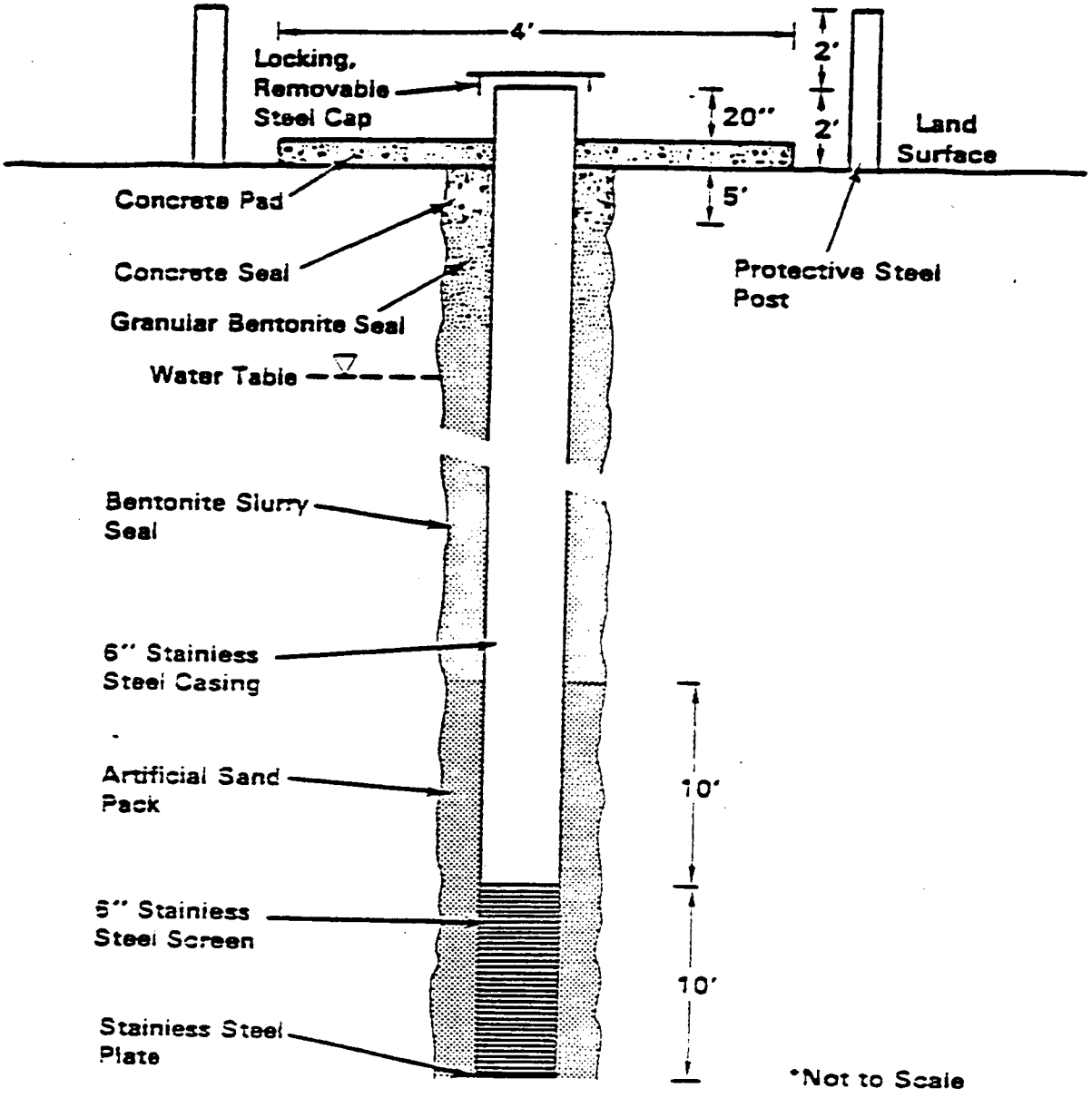


Fig. II-14 Completion Detail for Deep Wells within the Ringold Formation (From PNL, 1987)

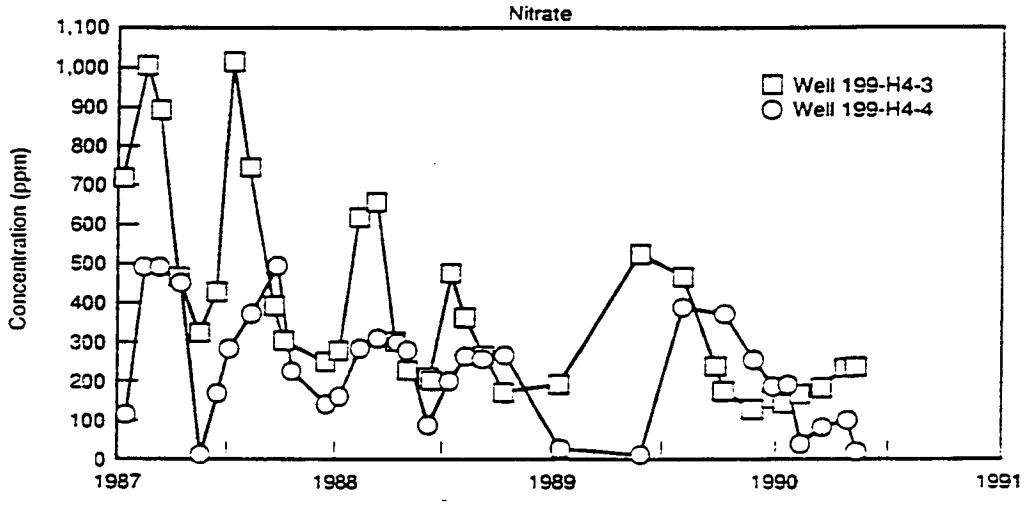


Fig. II-15 Nitrate Concentrations in Downgradient Wells 199-H4-3 and 199-H4-4 (From Fig. 2-2: DOE, 1991)

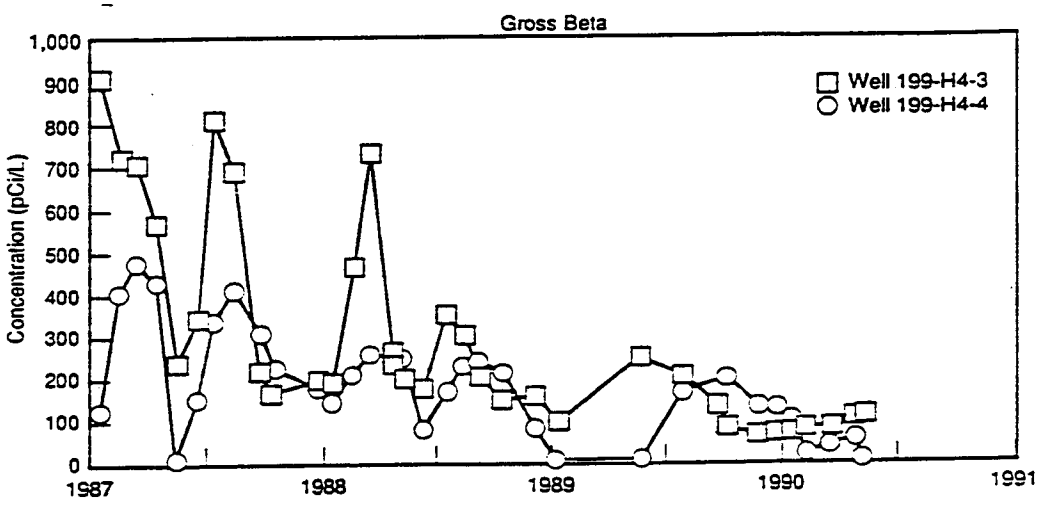


Fig. II-16 Gross Beta Concentrations in Downgradient Wells 199-H4-3 and 199-H4-4 (From Fig. 2-4: DOE, 1991)

Groundwater modeling and contaminant transport analysis, initiated in 1985 to help define the hydrologic system, was aided by completion of the monitoring wells added under Phases II and III in 1987. The flow gradient reversal phenomenon, attributable to the often-abrupt changes in Columbia River levels, created a complex modeling problem. Another issue adding to the complexity of the problem is that the contamination from the 183-H Basins is superimposed on pre-existing contamination from the 100-H reactor site (managed separately under CERCLA). This becomes obvious when reviewing data collected for chromium contamination. Figures II-17 and II-18 show the chromium plume as of 1989 and 1990, respectively. Although the chromium contamination is rapidly decreasing, both plots suggest that the plume may originate from other sources in addition to the 183-H Basins. The plume is apparently migrating northeasterly toward the Columbia River. Figures II-19 and II-20 show the migration of the nitrate plume at the 183-H Basins. Nitrate contamination levels decreased an average of nearly 30% from 1989 to 1990. The peak contaminant value recorded at the end of 1990 was 194 ppm nitrate (slightly over four times the drinking water standard of 45 ppm (EPA 1990)).

Appendix A contains a complete hard copy of the raw data available for nitrate and gross beta sampling results by well number since monitoring began under the AEC until May 1990. This data are also provided on the Appendix D computer disk.

E. REMEDIATION/CLOSURE/POST-CLOSURE

Introduction

The remediation process was initiated in 1985 concurrent with site characterization and sampling program development. Basins 2 and 3 were cleaned and relined, then the liquid waste was replaced, and they were used to continue to evaporate the remaining 370,000 gallons of liquid waste as an approved step in the closure process. In April 1988, sludge removal began in Basin 4. In October 1988, the evaporation activity ceased, and sludge removal proceeded for Basins 1, 2, and 3.

Regulatory Considerations

Although the 183-H Basins are a designated RCRA site, they are located within two CERCLA operable units: 100-HR-1, which addresses surface sources of contamination, and 100-HR-3, which covers groundwater contamination. Draft

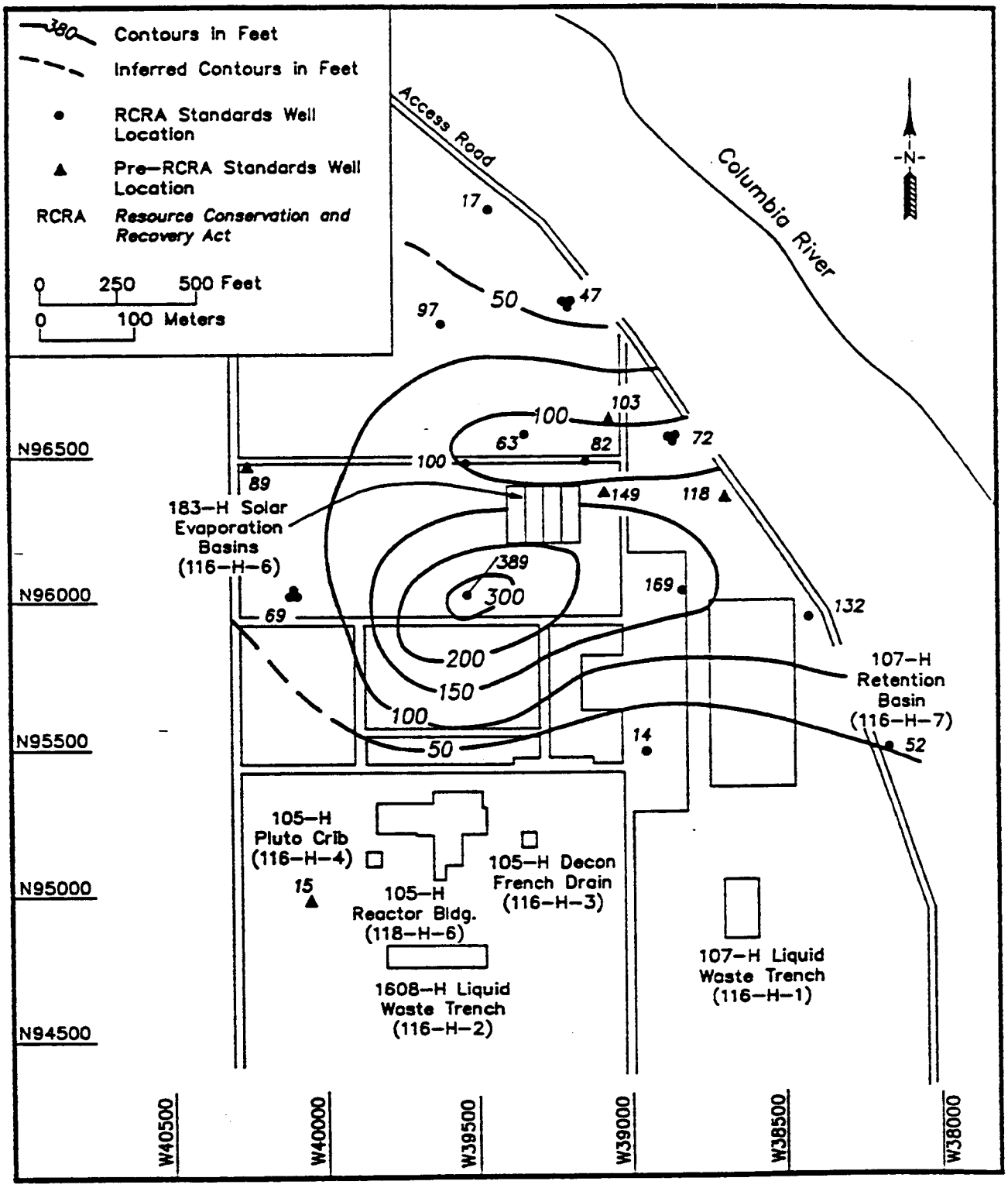


Fig. II-17 Average Chromium Concentrations in Shallow Wells (μg/l): 1989 (From Fig. 2-13: DOE, 1991)

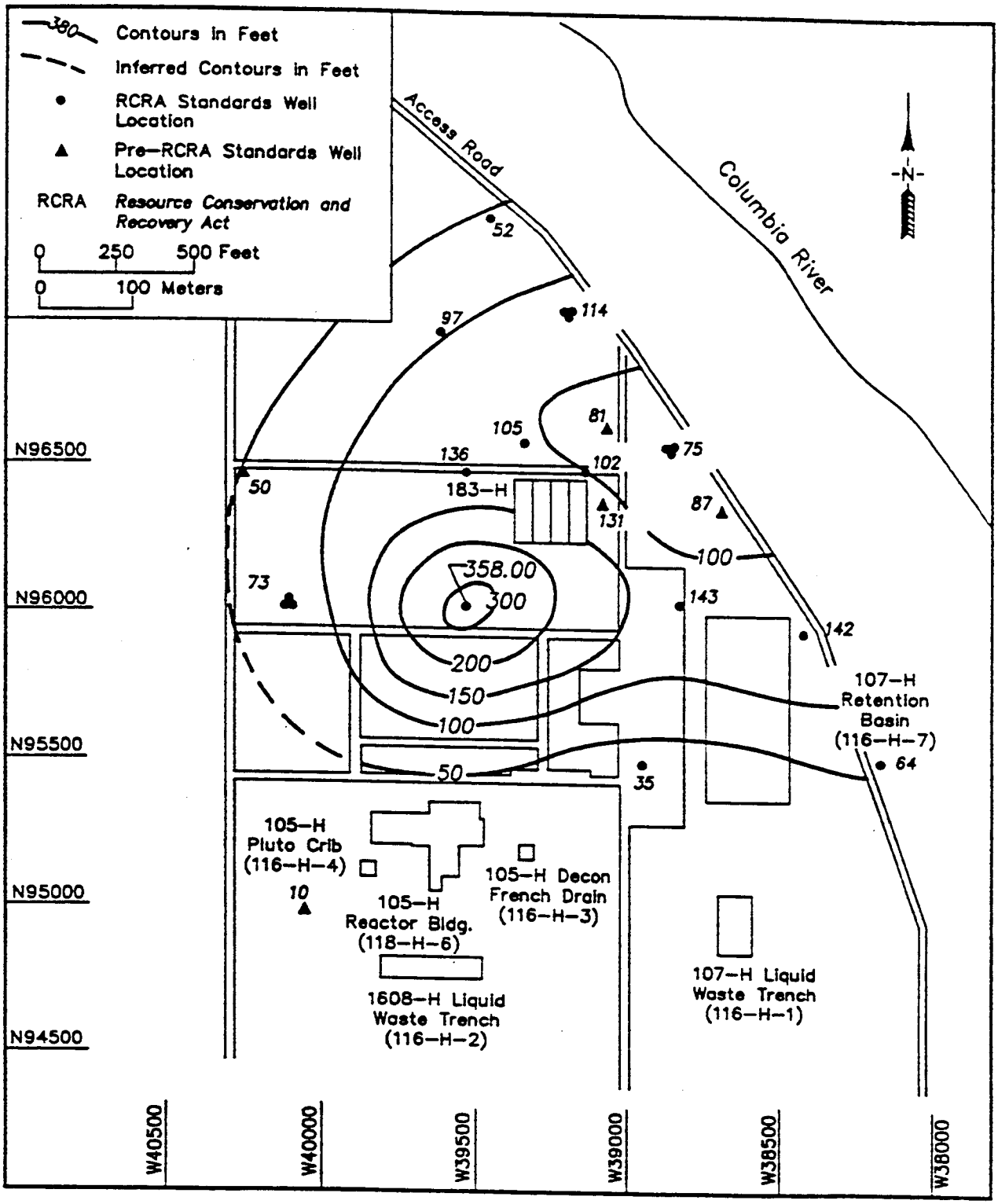


Fig. II-18 Average Chromium Concentrations: 1989 (From Fig. 2-14: DOE, 1991)

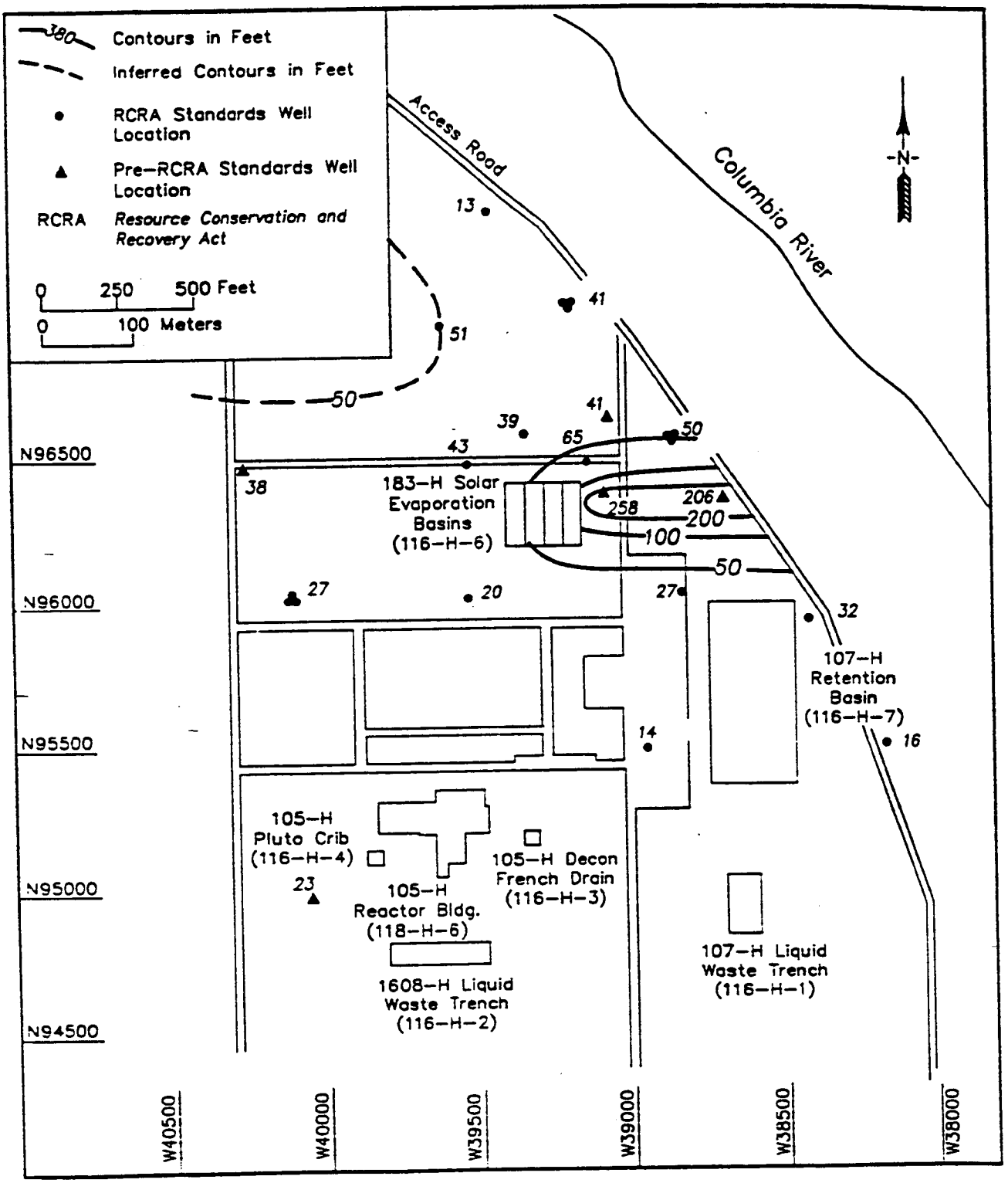


Fig. II-19 Average Nitrate Concentrations in Shallow Wells (mg/l): 1989 (From Fig. 2-11: DOE, 1991)

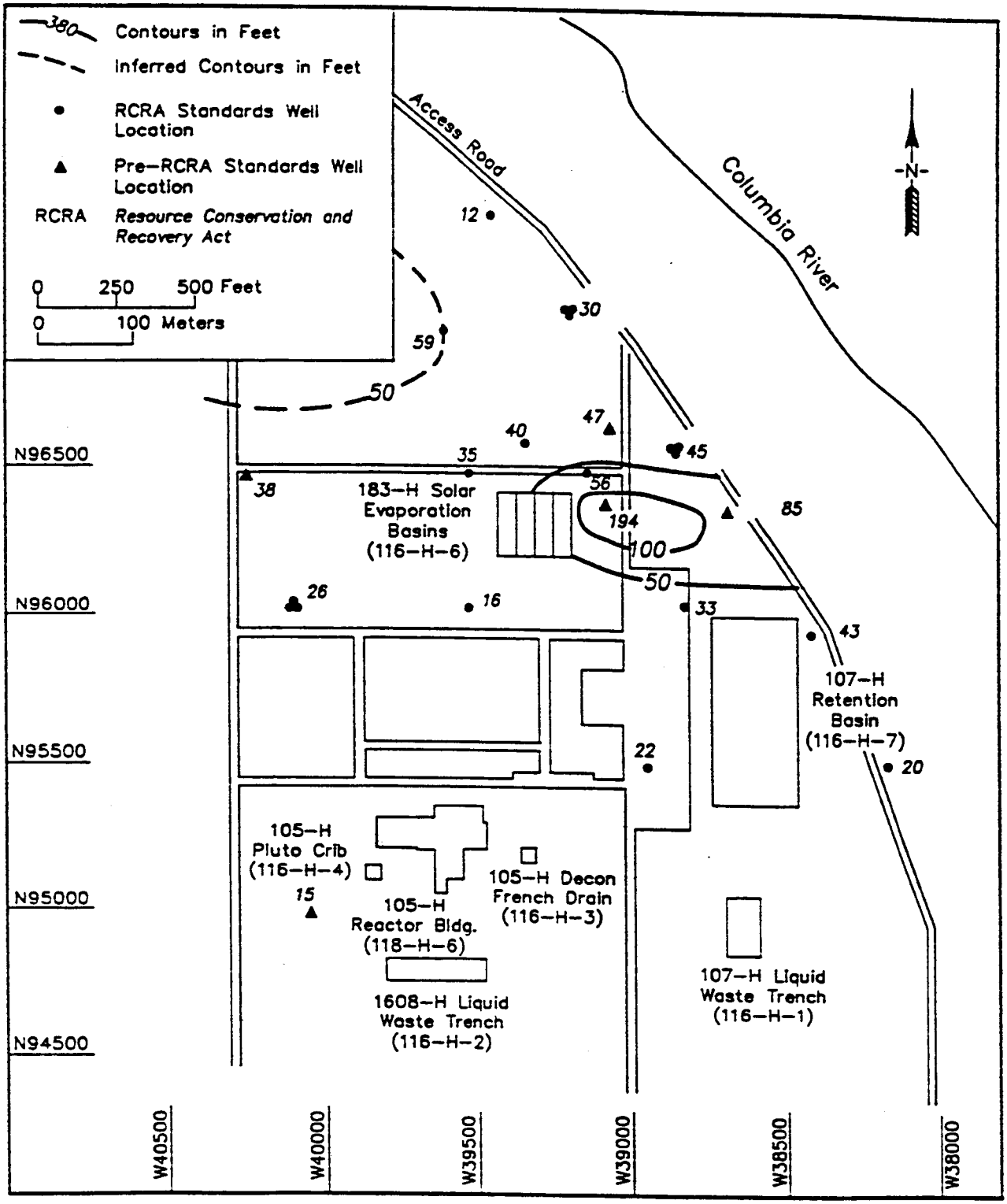


Fig. II-20 Average Nitrate Concentrations in Shallow Wells (mg/l): 1990 (From Fig. 2-12: DOE, 1991)

work plans for these CERCLA sites have been completed. However, the current plan is that remediation activities for the 183-H Basins will be accomplished under the requirements for a RCRA past-practices unit.

Remediation/Closure Process Outline

The combined remediation and closure process for the 183-H Basins has been planned from 1988 through fiscal year 1993. The nine major steps leading to certified closure of the facility are as follows:

Activity 1: Hazardous Waste Volume Reduction.

Evaporation of liquids in basins was allowed to continue until October 1988 in Basins 2 and 3 under the RCRA process.

Activity 2: Solid Waste Removal-Basin #4.

The estimated 5000 cubic feet of sludge in Basin 4 was removed and placed in DOT approved 55 gallon drums for transport to a holding facility in the 200-E Area.

Activity 3: Liquid Waste Removal.

Liquids remaining in Basins 2 and 3 after the 1988 evaporation season were pumped into containers and then solidified in place, creating a volume increase of approximately 30 percent. Integrity testing, in accordance with 40 CFR 261, was performed on the solidified mass.

All loaded drums and containers were manifested and transported to the Radioactive Mixed Waste Storage Facility in the 200-E Area pending identification of permitted facility. All transport roads are within the Hanford Site.

Activity 4: Basin Decontamination.

The cleanup involved high pressure washing of the basins using water and abrasive material; no solvents were allowed. Rinsate material was collected, solidified, and packaged for transport and storage.

Activity 5: Basin Sampling and Testing.

This work involves both the surface of the concrete basins using a swabbing technique, and interior concrete sampling by cutting prism shaped cores out of the walls. A 1 foot grid system was set up for each surface in each basin with the high liquid

level marked. A random selection program was used to choose sample locations. A minimum of five samples from each floor and three samples from each wall section above the high water mark were collected for a total of at least 29 concrete swab and core samples for each basin. Statistical analysis of the results may dictate increasing the total number of samples.

Metal structures and components were also being tested using the wet swab technique. The test methods used for the structure samples complied with EPA standards (SW-846).

Activity 6: Facility Demolition.

Upon completion of sampling and characterization, the structures will be demolished using standard construction techniques. The rubble will be disposed in adjacent abandoned clearwells, which were also part of the 100-H water treatment system. In the event that the sample analysis determines that the decontamination is incomplete, then the rubble will be compacted for in-situ disposal in accordance with 40 CFR 197(c)(1).

Activity 7: Contaminated Soil Characterization.

Following demolition of the 183-H Basins, soil samples will be collected. The closure plan does not presently provide for any remedial activity other than characterization and containment for the soil.

Activity 8: Cover Installation.

A 30 year life cover will be installed over the site after demolition of the structures. The cover will extend over all of the area where contaminated soil is identified. The proposed cover design is provided as Appendix A-2.

Activity 9: Certification of Closure.

This is an administrative requirement under 40 CFR 265.115 and WAC 173-303-610. Following the certification of closure, the closure plan calls for a 30-year maintenance and monitoring period which is standard for landfill closure plans under RCRA. Typical activities that would take place during this period include: continued groundwater monitoring, surface maintenance and monitoring, security of the site, and periodic reporting.

Current Status Review

As of the date of this report, the testing of the structural components (Activity 5) was complete, though the results were not available for public release. Soil testing and characterization work began in August and September 1991. Concrete core samples are being taken from inside the basins. Soil samples are being collected from penetrations through the basin walls. There is no preliminary indication at this point whether the results of the soil tests might lead to a revision of the present remediation plan.

F. EVALUATION/CRITIQUE

Contaminant Migration Modeling

Based on the modeling information contained in this report and the data provided in Appendix A-1, evaluate how long it will take for the nitrate and gross beta contamination to decrease to EPA drinking water standards. What assumptions must you make?

Remediation Planning

Evaluate why the 183-H Basins should be regulated as a RCRA site as opposed to consolidation under one of the two CERCLA operable units overlapping the basins.

Closure Plan

In your opinion is the impermeable cover necessary for the 183-H Basins? State your reasons in technical terms as well as in terms of RCRA and CERCLA requirements.

Soil Sampling/Demolition of Basins

Soil sampling is ongoing at this time. What are the implications for remediating the site if substantial nitrate and gross beta contamination exist in the soil? Would a fill and cover solution be the best approach? Suggest other alternatives. Should the remediation plan include demolition and/or cover of the basins if the concrete and soil are found not to be contaminated (i.e. could the basins serve a viable purpose during remediation of the entire Hanford Site?

Well Sampling

The cost of constructing an average monitoring well at Hanford is over $100,000 compared to the $12,000 cost of an equivalent well in Western Washington. Based on the available information in 1986, was the addition of 19 wells at the 183-H Basins site a prudent decision. What would you have done differently as a site manager?

Columbia River/Groundwater Interactions

Contaminant concentrations in sampling wells surrounding the 183-H Basins have been shown to be affected by Columbia River stage. How should this affect cleanup strategies?

G. HANFORD SITE REFERENCES

(PNL, 1986) PNL, Revised Groundwater Monitoring Compliance Plan for the 183-H Solar Evaporation Basins; PNL-6470, Prepared by Pacific Northwest Laboratories for the U.S. Department of Energy, Richland, WA. September 1986.

(PNL, 1987) PNL, Interim Characterization Report for the Area Surrounding the 183-H Basins; PNL-6471, Prepared by Pacific Northwest Laboratories for the U.S. Department of Energy, Richland, WA. April 1987.

(DOE, 1988) DOE, Interim Status Closure/Post Closure Plan: 183-H Solar Evaporation Basins; Westinghouse Hanford Company for the U.S. Department of Energy, Richland, WA. March 1988.

(Likala, et al., 1988) Likala, T.L., et al., Geohydrologic Characterization of the Area Surrounding the 183-H Basins; PNL-6728, prepared by Pacific Northwest Laboratories for the U.S. Department of Energy, Richland, WA. December 1988.

(DOE, 1989) DOE, Proposed Action Plan for the Implementation of the Hanford Federal Facilities Agreement; U.S. Environmental Protection Agency, U.S. Department of Energy, and Washington State Department of Ecology. February 1989.

(DOE, 1991) DOE, Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1990; Geosciences Group of Westinghouse Hanford Company for the U.S. Department of Energy. February 1991.

(Rokkan, 1986) Rokkan, D.J., UNC Nuclear Industries Reactor and Fuels Production Facilities 1985 Effluent Release Report; UNI-3880, UNC Nuclear Industries, Richland, WA. 1986.

CHAPTER III - THE WYCKOFF/EAGLE HARBOR CASE STUDY

A. INTRODUCTION

The Wyckoff Company/Eagle Harbor site is located near the town of Winslow on Bainbridge Island, Washington (see Figure III-1). The site occupies approximately 40 acres, covering 0.8 miles of shoreline at the mouth of Eagle Harbor, which opens into Puget Sound. This site has been the location of a wood treatment operation since 1905. In general, industrial activities at the Wyckoff site have primarily centered on the application of creosote and pentachlorophenol (PCP) to wood piles and poles. Creosote and PCP are biocides that preserve wood by deterring degradation, fouling or infestation by bacteria, fungi, or wood boring pests.

The highly permeable area occupied by Wyckoff has been extensively contaminated with creosote and pentachlorophenol. Contaminated media at the site include soils, groundwater, marine sediments, and marine biota. Although contamination was first suspected in the early 1970's, little physical action was taken at the site to contain the contaminants until the late 1980's. Reasons for these clean-up delays will be a primary focus of this case study.

Overall, the major issues in this case study are: 1) could site clean-up delays have been avoided given the existing laws, technology constraints, and litigation by Wyckoff in the 1970's and 80's, 2) was the approach taken to solve short-term contaminant migration problems technically sound, practical, within budget, and compatible with a long-term solution, and 3) what alternatives are there for long-term remediation at the site and what would be their environmental and economic impacts?

B. SITE HISTORY

The Wyckoff Company owns the tidelands surrounding the site to the extreme low tide level (approximately -4.5 ft.) and has a 12-year lease on bedlands in the log boom storage and docking areas located near the Creosote Dock and the West Dock, as shown in Figure III-2. This site underwent two major reconstructions during the 1920's and 1940's as documented by various historical records. The modifications to the site included bulkheading and the placement of permeable fill to extend the natural shoreline into Puget Sound and Eagle Harbor. In addition, the nature and location of process structures and equipment has also changed.

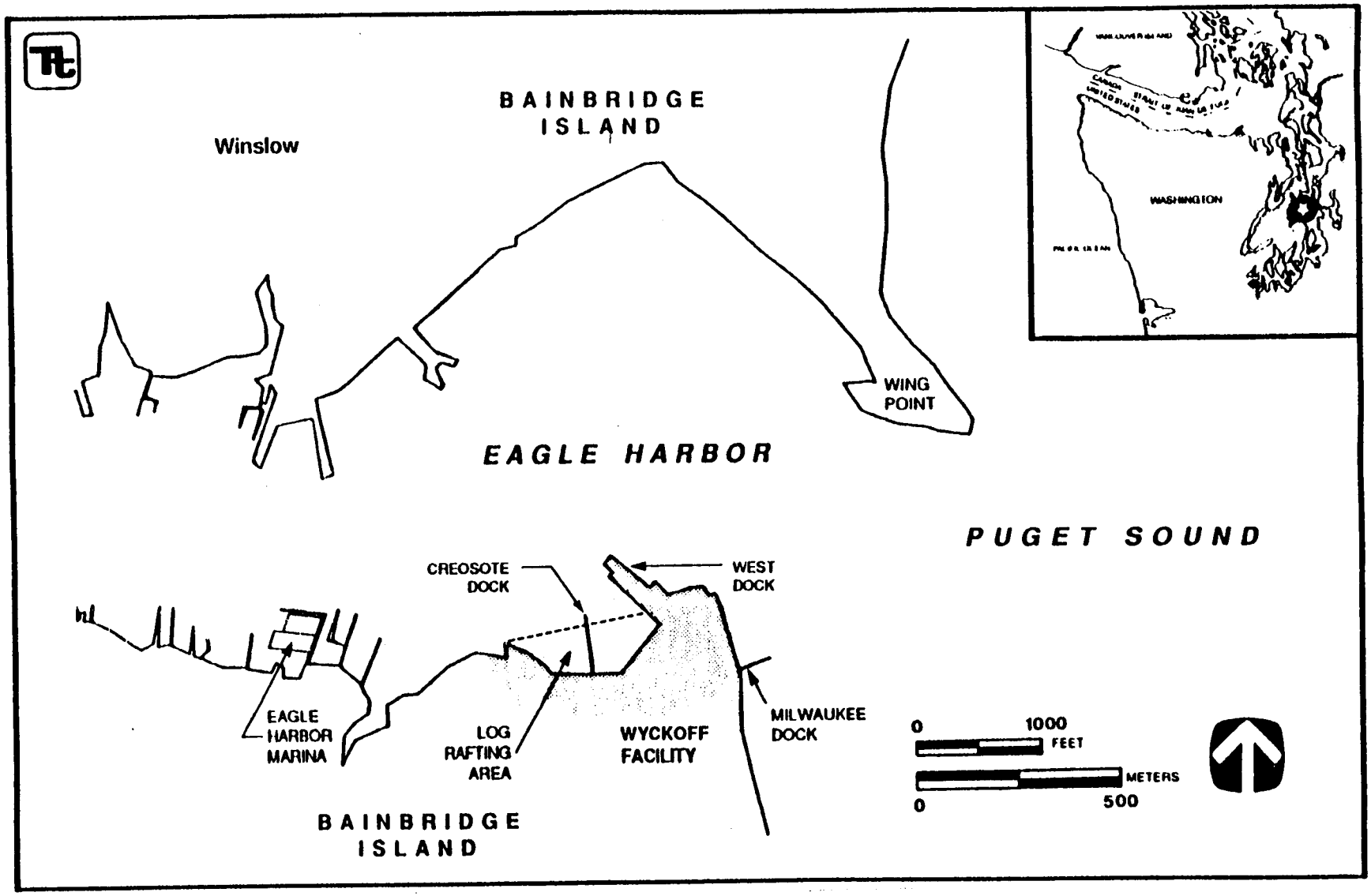


Fig. III-1 Location Map of the Wyckoff Bainbridge Island Facility (From Fig. 1: Jacobs, 1988)

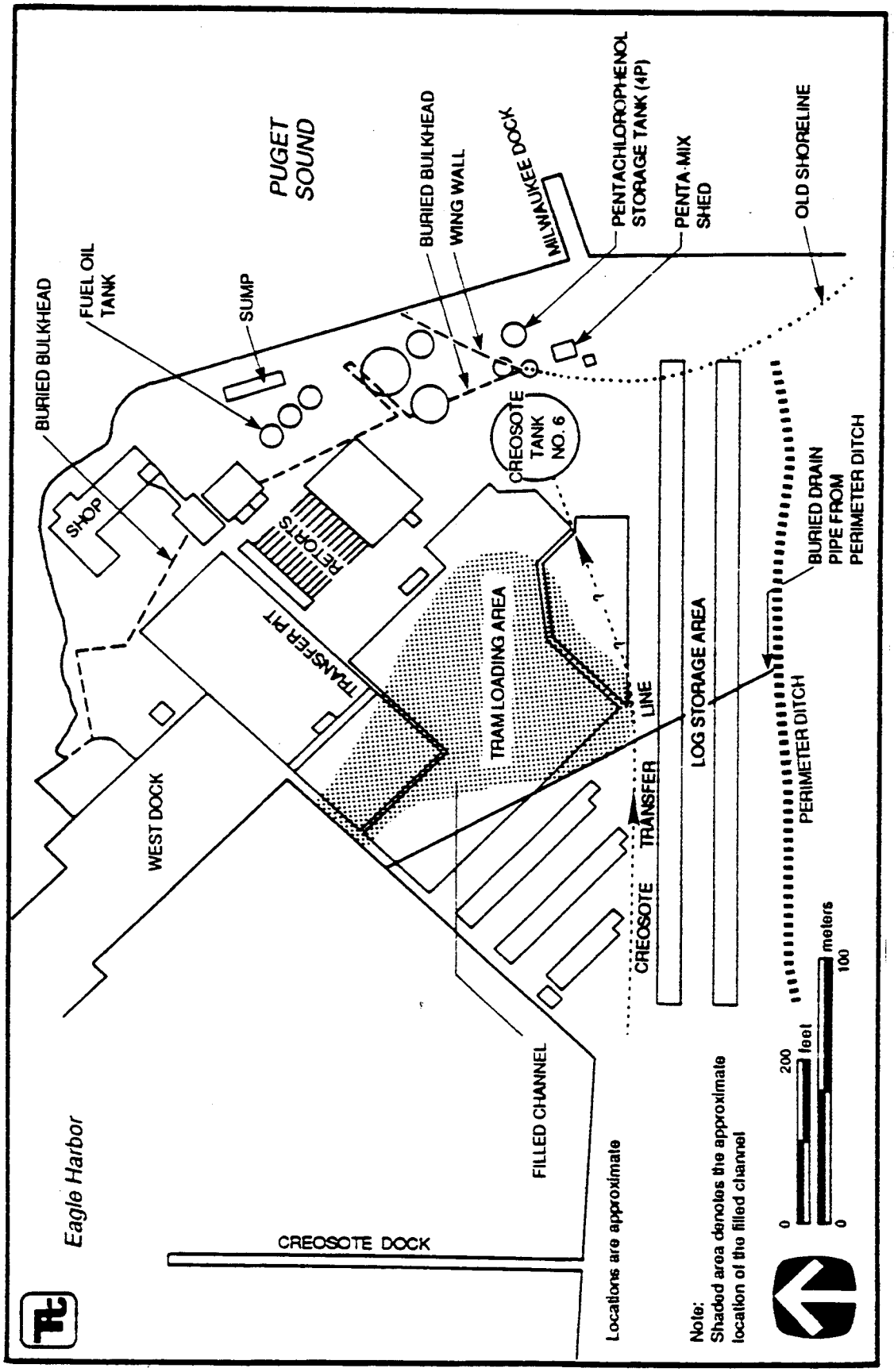


Fig. III-2 Site Map of the Wyckoff Bainbridge Island Facility (From Fig. 2: Jacobs, 1988)

The original wood treating operation was constructed on a small peninsula formed by currents which pass across the mouth of Eagle Harbor. The existing Milwaukee Dock and the West Dock were attached to the peninsula and extended into Puget Sound and Eagle Harbor, respectively. The area of the Harbor between the peninsula and the shoreline of the island formed a cove which was used as a treated log storage area as well as an access area for the delivery of treating stock before it was filled in the 1920's.

Prior to 1929, the eastern and northern shorelines of the peninsula, facing Puget Sound, were protected from tidal action by a bulkhead located west of the present bulkhead. The location of the old bulkhead is shown on Figure III-2 by a dashed line ending adjacent to the present location of Tank No. 6. At this end, a wing wall was constructed in a northeasterly direction. Later, the bulkhead may have been extended from its southern end to intersect the beach at the southeast corner of the site.

According to early maps of Bainbridge Island, the old bulkhead extended to the northernmost corner of the site near the West Dock. In 1929, the present bulkhead was constructed and the area between the two bulkheads was filled with sandy dredge spoils and, in part, with sludge removed from storage tanks. The new bulkhead is protected from tidal action by riprap placed along its length. Although the exact depth of the new bulkhead into the substrata is not known, it is believed to be less than 6 feet below the land surface. Site expansion into this newly filled area included a general reconstruction of the facility and relocation of the boiler house and other auxiliary facilities.

In 1956, the State of Washington issued a waste discharge permit to West Coast Wood Preserving Co. (WCWPC), the operator of the site at the time. Under this permit, cooling and effluent wastewater from the wood treating process were discharged from an outfall into Puget Sound. Effluent limitations set by the permit were 10 ppm total oils and 1 ppm phenols. In 1957, WCWPC, with the knowledge and cooperation of the State of Washington, constructed a 40' x 12' x 6' treated piling-lined pit (sump) in the sand fill between the old and new bulkheads. This sump was constructed to receive wastewater from the treatment process and to act as a seepage basin to collect oily materials. The location of the sump was southeast of the shop area and parallel to the shoreline between the two bulkheads. In 1961, another permit was issued to WCWPC to allow process wastewater to be discharged to groundwater via the sump. This permit further required that sludges from the sump be deposited at some distance from the new bulkhead. In 1971, the State issued a follow-on permit allowing the continued discharge of wastewaters via the sump.

In the 1970's, the Washington State Ferry system (operated by the Washington Department of Transportation -- WDOT) operation from Winslow began using larger, more powerful ferries, known as jumbo or superferries. These vessels cause a shock wave which resuspends a large amount of sand upon impact with the beach. The ferry wake impacts on the beach less than one minute later, creating further sand suspension. In addition, the beach along the east boundary of the plant site is subject to a natural drift current which carries suspended sand from the beaches and deposits it beneath West Dock. As a result of these forces, the area beneath West Dock has been considerably filled, which may in turn affect groundwater flow patterns.

The southern portion of the present site has been used as a pole storage area as shown in Figure III-2. A bluff south of this area forms the southern boundary of the site. This bluff rises toward the island interior to an elevation exceeding 200 feet. Below this bluff, a drainage ditch is located at the southern perimeter of the storage yard. Drainage from the bluff and from portions of the pole storage area enters this ditch. A drain in the ditch discharges via a buried pipe to the northwest bulkhead. Water in the westernmost portion of the ditch drains west to Eagle Harbor. The ditch is a major surface drainage feature controlling surface water flow at the site. During high tides and periods of heavy rainfall, a significant volume of standing water is present in the log storage area and wood treating operations area. This water is pumped into the process wastewater system from several points at the site for eventual evaporation.

Technical Operations at the Site

Wyckoff operations at Eagle Harbor included aromatic oil and creosote unloading and storage, chemical storage, wastewater treatment, untreated pole and pile storage, log rafting, log peeling, wood preserving, treated wood storage, and shipping as shown in Figure III-2. All wood treating activities were conducted in a 6 acre operations area, surrounded by the Milwaukee Dock, Tank No. 6, and the West Dock.

The Wyckoff facility used what is known as the Boulton process for impregnating wood products. In this process, stock to be treated is moved to the retort, the retort is filled with treating solution, and the contents of the retort are heated under vacuum to remove water, wood sugars, and natural oils from the stock. The natural products are then removed from the retort by a vacuum system and condensed. When creosote is the treating chemical, condensible components consist of light hydrocarbons. When pentachlorophenol is the treating chemical, condensible components consist of small quantities of PCP and low boiling point polyaromatic hydrocarbons. The condensed vapors, known as process wastewaters, are transported to a series of oil/water

separators, which reclaim treating chemicals for reuse in the treating process. The water phase from the oil/water separators is pumped out the evaporation system.

After the Boulton process, pressure and heat is applied to the stock in the retort to force the treating solution into the wood. Following completion of the treating cycle, the retort is opened and any residual treating solution is drained from the retort into metal-lined concrete catch basins and recycled by pumping the solution to storage tanks for reuse. The treated wood is removed from the retort and transferred to the treated product storage area using the transfer table.

Prior to Wyckoff's implementation of a closed recycle-evaporation system in 1981, wastewater was discharged via the sump mentioned earlier. Prior to discharge, treating chemicals were reclaimed and most of the water phase captured. Only a portion of the water and the lighter, volatile hydrocarbons were, therefore, discharged into the sump. After the closed recycle process was implemented, all process wastewaters were recycled. Sludges which settled out of these wastewaters were collected for disposal pursuant to State and federal regulations. In November 1981, the Washington Department of Ecology (WDOE) required discharges via the sump to cease. The sump was then filled and covered under the supervision of the State.

C. REGULATORY HISTORY

The seepage of petroleum products into Puget Sound was first noticed along sections of the 0.8 mile Wyckoff shoreline in the early 1960's. Wyckoff, however, continued to function within the permits previously issued until potential contamination of the harbor became a greater concern in the 1970's. More severe contamination within the vicinity of the Wyckoff operation was first reported in 1972 when a floating sheen of oil-like material was reported by area residents. From 1972 until the early 1980's few restrictions were placed on the Wyckoff wood treatment operation. During this period, the WDOE and the WDOT conducted an initial study and evaluation of Eagle Harbor through various environmental consulting engineers. These limited technical reports, based primarily on visual findings and surface soil samples, concluded that the problems at Wyckoff did not warrant immediate shutdown of the facility. Instead, these studies recommended that more detailed and costly analysis of the site should be performed.

In 1981, based on the WDOT and WDOE studies, it was estimated that 23 million gallons of contaminated wastewater and sludge were either buried on the site or had been discharged to the seepage basin around the Wyckoff facility. In the early

1980's, WDOE and the U.S. Environmental Protection Agency (EPA) attempted to reach timely cooperative agreements with the Wyckoff Company to develop a successful contamination investigation program. These attempts were unsuccessful, however, and EPA issued a RCRA (Resource Conservation and Recovery Act) Section 3013 order on August 8, 1984. Section 3013 of RCRA authorizes EPA to perform on-site investigations of known or suspected contaminated sites.

The RCRA 3013 order was the first significant step toward resolution of the problems at Eagle Harbor. This directive required Wyckoff to submit and implement a proposal for sampling, analyzing, monitoring and reporting the contamination discovered in their operating area. Specifically, this order also required Wyckoff to sample and report water quality data from two freshwater supply wells (one 500 foot well and one 813 foot well) at the site which supplies several private residences within close proximity. In addition, the Kitsap County Health Department published an advisory recommending against harvest or consumption of crabs and shellfish from Eagle Harbor.

Through the mid-1980's, Wyckoff's response was primarily to litigate the RCRA order. Meanwhile, on September 15, 1985, the Wyckoff/Eagle Harbor site was proposed as a Superfund clean-up site due to initial contamination discovered by EPA technical studies. On August 16, 1986 (over 2 years after the 3013 order was issued), the 9th Circuit Court of Appeals issued a formal decision in the case of Wyckoff v EPA declaring that the EPA directive was a "correct order" and ordering Wyckoff's compliance with the order.

In March 1987, a Consent Order was signed by Wyckoff and EPA under Section 106 of CERCLA (Comprehensive Environmental Response Compensation and Liabilities Act). A provision of this Consent Order was that additional site investigation would be conducted by Jacobs Engineering Group and Tetra Tech, Inc. under EPA contract. Under this order, Wyckoff provided unrestricted site access and a drilling contractor to drill a minimum of five monitoring wells and to provide drilling support for the Tetra Tech (Jacobs' subcontractor) investigation and sampling. The goal of this six-week detailed investigation of the site was for Jacobs to provide special ERA (Expedited Response Action) recommendations to EPA for immediate consideration to begin a series of short term remediation objectives. It is important to note that the six-week investigation period, limited by court order, did not include sufficient time for Jacobs and Tetra Tech to complete their full investigation including quality control checks of all data obtained and of testing performed. Shortly after this investigation,

the Wyckoff site was listed on the Superfund National Priority List (NPL) on July 22, 1987 based on the high probability of further contaminant migration.

Throughout the summer of 1987 until early 1988, EPA reviewed several iterations of the Jacobs/Tetra Tech reports. Finally, on 29 July 1988, EPA and Wyckoff signed a second consent order under the Superfund Amendments and Reauthorization Act of 1986 (SARA) based on the findings of the Jacobs/Tetra Tech report. This order directed Wyckoff to "contain and treat hazardous substances on site before discharge off-site ... and to comply with effluent limitations".

Specific directives under this order included the following requirements:

* posting limited access signs to the site.
* providing EPA with historical records and site inspection reports.
* performing tank/pipeline integrity testing.
* providing temporary sludge removal.
* performing corrective action on problem tanks/pipes.
* providing runoff control and spill containment.
* constructing a hydraulic barrier system around part of the site perimeter to try to contain the contamination.
* designing and installing a groundwater extraction system based on site pump tests.
* performing regular groundwater quality sampling.
* providing groundwater treatment if necessary.
* the option to reconstruct/rework site facilities to prevent further contamination or to cease operations at the Eagle Harbor plant altogether.

By early 1991, Wyckoff asserted that it had complied with many of these directives including surface water control, pipeline/tank testing and repair, and the installation of a groundwater extraction and treatment system. Wyckoff agreed to cease operations at the end of 1988 at their Eagle Harbor plant because they determined closing down was their only feasible option: they could not comply with the costly directive to reconstruct site facilities. The only operations currently occurring on-site are wood stripping in preparation for treatment at another Wyckoff plant. Tank 6C still contains sludge pending the final disposition of legal action.

In September 1989, EPA and Wyckoff also agreed that the installation of a hydraulic barrier surrounding the site would not work as well as originally determined given the highly permeable soil conditions and the tidal influences at the Wyckoff/Eagle Harbor site. Therefore, in lieu of this barrier, only the groundwater

extraction system was installed to minimize contaminant migration to Puget Sound. Presently, Wyckoff is submitting monthly progress reports and data to EPA in compliance with the 1988 consent order. Two Superfund sites now exist at this location: the Harbor (known as the Eagle Harbor Operable Unit) and the land portion of the site (known as the Wyckoff Operable Unit). Remedial Investigation/Feasibility Study planning is currently underway. An RI/FS is presently planned for late 1992 for the Eagle Harbor Site while an RI/FS is tentatively scheduled to start before 1993 for the Wyckoff property.

D. SITE CHARACTERIZATION/DATA COLLECTION

Geology

Site geology is typical of the Puget Sound lowlands. Glacial and nonglacial deposits have resulted in sediments that vary substantially throughout the depth of the site consisting of lenses of sand, gravelly sand, silts and clays. The thickness of each lense varies within the site, and no consistent stratification of soil types has been identified in any of the various studies to date. Figure III-3 presents the best current interpretation of the soil profile (Tetra Tech, 1987). The vertical scale is exaggerated to emphasize site variability. In general, fine-grained sediments dominate the southern site area, and course grained sediments dominate in the north. Fill is comprised of natural sediments, construction debris, and tank sludges.

Hydrology

The general direction of groundwater flow across the site is from the bluffs south of the site to the north. There are a number of private wells located southwest and south of the site that penetrate the shallow course-grained aquifer that experiences seasonal water fluctuations of a few to a few tens of feet below sea level (ENTRIX, 1986). Wells along the shoreline have water tables at or just above sea level. Static water levels range between 20 and 30 feet above mean sea level in wells located in the foothills south of the site.

The site is underlain by unconsolidated deposits that vary in their ability to transmit water. These consist of till, gravel, silts and sands to a depth of about 330 feet, with interspersed clay layers below to a depth of about 1,300 feet (where bedrock is anticipated). The absence of significant confining layers allows wide fluctuations in the groundwater elevations as a result of tidal influence and recharge. The only portion of the water table that may be confined is at the base of the bluffs on the southern end of

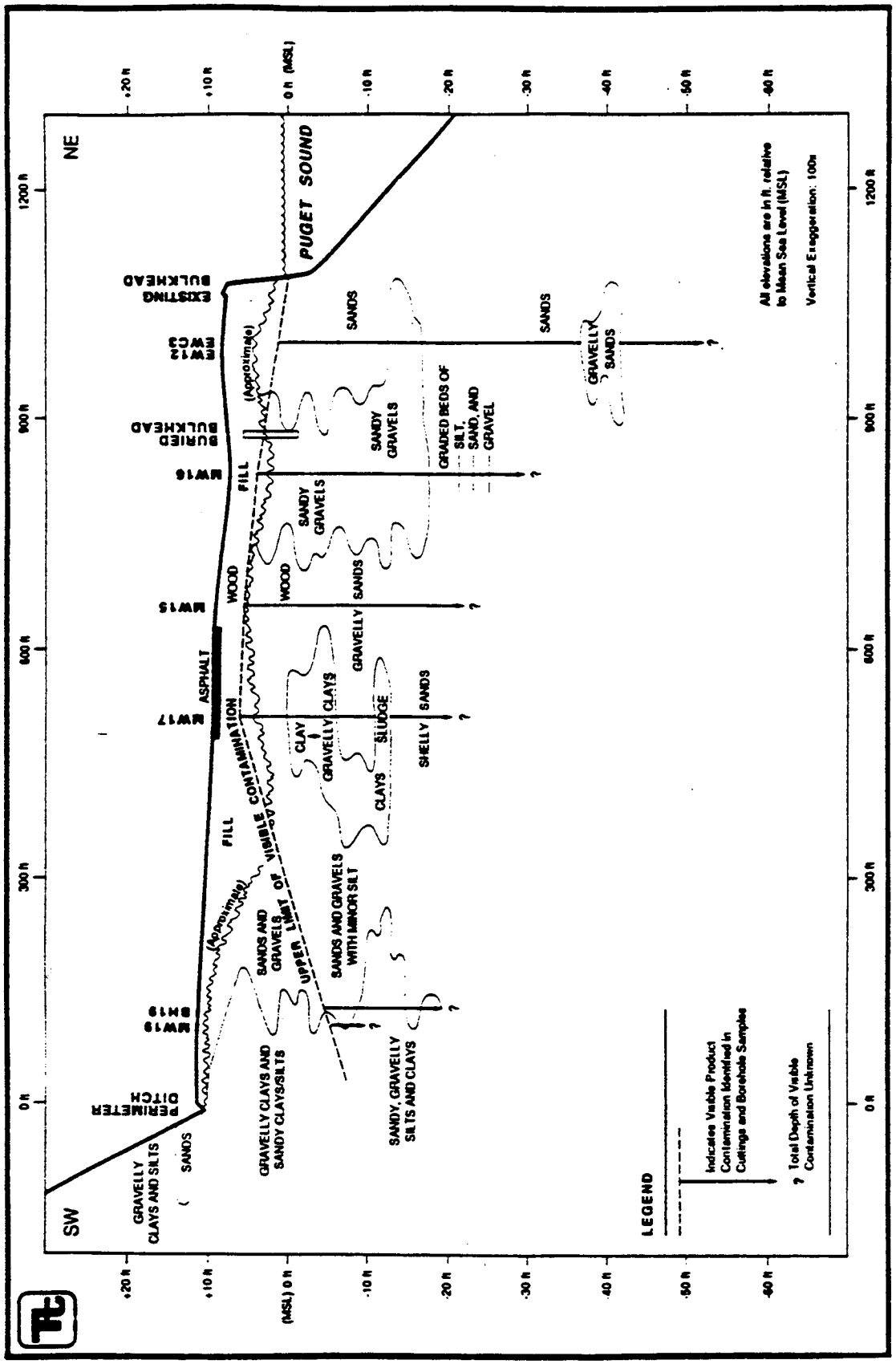


Fig. III-3 Southwest-Northeast Geologic Cross-Section of the Wyckoff Bainbridge Island Site (From Fig. 23: Jacobs, 1988)

the site. Contours of the water profile on the site are complicated by the tidal influence. The extensive fill material also influences the relative permeabilities of different site areas, and the relative confidence in constructed soil water profiles is not high. Soil sampling and groundwater monitoring well locations are identified in Figures III-4 and III-5. Figure III-6 gives the sodium and chloride concentrations of the water encountered in each well.

A high sodium concentration is an indicator of the degree of salt water intrusion. Figures III-7 and III-8 show the tidal influence on four of the wells. These values are much higher on the eastern side of the site between the old and new bulkheads, suggesting that the old bulkhead acts as a barrier to groundwater flow. The gradual decay of tidal influence across the site can also be observed.

Groundwater discharge occurs all along the waterfront and is evident from the tidal seeps observed at low tide. Additional discharge is evident in the springs that are intercepted by the drain ditch located south of the log storage area. Based on earlier studies of Long Island hydrology (Bokuniewicz, 1980), it is believed that the largest groundwater volume discharge from the site is through subsurface sediments located below sea level. This discharge is the least observable, however.

Free product contamination is evident in the intertidal seeps, especially in the area north of the Milwaukee Dock. This suggests that floating product is being transported with the groundwater and is being directly discharged to Eagle Harbor.

The hydraulic head across the site is minimal, but it is clear that the groundwater flow direction is south to north under the site and that it drains laterally from the center to the tidal zones within the site boundaries. During very high tides the flow can be reversed. Seasonal flooding occurs on the site as high groundwater saturates the surface.

The heterogeneity of the soil matrix allows interconnected pores of low and high permeability soils. This seems to allow upward vertical gradients of groundwater over much of the site which are one to two orders of magnitude greater than the horizontal gradients. The lone exception is well EW12, which experiences downward gradients regardless of tide stage.

Low rate/low volume aquifer testing was conducted to determine transmissivity and typical hydraulic conductivity. Because of the high water table, the limited well penetration as a percent of aquifer thickness, highly permeable soils, and the desire to avoid collecting large amounts of contaminated water, a modified single bore slug test was used. The limited drawdown and pump time require that transmissivity and

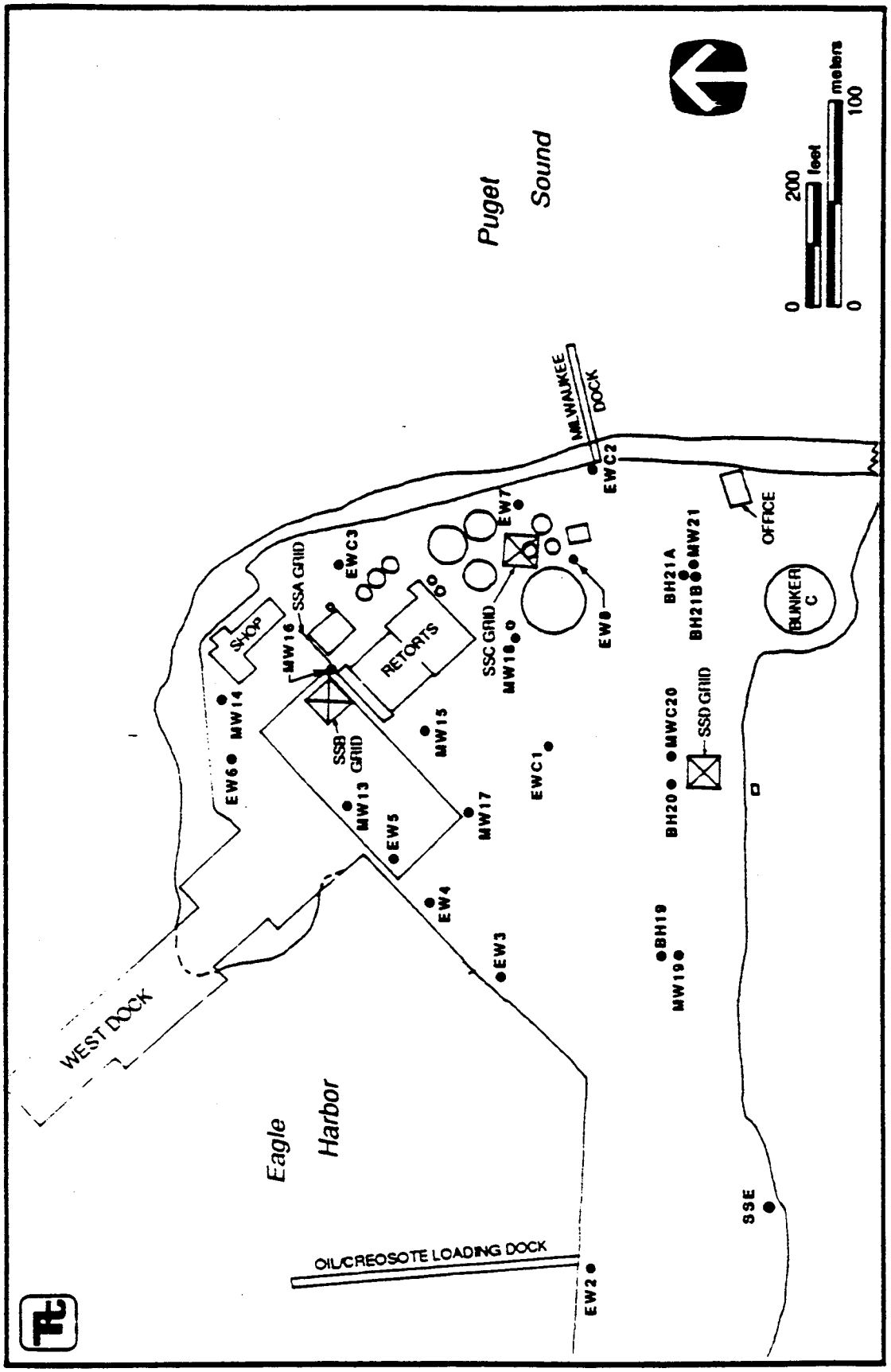


Fig. III-4 Surface Soil and Subsoil Sampling Station Locations (From Fig. 7: Jacobs, 1988)

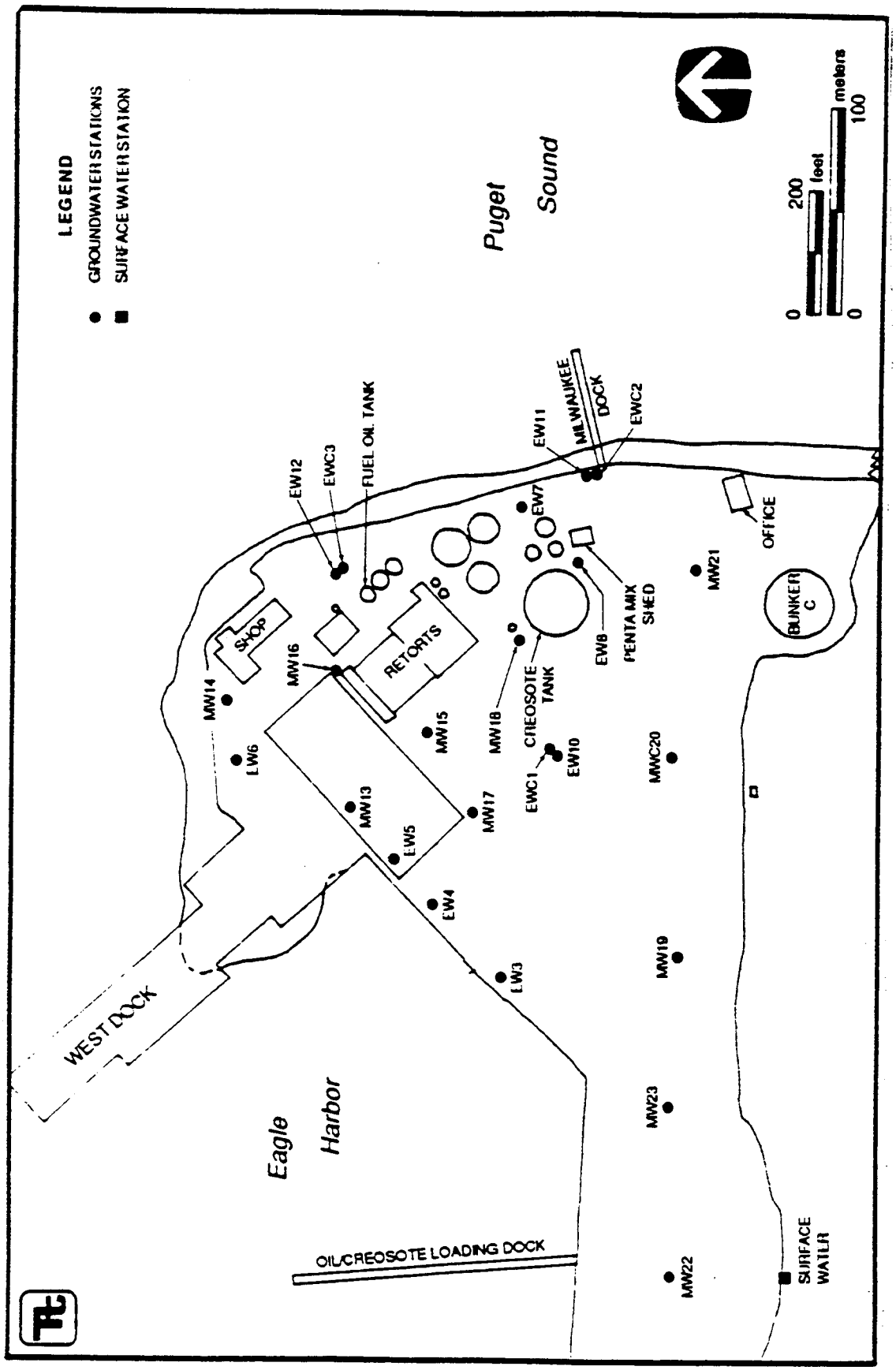


Fig. III-5 Groundwater and Surface Water Sampling Locations (From Fig. 5: Jacobs, 1988)

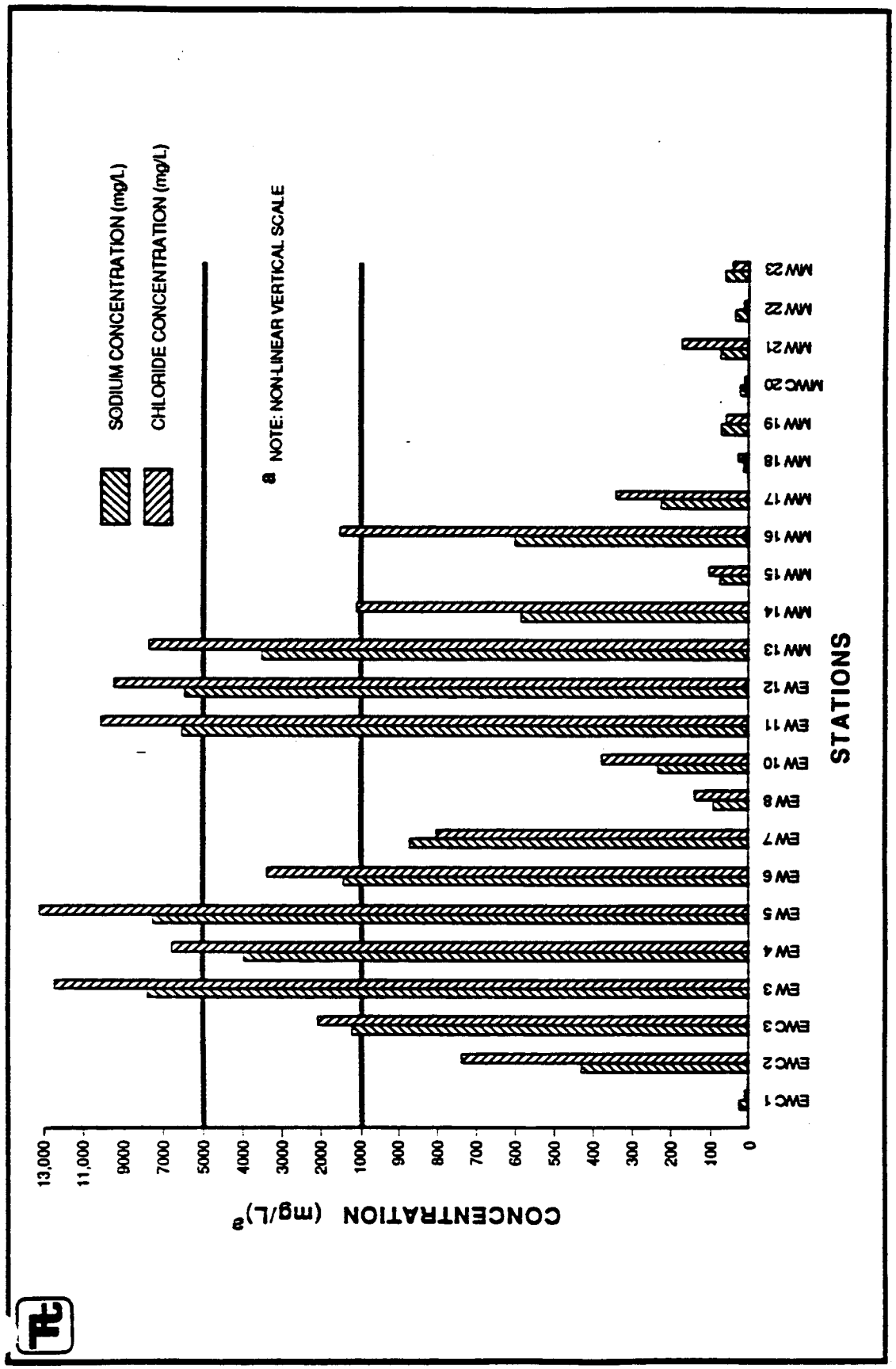


Fig. III-6 Sodium and Chloride Concentrations in Groundwater at Wyckoff Site (Fig. 35: Jacobs, 1988)

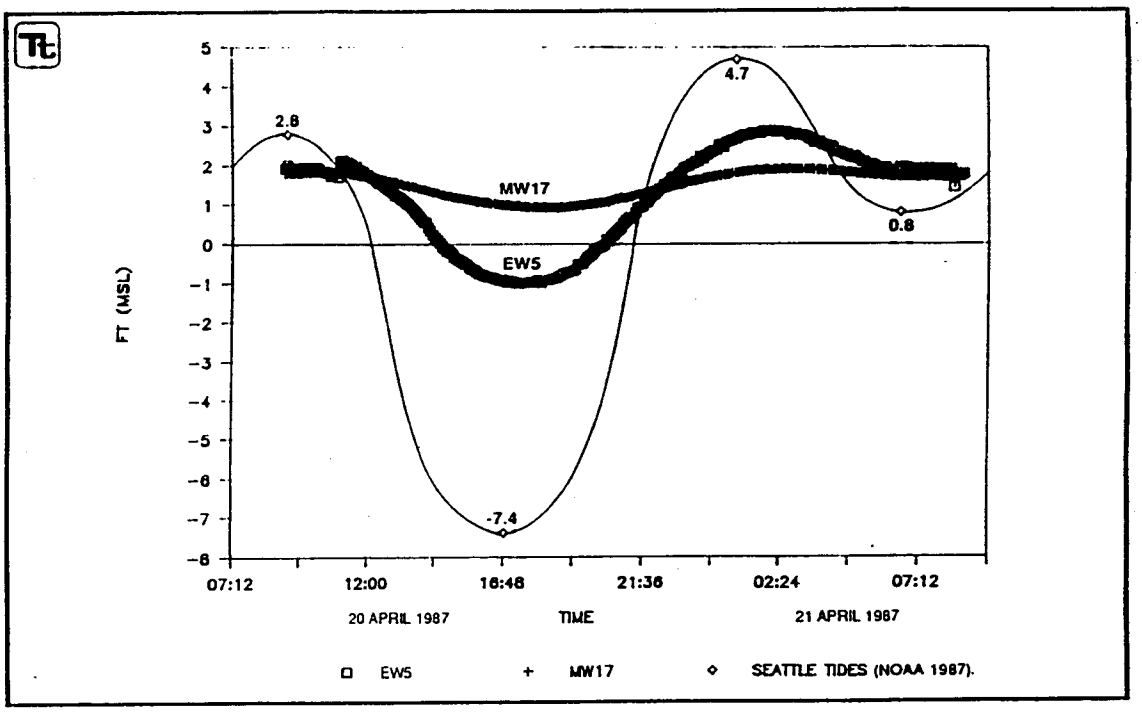


Fig III-7 Tidal Monitoring Record - Wells EWS and MW17 (From Fig. 31: Jacobs, 1988)

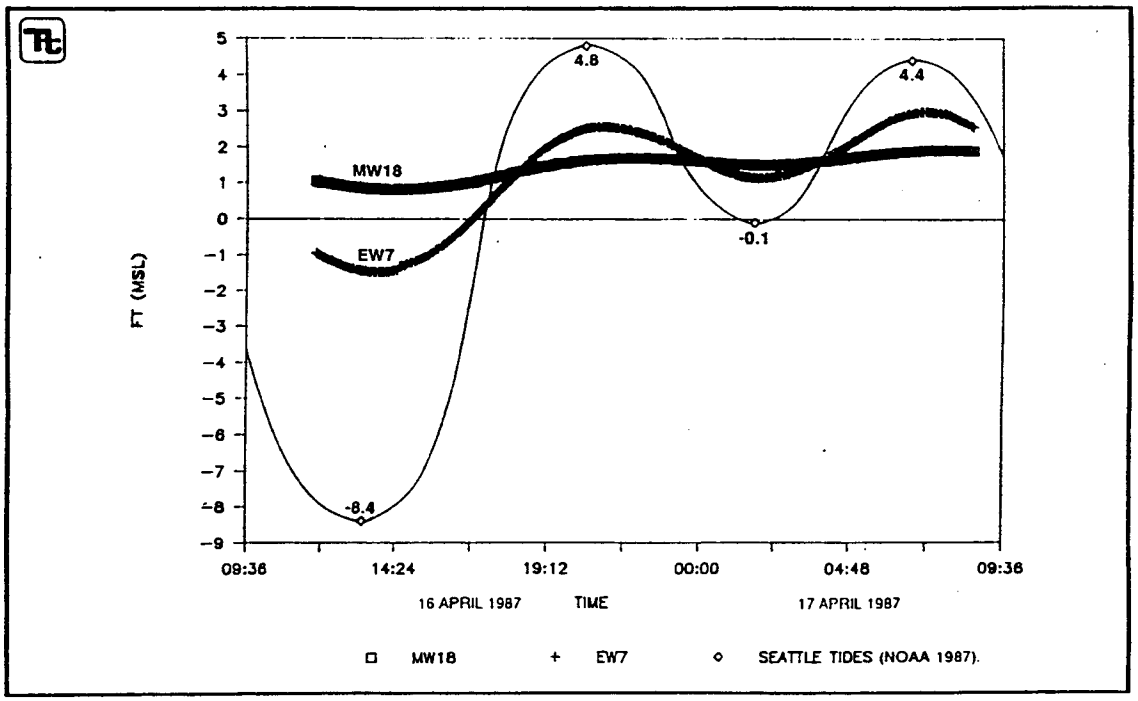


Fig. III-8 Tidal Monitoring Record - Wells MW18 and EW7 (From Fig. 32: Jacobs, 1988)

conductivity data be interpreted as point values, which may not be representative of large portions of the aquifer.

By performing slug test and recovery test analyses on the well data, upper and lower limits of hydraulic parameters were determined as indicated in Table III-1. These data were considered adequate for determining the feasibility of alternative Emergency Response Actions. The A and B values indicate that the tests were reproduced on the indicated wells.

In November 1988, four additional pumping wells were installed by Applied Geotechnology, working under a contract to Wyckoff Company and in accordance with the consent order terms, in an effort to determine feasibility of controlling groundwater flow and contaminant migration to Puget Sound. The location of these four additional wells is given in Appendix B-1. Soil boring data and well logs are given in Appendix B-2. The new pumping wells were screened between five and 35 feet below ground surface elevation and were sited in areas of known high contaminant concentrations. Previously drilled monitoring wells were nearby and new observation wells (screened from 6 to 36 feet below ground surface) were drilled within a twenty foot radius of the new pumping wells as needed to provide adequate drawdown observations. Observation well locations in relation to the pumping wells are also indicated in Appendix B-1. These four wells were intended to be in operation for the life of the remediation effort and were constructed with stainless steel casings and screens. Water and free product depths after well development are given in Appendix B-3 as estimated by Applied Geotechnology.

A model was developed to predict tidal influence and time lags and long term pump tests were conducted. In general, earlier observations of waning tidal influence as distance from the Sound increased were validated. However, the geology immediately around the well and the soil transmissivity also have substantial influence on the well/tide interactions.

Free product interactions and transport are even more difficult to predict than the movement of groundwater due to the different polarity, density, and viscosity of the two liquids. Free product was found in most of the wells (see Table III-2), but there is no assurance that it moves with the same velocity or direction as the groundwater. In addition, the free product may not be observed in a monitoring well if the upper screen opening is below the water table, since the floating product does not have access to the screened portion of the well.

The tidal influence at the Wyckoff site is probably the reason that sinking product has been observed, although the depth to sinking product has not been well

Table III-1 Summary of Aquifer Test Results (From Table 29: Jacobs, 1988)

WELL	TEST[a]	TRANSMISSIVITY (gal/day/ft) Theis Recovery	TRANSMISSIVITY (gal/day/ft) Slug Test	HYDRAULIC CONDUCTIVITY (gal/day/ft^2) Theis Recovery	HYDRAULIC CONDUCTIVITY (gal/day/ft^2) Slug Test	SATURATED THICKNESS (ft)	ELEVATION OF SCREENED INTERVAL (ft MSL)
EWC1	A	929	310	186	61.0	5.0	--
	B	2,587[c]	28	517[c]	5.6	5.0	-44.20 to -49.20
EWC2	A	28	4	5.6	0.8	5.0	--
	B	44	6	8.8	1.3	5.0	-44.80 to -49.80
EWC3	A	644	22.5	129	4.5	5.0	--
	B	228	5.0	45.6	1.0	5.0	-50.19 to -55.19
EW3	NT[b]	--	--	--	--	-	-7.00 to -12.00
EW4	--	33	7.5	6.6	1.5	5.0	-8.42 to -13.42
EW5	A	30	6	6.0	c	5.0	--
	B	44	34.5	8.8	6.9	5.0	-2.02 to -7.02
EW6	--	2,054	27.1	478	6.3	4.3	2.51 to -2.49
EW7	--	229	14.0	45.8	2.8	5.0	-4.95 to -9.95
EW8	A	c	c	c	c	-	--
	B	2,836[c]	22.4	2,383[c]	18.7	1.2	5.76 to 0.76
EW10	--	222	9.5	44.4	1.9	5.0	-7.18 to -12.18
EW11	A	715	55.0	143	11.0	5.0	--
	B	734	48.5	147	9.7	5.0	-14.24 to -19.69
EW12	A	146	12.0	29.2	2.4	5.0	--
	B	159	24.0	31.8	4.8	5.0	-5.69 to -10.69
MW13	--	4,887[c]	c	543[c]	c	9.0	1.51 to -8.49
MW14	A	525	25.6	62.5	9.0	8.4	--
	B	455	32.3	53.5	3.8	8.5	1.72 to -8.28
MW15	--	1,633	56.1	207	7.1	7.9	4.03 to -5.97
MW16	NT[b]	--	--	--	--	-	2.22 to -7.78
MW17	NT[b]	--	--	--	--	-	4.33 to -5.97

Table III-1 (Continued)

MW18	--	251	c	26.7	c	9.	2.26 to -7.74
MW19	A	76	9.5	8.0	1.0	9.5	--
	B	89	13.1	9.5	1.4	9.4	6.25 to -3.75
MWC20	A	87	26.0	8.7	2.6	10.0	--
	B	112	34.0	11.2	3.4	10.0	-28.34 to -38.34
MW21	--	513	13.0	55.2	1.4	9.3	3.00 to -7.00
MW22	A	48	7.6	5.0	0.8	9.5	--
	B	45	2.9	4.7	0.3	9.5	5.25 to -4.75
MW23	A	28	c	3.0	c	9.3	
	B	37	c	4.0	c	9.3	5.68 to -4.32

Notes:

[a] Multiple tests conducted in most wells to evaluate test reproduciblity.
[b] NT = Not Tested
[c] Results not considered reliable.

Table III-2 Product Occurrence and Thickness in Wells Between 30 March and 27 April 1987 (From Table 10: Jacobs, 1988)

WELL	Floating Product Detected (Thickness, in ft)	Sinking Product Detected (Thickness, in ft)	Screened Interval Extends above Water Table?
EWC1	2 of 5[a] (<0.01)[b]	Not detected (<0.01)[b]	no
EWC2	2 of 5 (<0.01)	Not detected (<0.01)	no
EWC3	7 of 9 (<0.01)	4 of 4 (1-3)	no
EW2	Not measured	Not measured	Not known[c]
EW3	Not detected(<0.01)	Not detected (<0.01)	no
EW4	3 of 5 (<0.01)	1 of 2; not measurable	no
EW5	1 of 7 (<0.01)	Not detected (<0.01)	no
EW6	1 of 7 (<0.01)	Not detected (<0.01)	yes
EW7	5 of 9 (<0.01)	Not detected (<0.01)	no
EW8	1 of 5 (<0.01)	Not detected (<0.01)	yes
EW10	2 of 7 (<0.01)	Not detected (<0.01)	no
EW11	17 of 17 (0.51-3.01)	Not detected (<0.01)	no
EW12	6 of 12 (<0.01)	10 of 10 (0.5-1.5)	no
MW13	3 of 8 (<0.01)	Not detected (<0.01)	yes
MW14	4 of 10 (<0.01)	Not detected (<0.01)	yes
MW15	16 of 16 (1.84-6.87)	Not detected (<0.01)	yes
MW16	5 of 6 (<0.01)	3 of 4; not measurable	yes
MW17	4 of 6 (<0.01)	Not detected (<0.01)	yes
MW18	7 of 10 (<0.01)	1 of 1; not measurable	yes
MW19	3 of 6 (<0.01)	Not detected (<0.01)	yes
MWC20	6 of 8 (<0.01)	Not detected (<0.01)	yes
MW21	3 of 8 (<0.01)	Not detected (0.01)	yes
MW22	Not detected(<0.01)	Not detected (<0.01)	yes
MW23	Not detected(<0.01)	Not detected (<0.01)	yes
H7	3 of 3 (0.04-0.09)	2 of 2; not measurable	Not known[c]

[a] Detections are given as the number of detections per number of measurements made.

[b] A less than value indicates that the product layer thickness was less than the lower level of detection for the measuring intrument (0.01 ft)

[c] Well construction details not available.

identified. As the salt water in the tide mixes with the freshwater, the density increases and creosote, with a density of between 1.05 and 1.09 g/cm3, is observed as a floating product As the saltwater is diluted, the creosote is converted to a sinking product.

The drawdown of well water creates a gradient on the surface which floating product can follow, suggesting that well pumping could be effective in capturing and recovering floating product plumes. Sinking product could be recovered by screening the well at depths below the groundwater/sinking product interface.

Contamination Sampling

Although many contaminants were discovered at Wyckoff, the sampling results presented here are limited to the combined categories of Total Polynuclear Aromatic Hydrocarbons (PAH) and Total Chlorinated Phenols (primarily PCP). The engineering consultants combined the product in these two categories because it gave the best representation of the overall characterization of the site. Sampled PAH and PCP concentrations in groundwater and subsurface soils are provided in Tables III-3 and III-4. Graphical presentations of subsoil contamination on specific sections are provided by Figures III-9 through III-11.

E. REMEDIATION

In an effort to achieve remediation results at Wyckoff without waiting for the standard Superfund RI/FS approach, which was still several years away, EPA obtained special approval to pursue Expedited Response Action (ERA) initiatives. EPA elected to use the ERA approach to beginning site remediation because they had already obtained enough information on the site to take corrective action. The potential for product recovery by well drawdown eventually led to the selection of a barrier well alternative for emergency remediation action to contain the contaminated groundwater, to remove contaminated groundwater, and stop the seeps which were damaging the marine environment. This section discusses the other options that were considered and rejected. The ERA included requirements for source control since stopping the source of contaminants is easier and more cost effective than cleaning up the pollutants in the environment.

Selection of the remedial technology appropriate for an expedited response action must consider:

Table III-3 Concentrations of Total PAH and Total Chlorinated Phenols in Groundwater and Surface Water Samples (From Table 14: Jacobs, 1988)

LOCATION	CONCENTRATIONS (ug/L) Total PAH[a]	Total Chlorinated Phenols[b]
Groundwater:		
EW3	147	<60
EW4	1,910	<120
EW5	220	<60
EW6	115	<60
EW7	50,900	<6,000
EW8	26,200	4,350
EW10	2,940	<300
EW11	11,400	<1,800
EW12	108,000	<6,000
EWC1	<80	<60
EWC2[c]	1,160	<240
	1,060	<240
EWC3	27,400	<3,000
MW13	<80	<60
MW14	300	85
MW15	166,000	<30,000
MW16	10,100	2,650
MW17	13,400	<2,400
MW18	5,150	<1,900
MW19	<80	<60
MWC20[c]	72	34
	<80	<60
MW21	<80	<60
MW22	<80	<60
MW23	<80	<60
Surface Water:		
South Drain Ditch	<80	<60

[a] Total PAH = Total polynuclear aromatic hydrocarbons. The concentration is the sum of the concentrations of napthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, chrysene, etc..

[b] Total chlorinated phenols = the total concentration of 2,3,4,5-,2,3,4,6-, and 2,3,5,6-tetrachlorophenol and pentachlorophenol.

[c] Field duplicate samples.

Table III-4 Concentrations of Total PAH and Total Chlorinated Phenols in Subsoil Samples (From Table 20: Jacobs, 1988)

Sample Location	Sample Depth (ft)	Concentration (ug/kg) Total PAH[a]	Total Chlorinated Phenols[b]
MW13	3 - 3.9	105,000	<11,300
MW13	9.2 - 9.6	<3,280	<2,410
MW13	19 - 20	12,300	<2,280
MW13	30.3 - 31.5	3,200	<2,170
MW13	34.9 - 36	<2,960	<2,170
MW14[d]	3 - 4.5	<3,440	<2,530
MW14[d]	3 - 4.5	<3,440	<2,530
MW14	8.5 - 10.5	4,670	<2,290
MW14	19 - 20.5	25,200	<4,700
MW14	29 - 30.5	11,500	<2,180
MW14	35 - 36	9,140	<2,170
MW15	9 - 10	258,000	<132,000
MW15	19 - 20.5	194,000	<21,600
MW15	25 - 26.5	250,000	<43,300
MW15	30 - 30.5	154,000	<9,000
MW16	3 - 4	243,000	<133,000
MW16	9 - 10	1,800,000	<446,000
MW16	19 - 20.5	440,000	<64,300
MW16	25 - 27	156,000	<14,600
MW16	34.8 - 36	7,650	<6,900
MW17[d]	3 - 4.5	1,610,000	<265,000
MW17[d]	3 - 4.5	1,840,000	<277,000
MW17	9 - 9.8	126,000	<23,600
MW17	20 - 21.5	5.9×10^{8}	<158,000
MW17	25 - 27	1,500,000	<740,000
MW18	3 - 5	29,000	<21,700
MW18	9 - 10.5	663,000	<483,000
MW18	20 - 21.5	331,000	<44,700
MW18	30 - 31.1	26,300	<4,340
MW19	3.7 - 4.8	<2,960	<2,170
MW19	9 - 9.7	<2,880	<2,170
MW19	19.3 - 20	<2,960	<2,170

Table III-4 (Continued)

Sample Location	Sample Depth (ft)	Concentration (ug/kg) Total PAH[a]	Total Chlorinated Phenols[b]
BH19	4.5 - 6.0	<2,960	<2,170
BH19	8.5 - 10	<2,960	<2,170
BH19	30 - 30.5	<2,960	<2,310
MWC20	5 - 6.3	69,300	<17,000
MWC20	11 - 12	2,790	<2,170
MWC20[d]	15 - 16.4	<2,960	<2,170
MWC20[d]	15 - 16.4	<2,960	<2,170
MWC20	25 - 26.8	<2,800	<2,050
MWC20	45 - 45.7	3,020	<2,290
MWC20	55.8 - 56.5	<3,120	<2,360
BH20	20 - 21.5	2,840	1,270
BH20	30 - 31.5	<2,960	<2,170
BH20	40 - 41.1	<3,120	<2,290
BH20	60.5 - 61	2,750	<2,280
MW21	5 - 6.5	300[e]	ND[f]
MW21	10 - 11	<5,680	<4,290
MW21	15.3 - 16.5	<3,120	<2,290
MW21	18.2 - 19.7	<3,280	<2,410
BH21A	20 - 22	<3,120	ND
BH21A	30 - 31.5	<3,120	<2,290
BH21B	15 - 16.5	<3,280	<2,410
BH21B	25 - 27	<3,120	<2,290
EW2[g]	1.5 - 3.0	19,700	20[h]
EW2[g]	20.0 - 21.8	71,400	130[h,i]
EW3[g]	4.5 - 6.0	47,500	40[h]
EW3[g]	20 - 21.5	200,000[i]	50[h]
EW4[g]	3.0 - 4.5	61,000	100[h]
EW4[g]	4.5 - 6.0	NA[j]	140[h]
EW4[g]	6.0 - 7.5	NA	370[h]
EW4[g]	20.0 - 21.5	167,000	70[h]
EW5[g]	0.0 - 1.5	NA	220[h]
EW5[g]	1.5 - 3.0	308,000	240[h]
EW5[g]	6.0 - 7.5	NA	30[h]
EW5[g]	10.0 - 11.5	42,000	70[h]

Table III-4 (Continued)

Sample Location	Sample Depth (ft)	Concentration (ug/kg) Total PAH[a]	Total Chlorinated Phenols[b]
EW6[g]	0.0 - 1.5	193,000	170[h]
EW6[g]	1.5 - 3.0	NA	110[h]
EW6[g]	3.0 - 4.5	NA	450[h]
EW6[g]	4.5 - 6.0	NA	170[h]
EW6[g]	10.0 - 11.5	72,000	60[h]
EW7[g]	1.5 - 3.0	NA	830[h]
EW7[g]	3.0 - 4.5	3.5×10^7	520[h]
EW7[g]	4.5 - 6.0	2.5×10^7	9,800[h]
EW7[g]	18.0 - 19.5	402,000	120[h]
EW8[g]	1.5 - 3.0	NA	3,900[h]
EW8[g]	3.0 - 4.5	NA	130[h]
EW8[g]	4.5 - 6.0	261,000	20,000[h]
EW8[g]	7.5 - 9.0	459,000	25,000[h]
EWC1[g]	1.5 - 3.0	<24,000	110[h]
EWC1[g]	3.0 - 4.5	NA	100[h]
EWC1[g]	4.5 - 6.0	NA	150[h]
EWC1[g]	20.0 - 21.5	58,000	80[h]
EWC1[g]	65.0 - 66.5	31,500	50[h]
EWC2[g]	1.5 - 3.0	38,000[k]	120[h,k]
EWC2[g]	3.0 - 4.5	NA	ND (20)[h,l]
EWC2[g]	25.0 - 26.5	318,000	1,300[h]
EWC3[g]	1.5 - 3.0	NA	1,100[h]
EWC3[g]	3.0 - 4.5	NA	160[h]
EWC3[g]	4.5 - 6.0	NA	2,000[h]
EWC3[g]	6.0 - 7.5	1,610,000[m]	23,000[h,m]
EWC3[g]	60.0 - 61.5	1,880,000	270[h]

[a]Total PAH = Total polynuclear aromatic hydrocarbons. The concentration is the sum of the concentrations of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(ghi)perylene. The method used for calculating the total PAH concentration is given in the text of this report.

[b]Total chlorinated phenols = the total concentration of 2,3,4,5-, 2,3,4,6-, and 2,3,5,6-tetrachlorophenol and pentachlorophenol the calculation of total chlorinated phenols concentration is discussed in the text.

Table III-4 (Continued)

[c]A less than symbol (<) indicates that none of the compounds used in calculating the concentration was detected. The concentration reported is one-half the sum of the detection limits. Further discussion is presented in the text.

[d]Field duplicate samples.

[e]Data for non-detected values rejected during quality assurance review due to exceedance of quality control criteria.

[f] ND = no compounds detected. Detection limit values rejected during quality assurance review.

[g]Data fromRCRA 3013 Investigation (Entrix 1986).

[h]Concentration of pentachlorophenol only (no tetrachlorophenol isomers analyzed).

[i]Average value for two measurements. Relative percent difference (RPD) = 14.5 percent for the total PAH concentrations. RPD for pentachlorophenol concentrations = 0 percent.

[j]NA = Not analyzed.

[k]Average value for two measurements. RPD = 40 percent for the total PAH concentrations. RPD for pentachlorophenol concentration = 50 percent.

[l]ND = Not detected. Value in parentheses is reported detection limit.

[m]Average value for two measurements. RPD = 31 percent for the total PAH concentration. RPD = 26 percent for the pentachlorophenol concentrations.

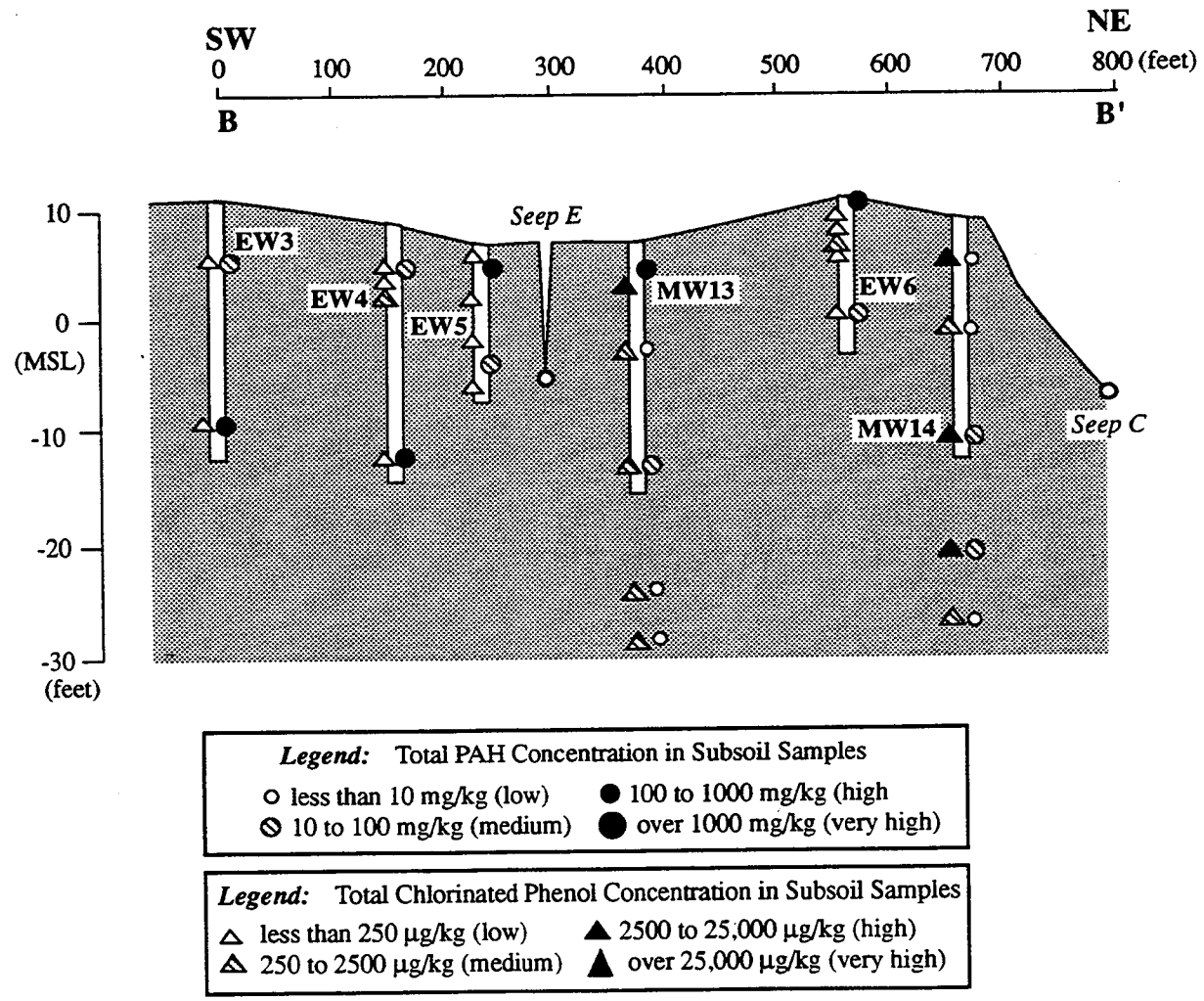


Fig. III-9 Total PAH and Chlorinated Phenol Concentrations in Subsoil Samples (Cross-Section A-A′)

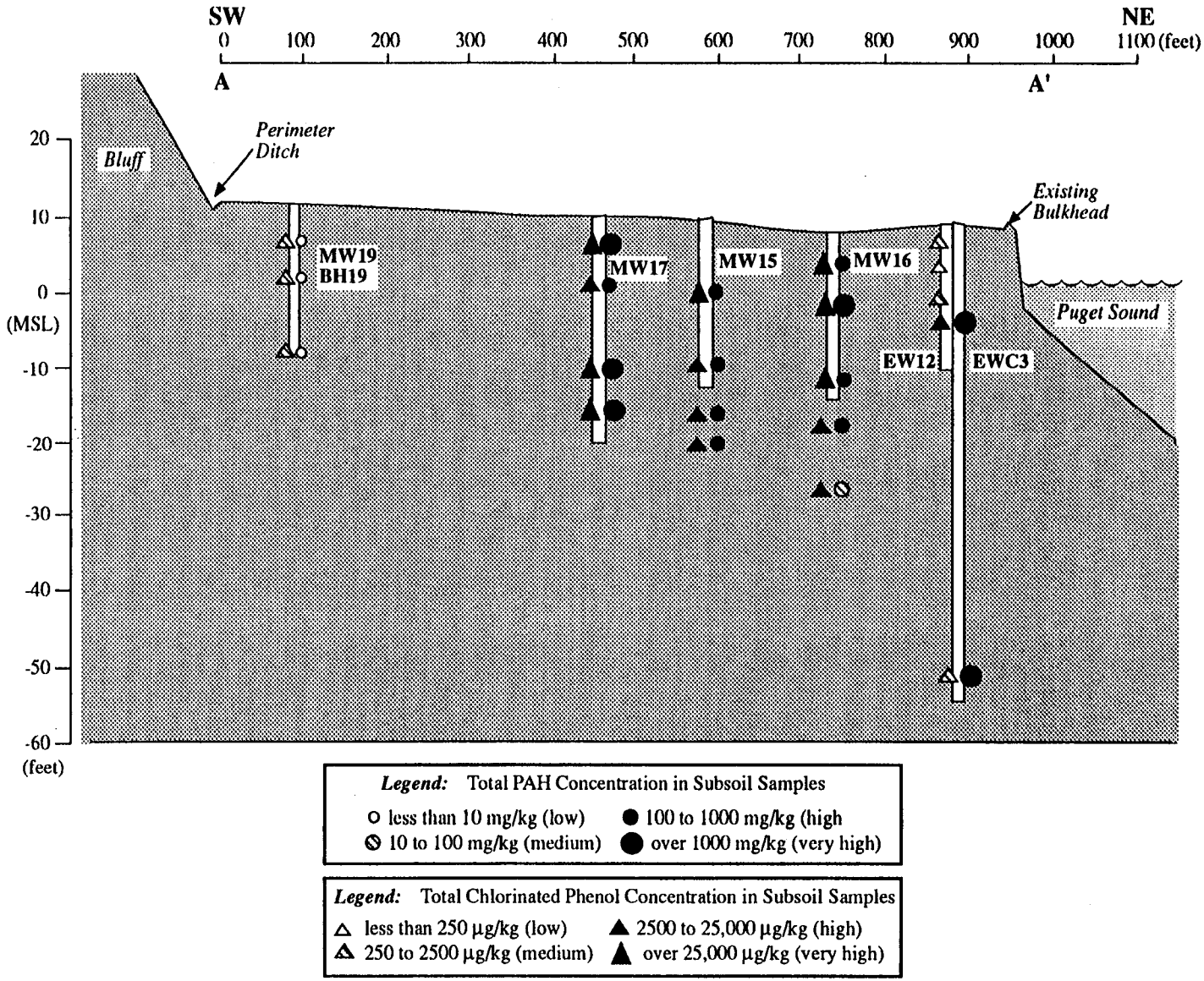


Fig. III-10 Total PAH and Chlorinated Phenol Concentrations in Subsoil Samples (Cross-Section B-B′)

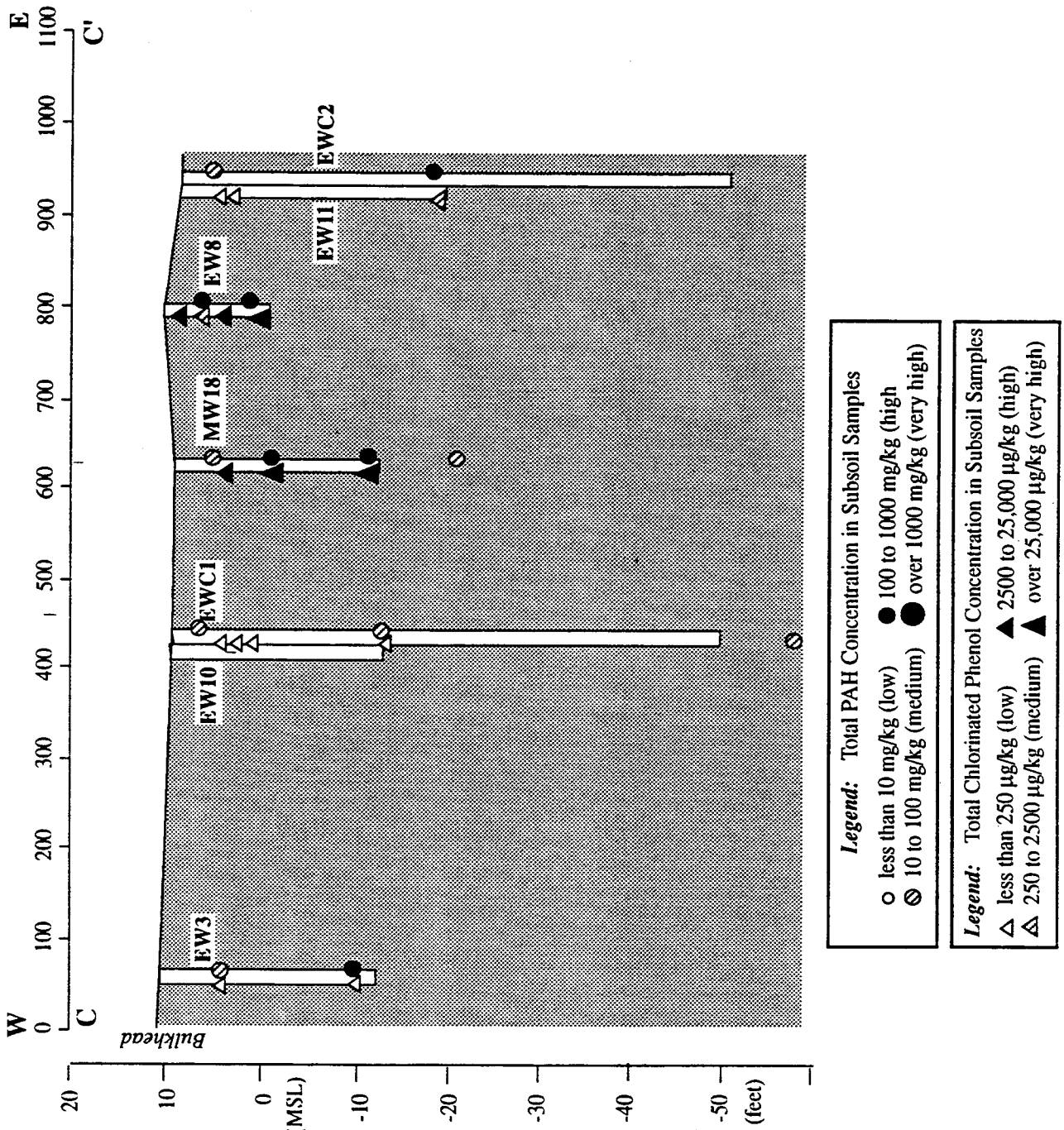


Fig. III-11 Total PAH and Chlorinated Phenol Concentrations in Subsoil Samples (Cross-Section C-C')

* Federal and state applicable or relevant and appropriate requirements (ARAR's)
* Protection of human health and the environment
* Contribution to long term effective action
* Alternative (non-land disposal) technologies
* Time (1 year) and cost ($2 million) limitations
* Feasibility and reasonable cost

A preliminary screening of 31 remedial technologies that may have been appropriate for this site was conducted. From this list, seven technologies were identified for more detailed evaluation. These included slurry walls, sheet piling, extraction wells (to establish a barrier), product recovery, phase separation, oil absorption column, and carbon absorption, or some combination of these technologies. A summary of the advantages and disadvantages of each option, as taken from the final Jacobs Engineers ERA Report for EPA, is as follows:

Slurry Wall

Constructed to a depth of 30 feet between the breakwater and facility structures on the tidal edges of the site, a slurry wall could stop much of the groundwater movement. However, it would not control the contaminants that have already reached the marine environment, and cost and durability would depend on the selection of appropriate materials for construction of this low permeability barrier. Salt environments degrade locally available bentonite clays, and non-degradable material costs would be high. In addition, there is limited locally available clean fill material to mix with the bentonite, and excavated material (5,000 CY) would most likely require off-site disposal as hazardous waste.

Sheet Piling

Steel sheet piling would provide an effective cutoff wall if properly constructed. However, damage may increase if sheet piles are driven to depths greater than 15 feet. Driving in compacted cobbles, boulders and fill material at the Wyckoff site would be difficult and could increase the likelihood of pile damage. Leakage around newly driven piles is common, but decreases with time as silt fills in the gaps left during pile driving. The piles could be driven from a barge, allowing minimal impact on continuing facility operations and the collection of product seeping from the shoreline with booms,

skimmers or oil sorbents. Salt water would eventually degrade the sheet steel, but this degradation could be controlled with appropriate design.

Barrier Wells

Properly designed and located extraction wells could provide a hydraulic barrier to minimize groundwater flow by reversing the hydraulic gradient with continuous pumping. Extracted water would require treatment prior to discharge to Puget Sound. The movement of water could result in flushing of the contaminants from the soil matrix. Numerical modeling done by Tetra Tech indicated that six 35 foot deep wells located about 100 feet from the high tide boundary could provide this barrier. Spaced at 175 feet and pumping at 35 gallons/minute, the model predicted the wells would intercept all the flow with the exception of a 10 to 20 foot border on the shoreline. The cones of depression were not designed to meet the shoreline to minimize problems with the interception of Puget Sound water. The barrier can be established very quickly (within days) and at low cost.

Operating costs are high, both for the pumping and the subsequent treatment of contaminated water. In addition, the model indicated that 90 percent of the pumped water would be drawn from Puget Sound, despite efforts to design the barrier to minimize capture of water from Puget Sound. Ingestion of salt water could make treatment of recovered product difficult and cause the floating product to sink (and be more difficult to recover in a subsequent cleanup).

Product Recovery

The product recovery techniques considered involve actively pumping contaminant layers (floating and sinking) from groundwater. These techniques can work well for floating product; for this reason the primary emergency response action at this site was directed toward interception of the floating product. In this approach, dual pumps operate in the well. One recovers free product flowing into the well within a cone of depression created by the second pump, which draws down the water table. The recovered product can be treated and reused or removed from the site for disposal. Withdrawn water requires treatment for dissolved contaminants prior to discharge to Puget Sound. Sinking product can be recovered in a similar way, and commercially available systems have been demonstrated on creosote products before. The cost of such a system is higher than the barrier wells alone, since additional well setup costs are necessary. The water treatment facilities may be smaller, however, since the drawdown would not have to be as large as in the barrier system.

For this project, active recovery was estimated to require at least three dual pump floating product recovery wells and two dual pump sinking product wells sited in the areas where greatest product thickness was observed. Tetra Tech estimated the required pumping rate using a Theis non-equilibrium formula, assuming isotropic, homogeneous conditions and an artesian aquifer with a fully penetrating well and constant discharge. Using an estimated hydraulic conductivity of 50 gal/day/ft^2, 30 foot screened intervals, transmissivity of 1500 gal/day/ft, storage coefficient of 0.0001, borehole radius of 0.5 ft, and drawdown of three feet over seven days, the required pumping rate was computed as 2.1 gal/min. Artesian conditions were assumed because the storage coefficient developed during well tests indicated confined conditions. Tidal influence and well interference was ignored. The pumping systems could be rotated among the five recovery wells based on actual production during operations.

Phase Separation

This is a treatment process for groundwater removed by barrier or product recovery wells. It involves exploiting the different densities of the contaminants to separate oily materials from the water prior to treating the water for soluble constituents. Typical phase separation equipment includes oil/water separators, parallel plate gravity settlers, and large clarifiers. Sludge handling capabilities are needed for this site, and chemical addition may be necessary to maximize separation. Proper design may require a pilot plant to test design assumptions. Cost varies based on selected equipment, but is generally not significant compared with the groundwater extraction cost.

Oil Absorption Column

This technology uses granular oil absorbents to remove residual emulsified oils following basic phase separation. The absorbents are used in a contact chamber and may require hazardous waste disposal once their capacity is reached. Cost is relatively modest.

Carbon Adsorption

This is a proven technology that uses granular activated carbon to adsorb pollutants physically. Wastewater flows past the carbon, which is held in a contact vessel. Solids pre-separation is not necessary if the system is pressurized, but backwashing will be needed to recover the hydraulic capacity. If a nonpressure system is selected, the concentration of suspended solids must be reduced below 50 parts per

million for effective treatment. Spent carbon must be regenerated or disposed of, and backwash liquid must be treated. Capital costs are not excessive, but operating expenses can be quite high depending on the required frequency of carbon regeneration.

Alternative Selection

None of the above technologies are stand-alone options, but each was packaged with the others as part of the review of response alternatives. The documentation for these alternatives including selection criteria and schematic representations are provided as Appendix B-4 to this case study. The following descriptions explain how each of these alternatives were packaged and evaluated.

The final five alternatives were:

Alternative 1:.	No Action.
Alternative 2:	Active product recovery and groundwater treatment.
Alternative 3:.	Slurrywall, active product recovery, and groundwater treatment.
Alternative 4:.	Sheet piling, active product recovery and groundwater treatment.
Alternative 5:.	Barrier wells, active product recovery, and groundwater treatment.

Alternative 1

This alternative was evaluated as required by the National Contingency Plan. Since failure to stop the contaminant transport would not be possible, this option is not feasible.

Alternative 2

This alternative consists of active product recovery in five wells, two of which were existing, that pump at a rate of 2.1 gal/min, in conjunction with phase separation, oil absorption column, and activated carbon treatment of the well water. Total estimated capital cost was $372k with annual O&M costs of $125k.

Alternative 3

An 1,800 ft slurry wall would be constructed to 30 foot depth from salt resistant clay, which would significantly reduce contaminant flow and seawater interaction with the site. Product recovery wells would pump at a rate of 10 gal/min and should work better than at the lower pumping rate specified for Alternative 2. The water treatment process would be the same as for Alternative 2. Estimated capital cost was $2,158k and annual O&M costs would be $182k.

Alternative 4

Steel sheet piling would be installed to 20 foot depth along 2000 ft of the seaward side of the site. Product recovery and water treatment would be the same as described for Alternative 3. Estimated capital cost was $2,024k and annual O&M costs would be $184k.

Alternative 5

Six barrier wells placed in a semicircle around the site perimeter would be used to control groundwater flow and stop product seepage. Based on the Tetra Tech model, drawdown of 7 feet at each well and a pumping rate of 35 gal/min would be necessary to establish the barrier. The barrier wells would operate as product recovery wells, so one additional pumping system would be needed. The water treatment process would be the same, but costs would rise because significantly more water would be treated. Assuming the treatment cost is linear with respect to the quantity of water treated (and not with respect to the concentration of the contaminated water) yields a capital cost of $894k and an annual O&M cost of $794k.

Alternative Decision Summary

As shown in the Appendix B-4 alternative evaluations, essentially all alternatives could be implemented within one year. Only two of the alternatives were rejected: Alternative 1 because it fails to address public health risks or contaminant migration, and Alternative 2 because it fails to address contaminant migration. The remaining alternatives were evaluated based on reliability and technical feasibility, administrative feasibility and cost reasonableness. Significant problems considered included effectiveness, constructibility, reliability, useful life and environmental impacts such as noise, dust during construction, waste disposal, and beach access. Based on this review, Alternative 5 was selected by EPA.

The Dispute/Current Status

Wyckoff and their consultants, Entrix Inc., took exception to the EPA's decision. Their primary objection was to the use of high cost carbon filters for treatment. Although the cost of the remedial action was a serious concern, the technical adequacy of the containment technology was also questioned. The technical objections were based on the use of a confined aquifer model to simulate groundwater flow in an aquifer that was clearly not confined, and ignoring the potential for upward vertical flow behind any slurry or sheet pile walls.

As a partial result of this dispute, EPA and Wyckoff agreed not to install the barrier well system and only the groundwater extraction/treatment system was installed. The system was constructed, completed and tested by early 1990 at which time active recovery of contaminant began. Only 12,000 gallons of contaminant had been recovered as of September, 1990, out of the estimated 23 million gallons of contaminant and sludge buried at the site.

The groundwater extraction system consists of four wells drilled to an estimated 30 foot depth which enter a manifold piping system. Depending on the quality of the extract, it follows one of two paths in the treatment system. Under the poorest quality extraction conditions, Path 1 involves an oil/water separator followed by a depurator which then flows to an equalization tank before going to the biological treatment stage. The equalization tank allows for dilution of current extract with previous extract to prevent "spikes" of higher contaminant directly entering the aeration lagoon where biological treatment takes place. This setup is necessary because the organisms in the lagoon are extremely sensitive to pentachlorophenol. Once the product leaves the aeration lagoon, it is sent to three carbon filter towers before being sent to the Effluent Storage Tank for eventual release to the harbor. In Path 2, when the extract is relatively cleaner, the extract skips the oil/water separator stage, the depurator, and the biological treatment lagoon and flows directly to the carbon filter towers. An as-built schematic of the system in place is shown on Figure III-12. The organisms used at the Wyckoff site were obtained from a Mobile Oil facility in Anacortes, WA.

During the summer of 1991, due to EPA's dissatisfaction with both Wyckoff's overall progress and the quality of routine monitoring and extraction reports, EPA executed a unilateral order against Wyckoff. This order provides specific direction to Wyckoff to increase the groundwater pumping output/capacity from an intermittent 30 gpm to a consistent 165 gpm by upgrading the extraction system. (Currently, under active pumping operations, a column of five to six feet of sinking product is removed from the site every six hours) Nine new wells are to be drilled and added to the system

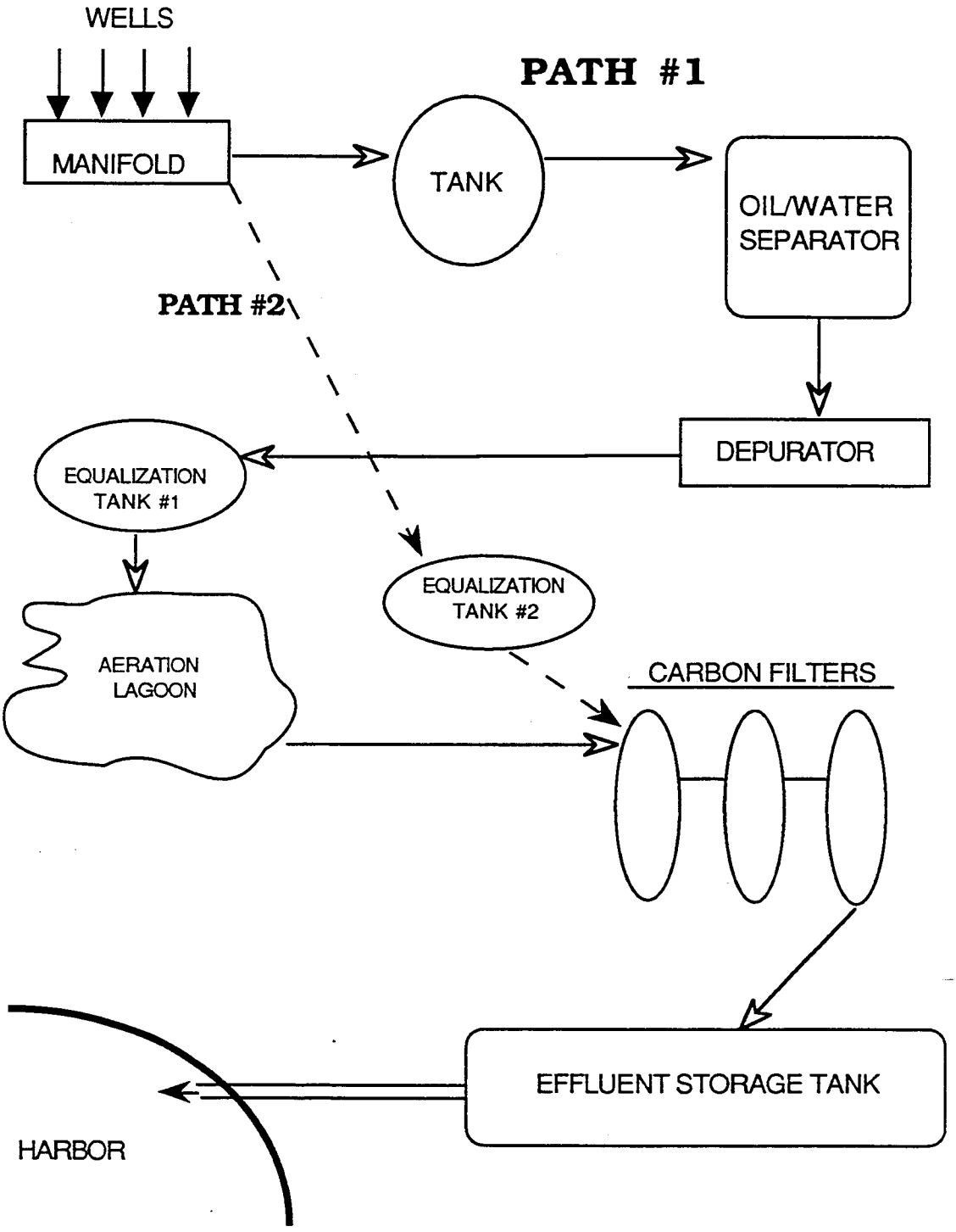


Fig. III-12 Wyckoff Groundwater Extraction System Schematic

along with an improved monitoring/control schematic for the pumping operation. Wyckoff is presently in the process of submitting plans to meet this new directive, while EPA is targeting spring 1992 for the completion of these new requirements.

F. EVALUATION/CRITIQUE

Contaminant Migration Modeling

Given the contamination sampling data contained in this report and on the computer disk provided as Appendix D, implement a migration plume model to predict how much contamination is seeping into the Harbor on a monthly basis. How much contamination would you predict is moving beneath the southern bluff at the site? Could you model the water body as a continuation of the highly permeable fill at the Wyckoff site? Why or why not? What limitations or data restrictions would you have in creating this model? What assumptions would you have to make? Is the existing sampling adequate to create this model? Do you concur withthe modeling assumptions made by Jacobs/Tetra Tech in providing the ERA alternatives?

Expedited Remediation

Do you concur with the 1988 ERA alternative selected by EPA? Why or why not? Constrained by the $2 million ERA budget, could a compromise have been made with the other three alternatives not selected? Explain what you would have done as a prudent site manager at EPA in 1987-1988. If you elect to choose another alternative, explain your course of action to implement including timeline, milestones, and how you would satisfy public/political concerns.

Groundwater Extraction/Treatment Critique

Based on knowledge of the current remediation system in place, how would you improve the existing extraction/treatment system to be more effective? Is it an adequate design for the purpose intended? What is the purpose intended? What factors limit its capacity and why?

Permanent Remediation

Several remediation alternatives will be evaluated for the Wyckoff site during the RI/FS process. These may include vapor extraction, capping, excavation, or in-situ bioremediation. Explain the disadvantages and advantages of each of these procedures. Explain which you would select and why (include your own alternatives as well).

G. WYCKOFF/EAGLE HARBOR REFERENCES

(Bokuniewicz, 1980) Bokuniewicz, H.J. and M.J. Zeitlin, Characteristics of the Ground-Water Seepage into Great South Bay; Special Report 35, Marine Science Research Center, State University, New York. 1980.

(ENTRIX, 1986) ENTRIX Inc., Data Report for the RCRA 3013 Investigation - The Wyckoff Co Eagle Harbor; Bainbridge Island, WA. December 1986.

(ENTRIX, 1988) ENTRIX Inc., Comments of Final Report: Assessment of Expedited Response Actions: Wyckoff Co. Bainbridge Island; Walnut Creek, CA. April 1988.

(Jacobs 1988) Jacobs Engineering Group Inc., Final Report: Assessment of Expedited Response Actions for Wyckoff Company - Bainbridge Island; for the U.S. Environmental Protection Agency, Seattle, WA. February 1988.

(Tetra Tech, 1987) Tetra Tech Inc., Preliminary (Draft) Assessment of Expedited Response Actions at the Wyckoff Co Site - Bainbridge Island; for Jacobs Engineering Group., Seattle, WA. 1987.

CHAPTER IV - TACOMA LANDFILL CASE STUDY

A. INTRODUCTION

The Tacoma Landfill is a City of Tacoma Refuse Utility (CTRU) solid waste disposal facility located near the city's border with the town of Fircrest, Washington. The site is about five miles from Commencement Bay to the north/northeast and four miles from the Narrows of Puget Sound to the west/northwest (see Figure IV-1). The total landfill area is approximately 190 acres.

Wastes received at the landfill include: garbage, rubbish, industrial wastes, construction and demolition debris, street refuse, litter, and bulky waste (Black & Veatch, 1987a). Since 1960, it is estimated that 4 million tons of refuse have been deposited at the site. Filled areas vary from 20 to 80 feet deep; in 1991, the site received about 600 tons per day of refuse from a surrounding community of nearly 220,000 people. Presently the landfill is operating beyond its original expected lifespan.

The landfill does not accept hazardous waste, however, during the 1960's and 1970's substances since designated as hazardous are suspected to have been deposited at the site. Additionally, according to EPA records, hazardous substances may also have been deposited as recently as 1983 or 1984.

Nearly all of the property surrounding the landfill is residential: the major exceptions are a large industrial tract of land east of the landfill between Tyler Street and Tacoma Way and a small industrial plot of land between the landfill and the corner of 48th Street and Orchard Street (see Figure IV-2). The major issues at the Tacoma Landfill are control of the migration of leachate to potable water sources and the reduction of toxic gases within the landfill and the surrounding property.

B. SITE HISTORY

The landfill began operations in 1960. The initial fill placement began in the northwest section of the current site and covered approximately 47 acres. In 1965 when the initial section of landfill reached final elevation, additional land was purchased. The original entrance was then closed and the present entrance, close to the center of the landfill, was opened. Scales were installed at the entrance in 1969.

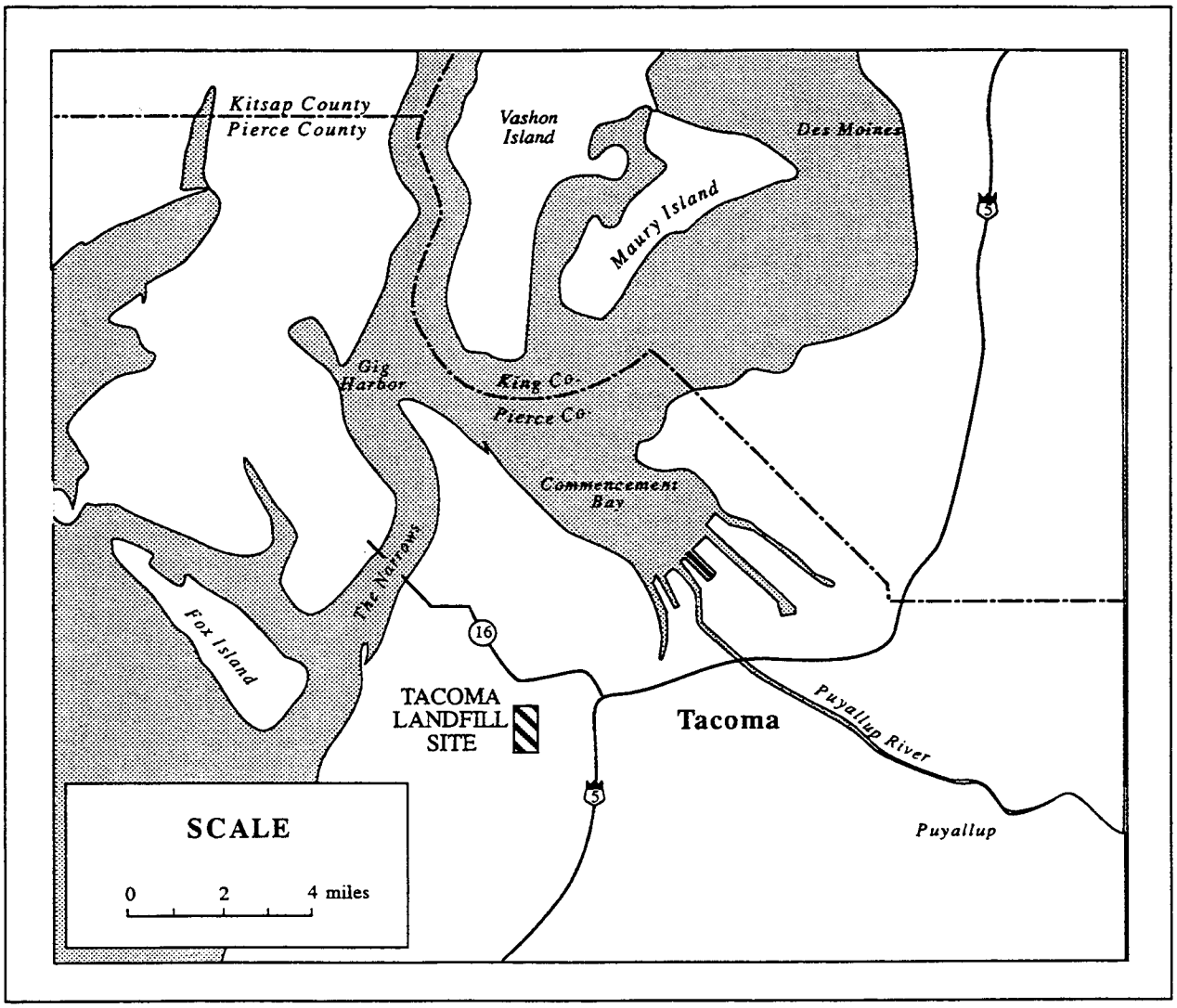


Fig. IV-1 Tacoma Landfill Location Map

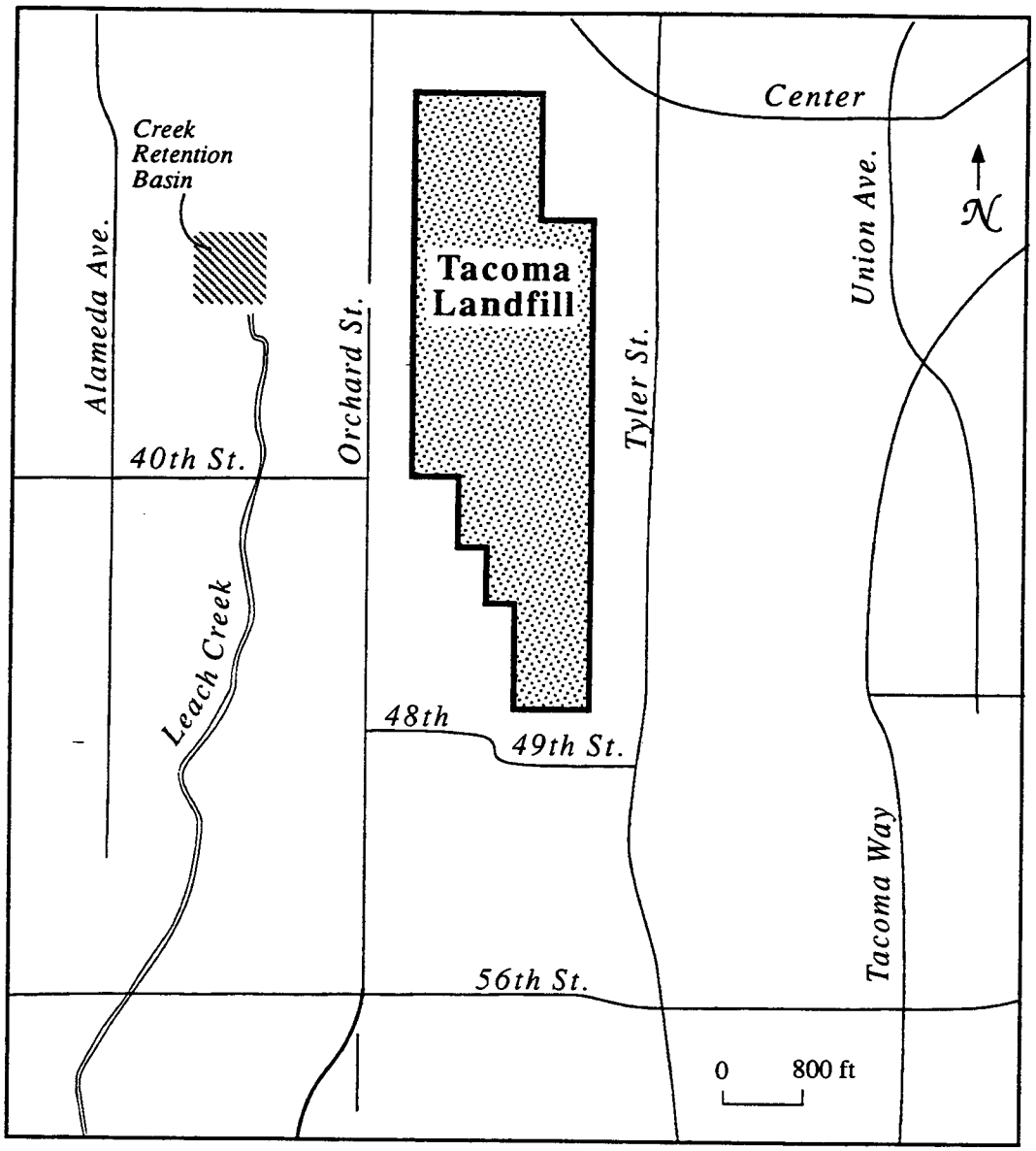


Fig. IV-2 Tacoma Landfill Site Map
(From Fig.1-2: Black & Veatch, 1987d)

In late 1968, the City of Tacoma Department of Public Works began receiving complaints of contamination in a Home Builder's Association well near the corner of 40th Street and Orchard Street at the then southwest edge of landfill operations. This well was 80 feet deep, but no record of the well's design or construction date existed (Larsen, 1963). A chemical analysis of the well water revealed a higher than normal dissolved iron content, discoloration, and a slight odor. There was no background well water quality data prior to construction of the landfill for comparison. Site investigations revealed that a possible source of contamination of the well was leachate that was breaking through the outer cover of the landfill at the southwest corner, flowing down a natural drainage course, and then ponding and percolating into exposed gravels near the well (Black & Veatch, 1987a).

To correct the problem, CTRU installed a leachate collection system consisting of a gravel drain and a dike made of glacial till. The dike was constructed to direct leachate flow to the drain which emptied into a perforated sewer manhole located east of the Home Builder's property. Also, landfill surface drainage was improved and an additional cover was placed over the landfill to minimize infiltration into the underlying soil. CTRU personnel indicated there was a steady flow out of the manhole for about two years between 1969 and 1971, and that the flow has been minimal thereafter. The Home Builder's Association property was later connected to the City of Tacoma water system.

In the late 1970's, several wells owned by the University Place Water Company located west of the landfill within the Leach Creek Retention Basin (shown on Figure IV-2) were found to have elevated concentrations of iron and manganese. Residents using University Place water complained of taste, color, and odor problems. An investigation of the water problems by the Washington Department of Ecology (WDOE) indicated that contamination of the wells could have resulted from surface sources by inundation of one or more of the well heads, groundwater contamination from the landfill, or water movement through glacial material high in iron and manganese. The wells within the retention basin were taken out of service and the residents connected to City water.

In 1977, CTRU completed construction of a resource recovery system at the site in order to extend the life of the landfill. This system consisted of a shredder, air classifier, and magnetic separator as its basic components. Since 1981, the resource recovery facility has been used solely to reduce the volume of refuse by compaction. In early 1987, Tacoma selected a consultant to modify the existing system to process

Tacoma's solid waste to produce a refuse-derived fuel which was to be incinerated by a Tacoma City Light cogeneration plant.

General concern about lateral gas migration at municipal landfills prompted CTRU to retain a consultant in 1986 to determine if gas from the landfill was migrating off-site. An initial survey revealed the presence of methane gas beyond the property line. Simultaneous methane monitoring at structures off-site indicated that gas migration was predominantly towards the southwest. Five businesses were monitored in this area on a daily basis and other structures were measured less frequently. Low gas readings were detected in the floors on top of fill and around unsealed utility penetrations. Sample results were reviewed by the Tacoma-Pierce County Health Department (TPCHD) for potential corrective action such as sealing slab cracks of improving building ventilation. Sampling conducted on private wells located southwest of the landfill revealed the presence of volatile organic carbons and vinyl chloride, a known carcinogen, in three of the wells (Black and Veatch, 1987e). Until these well users were connected with city water, WDOE supplied bottled water for over 1 year to several residences.

As a result of the findings, a decision was made to install an on-site gas extraction system on an emergency basis. In June 1986, the City began drilling 128 gas extraction wells and gas probes at 66 locations. A temporary extraction system was installed in the southwest corner at first, followed by a complex permanent system which overlaid the site. The gas extraction system was completed by July 16, 1986. Additionally, a temporary flare station, utilizing two temporary blowers and two flares, was used to burn the landfill gas. The off-site methane concentrations generally fell during the period of operation, although concentrations occasionally increased during periods of high barometric pressure. Two permanent flares subsequently replaced the temporary units in November 1986. The flares burn approximately 2200 CFM of gas, 44 percent of which is methane.

As of 1991, most of the site had been already filled. Approximately one third of the landfill is at final grade, covered, and sodded. The next section of the site to be filled covers approximately 18 acres and is called the central area pit. A flexible membrane liner and leachate collection system were installed in the summer and fall of 1987. Both were installed to maximize volume for waste disposal. Progress on the remaining sections has been hampered by both legal/regulatory battles on the methods to be used to cover the landfill and the City's request for an extension of the site's use. WDOE, EPA, and the City of Tacoma agree that the landfill has about 2-3 years use remaining.

C. REGULATORY HISTORY

CTRU has operated the Tacoma Landfill since 1960 under permit from the State of Washington. Before the landfill was expanded during the 1960's, the Tacoma Public Works Department contracted ground water geologic investigations and pollution potential reports for the site extension. The State apparently raised no objections to the proposed landfill expansion.

Between the late 1960's and the late 1970's, several forms of contamination began to appear in many areas outside the landfill boundary; however, the landfill continued to operate with annual permits issued by TPCHD. In 1976, RCRA was enacted by Congress, subjecting CTRU to increased waste disposal standards - particularly to ensure specified hazardous wastes were not deposited in the landfill. In 1976, CTRU drafted an Environmental Impact Statement (EIS) to EPA for operation of the solid waste disposal site and the addition of a resource recovery system. The EIS was reviewed, approved, and CTRU proceeded as planned with landfill operations and construction of the resource recovery system, which was completed in 1977.

In 1983, an investigation was conducted by EPA into the potential for groundwater and surface contamination in the area adjacent to the Tacoma Landfill. Several hazardous compounds were detected. The contaminants of concern were vinyl chloride, benzene, 1,2-dichloroethane, methylene chloride, 1,1-dichloroethane, chloroethane, and toluene. As a result of the EPA investigation, the landfill was placed on the National Priorities List (NPL) as part of the South Tacoma Channel Site. This action subjected the landfill to the 1980 CERCLA (Superfund) legislation on September 3, 1983.

DOE, through a cooperative agreement with EPA, initiated the remedial investigation (RI) in 1984 with Black and Veatch as consultants. Black and Veatch prepared a Current Situation report and the RI/FS planning documents in 1985. Just prior to the RI/FS, additional investigations were performed to determine the level and extent of the contamination. These were conducted by various agencies: EPA, DOE, TPCHD, and the City of Tacoma. Results of the investigation confirmed that hazardous waste compounds from the site had infiltrated into the aquifer and had contaminated three wells. A total of 24 volatile organic compounds were found in the contaminated wells.

In 1986, the City of Tacoma assumed responsibility as the potentially responsible party (PRP) for conducting the RI/FS under a Response Order on Consent issued by DOE in June 1986. This RI/FS subsequently commenced on July 27, 1986

and was completed in November 1987. The final reports were published in December 1987 with public comment on the studies completed in March 1988.

The Feasibility Study screened forty available alternatives of which six were selected. The six alternatives were subjected to detailed analysis as described in Section IV.E. After public comments on the RI/FS were summarized, EPA issued a community relations Responsiveness Summary and a Record of Decision (ROD) on March 31, 1988, which specified several cleanup actions. The selected remediation methods consisted of the following: capping the landfill, pumping/treating groundwater, continued elimination of gas migration, continued environmental monitoring, provisions of alternate water supplies, and landfill closure.

On November 13, 1989, a Consent Decree signed by EPA, WDOE, and the City of Tacoma was lodged with the U.S. District Court for the Western District of Washington (the Court) describing the ROD and the scope of work agreed between the three parties to effect remediation. The Court approved the order to proceed with work on November 28, 1989. Minor site cleanup work and Stage 1 remediation, primarily entailing remediation design planning, subsequently began in early 1990.

Upon further detailed review of the remediation plan outlined in the Consent Decree, the Court later objected to two central issues in the agreement: 1) that the planned landfill cap design was not as strict as current RCRA technical guidance and 2) that there was no remediation environmental impact assessment contained in the original decree. Therefore, on September 21, 1990, the Court halted all action on the Consent Decree until a new proposal was submitted. To add further delay, WDOE clean-up standards became effective on February 28, 1991. These standards were more stringent than those provided for in the original Consent Decree.

A revised Consent Decree was submitted to the Court on March 25, 1991. After the public comment period expired in June, the Court signed the second decree in July 1991. Currently, WDOE is negotiating construction design of the landfill cap and design of the extraction and treatment system.

D. SITE CHARACTERIZATION/DATA COLLECTION

Geology/Hydrology

The geology of the site consists of a series of glacial materials, mostly sand and gravel over older alluvial silts and sands. The stratigraphic layers from the top down,

shown in Figure IV-3, are as follows:

Nomenclature	Composition	Designation
Vashon Till	dense gray, gravelly, silty, sand	Qvt
Vashon Advance Outwash	sands/gravels	Qva
Colvos Sand	dense sand/some gravel	Qc
Older Gravel	dense sandy gravel	Qog
Older Till	dense silty, gravelly sand	Qot
Older Outwash	dense silty, gravelly sand	Qoa
Older Sand	dense fine/medium sand	Qos
Older Lacustrine	lake bottom silts	Qol/Qk
Undifferentiated Quaternary Sediments	miscellaneous sediments and silts	Qu

The Tacoma Landfill lies within a groundwater recharge area. Precipitation which infiltrates the landfill flows downward through the unsaturated zone (and possibly through perched saturated zones) under the influence of gravity toward the water table. The affected aquifer is located between the lower zones of the Colvos Sand and the Older Lacustrine, with the latter serving as the regional aquitard in the landfill area. The cross-section through the area indicated on Figure IV-3 shows the ridges, valleys, and layer structure. When water passes through the landfill it leaches contaminants and, where Vashon Till is absent beneath the waste, it is thought to transport the contaminants through the unsaturated zone and into the aquifer. The water table is located about 70 feet below the bottom of the landfill within the Colvos Sand layer.

The normal flow direction of the water table aquifer is southwesterly towards Leach Creek, the closest discharge point of the aquifer. However, during periods of heavy water use by Tacoma city wells (summer and early fall), the groundwater flow is reversed. Wetlands downstream of the landfill on Chambers Creek potentially could be exposed to contaminants in the surface and groundwater under such conditions.

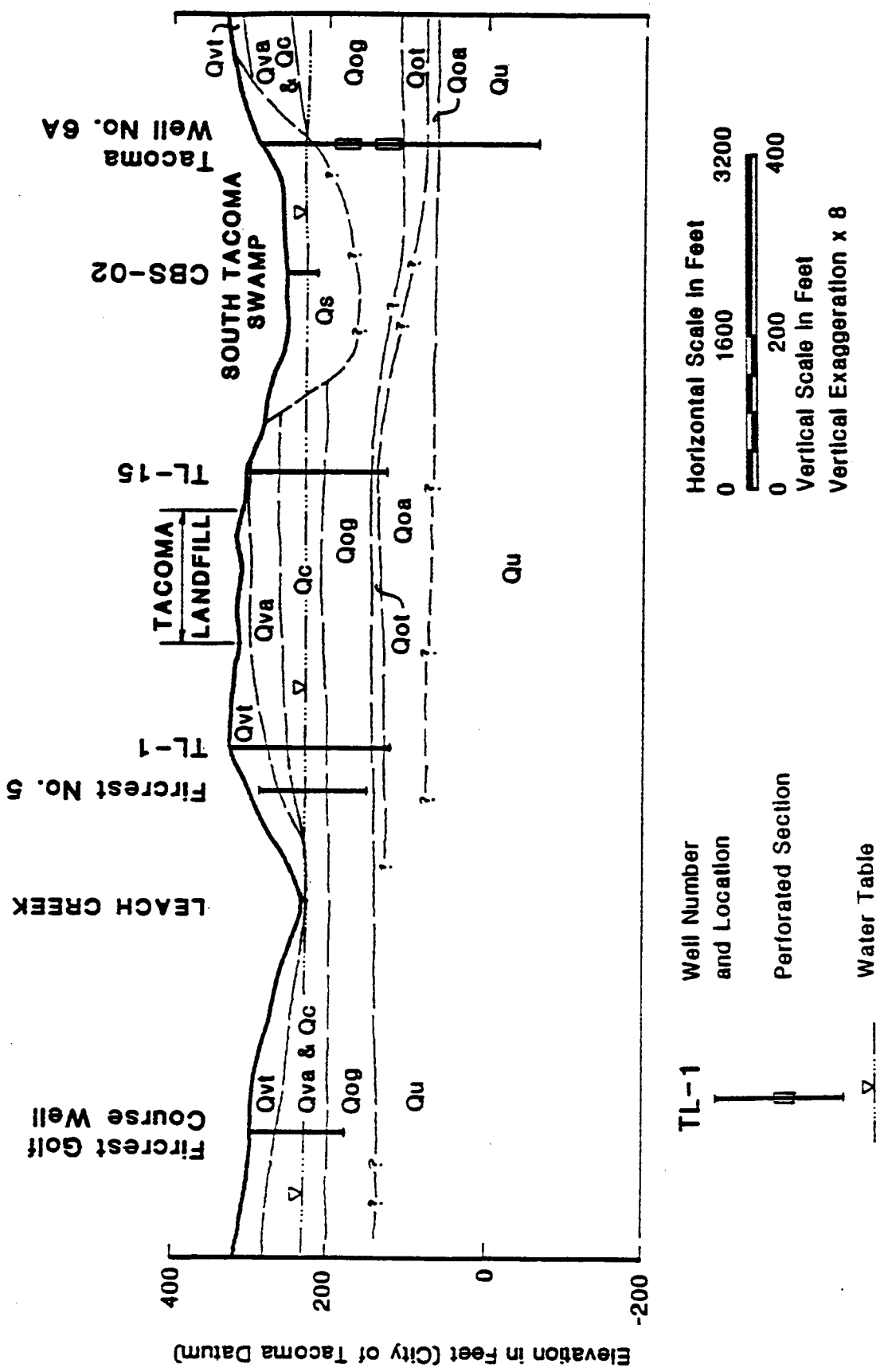


Fig. IV-3 Tacoma Landfill Regional Geologic Cross-Section (From Fig. 4-1: Black & Veatch, 1987a)

Figure IV-4 shows the Leach Creek Catchment Basin. Generally, the flow of surface water is to the south through the catchment, emptying into Chambers Creek and ultimately to Puget Sound. Nearly all of the Tacoma Landfill is contained within the catchment. At the northernmost tip of Leach Creek is a large retention basin (shown also on Figure IV-2) where some ponding of surface water occurs during storm periods.

Annual precipitation in Tacoma averages 37 inches. An estimated value for infiltration of 30 percent of precipitation is considered reasonable for the region based on prior studies (Hart-Crowser, 1982). The following transmissivity values for the site were derived from slug tests performed at various wells during the RI/FS:

Well No.	Hydraulic Conductivity	Screened Unit
TL-1b	5×10^{-3} cm/sec	Older Gravel
TL-1c	3×10^{-3} cm/sec	" "
TL-8a	3×10^{3} cm/sec	Colvos Sand
TL-8b	1×10^{-2} cm/sec	Older Gravel
TL-8c	2×10^{-3} cm/sec	" "
TL-11	4×10^{-3} cm/sec	Colvos Sand
TL-15a	2×10^{-3} cm/sec	Colvos Sand
TL-15c	1×10^{-2} cm/sec	Older Gravel
TL-17a	4×10^{-5} cm/sec	Colvos Sand
TL-17b	2×10^{-3} cm/sec	Older Gravel

Data Collection

Remedial Investigation sampling activities in 1986 consisted of the following: installation of groundwater monitoring wells and landfill leachate detection wells; and collection and analysis of surface water, groundwater, leachate, soil, sediment and landfill gas samples. This case study will focus on groundwater contamination and gas migration alone since these issues are the determining factors in remediation design for this site. Borings were drilled at fourteen locations using auger and cable tool drilling techniques. Twenty-one groundwater monitoring wells were installed at the seven boring locations adjacent to the landfill. Leachate monitoring wells were installed in the four borings drilled in the landfill refuse. An additional three borings were drilled in the proposed 18 acre landfill development area in the center of the site. In addition, many existing wells, including private wells, were sampled for the presence of contaminants.

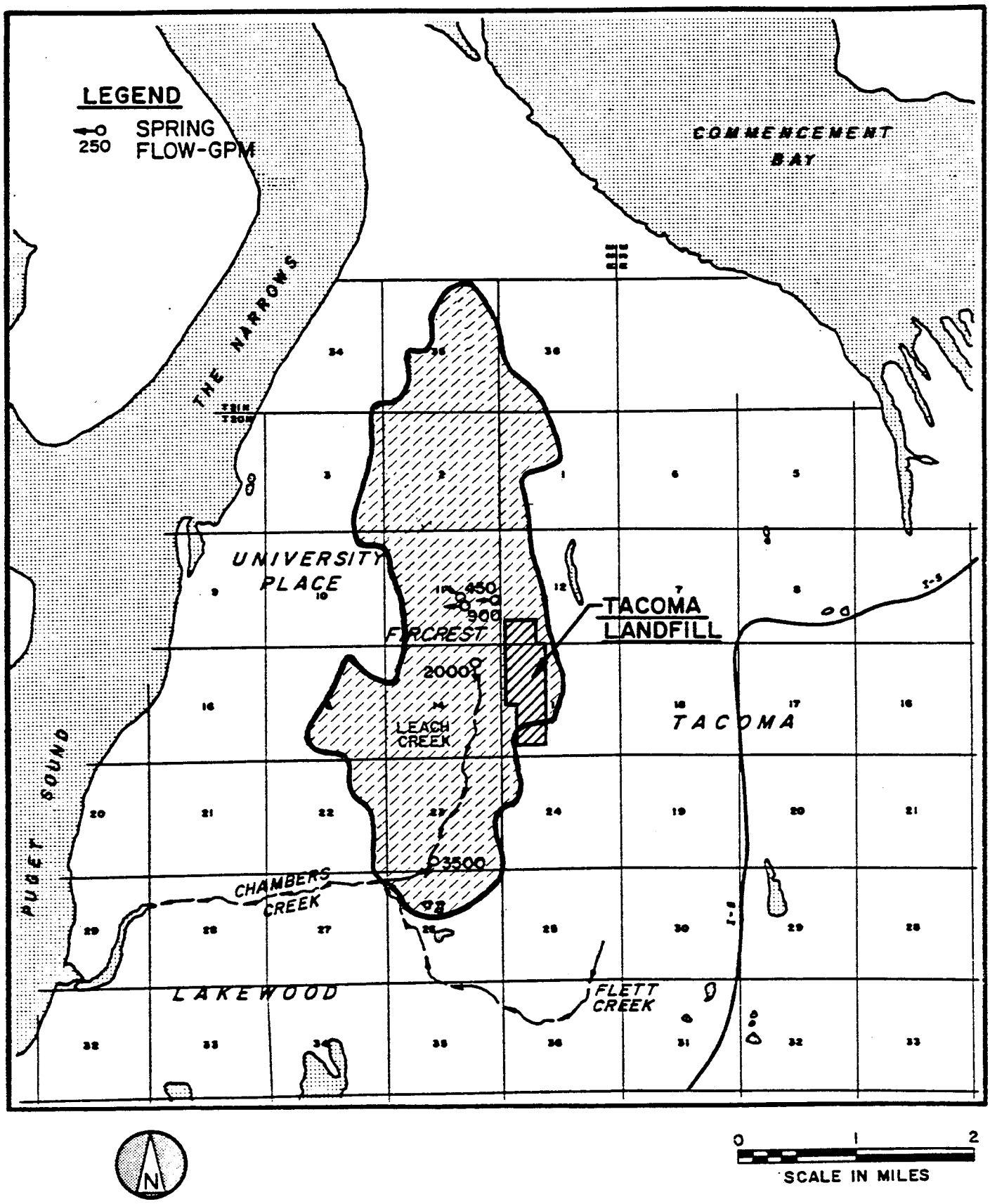


Fig. IV-4 Leach Creek Drainage Basin (From Fig. 5-1: Black & Veatch, 1987a)

Samples were collected and analyzed for EPA priority pollutants. Volatile organic compounds on the list of priority pollutants were detected in 20 of the groundwater monitoring wells installed during the RI and in six private wells sampled. Due to their toxicity, the following ten chemicals were identified as being of the most concern:

- vinyl chloride
- 1,2-dichloroethane
- 1,1-dichloroethane
- toluene
- 1,1,1-trichloroethane
- benzene
- methyl chloride
- chloroethane
- xylenes
- ethyl benzene

The highest concentrations and number of compounds detected were generally in the shallow monitoring wells (screened in Colvos Sand) located on the west and south edges of the landfill. Vinyl Chloride was detected in 14 of the monitoring wells and in 3 private wells sampled. Since volatile organics were detected in groundwater samples collected from wells located upgradient of the landfill, it is thought that the contaminated groundwater is due in part to diffusion of landfill gas into groundwater. The monitoring program also revealed that the shallower gases were controlled by the extraction system, however, gas found deeper than 35 to 40 feet was not controlled as well. (Due to these findings, TCRU installed 74 additional deep extraction wells beginning in 1988).

Figure IV-5 indicates the gas and groundwater monitoring plans used during the RI/FS. Sample locations are designated by the following code scheme:

- Gas Well (GW)
- Gas Extraction (Well 1A)
- Leachate Monitoring (L)
- New Monitoring well (TL)
- Existing Fircrest Well (FW)
- Gas Probe (GP)
- Flare Station (FS)
- Existing Groundwater Well(EW)
- University Place Well (UP)

The chemicals detected were divided into two categories: potential carcinogens and non-carcinogens. Contaminants were then ranked according to their maximum and representative concentrations. The final indicator carcinogens EPA chose to represent the site were vinyl chloride, benzene, 1,2-dichloroethane, and methylene chloride. Two indicator contaminants were chosen to characterize the site in this case study: benzene and vinyl chloride. Both of these constituents were also ranked in the top four characterization contaminants in the RI/FS for private well contamination. Only two contaminants were chosen to ensure simplicity of the case study model. Table IV-1

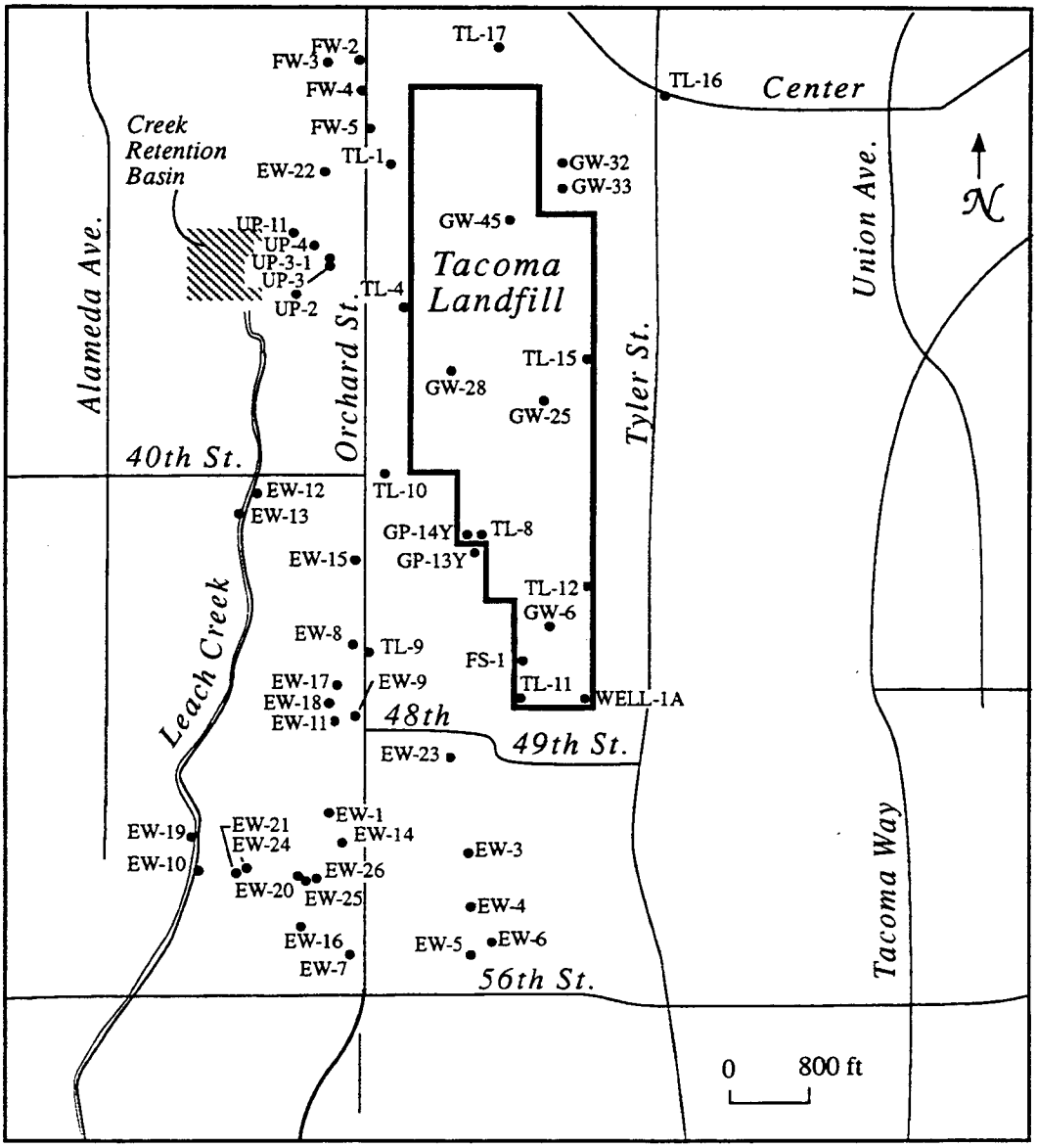


Fig. IV-5 Tacoma Landfill RI/FS Groundwater and Gas Monitoring Points (From Fig. 4-7: Black & Veatch, 1987d)

represents the dates and locations of samples collected to study the gas migration during the RI/FS data collection effort. Appendix C-1 provides the gas sample data tables showing constituents and contaminant concentrations found at each of the sample locations.

TABLE IV-1: DESCRIPTION OF TACOMA LANDFILL REMEDIAL INVESTIGATION LANDFILL GAS SAMPLES (Black and Veatch, 1987a)

Sample No.	Date	Location
GS-001	6/25/86	Gas Well GW-1
GS-002	6/25/86	Gas Well GW-28
GS-003	6/25/86	Gas Well GW-45
GS-004	6/25/86	Gas Well GW-32
GS-005	6/25/86	Duplicate of GS-004
GS-006	6/25/86	Gas Well GW-33D
GS-007	6/25/86	Gas Well GW-33S
GS-008	6/25/86	Gas Well GW-25D
GS-009	6/25/86	Gas Well GW-25S
GS-010	6/25/86	Gas Well GW-6D
GS-011	6/25/86	Gas Well GW-6S
GS-012	6/25/86	Flare Station FS-1
GS-013	8/26/86	Gas Probe GP-13Y
GS-014	8/26/86	Gas Probe GP-14Y

As indicated in the Appendix C-1 data tables, vinyl chloride gas appears in the highest concentrations at wells GW-1 (well 1A), GW-6 (both shallow and deep), FS-1 at the southern end of the landfill, and at well GW-45 and GW-33 (shallow) at the north end. Detectable concentrations of vinyl chloride gas were also present in the undeveloped section of the landfill at GW-28 and GW-25. Benzene however, was almost uniformly distributed in high quantities throughout the entire landfill (in both deep and shallow samples) with the exception of GW-28 in the undeveloped center of the landfill and GP-13Y off the southwest edge of the landfill.

Table IV-2 below indicates dates and sample locations of the RI/FS groundwater monitoring phase:

TABLE IV-2: DESCRIPTION OF TACOMA LANDFILL REMEDIAL INVESTIGATION GROUNDWATER SAMPLES (Black and Veatch, 1987a)

Sample No.	Date	Location
GW-001	8/7/86	EW-1, Private well, 5020 S.Orchard
GW-003	8/4/86	EW-3, Private well, 5124 S. Mullen
GW-005	8/7/86	EW-5, Private well, 5402 S. Mullen
GW-007	8/5/86	EW-7, Private well, 5106 54th Street
GW-008	8/4/86	EW-8, Private well, 4520 S. Orchard
GW-009	8/5/86	EW-9, Private well, 4716 S. Orchard
GW-010	8/5/86	Duplicate of GW-009
GW-011	8/4/86	EW-10, Private well, 5515 53rd Street
GW-012	8/5/86	EW-11, Private well, 4706 S. Orchard
GW-013	8/4/86	EW-12, Private well, 4009 W. Boise
GW-014	8/4/86	EW-13, Private well, 4030 W. Boise
GW-015	8/5/86	EW-14, Private well, 5102 S. Orchard
GW-016	8/4/86	Shipping Blank
GW-017	10/21/86	Well TL-1a
GW-018	10/21/86	Well TL-1b
GW-019	10/21/86	Well TL-1c
GW-020	11/18/86	Well TL-4
GW-021	10/21/86	Well TL-8a
GW-022	10/21/86	Well TL-8b
GW-023	10/21/86	Well TL-8c
GW-024	10/23/86	Well TL-9a
GW-025	10/23/86	Well TL-9b
GW-026	10/23/86	Duplicate of GW-025
GW-027	10/22/86	Well TL-11
GW-028	10/22/86	Well TL-15a
GW-029	10/22/86	Well TL-15b
GW-030	10/22/86	Well TL-15c
GW-031	10/22/86	Well TL-17a
GW-032	10/22/86	Well TL-17b
GW-033	10/22/86	Transfer Blank
GW-034	10/22/86	Shipping Blank
GW-100	8/7/86	EW-15, Private well, 4210 S. Orchard
GW-101	8/7/86	EW-16, Private well, 5209 54th Street
GW-102	10/27/86	EW-17, Private well, 5212 46th Street

Groundwater contamination levels discovered during the sampling are included in Appendix C-2. All existing private wells (EW) except EW-17 exceeded the drinking water standard of 5.0 ug/l for benzene. Wells TL-4 and TL-8 at the edge of the landfill contained the highest levels of benzene: 9.0 ug/l and 6.0 ug/l, respectively. Vinyl chloride contamination in groundwater exceeded the drinking water standard of 2.0 ug/l at all sample locations except TL-1 at the northwestern edge of the landfill and

at TL-8 and TL-9 near the southwest corner of the landfill. However, the highest concentrations of vinyl chloride in groundwater were found at many private wells nearly 1000 feet off-site to the southwest, close to Leach Creek. During the sampling effort, many samples of water were also taken in Leach Creek. None of these samples contained significant levels of contamination attributable to the landfill.

Endangerment Assessment: Interpreting the Data

As part of the RI/FS, an endangerment assessment was also conducted to develop a worst case model in order to try to predict the route/path of contaminant migration. This model is a migration baseline, assuming no remediation action. Under a no action alternative, the endangerment assessment found that there was a potential risk to human health at the landfill, however, the evaluation concluded that this risk can effectively be eliminated by connecting residences in the affected area to an alternate drinking water supply. In addition, this assessment determined that there would be no adverse impact on aquatic or terrestrial species.

To estimate the impact the landfill would have on groundwater quality if no action was taken at the site, a conservative groundwater contaminant transport model was used. This model was used to obtain the following information required to conduct the public health assessments:

* The maximum constituent concentration levels that would occur at potential receptors within the next 70 years. (Potential receptors included private wells and surrounding creeks.)

* The timeframe relative to the RI/FS when contaminant concentrations would approach their maximum.

* The time at which contaminant concentrations decreased to below a specified acceptable threshold concentration.

Major assumptions of the plume model used for the endangerment analysis were:

* One-dimensional steady groundwater flow exists with a constant seepage velocity of 0.8 feet per day.

* The aquifer is homogeneous with a porosity of 25% and longitudinal dispersity of 100 feet.

* The source of contamination will generate a constant concentration equal to the approximate maximum concentration measured in groundwater in the Qc aquifer at the landfill. The life of the source was assumed to be 100 years.

* Contaminants will move at a rate that is equal to the groundwater seepage velocity divided by the retardation factor for the contaminant.

* Degradation of the contaminants does not occur.

Based on this model, the predicted contaminant concentrations and travel times for both close-in and distant wells were as follows:

Indicator Chemical	Maximum Predicted Concentration Off-site (ug/l)	Time from RI/FS to Reach Max Conc. Close-in Wells	Distant Wells	Threshold Conc.(ug/l)	Years Until Below Limit
Vinyl Chloride	60-70	10-15 yrs	25-30 yrs	2.0	> 100
Benzene	8-10	55-60 yrs	85-90 yrs	5.0	> 100

The contaminant migration plume predicted by this model is shown in Figure IV-6. The results of this model indicate a contamination plume extending slightly to the northeast due to occasional reversals in groundwater flow. About half of the predicted plume falls within the Tacoma and Fircrest city limits. Both cities presently have ordinances requiring new residences and businesses to be connected to the city water systems. The other half of the projected plume area (west of Orchard Street, south of 40th Street, east of Leach Creek, and north of 56th Street) is in unincorporated Pierce County. Most of the private wells in the vicinity of the landfill are located within this area.

Overall, an 8000 foot long edge of the plume is predicted to reach Leach Creek if no remedial action occurs. Close-in wells in which contaminants have already been detected have been hooked up to Tacoma City water. When the RI/FS was performed, there were still three close-in wells (EW-01, EW-14, and EW15) in which contaminants had not been detected. Concerning distant wells, no contaminants were detected in these wells during the RI/FS and, according to the contaminant transport modeling, it will be several years before the wells in this group will be impacted by contaminant migration, even under the no action scenario.

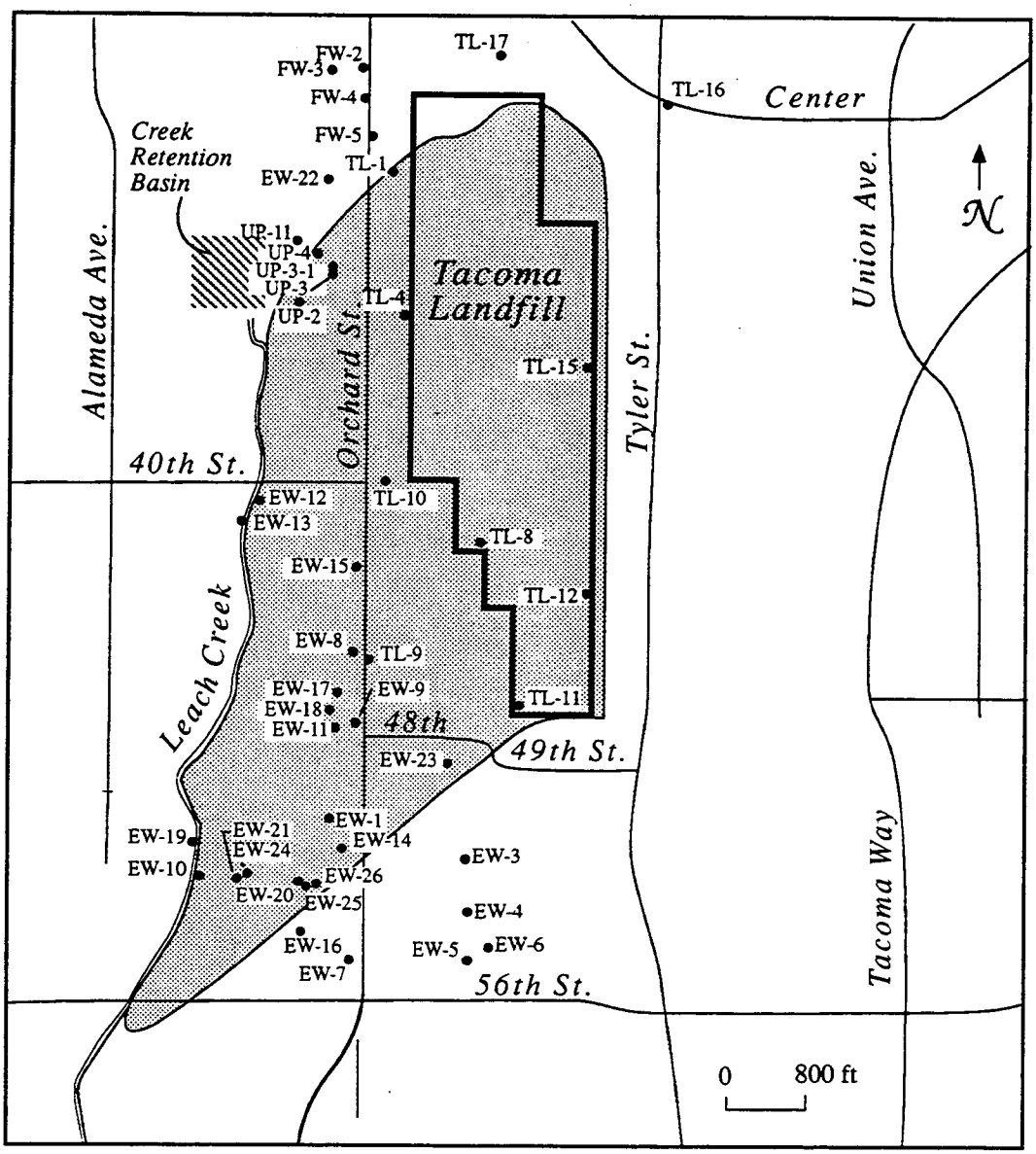


Fig. IV-6 Tacoma Landfill Contamination Plume
(From Fig. 1-5: Black & Veatch, 1987d)

E. REMEDIATION ALTERNATIVES

The following specific goals of remedial action were established by EPA for the Tacoma Landfill:

* Reduce or eliminate the threat of ingestion or inhilation of contaminants in groundwater, based on the levels established during the endangerment assessment.

* Improve the quality of groundwater at the site which has been contaminated.

* Reduce or eliminate future production of landfill leachate.

* Reduce or eliminate the subsurface migration of methane gas (as well as other gases) off-site.

* Reduce or eliminate the degradation of ambient air quality, if occurring, from the diffusion of landfill gas through the landfill cover and the incineration of landfill gas.

Forty potential remedial technologies for controlling contaminant migration were screened. Thirty-one potential remedial technologies were identified for the groundwater pathway and nine potential remedial technologies were identified for the gas migration/air quality pathway. These general response actions fell into the following seven categories:

(1) No action
(2) Institutional Controls
(3) Containment Technologies
(4) Removal Technologies
(5) On-site Treatment and Discharge
(6) Off-site Treatment and Disposal
(7) Other Management Options

Tables IV-3 and IV-4 list the specific remedial technologies reviewed for the groundwater and gas contaminant migration, respectively. A summary of the detailed evaluation of these potential remediation measures has been provided in Appendix C-3.

As indicated in Appendix C-3, most of the potential remedial technologies available for this site were rejected based on cost considerations, possible performance problems, construction difficulties, or non-applicability to the Tacoma Landfill site. However, the RI/FS summarized sixteen potential technologies which were considered viable remediation alternatives.

TABLE IV-3:
POTENTIAL REMEDIAL TECHNOLOGIES FOR GROUNDWATER PROBLEM

GENERAL RESPONSE ACTION	POTENTIAL REMEDIAL TECHNOLOGY
No Action	- None
Institutional Control	- Groundwater Use Restrictions - Groundwater Monitoring - Surface Water Monitoring
Containment	- Capping - Vertical Barriers - Horizontal Barriers - Surface Controls - Gradient Controls
Removal	- Groundwater Wells - Subsurface Pipe Drains - Enhanced Removal Processes
On-site Treatment and Discharge	- Equalization and Detention - Physical Treatment - Chemical Treatment - Biological Treatment - Thermal Treatment - In-Situ Treatment - Surface Discharge - On-site Subsurface Discharge - Publicly Owned Treatment Works (POTW) Discharge - Water Treatment Facility - On-site Solids Disposal
Off-site Treatment and Disposal	- RCRA Incineration Facility - RCRA Treatment Facility - RCRA Deep Well Injection Facility - Publicly Owned Treatment Works - Reusable Products - RCRA Disposal Facility
Other Management Options	- Alternative Water Supply - Individual Treatment Units

TABLE IV-4: POTENTIAL REMEDIAL TECHNOLOGIES FOR GAS MIGRATION PROBLEM/AIR QUALITY IMPROVEMENT

GENERAL RESPONSE ACTION	POTENTIAL REMEDIAL TECHNOLOGIES
No Action	- None
Institutional Control	- Air Quality Monitoring - Subsurface Gas Monitoring
Containment	- Capping - Vertical Barriers
Removal	- Passive Perimeter Gas Control Systems - Gas Extraction Wells
On-site Treatment	- Physical Treatment - Thermal Treatment - Gas Utilization
Other Management Options	- Evacuation of Residents and Businesses

A detailed summary of the sixteen feasible alternatives considered for remediating contamination at the Tacoma Landfill is provided below:

Activity 1: No Action.

Several remedial measures were proposed to meet the State Minimum Functional Standards for solid waste landfills, even under the no action alternative. These steps include groundwater monitoring, gas monitoring, prevention of gas migration, and construction of a final landfill cover. The No Action alternative was primarily passive in nature. Under this option, CTRU would continue to monitor downgradient wells on a quarterly basis, operate the gas extraction system to prevent off-site migration of methane, and only take extensive action when monitoring results indicated potential health risks. To establish a baseline of comparison to the other alternatives. no costs were assumed for groundwater monitoring or for alternate water supply provisions under this alternative.

Alternative 2: Containment by Pumping, POTW Discharge.

Under this alternative, groundwater extraction wells would be used to pump contaminated groundwater and prevent continued migration of contaminants. These wells would be located downgradient of the landfill. Ten 80-ft deep wells with a total

pumping rate of approximately 1.0 million gallons per day were planned in the evaluation of this alternative. In addition, ten 70-ft deep monitoring wells outside the estimated area of the contamination plume would be installed. Finally, this alternative included construction of a soil-synthetic membrane landfill cap and surface water drainage controls including grading, revegetation, and the installation of proper drainage channels. The central area of the landfill was to receive an impermeable synthetic liner and a leachate collection system as part of this plan. The estimated capital cost for Alternative 2 was $15,268,338 and the estimated annual operations/maintenance cost was $712,420.

Alternative 3: Alternate Water Supply and Groundwater Use Restrictions.

This alternative provided for an alternate water supply to residents affected, or likely to be affected by contaminant migration, by connecting these residences to the City of Tacoma water system. Groundwater use restrictions would be imposed for the area within the contaminant plume to prevent exposure to contamination and potential health risks. This alternative provides for landfill capping as in Alternative 2, but assumes that capping and gas extraction would result in eventual reduction of groundwater contaminant reduction caused by leachate and gas transport. Ultimately, under the Alternative 3 scenario, the contaminant plume would migrate away from the landfill, discharge into Leach Creek, and volatize to the atmosphere within 0.5 to 6 hours upon reaching the creek. After the plume passed the boudaries of the landfill, the groundwater monitoring wells would be sampled semi-annually. The estimated cost of this alternative was $14,878,765 with an anticipated cost of $211,520 for annual operation and maintenance.

Alternative 4: Containment by Pumping, On-site Air Stripping/Carbon Adsorption, and Surface Discharge.

This alternative utilizes on-site treatment of contaminated groundwater. The treatment technologies utilized would include air stripping followed by carbon adsorption processes which would provide the highest level of treatment (other than incineration) considered in any of the alternatives.

Contaminated groundwater would be pumped from the extraction wells (as described in Alternative 2) to an equalization basin at the on-site treatment facility. From the equalization basin the contaminated groundwater would travel to packed tower air strippers for removal of the more volatile organic compounds. As proposed, from there, the effluent would be pumped to down gradient fixed bed carbon

adsorption units. The carbon adsorption process would remove the volatile organics not removed by air stripping as well as removing some semi-volatile compounds and inorganic contaminants. This alternative also included groundwater monitoring and construction of the soil-synthetic membrane landfill cap and surface water drainage controls described in Alternative 2.

The treatment process for Alternative 4 would result in two byproducts: off-gases from the air stripper and exhausted carbon from the adsorption units. After an initial estimated cost of $18,360,096 to install this technology, operations and maintenance costs would be approximately $608,920 annually.

Alternative 5: Containment by Pumping, On-Site Air Stripping/Carbon Adsorption, Recharge Well Discharge.

Alternative 5 is the same as Alternative 4 except the treated water is piped to recharge wells located on or near the landfill site. The recharge wells would be located beyond the area of influence of the extraction well network. This activity would cost an estimated $18,525,846 in capital funds plus approximately $630,920 for annual operations and maintenance.

Alternative 6: Containment by Pumping, On-Site Air Stripping/Carbon Adsorption, Seepage Channel Discharge.

This alternative is the same as Alternative 4 and 5 except a seepage channel would be used to discharge treated water to the subsurface. The seepage channel would be located beyond the area of influence of the extraction wells. The channel would also be excavated deep enough to penetrate through the Vashon Till layer and discharge the treated water into the underlying Advance Outwash or Colvos Sand units. To avoid any potential recharge to the wastes and to avoid resultant leachate production, the trench would be located away from the fill. Estimated costs for this option were $18,436,756 for the initial construction, followed by $626,420 annually for maintenance and operations.

Alternative 7: Containment by Pumping, On-site Air Stripping/Carbon Adsorption, Discharge to Municipal Water Treatment Plant.

Alternative 7 is the same as Alternatives 4, 5,and 6 except discharge would be to the Tacoma water treatment plant located northeast of the landfill on Center Street, north of the South Tacoma Swamp. The treated water would be conveyed to the treatment plant by a force main. This alternative would allow the City to recoup some

of the cost of treating the water by providing it for sale and use in the drinking water system. Although technically feasible, political viability was a serious concern for acceptance of this alternative. This option would cost approximately $18,393,286 to install, followed by estimated annual operations and maintenance (O&M) expenses of $623,920.

Alternative 8: Containment by Pumping, On-Site Carbon Adsorption, Surface Discharge.

Alternative 8 utilizes carbon adsorption as the sole treatment technology. The difference between this alternative and Alternative 9, 10, and 11 is the mode of discharge for treated groundwater. Since air stripping is slightly more efficient in removing the more volatile organic compounds, the disadvantage of using only carbon units is that the increased loading of organic material on the carbon results in greater O&M costs over the life of the treatment plant. This alternative would cost approximately $17,451,976 initially with $493,120 in future annual O&M costs.

Alternative 9: Containment by Pumping, On-Site Carbon Adsorption, Recharge Well Discharge.

Alternative 9 has the same treatment scheme as Alternative 8 except the treated water is discharge by recharge wells as discussed in Alternative 5. Estimated costs for this option were $17,617,726 for initial capping, installation and set up, followed by $508,120 in annual O&M expenses.

Alternative 10: Containment by Pumping, On-Site Carbon Adsorption, Seepage Channel Discharge.

This alternative is the same as Alternatives 8 and 9 except the treated water is discharged by seepage channel as discussed in Alternative 6. Costs were evaluated at $17,528,636 for capital installation and $510,620 for annual O&M.

Alternative 11: Containment by Pumping, On-Site Carbon Adsorption, Discharge to Municipal Water Treatment Plant.

Alternative 11 is the same as Alternative 8, 9, and 10 except the treated water is discharged to the influent of the Tacoma water treatment plant as discussed in Alternative 7. Capital costs were presumed to be about $17,485,000 with $508,120 estimated for annual O&M.

Alternative 12: Containment by Pumping, On-Site Air Stripping, Surface Discharge.

This alternative along with Alternatives 13, 14, and 15 utilizes air stripping as the process for treating the contaminated groundwater. Treatment with air stripping alone would not reduce the less volatile organic compounds to the concentrations that would be achieved with carbon adsoption nor would any semi-volatile and inorganic compounds be removed. A pilot study would probably have to be performed prior to implementation to determine if the required level of treatment would be achieved. Other aspects of this alternative were described in Alternative 4. Costs were estimated at $17,180,896 for initial construction/installation with $356,320 anticipated for annual O&M.

Alternative 13: Containment by Pumping, On-Site Air Stripping, Recharge Well Discharge.

Alternative 13 is the same as Alternative 12 except the discharge of treated groundwater would be through recharge wells into the aquifer as discussed in Alternative 5. Preliminary cost estimates placed initial capital cost at $17,346,646 with $371,320 in annual O&M.

Alternative 14: Containment by Pumping, On-site Air Stripping, Seepage Channel Discharge.

This alternative is the same as Alternative 12 and 13 except treated groundwater discharge would be the same as Alternative 6. Estimated costs for this technology were $17,257,556 for capital investment and $373,820 for predicted annual O&M.

Alternative 15: Containment by Pumping, On-Site Air Stripping, Discharge to Municipal Water Treatment Plant.

Alternative 15 is the same as Alternative 12, 13, and 14, with discharge via the option discussed in Alternative 7. The cost of this alternative was estimated to be $17,214,086 with annual O&M expenses of $371,320.

Alternative 16: Containment by Pumping, On-Site Liquid Injection, Incineration, On-Site Solids Disposal.

Alternative 16 is a thermal treatment intended to completely eliminate the organic contaminant in the contaminated groundwater. Contaminated groundwater would be removed by extraction wells as described in Alternative 4. The groundwater

would be pumped to an equalization basin and from there to the incineration equipment. An advantage to the incineration alternative is that there is no liquid effluent to contend with as there is with all the other treatment options. However, the incineration process does release by-products: fly ash and bottom ash, and a gas (which must be monitored periodically and may require scrubbing or filtering). For the purposes of evaluating this alternative, no cost estimate was added for treatment of off-gas. This alternative also assumes any ash generated would be disposed of on-site in the central area of the landfill. Estimated costs for this alternative were $17,243,558 for capital expenses and annual O&M requirements were estimated at over $13,000,000.

Summary/Selected Alternative

Of the sixteen methods initially screened, Black and Veatch recommended six for detailed analysis and consideration. These technologies and their detailed analysis are provided in Appendix C-4. The technologies selected were Alternative 1, Alternative 2, Alternative 3, Alternative 4, Alternative 8, and Alternative 12.

For the Record of Decision, three primary remedial alternatives were developed between EPA and WDOE: (1) no action, (2) alternative water supply and landfill cap, (3) pump, treat, and discharge with a landfill cap. Each alternative was evaluated with respect to technical feasibility, public health impacts, environmental impacts, institutional requirements, and cost analysis. (It is worthwhile to note that the "no action" alternative represents low risk in the public health impact category, has no cost associated with its evaluation, and ranked relatively low in terms of community concern.) Technical evaluations considered performance, reliability, implementability, and safety factors of the remedial actions. The Environmental Impact Analysis of these alternatives is provided in Appendix C-5 of this report.

The chosen remedial alternative included a landfill cap, a gas extraction system to control the source, and a groundwater extraction and treatment system to control migration of the plume. Water extracted from the system would be treated to specific performance standards, monitored to ensure compliance, then discharged via sewer system. In addition, to ensure sufficient water would be available in case of future contamination, the Tacoma water supply system would be expanded. The remedy would further protect public health and the environment via monitoring of groundwater, surface water, gas probes, air emissions, and provision of alternate water supplies where needed.

F. EVALUATION/CRITIQUE

Contamination Plume Prediction

Given the contamination data, transmissivity rates, and geologic profiles provided in this report, do you concur with the plume prediction provided by the RI/FS consultant? What assumptions must you make in your model? How much time do you predict it will take for the contamination to travel from the landfill to Leach Creek? What assumptions, if any, do you dispute in the Endangerment Assessment and how would your criticisms/changes influence the transport model?

Potable Well Contamination

The Tacoma Landfill's site history documents well contamination several years before the RI/FS detailed investigation and the connection of many private wells to City water. Was there enough documentation available to act on a detailed site investigation before the RI/FS? If so, how would you have implemented this study, where would these funds have come from, and when would it have been prudent to make the decision to connect all (or many) private wells to City water? Explain your answers with technical as well as management reasoning as if you were a project manager at EPA of WDOE.

Remediation Alternatives

The discussion of the 16 viable remedial alternatives recommended by the RI/FS consultants suggests that other, less costly initiatives than those selected by EPA for remediation could have been acceptable. Could the "no action" alternative or the groundwater use restrictions and alternate water supply system suggested by Alternative 3 be the best and most inexpensive solutions? Discuss why or why not? What other less expensive potential remediation solutions can you suggest for this site (consider both capital and O&M costs)?

G. TACOMA LANDFILL REFERENCES

(Black and Veatch, 1987a) Black and Veatch Engineers - Architects, Phase 1 Remedial Investigation Report, Tacoma Landfill; Prepared for the City of Tacoma, Tacoma, WA. January 1987.

(Black and Veatch, 1987b) Black and Veatch Engineers - Architects, Draft Remedial Investigation Report, Tacoma Landfill; Vol. 2, for the City of Tacoma, Tacoma, WA. September 1987.

(Black and Veatch, 1987c) Black and Veatch Engineers - Architects, Draft Feasibility Study Report, Tacoma Landfill; Vol.2, for the City of Tacoma, Tacoma, WA. September 1987.

(Black and Veatch, 1987d) Black and Veatch Engineers - Architects, Feasibility Study Report, Tacoma Landfill; Vol. 1, for the City of Tacoma, Tacoma, WA. December 1987.

(Black and Veatch, 1987e) Black and Veatch Engineers - Architects, Remedial Investigation Report, Tacoma Landfill; Vol. 3, for the City of Tacoma, Tacoma, WA. December 1987.

(Hart Crowser, 1982) Hart Crowser, Final Geotechnical Report, Chambers Creek Interceptor Tunnel; ULID 73-1, Pierce County, Washington. November 1982.

(District Court, 1991a) Memorandum Regarding Lodging of Consent Decree; Civil Action No. C89-583T, U.S. District Court for the Western District of Washington, Olympia, WA. March 25, 1991.

(District Court, 1991b) Second Pre-Settlement Remedial Design Stipulation and Agreement Order; Civil Action No. C89-583T, U.S. District Court for the Western District of Washington, Olympia, WA. March 25, 1991.

(District Court, 1991c) Consent Decree(Proposal); Civil Action No. C89-583T, U.S. District Court for the Western District of Washington, Olympia, WA. March 25, 1991.

(EPA, 1988) Record of Decision: Tacoma Landfill Site; U.S. Environmental Protection Agency Region 10, Seattle, WA. March 1988.

(Larsen, 1963) Larsen, B.I., Investigation of Groundwater Geology and Pollution Potential Vicinity of Proposed Orchard Street, Sanitary Landfill Site Extension; B.I. Larsen & Associates, Tacoma, WA. 1963.

CHAPTER V - SUMMARY AND CONCLUSIONS

The case study approach to educating management personnel is a proven technique, particularly in the Business Administration field. The method is widely used in courses which emphasize strategic planning to achieve both short and long-term organizational goals. This report applies a similar approach to the problem of hazardous waste remediation.

Strategic planning involves the formulation of a mission statement and a review of technology, regulations/policies, economic factors, social factors, and a detailed data analysis. All of these factors play an essential role in developing remediation alternatives at hazardous waste sites.

Three diverse Superfund sites have been examined in this report. In the Hanford Reservation 183-H Basins (Chapter II), decisions must be made in the short term about how to remediate nitrate and radioactive contamination for a relatively small site adjacent to the Columbia River. This site lies within a much larger plume of contamination which will take decades to remediate, and is the result of contamination from many sources. The 183-H Basin contamination does not pose an immediate threat to human life due to its isolation from the public. In addition, contaminant levels measured in groundwater nearby appear to have been decreasing over time. This case study prompts such questions as the advisability of undertaking remediation unless the remediation is closely tied to the solution for the underlying larger plume resulting from multiple sources.

At the Wyckoff (Eagle Harbor) site (Chapter III), PNA and Chlorinated Phenol contamination resulting from a wood treatment operation are clearly observed to be migrating from the site to the surrounding estuary, and there is an immediate threat to aquatic life in Eagle Harbor. This site is complicated by the technical problem of remediating extensive and deep soil and groundwater contamination without resuspending contaminants in the adjoining water body. Further, sensitive legal disputes must be addressed and resolved between the EPA and Wyckoff (the PRP) to accomplish remediation goals.

By contrast, at the Tacoma Landfill (Chapter IV), which lies adjacent to several residential areas, a high degree of cooperation between EPA, WDOE, and the City of Tacoma (the owner) has been evident in developing a remediation plan to prevent contaminants from reaching Leach Creek. However, carcinogens such as benzene and vinyl chloride have been migrating off the landfill site for years and a key question

addressed was: could migration have been reduced through earlier steps based on the information available prior to the RI/FS?

The intent of this report is to provide case studies which can be evaluated in order to prevent the same mistakes and/or delays from occurring at other hazardous waste sites. In this way, we hope that the process of remediating the thousands of identified hazardous waste sites throughout the country can be expedited.

These three Case Studies are likely to have similarities with many NPL and other hazardous waste sites nationwide. Problems associated with radioactive contamination exist at a number of nuclear reservations and military facilities around the country. Industrial contamination is a widespread problem: industrial sites make up a large proportion of NPL sites. The migration of gas and leachate from landfills is a pervasive problem nationally. Improvement in the record of remediating hazardous waste sites will be essential to justify the expenditure of public funds made over the past eleven years since CERCLA was passed by Congress. We hope these case studies can help in this pursuit.

V. APPENDICES

APPENDIX: A

A-1: Well Sampling Data - Gross Beta and Nitrate
A-2: Proposed Closure Design for 183-H Basins

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H3-1	1/18/62	NO3-PDS		1.2000E+01	MG/L
1-H3-1	7/11/62	NO3-PDS		1.1000E+01	MG/L
1-H3-1	6/11/71	NO3-PDS		8.1000E+00	MG/L
1-H3-1	11/04/71	NO3-PDS		8.8000E+00	MG/L
1-H3-1	1/11/72	NO3-PDS		1.5000E+01	MG/L
1-H3-1	5/12/72	NO3-PDS		1.0000E+01	MG/L
1-H3-1	9/26/72	NO3-PDS		9.3000E+00	MG/L
1-H3-1	4/05/73	NO3-PDS		1.4000E+01	MG/L
1-H3-1	7/31/73	NO3-PDS		1.5000E+01	MG/L
1-H3-1	10/04/73	NO3-PDS		2.2000E+01	MG/L
1-H3-1	2/01/74	NO3-PDS		2.6000E+01	MG/L
1-H3-1	4/02/74	NO3-PDS		1.9000E+01	MG/L
1-H3-1	7/30/74	NO3-PDS		1.6000E+01	MG/L
1-H3-1	10/01/74	NO3-PDS		1.7000E+01	MG/L
1-H3-1	1/27/75	NO3-PDS		4.0000E+01	MG/L
1-H3-1	4/01/75	NO3-PDS		3.1000E+01	MG/L
1-H3-1	7/30/75	NO3-PDS		1.8000E+01	MG/L
1-H3-1	9/30/75	NO3-PDS		2.7000E+01	MG/L
1-H3-1	1/27/76	NO3-PDS		2.7000E+01	MG/L
1-H3-1	3/30/76	NO3-PDS		2.1000E+01	MG/L
1-H3-1	8/04/76	NO3-PDS		2.4000E+01	MG/L
1-H3-1	12/07/76	NO3-PDS		3.2000E+01	MG/L
1-H3-1	3/03/77	NO3-PDS		2.9000E+01	MG/L
1-H3-1	6/07/77	NO3-PDS		8.3000E+01	MG/L
1-H3-1	8/02/77	NO3-PDS		2.7000E+01	MG/L
1-H3-1	9/01/77	NO3-PDS		2.4000E+01	MG/L
1-H3-1	12/06/77	NO3-PDS		3.4000E+01	MG/L
1-H3-1	2/28/78	NO3-PDS		1.1000E+02	MG/L
1-H3-1	6/02/78	NO3-PDS		5.3000E+01	MG/L
1-H3-1	11/06/78	NO3-PDS		4.3000E+01	MG/L
1-H3-1	3/05/79	NO3-PDS		5.0000E+01	MG/L
1-H3-1	5/25/79	NO3-PDS		6.2000E+01	MG/L
1-H3-1	8/28/79	NO3-PDS		5.0000E+01	MG/L
1-H3-1	11/01/79	NO3-PDS		4.4000E+01	MG/L
1-H3-1	3/04/80	NO3-PDS		4.4000E+01	MG/L
1-H3-1	5/15/80	NO3-PDS		4.4000E+01	MG/L
1-H3-1	8/14/80	NO3-PDS		2.1000E+01	MG/L
1-H3-1	10/29/80	NO3-PDS		5.4000E+01	MG/L
1-H3-1	2/26/81	NO3-PDS		5.3000E+01	MG/L
1-H3-1	5/30/81	NO3-PDS		6.4000E+01	MG/L
1-H3-1	8/20/81	NO3-PDS		3.9000E+01	MG/L
1-H3-1	2/26/82	NO3-PDS		5.5000E+01	MG/L
1-H3-1	5/20/82	NO3-PDS		3.5000E+01	MG/L
1-H3-1	10/27/82	NO3-PDS		3.6000E+01	MG/L
1-H3-1	2/16/83	NO3-PDS		5.3000E+01	MG/L
1-H3-1	5/16/83	NO3-PDS		4.1000E+01	MG/L
1-H3-1	8/11/83	NO3-PDS		4.5000E+01	MG/L
1-H3-1	11/10/83	NO3-PDS		5.3000E+01	MG/L
1-H3-1	2/22/84	NO3-PDS		6.9000E+01	MG/L
1-H3-1	5/23/84	NO3-ION		7.5000E+01	MG/L
1-H3-1	9/19/84	NO3-ION		7.8000E+01	MG/L
1-H3-1	1/02/85	NO3-ION		5.3000E+01	MG/L
1-H3-1	2/15/85	NO3-ION		9.2000E+01	MG/L
1-H3-1	4/18/85	NO3-ION		8.8000E+01	MG/L
1-H3-1	6/24/85	BETA		8.4000E+00	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H3-1	6/24/85	BETA		8.4200E+00	PCI/L
1-H3-1	6/24/85	BETA		1.4800E+01	PCI/L
1-H3-1	6/24/85	NITRATE		5.8000E+04	PPB
1-H3-1	6/24/85	NITRATE		6.0000E+04	PPB
1-H3-1	6/24/85	NITRATE	<	-1.6543E+37	PPB
1-H3-1	7/13/85	NO3-ION		1.2000E+02	MG/L
1-H3-1	8/01/85	BETA		1.0200E+01	PCI/L
1-H3-1	8/01/85	BETA		1.1600E+01	PCI/L
1-H3-1	8/01/85	BETA		4.1200E+02	PCI/L
1-H3-1	8/01/85	NITRATE		6.7500E+04	PPB
1-H3-1	8/01/85	NITRATE		6.8300E+04	PPB
1-H3-1	8/01/85	NITRATE		7.9100E+04	PPB
1-H3-1	8/27/85	BETA		8.4200E+00	PCI/L
1-H3-1	8/27/85	BETA		1.1800E+01	PCI/L
1-H3-1	8/27/85	BETA		1.5000E+01	PCI/L
1-H3-1	8/27/85	NITRATE		6.5700E+04	PPB
1-H3-1	8/27/85	NITRATE		6.8000E+04	PPB
1-H3-1	8/27/85	NITRATE		6.9800E+04	PPB
1-H3-1	10/03/85	BETA		1.4400E+01	PCI/L
1-H3-1	10/03/85	BETA	<	-6.5000E+00	PCI/L
1-H3-1	10/03/85	NITRATE		6.4600E+04	PPB
1-H3-1	10/03/85	NO3-ION		1.3000E+02	MG/L
1-H3-1	10/31/85	BETA		1.1400E+01	PCI/L
1-H3-1	10/31/85	NITRATE		7.2500E+04	PPB
1-H3-1	12/13/85	BETA		1.4800E+01	PCI/L
1-H3-1	12/13/85	NITRATE		4.7100E+04	PPB
1-H3-1	1/22/86	BETA		1.3200E+01	PCI/L
1-H3-1	1/22/86	NITRATE		5.2400E+04	PPB
1-H3-1	2/03/86	BETA	<	1.4000E+01	PCI/L
1-H3-1	2/03/86	NO3-ION		1.6000E+02	MG/L
1-H3-1	2/25/86	BETA		1.0000E+01	PCI/L
1-H3-1	2/25/86	NITRATE		7.1600E+04	PPB
1-H3-1	3/24/86	BETA		8.3300E+00	PCI/L
1-H3-1	3/24/86	NITRATE		7.4200E+04	PPB
1-H3-1	4/11/86	BETA	<	-1.9000E+00	PCI/L
1-H3-1	4/11/86	NO3-ION		1.0600E+02	MG/L
1-H3-1	4/25/86	BETA		1.3100E+01	PCI/L
1-H3-1	4/25/86	NITRATE		5.4100E+04	PPB
1-H3-1	5/28/86	BETA		1.8100E+01	PCI/L
1-H3-1	5/28/86	NITRATE		5.2900E+04	PPB
1-H3-1	6/26/86	BETA		3.4400E+01	PCI/L
1-H3-1	6/26/86	NITRATE		4.9000E+04	PPB
1-H3-1	7/25/86	BETA		1.2000E+01	PCI/L
1-H3-1	7/25/86	NITRATE		5.3100E+04	PPB
1-H3-1	7/28/86	BETA	<	4.0000E+00	PCI/L
1-H3-1	7/28/86	NITRATE		5.9700E+04	PPB
1-H3-1	8/21/86	BETA		1.4300E+01	PCI/L
1-H3-1	8/21/86	NITRATE		6.5700E+04	PPB
1-H3-1	9/16/86	BETA		1.2900E+01	PCI/L
1-H3-1	9/16/86	NITRATE		7.1700E+04	PPB
1-H3-1	10/24/86	BETA		2.6400E+01	PCI/L
1-H3-1	10/24/86	BETA	<	1.9000E+00	PCI/L
1-H3-1	10/24/86	NITRATE		5.7200E+04	PPB
1-H3-1	10/24/86	NITRATE		6.0900E+04	PPB
1-H3-1	11/19/86	BETA		1.5000E+01	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H3-1	11/19/86	NITRATE		7.0900E+04	PPB
1-H3-1	12/11/86	BETA		7.5600E+00	PCI/L
1-H3-1	12/11/86	NITRATE		6.7400E+04	PPB
1-H3-1	1/12/87	BETA		1.1400E+01	PCI/L
1-H3-1	1/12/87	NITRATE		6.2200E+04	PPB
1-H3-1	2/19/87	BETA		1.1400E+01	PCI/L
1-H3-1	2/19/87	NITRATE		6.6100E+04	PPB
1-H3-1	3/10/87	BETA		1.1800E+01	PCI/L
1-H3-1	3/10/87	NITRATE		6.4900E+04	PPB
1-H3-1	4/10/87	BETA		9.5800E+00	PCI/L
1-H3-1	4/10/87	NITRATE		9.8000E+04	PPB
1-H3-1	5/15/87	BETA		1.2200E+01	PCI/L
1-H3-1	5/15/87	NITRATE		5.2300E+04	PPB
1-H3-1	6/16/87	BETA		7.8100E+00	PCI/L
1-H3-1	6/16/87	NITRATE		5.4600E+04	PPB
1-H3-1	7/13/87	BETA		9.7000E+00	PCI/L
1-H3-1	7/13/87	NITRATE		6.2500E+04	PPB
1-H3-1	8/12/87	BETA		9.5400E+00	PCI/L
1-H3-1	8/12/87	NITRATE		6.6100E+04	PPB
1-H3-1	9/17/87	BETA		1.1800E+01	PCI/L
1-H3-1	9/17/87	NITRATE		7.0300E+04	PPB
1-H3-1	12/28/87	BETA		1.2000E+01	PCI/L
1-H3-1	12/28/87	NITRATE		6.9900E+04	PPB
1-H3-1	3/11/88	BETA		1.0600E+01	PCI/L
1-H3-1	3/11/88	NITRATE		6.3100E+04	PPB
1-H3-1	6/17/88	BETA		1.1100E+01	PCI/L
1-H3-1	6/17/88	NITRATE		5.9000E+04	PPB
1-H3-1	9/12/88	BETA		9.3800E+00	PCI/L
1-H3-1	9/12/88	NITRATE		6.2500E+04	PPB
1-H3-1	5/24/89	BETA		7.3200E+00	PCI/L
1-H3-1	5/24/89	NITRATE		2.3300E+04	PPB
1-H3-1	4/17/90	BETA		3.8300E+00	PCI/L
1-H3-1	4/17/90	NITRATE		1.4900E+04	PPB
1-H3-2A	1/30/87	BETA		3.3900E+00	PCI/L
1-H3-2A	1/30/87	NITRATE		1.7000E+04	PPB
1-H3-2A	2/13/87	BETA		6.5900E+00	PCI/L
1-H3-2A	2/13/87	NITRATE		2.0200E+04	PPB
1-H3-2A	3/04/87	BETA		8.1100E+00	PCI/L
1-H3-2A	3/04/87	NITRATE		2.2700E+04	PPB
1-H3-2A	4/07/87	BETA		9.6700E+00	PCI/L
1-H3-2A	4/07/87	NITRATE		1.7800E+04	PPB
1-H3-2A	5/12/87	BETA		1.0900E+01	PCI/L
1-H3-2A	5/12/87	NITRATE		1.5600E+04	PPB
1-H3-2A	6/11/87	BETA		6.1300E+00	PCI/L
1-H3-2A	6/11/87	NITRATE		2.9900E+04	PPB
1-H3-2A	7/14/87	BETA		6.8200E+00	PCI/L
1-H3-2A	7/14/87	NITRATE		2.2300E+04	PPB
1-H3-2A	8/06/87	BETA		9.4100E+00	PCI/L
1-H3-2A	8/06/87	NITRATE		2.3300E+04	PPB
1-H3-2A	9/14/87	BETA	<	3.2700E+00	PCI/L
1-H3-2A	9/14/87	NITRATE		1.9300E+04	PPB
1-H3-2A	10/07/87	BETA		6.9700E+00	PCI/L
1-H3-2A	10/07/87	NITRATE		1.8800E+04	PPB
1-H3-2A	12/22/87	BETA		6.1300E+00	PCI/L
1-H3-2A	12/22/87	NITRATE		1.6900E+04	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H3-2A	3/08/88	BETA		5.7200E+00	PCI/L
1-H3-2A	3/08/88	NITRATE		1.9200E+04	PPB
1-H3-2A	6/14/88	BETA		6.6400E+00	PCI/L
1-H3-2A	6/14/88	NITRATE		1.7100E+04	PPB
1-H3-2A	9/08/88	BETA		5.7500E+00	PCI/L
1-H3-2A	9/08/88	NITRATE		1.9700E+04	PPB
1-H3-2A	10/13/88	BETA		9.0600E+00	PCI/L
1-H3-2A	10/13/88	NITRATE		1.7800E+04	PPB
1-H3-2A	1/06/89	BETA		7.5700E+00	PCI/L
1-H3-2A	1/06/89	NITRATE		2.9000E+04	PPB
1-H3-2A	5/26/89	BETA		8.5100E+00	PCI/L
1-H3-2A	5/26/89	NITRATE		3.5300E+04	PPB
1-H3-2A	8/02/89	BETA		8.6700E+00	PCI/L
1-H3-2A	8/02/89	NITRATE		2.6300E+04	PPB
1-H3-2A	10/11/89	BETA		5.5700E+00	PCI/L
1-H3-2A	10/11/89	NITRATE		1.8100E+04	PPB
1-H3-2A	1/19/90	BETA		3.0700E+00	PCI/L
1-H3-2A	1/19/90	NITRATE		1.9200E+04	PPB
1-H3-2A	4/24/90	BETA		5.8100E+00	PCI/L
1-H3-2A	4/24/90	NITRATE		3.3500E+04	PPB
1-H3-2B	2/05/87	BETA		7.6500E+00	PCI/L
1-H3-2B	2/05/87	NITRATE		2.0300E+04	PPB
1-H3-2B	2/12/87	BETA		1.1700E+01	PCI/L
1-H3-2B	2/12/87	NITRATE		1.7600E+04	PPB
1-H3-2B	3/06/87	BETA		7.6500E+00	PCI/L
1-H3-2B	3/06/87	NITRATE		1.7200E+04	PPB
1-H3-2B	4/08/87	BETA		7.6600E+00	PCI/L
1-H3-2B	4/08/87	NITRATE		1.6100E+04	PPB
1-H3-2B	5/12/87	BETA		1.0900E+01	PCI/L
1-H3-2B	5/12/87	NITRATE		1.7400E+04	PPB
1-H3-2B	6/11/87	BETA		6.6000E+00	PCI/L
1-H3-2B	6/11/87	NITRATE		2.4400E+04	PPB
1-H3-2B	7/15/87	BETA		7.1600E+00	PCI/L
1-H3-2B	7/15/87	NITRATE		2.2800E+04	PPB
1-H3-2B	8/06/87	BETA		6.1600E+00	PCI/L
1-H3-2B	8/06/87	NITRATE		2.3400E+04	PPB
1-H3-2B	9/14/87	BETA		5.1000E+00	PCI/L
1-H3-2B	9/14/87	NITRATE		2.1100E+04	PPB
1-H3-2B	10/13/87	BETA	<	3.4700E+00	PCI/L
1-H3-2B	10/13/87	NITRATE		1.9700E+04	PPB
1-H3-2B	12/22/87	BETA	<	1.7300E+00	PCI/L
1-H3-2B	12/22/87	NITRATE		1.4700E+04	PPB
1-H3-2B	3/08/88	BETA		5.2100E+00	PCI/L
1-H3-2B	3/08/88	NITRATE		1.7400E+04	PPB
1-H3-2B	6/14/88	BETA		8.5900E+00	PCI/L
1-H3-2B	6/14/88	NITRATE		2.2100E+04	PPB
1-H3-2B	9/08/88	BETA		5.3600E+00	PCI/L
1-H3-2B	9/08/88	NITRATE		2.2500E+04	PPB
1-H3-2B	5/26/89	BETA		4.7700E+00	PCI/L
1-H3-2B	5/26/89	BETA		6.7800E+00	PCI/L
1-H3-2B	5/26/89	NITRATE		2.8100E+04	PPB
1-H3-2B	5/26/89	NITRATE		2.8200E+04	PPB
1-H3-2B	4/24/90	BETA		6.6900E+00	PCI/L
1-H3-2B	4/24/90	BETA		9.3900E+00	PCI/L
1-H3-2B	4/24/90	NITRATE		3.0900E+04	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H3-2B	4/24/90	NITRATE		3.1200E+04	PPB
1-H3-2C	12/23/86	BETA		1.2800E+01	PCI/L
1-H3-2C	12/23/86	NITRATE		8.1900E+03	PPB
1-H3-2C	1/07/87	BETA		7.7500E+00	PCI/L
1-H3-2C	1/07/87	NITRATE		9.1800E+03	PPB
1-H3-2C	2/10/87	BETA		1.3000E+01	PCI/L
1-H3-2C	2/10/87	NITRATE		8.9200E+03	PPB
1-H3-2C	3/06/87	BETA		1.0400E+01	PCI/L
1-H3-2C	3/06/87	NITRATE		8.1500E+03	PPB
1-H3-2C	4/06/87	BETA		1.2700E+01	PCI/L
1-H3-2C	4/06/87	NITRATE		5.0800E+03	PPB
1-H3-2C	5/11/87	BETA		9.2200E+00	PCI/L
1-H3-2C	5/11/87	NITRATE		4.0100E+03	PPB
1-H3-2C	6/11/87	BETA		4.7200E+00	PCI/L
1-H3-2C	6/11/87	NITRATE		3.7700E+03	PPB
1-H3-2C	7/14/87	BETA		3.6600E+00	PCI/L
1-H3-2C	7/14/87	NITRATE		3.4100E+03	PPB
1-H3-2C	8/04/87	BETA		3.9800E+00	PCI/L
1-H3-2C	8/04/87	NITRATE		3.8700E+03	PPB
1-H3-2C	9/14/87	BETA		8.4400E+00	PCI/L
1-H3-2C	9/14/87	NITRATE		3.2600E+03	PPB
1-H3-2C	10/13/87	BETA		5.6300E+00	PCI/L
1-H3-2C	10/13/87	NITRATE		3.2600E+03	PPB
1-H3-2C	3/08/88	BETA		4.1300E+00	PCI/L
1-H3-2C	3/08/88	NITRATE		3.6600E+03	PPB
1-H3-2C	6/14/88	BETA		1.1600E+01	PCI/L
1-H3-2C	6/14/88	NITRATE		3.3100E+03	PPB
1-H3-2C	9/08/88	BETA		5.1500E+00	PCI/L
1-H3-2C	9/08/88	NITRATE		3.2100E+03	PPB
1-H3-2C	6/01/89	BETA	<	2.2200E-01	PCI/L
1-H3-2C	6/01/89	NITRATE		4.6000E+03	PPB
1-H3-2C	4/24/90	BETA		2.6800E+00	PCI/L
1-H3-2C	4/24/90	NITRATE		3.1000E+03	PPB
1-H4-1	6/01/55	BETA		1.1000E+02	PCI/L
1-H4-1	7/01/55	BETA		2.2000E+02	PCI/L
1-H4-1	8/01/55	BETA		1.7000E+02	PCI/L
1-H4-1	9/01/55	BETA		1.3000E+03	PCI/L
1-H4-1	10/01/55	BETA		2.0000E+02	PCI/L
1-H4-1	11/01/55	BETA		1.4000E+02	PCI/L
1-H4-1	12/01/55	BETA		4.8000E+02	PCI/L
1-H4-1	1/01/56	BETA		7.3000E+01	PCI/L
1-H4-1	2/01/56	BETA		8.5000E+02	PCI/L
1-H4-1	7/01/59	BETA		3.2000E+03	PCI/L
1-H4-1	2/01/62	NO3-PDS		1.9000E+00	MG/L
1-H4-1	1/23/63	NO3-PDS		3.8000E-01	MG/L
1-H4-10	12/19/86	BETA		7.1900E+00	PCI/L
1-H4-10	12/19/86	NITRATE		2.2700E+04	PPB
1-H4-10	1/13/87	BETA		5.5400E+00	PCI/L
1-H4-10	1/13/87	NITRATE		2.0000E+04	PPB
1-H4-10	2/09/87	BETA		7.7400E+00	PCI/L
1-H4-10	2/09/87	NITRATE		2.3600E+04	PPB
1-H4-10	3/05/87	BETA		9.6200E+00	PCI/L
1-H4-10	3/05/87	NITRATE		2.3000E+04	PPB
1-H4-10	4/06/87	BETA		8.9600E+00	PCI/L
1-H4-10	4/06/87	NITRATE		2.6200E+04	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-10	5/14/87	BETA		5.2600E+00	PCI/L
1-H4-10	5/14/87	NITRATE		2.3100E+04	PPB
1-H4-10	6/10/87	BETA		7.7100E+00	PCI/L
1-H4-10	6/10/87	NITRATE		1.0400E+04	PPB
1-H4-10	7/07/87	BETA		6.3600E+00	PCI/L
1-H4-10	7/07/87	NITRATE		1.9000E+04	PPB
1-H4-10	8/07/87	BETA		8.1700E+00	PCI/L
1-H4-10	8/07/87	NITRATE		2.0100E+04	PPB
1-H4-10	9/18/87	BETA		8.0700E+00	PCI/L
1-H4-10	9/18/87	NITRATE		2.1800E+04	PPB
1-H4-10	10/05/87	BETA		6.2300E+00	PCI/L
1-H4-10	10/05/87	NITRATE		2.1900E+04	PPB
1-H4-10	3/09/88	BETA		5.8600E+00	PCI/L
1-H4-10	3/09/88	NITRATE		1.7000E+04	PPB
1-H4-10	6/08/88	BETA	<	3.5600E+00	PCI/L
1-H4-10	6/08/88	NITRATE		9.6200E+03	PPB
1-H4-10	9/02/88	BETA		5.1600E+00	PCI/L
1-H4-10	9/02/88	NITRATE		1.6900E+04	PPB
1-H4-10	5/18/89	BETA		2.6600E+00	PCI/L
1-H4-10	5/18/89	NITRATE		1.2700E+04	PPB
1-H4-10	4/18/90	BETA		4.1000E+00	PCI/L
1-H4-10	4/18/90	NITRATE		1.2300E+04	PPB
1-H4-11	12/23/86	BETA		6.0600E+01	PCI/L
1-H4-11	12/23/86	NITRATE		2.4300E+04	PPB
1-H4-11	1/09/87	BETA		5.8800E+01	PCI/L
1-H4-11	1/09/87	NITRATE		2.5600E+04	PPB
1-H4-11	2/06/87	BETA		6.4100E+01	PCI/L
1-H4-11	2/06/87	NITRATE		2.6400E+04	PPB
1-H4-11	3/06/87	BETA		6.5300E+01	PCI/L
1-H4-11	3/06/87	NITRATE		2.7400E+04	PPB
1-H4-11	4/06/87	BETA		6.7100E+01	PCI/L
1-H4-11	4/06/87	NITRATE		2.1800E+04	PPB
1-H4-11	5/18/87	BETA		7.4300E+01	PCI/L
1-H4-11	5/18/87	NITRATE		2.5400E+04	PPB
1-H4-11	6/10/87	BETA		6.6500E+01	PCI/L
1-H4-11	6/10/87	NITRATE		2.7000E+04	PPB
1-H4-11	7/08/87	BETA		8.4200E+01	PCI/L
1-H4-11	7/08/87	NITRATE		3.0700E+04	PPB
1-H4-11	8/07/87	BETA		8.0500E+01	PCI/L
1-H4-11	8/07/87	NITRATE		3.2600E+04	PPB
1-H4-11	9/18/87	BETA		6.5600E+01	PCI/L
1-H4-11	9/18/87	NITRATE		2.8200E+04	PPB
1-H4-11	10/14/87	BETA		6.6200E+01	PCI/L
1-H4-11	10/14/87	NITRATE		2.8900E+04	PPB
1-H4-11	12/16/87	BETA		6.1000E+01	PCI/L
1-H4-11	12/16/87	NITRATE		2.6600E+04	PPB
1-H4-11	1/07/88	BETA		1.0300E+02	PCI/L
1-H4-11	1/07/88	NITRATE		5.0400E+04	PPB
1-H4-11	2/10/88	BETA		8.1000E+01	PCI/L
1-H4-11	2/10/88	NITRATE		2.6100E+04	PPB
1-H4-11	3/07/88	BETA		6.0400E+01	PCI/L
1-H4-11	3/07/88	NITRATE		2.5800E+04	PPB
1-H4-11	4/14/88	BETA		6.5100E+01	PCI/L
1-H4-11	4/14/88	NITRATE		2.5400E+04	PPB
1-H4-11	5/03/88	BETA		7.0300E+01	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-11	5/03/88	NITRATE		2.2900E+04	PPB
1-H4-11	6/09/88	BETA		7.6400E+01	PCI/L
1-H4-11	6/09/88	NITRATE		2.9500E+04	PPB
1-H4-11	7/13/88	BETA		7.8400E+01	PCI/L
1-H4-11	7/13/88	NITRATE		2.8800E+04	PPB
1-H4-11	8/09/88	BETA		7.2100E+01	PCI/L
1-H4-11	8/09/88	NITRATE		2.6300E+04	PPB
1-H4-11	9/06/88	BETA		7.6900E+01	PCI/L
1-H4-11	9/06/88	NITRATE		2.6400E+04	PPB
1-H4-11	5/12/89	BETA		6.1100E+01	PCI/L
1-H4-11	5/12/89	NITRATE		3.2000E+04	PPB
1-H4-11	4/23/90	BETA		6.5300E+01	PCI/L
1-H4-11	4/23/90	NITRATE		4.2900E+04	PPB
1-H4-12A	2/02/87	BETA		9.1100E+01	PCI/L
1-H4-12A	2/02/87	NITRATE		1.0600E+05	PPB
1-H4-12A	2/13/87	BETA		1.0000E+02	PCI/L
1-H4-12A	2/13/87	NITRATE		1.0300E+05	PPB
1-H4-12A	3/03/87	BETA		3.2000E+02	PCI/L
1-H4-12A	3/03/87	NITRATE		1.7100E+05	PPB
1-H4-12A	4/07/87	BETA		1.1300E+02	PCI/L
1-H4-12A	4/07/87	NITRATE		9.4300E+04	PPB
1-H4-12A	5/13/87	BETA		7.9100E+00	PCI/L
1-H4-12A	5/13/87	NITRATE		2.2900E+04	PPB
1-H4-12A	6/12/87	BETA		8.6700E+00	PCI/L
1-H4-12A	6/12/87	NITRATE		2.6600E+04	PPB
1-H4-12A	7/09/87	BETA		5.9800E+01	PCI/L
1-H4-12A	7/09/87	NITRATE		7.7400E+04	PPB
1-H4-12A	8/05/87	BETA		6.0300E+01	PCI/L
1-H4-12A	8/05/87	NITRATE		8.7500E+04	PPB
1-H4-12A	9/16/87	BETA		5.8600E+01	PCI/L
1-H4-12A	9/16/87	NITRATE		7.9300E+04	PPB
1-H4-12A	10/05/87	BETA		4.5100E+01	PCI/L
1-H4-12A	10/05/87	NITRATE		8.8800E+04	PPB
1-H4-12A	12/15/87	BETA		3.8900E+01	PCI/L
1-H4-12A	12/15/87	NITRATE		5.6700E+04	PPB
1-H4-12A	1/05/88	BETA		1.3900E+01	PCI/L
1-H4-12A	1/05/88	NITRATE		3.3900E+04	PPB
1-H4-12A	2/08/88	BETA		2.3300E+01	PCI/L
1-H4-12A	2/08/88	NITRATE		3.5200E+04	PPB
1-H4-12A	3/07/88	BETA		1.1000E+02	PCI/L
1-H4-12A	3/07/88	NITRATE		1.3200E+05	PPB
1-H4-12A	4/13/88	BETA		1.2300E+02	PCI/L
1-H4-12A	4/13/88	NITRATE		1.3800E+05	PPB
1-H4-12A	5/02/88	BETA		5.4300E+01	PCI/L
1-H4-12A	5/02/88	NITRATE		7.3100E+04	PPB
1-H4-12A	6/06/88	BETA		1.1600E+01	PCI/L
1-H4-12A	6/06/88	NITRATE		1.5300E+04	PPB
1-H4-12A	7/12/88	BETA		4.0700E+01	PCI/L
1-H4-12A	7/12/88	NITRATE		5.8700E+04	PPB
1-H4-12A	8/08/88	BETA		1.0400E+02	PCI/L
1-H4-12A	8/08/88	NITRATE		1.1900E+05	PPB
1-H4-12A	9/01/88	BETA		6.0400E+01	PCI/L
1-H4-12A	9/01/88	NITRATE		8.7700E+04	PPB
1-H4-12A	10/11/88	BETA		4.4200E+01	PCI/L
1-H4-12A	10/11/88	NITRATE		7.4500E+04	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-12A	1/06/89	BETA		1.0900E+01	PCI/L
1-H4-12A	1/06/89	NITRATE		2.9100E+04	PPB
1-H4-12A	5/23/89	BETA	<	1.8500E+00	PCI/L
1-H4-12A	5/23/89	NITRATE		3.0200E+04	PPB
1-H4-12A	8/02/89	BETA		3.2600E+01	PCI/L
1-H4-12A	8/02/89	NITRATE		8.2000E+04	PPB
1-H4-12A	10/11/89	BETA		1.6100E+01	PCI/L
1-H4-12A	10/11/89	NITRATE		5.9000E+04	PPB
1-H4-12A	1/17/90	BETA		9.7100E+00	PCI/L
1-H4-12A	1/17/90	NITRATE		4.4700E+04	PPB
1-H4-12A	4/17/90	BETA		1.4100E+01	PCI/L
1-H4-12A	4/17/90	NITRATE		4.5800E+04	PPB
1-H4-12B	2/05/87	BETA		4.5800E+01	PCI/L
1-H4-12B	2/05/87	NITRATE		8.0400E+04	PPB
1-H4-12B	2/12/87	BETA		6.6600E+01	PCI/L
1-H4-12B	2/12/87	NITRATE		6.7300E+04	PPB
1-H4-12B	3/09/87	BETA		8.5100E+01	PCI/L
1-H4-12B	3/09/87	NITRATE		8.5900E+04	PPB
1-H4-12B	4/07/87	BETA		5.4600E+01	PCI/L
1-H4-12B	4/07/87	NITRATE		6.0200E+04	PPB
1-H4-12B	5/13/87	BETA		7.8700E+01	PCI/L
1-H4-12B	5/13/87	NITRATE		2.9300E+04	PPB
1-H4-12B	6/12/87	BETA		1.8500E+01	PCI/L
1-H4-12B	6/12/87	NITRATE		3.1800E+04	PPB
1-H4-12B	7/09/87	BETA		3.3000E+01	PCI/L
1-H4-12B	7/09/87	NITRATE		4.9300E+04	PPB
1-H4-12B	8/05/87	BETA		4.1700E+01	PCI/L
1-H4-12B	8/05/87	NITRATE		5.6400E+04	PPB
1-H4-12B	9/16/87	BETA		4.7600E+01	PCI/L
1-H4-12B	9/16/87	NITRATE		6.0600E+04	PPB
1-H4-12B	10/06/87	BETA		2.9700E+01	PCI/L
1-H4-12B	10/06/87	NITRATE		5.5000E+04	PPB
1-H4-12B	12/15/87	BETA		3.5300E+01	PCI/L
1-H4-12B	12/15/87	NITRATE		5.2500E+04	PPB
1-H4-12B	1/04/88	BETA		1.4700E+01	PCI/L
1-H4-12B	1/04/88	NITRATE		4.4600E+04	PPB
1-H4-12B	2/08/88	BETA		3.9400E+01	PCI/L
1-H4-12B	2/08/88	NITRATE		5.0000E+04	PPB
1-H4-12B	3/07/88	BETA		7.7600E+01	PCI/L
1-H4-12B	3/07/88	NITRATE		1.0100E+05	PPB
1-H4-12B	4/13/88	BETA		7.7500E+01	PCI/L
1-H4-12B	4/13/88	NITRATE		9.4200E+04	PPB
1-H4-12B	5/02/88	BETA		3.7200E+01	PCI/L
1-H4-12B	5/02/88	NITRATE		5.9200E+04	PPB
1-H4-12B	6/06/88	BETA		1.5200E+01	PCI/L
1-H4-12B	6/06/88	NITRATE		3.5300E+04	PPB
1-H4-12B	7/12/88	BETA		2.5800E+01	PCI/L
1-H4-12B	7/12/88	NITRATE		4.4400E+04	PPB
1-H4-12B	8/08/88	BETA		5.7500E+01	PCI/L
1-H4-12B	8/08/88	NITRATE		7.2600E+04	PPB
1-H4-12B	9/01/88	BETA		3.1400E+01	PCI/L
1-H4-12B	9/01/88	NITRATE		5.7700E+04	PPB
1-H4-12B	10/11/88	BETA		3.2600E+01	PCI/L
1-H4-12B	10/11/88	NITRATE		5.6000E+04	PPB
1-H4-12B	1/06/89	BETA		1.0400E+01	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-12B	1/06/89	NITRATE		3.9000E+04	PPB
1-H4-12B	5/22/89	BETA		5.9800E+00	PCI/L
1-H4-12B	5/22/89	NITRATE		2.7400E+04	PPB
1-H4-12B	8/02/89	BETA		3.3300E+01	PCI/L
1-H4-12B	8/02/89	NITRATE		4.9000E+04	PPB
1-H4-12B	1/17/90	BETA		6.5600E+00	PCI/L
1-H4-12B	1/17/90	NITRATE		4.2200E+04	PPB
1-H4-12B	4/17/90	BETA		1.1300E+01	PCI/L
1-H4-12B	4/17/90	NITRATE		3.9700E+04	PPB
1-H4-12C	12/31/86	BETA		9.5800E+00	PCI/L
1-H4-12C	12/31/86	NITRATE		5.1100E+03	PPB
1-H4-12C	1/07/87	BETA		4.7200E+00	PCI/L
1-H4-12C	1/07/87	NITRATE		5.2800E+03	PPB
1-H4-12C	2/11/87	BETA		9.7200E+00	PCI/L
1-H4-12C	2/11/87	NITRATE		4.6600E+03	PPB
1-H4-12C	3/03/87	BETA		9.7000E+00	PCI/L
1-H4-12C	3/03/87	NITRATE		5.3800E+03	PPB
1-H4-12C	4/07/87	BETA		8.8100E+00	PCI/L
1-H4-12C	4/07/87	NITRATE		4.7800E+03	PPB
1-H4-12C	5/13/87	BETA		7.8600E+00	PCI/L
1-H4-12C	5/13/87	NITRATE		3.8100E+03	PPB
1-H4-12C	6/10/87	BETA		7.1000E+00	PCI/L
1-H4-12C	6/10/87	NITRATE		2.6400E+03	PPB
1-H4-12C	7/09/87	BETA		7.9300E+00	PCI/L
1-H4-12C	7/09/87	NITRATE		3.7200E+03	PPB
1-H4-12C	8/05/87	BETA		8.1800E+00	PCI/L
1-H4-12C	8/05/87	NITRATE		5.3200E+03	PPB
1-H4-12C	9/16/87	BETA		8.2800E+00	PCI/L
1-H4-12C	9/16/87	NITRATE		6.1400E+03	PPB
1-H4-12C	10/05/87	BETA		4.3600E+00	PCI/L
1-H4-12C	10/05/87	NITRATE		5.7800E+03	PPB
1-H4-12C	12/15/87	BETA		4.0800E+00	PCI/L
1-H4-12C	12/15/87	NITRATE		5.8800E+03	PPB
1-H4-12C	1/04/88	BETA		5.3800E+00	PCI/L
1-H4-12C	1/04/88	NITRATE		6.3300E+03	PPB
1-H4-12C	2/08/88	BETA		3.8800E+00	PCI/L
1-H4-12C	2/08/88	NITRATE		5.5700E+03	PPB
1-H4-12C	3/07/88	BETA		6.2700E+00	PCI/L
1-H4-12C	3/07/88	NITRATE		6.4200E+03	PPB
1-H4-12C	4/12/88	BETA		6.8000E+00	PCI/L
1-H4-12C	4/12/88	NITRATE		6.0000E+03	PPB
1-H4-12C	5/02/88	BETA		5.5200E+00	PCI/L
1-H4-12C	5/02/88	NITRATE		6.1100E+03	PPB
1-H4-12C	6/06/88	BETA		1.0600E+01	PCI/L
1-H4-12C	6/06/88	NITRATE		6.2100E+03	PPB
1-H4-12C	7/12/88	BETA		4.9400E+00	PCI/L
1-H4-12C	7/12/88	NITRATE		5.7100E+03	PPB
1-H4-12C	8/08/88	BETA		4.1500E+00	PCI/L
1-H4-12C	8/08/88	NITRATE		6.2100E+03	PPB
1-H4-12C	9/01/88	BETA	<	3.8100E+00	PCI/L
1-H4-12C	9/01/88	NITRATE		6.5000E+03	PPB
1-H4-12C	10/11/88	BETA		5.9800E+00	PCI/L
1-H4-12C	10/11/88	NITRATE		6.3500E+03	PPB
1-H4-12C	1/06/89	BETA		3.9200E+00	PCI/L
1-H4-12C	1/06/89	NITRATE		6.4000E+03	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-12C	5/22/89	BETA		2.7300E+00	PCI/L
1-H4-12C	5/22/89	NITRATE		6.4000E+03	PPB
1-H4-12C	8/02/89	BETA		5.7000E+00	PCI/L
1-H4-12C	8/02/89	NITRATE		6.8000E+03	PPB
1-H4-12C	10/11/89	BETA		4.7200E+00	PCI/L
1-H4-12C	10/11/89	NITRATE		6.3000E+03	PPB
1-H4-12C	1/17/90	BETA		2.8600E+00	PCI/L
1-H4-12C	1/17/90	NITRATE		6.9000E+03	PPB
1-H4-12C	4/17/90	BETA		4.1200E+00	PCI/L
1-H4-12C	4/17/90	NITRATE		6.6000E+03	PPB
1-H4-13	2/06/87	BETA		6.5800E+01	PCI/L
1-H4-13	2/06/87	NITRATE		4.0300E+04	PPB
1-H4-13	2/13/87	BETA		6.7900E+01	PCI/L
1-H4-13	2/13/87	NITRATE		2.8100E+04	PPB
1-H4-13	3/04/87	BETA		9.8200E+01	PCI/L
1-H4-13	3/04/87	NITRATE		2.9000E+04	PPB
1-H4-13	4/08/87	BETA		7.3200E+01	PCI/L
1-H4-13	4/08/87	NITRATE		2.2000E+04	PPB
1-H4-13	5/12/87	BETA		5.6200E+01	PCI/L
1-H4-13	5/12/87	NITRATE		1.8700E+04	PPB
1-H4-13	6/12/87	BETA		5.6200E+01	PCI/L
1-H4-13	6/12/87	NITRATE		1.2100E+04	PPB
1-H4-13	7/15/87	BETA		7.7900E+01	PCI/L
1-H4-13	7/15/87	NITRATE		2.3000E+04	PPB
1-H4-13	8/07/87	BETA		7.7400E+01	PCI/L
1-H4-13	8/07/87	NITRATE		2.1500E+04	PPB
1-H4-13	9/17/87	BETA		6.4800E+01	PCI/L
1-H4-13	9/17/87	NITRATE		1.9800E+04	PPB
1-H4-13	10/14/87	BETA		7.4200E+01	PCI/L
1-H4-13	10/14/87	NITRATE		1.9800E+04	PPB
1-H4-13	12/16/87	BETA		7.6300E+01	PCI/L
1-H4-13	12/16/87	NITRATE		1.9700E+04	PPB
1-H4-13	3/25/88	BETA		7.1800E+01	PCI/L
1-H4-13	3/25/88	NITRATE		1.6300E+04	PPB
1-H4-13	6/09/88	BETA		7.4600E+01	PCI/L
1-H4-13	6/09/88	NITRATE		1.4600E+04	PPB
1-H4-13	9/06/88	BETA		8.8800E+01	PCI/L
1-H4-13	9/06/88	NITRATE		1.7600E+04	PPB
1-H4-13	5/23/89	BETA		4.8700E+01	PCI/L
1-H4-13	5/23/89	BETA		5.0200E+01	PCI/L
1-H4-13	5/23/89	NITRATE		1.5800E+04	PPB
1-H4-13	5/23/89	NITRATE		1.6200E+04	PPB
1-H4-13	4/24/90	BETA		5.4800E+01	PCI/L
1-H4-13	4/24/90	BETA		6.0900E+01	PCI/L
1-H4-13	4/24/90	NITRATE		1.9900E+04	PPB
1-H4-13	4/24/90	NITRATE		2.0800E+04	PPB
1-H4-14	2/05/87	BETA		6.4300E+00	PCI/L
1-H4-14	2/05/87	NITRATE		1.8600E+04	PPB
1-H4-14	2/12/87	BETA		8.0000E+00	PCI/L
1-H4-14	2/12/87	NITRATE		1.9100E+04	PPB
1-H4-14	3/05/87	BETA		8.0500E+00	PCI/L
1-H4-14	3/05/87	NITRATE		1.9300E+04	PPB
1-H4-14	4/08/87	BETA		8.6700E+00	PCI/L
1-H4-14	4/08/87	NITRATE		1.8400E+04	PPB
1-H4-14	5/12/87	BETA		1.2500E+01	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-14	5/12/87	NITRATE		2.0500E+04	PPB
1-H4-14	6/12/87	BETA		5.2500E+00	PCI/L
1-H4-14	6/12/87	NITRATE		1.9900E+04	PPB
1-H4-14	7/13/87	BETA		4.5500E+00	PCI/L
1-H4-14	7/13/87	NITRATE		1.7100E+04	PPB
1-H4-14	8/07/87	BETA		1.0100E+01	PCI/L
1-H4-14	8/07/87	NITRATE		1.7900E+04	PPB
1-H4-14	9/17/87	BETA		7.5900E+00	PCI/L
1-H4-14	9/17/87	NITRATE		1.9200E+04	PPB
1-H4-14	10/07/87	BETA		7.8700E+00	PCI/L
1-H4-14	10/07/87	NITRATE		1.9400E+04	PPB
1-H4-14	12/22/87	BETA		7.7000E+00	PCI/L
1-H4-14	12/22/87	NITRATE		1.9800E+04	PPB
1-H4-14	3/15/88	BETA		5.3800E+00	PCI/L
1-H4-14	3/15/88	NITRATE		2.1100E+04	PPB
1-H4-14	6/16/88	BETA		6.3000E+00	PCI/L
1-H4-14	6/16/88	NITRATE		1.7000E+04	PPB
1-H4-14	7/14/88	BETA	<	3.1300E+00	PCI/L
1-H4-14	7/14/88	NITRATE		1.7400E+04	PPB
1-H4-14	8/10/88	BETA		8.2100E+00	PCI/L
1-H4-14	8/10/88	NITRATE		1.8600E+04	PPB
1-H4-14	9/13/88	BETA		1.3200E+01	PCI/L
1-H4-14	9/13/88	NITRATE		2.0500E+04	PPB
1-H4-14	5/18/89	BETA		6.3600E+00	PCI/L
1-H4-14	5/18/89	NITRATE		1.8600E+04	PPB
1-H4-14	10/17/89	BETA		5.9300E+00	PCI/L
1-H4-14	10/17/89	NITRATE		2.1700E+04	PPB
1-H4-14	4/25/90	BETA		4.1700E+00	PCI/L
1-H4-14	4/25/90	NITRATE		1.5700E+04	PPB
1-H4-15A	1/30/87	BETA		1.3100E+01	PCI/L
1-H4-15A	1/30/87	NITRATE		2.8600E+04	PPB
1-H4-15A	2/11/87	BETA		1.0600E+01	PCI/L
1-H4-15A	2/11/87	NITRATE		2.8000E+04	PPB
1-H4-15A	3/05/87	BETA		9.1300E+00	PCI/L
1-H4-15A	3/05/87	NITRATE		2.7600E+04	PPB
1-H4-15A	4/09/87	BETA		9.6600E+00	PCI/L
1-H4-15A	4/09/87	NITRATE		2.5900E+04	PPB
1-H4-15A	5/14/87	BETA		6.0800E+00	PCI/L
1-H4-15A	5/14/87	NITRATE		2.5400E+04	PPB
1-H4-15A	6/11/87	BETA		1.0200E+01	PCI/L
1-H4-15A	6/11/87	NITRATE		4.5000E+04	PPB
1-H4-15A	7/13/87	BETA		7.4700E+00	PCI/L
1-H4-15A	7/13/87	NITRATE		2.6400E+04	PPB
1-H4-15A	8/06/87	BETA		5.5400E+00	PCI/L
1-H4-15A	8/06/87	NITRATE		2.9600E+04	PPB
1-H4-15A	9/18/87	BETA		1.1400E+01	PCI/L
1-H4-15A	9/18/87	NITRATE		2.8100E+04	PPB
1-H4-15A	10/07/87	BETA		1.0100E+01	PCI/L
1-H4-15A	10/07/87	NITRATE		2.8900E+04	PPB
1-H4-15A	12/14/87	BETA		9.0600E+00	PCI/L
1-H4-15A	12/14/87	NITRATE		3.0500E+04	PPB
1-H4-15A	3/10/88	BETA		5.0000E+00	PCI/L
1-H4-15A	3/10/88	NITRATE		3.1700E+04	PPB
1-H4-15A	6/08/88	BETA		6.5600E+00	PCI/L
1-H4-15A	6/08/88	NITRATE		2.4200E+04	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-15A	9/02/88	BETA		1.1300E+01	PCI/L
1-H4-15A	9/02/88	NITRATE		2.9100E+04	PPB
1-H4-15A	5/25/89	BETA		4.5800E+00	PCI/L
1-H4-15A	5/25/89	NITRATE		4.1400E+04	PPB
1-H4-15A	4/18/90	BETA		5.1500E+00	PCI/L
1-H4-15A	4/18/90	NITRATE		2.9600E+04	PPB
1-H4-15B	2/10/87	BETA		8.6800E+00	PCI/L
1-H4-15B	2/10/87	NITRATE		2.6300E+04	PPB
1-H4-15B	2/13/87	BETA		9.8400E+00	PCI/L
1-H4-15B	2/13/87	NITRATE		2.4400E+04	PPB
1-H4-15B	3/09/87	BETA		1.1000E+01	PCI/L
1-H4-15B	3/09/87	NITRATE		2.4400E+04	PPB
1-H4-15B	4/09/87	BETA		1.0900E+01	PCI/L
1-H4-15B	4/09/87	NITRATE		2.3300E+04	PPB
1-H4-15B	5/14/87	BETA		1.0900E+01	PCI/L
1-H4-15B	5/14/87	NITRATE		2.6200E+04	PPB
1-H4-15B	6/11/87	BETA		7.6300E+00	PCI/L
1-H4-15B	6/11/87	NITRATE		2.4600E+04	PPB
1-H4-15B	7/13/87	BETA		7.5900E+00	PCI/L
1-H4-15B	7/13/87	NITRATE		2.3200E+04	PPB
1-H4-15B	8/06/87	BETA		1.3200E+01	PCI/L
1-H4-15B	8/06/87	NITRATE		2.4400E+04	PPB
1-H4-15B	9/18/87	BETA		9.5400E+00	PCI/L
1-H4-15B	9/18/87	NITRATE		2.4800E+04	PPB
1-H4-15B	10/07/87	BETA		4.2700E+00	PCI/L
1-H4-15B	10/07/87	NITRATE		2.5500E+04	PPB
1-H4-15B	12/14/87	BETA		8.1100E+00	PCI/L
1-H4-15B	12/14/87	NITRATE		2.8500E+04	PPB
1-H4-15B	3/10/88	BETA		7.9500E+00	PCI/L
1-H4-15B	3/10/88	NITRATE		2.8200E+04	PPB
1-H4-15B	6/08/88	BETA		4.7300E+00	PCI/L
1-H4-15B	6/08/88	NITRATE		2.7000E+04	PPB
1-H4-15B	9/02/88	BETA		1.0200E+01	PCI/L
1-H4-15B	9/02/88	NITRATE		2.8900E+04	PPB
1-H4-15B	5/25/89	BETA		5.1300E+00	PCI/L
1-H4-15B	5/25/89	NITRATE		2.2500E+04	PPB
1-H4-15B	4/18/90	BETA		4.4500E+00	PCI/L
1-H4-15B	4/18/90	NITRATE		2.3300E+04	PPB
1-H4-16	5/07/87	BETA		1.8900E+01	PCI/L
1-H4-16	5/07/87	NITRATE		1.0700E+04	PPB
1-H4-16	6/10/87	BETA		2.5100E+01	PCI/L
1-H4-16	6/10/87	NITRATE		1.8900E+04	PPB
1-H4-16	7/15/87	BETA		1.6700E+01	PCI/L
1-H4-16	7/15/87	NITRATE		1.5900E+04	PPB
1-H4-16	8/07/87	BETA		1.7500E+01	PCI/L
1-H4-16	8/07/87	NITRATE		1.8800E+04	PPB
1-H4-16	9/16/87	BETA		2.2000E+01	PCI/L
1-H4-16	9/16/87	NITRATE		5.3200E+03	PPB
1-H4-16	10/13/87	BETA		1.6800E+01	PCI/L
1-H4-16	10/13/87	NITRATE		6.5600E+03	PPB
1-H4-16	12/23/87	BETA		8.9900E+00	PCI/L
1-H4-16	12/23/87	NITRATE		1.3000E+04	PPB
1-H4-16	1/05/88	BETA		1.5100E+01	PCI/L
1-H4-16	1/05/88	NITRATE		1.8300E+04	PPB
1-H4-16	2/09/88	BETA		1.3800E+01	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-16	2/09/88	NITRATE		1.5100E+04	PPB
1-H4-16	3/15/88	BETA		1.6500E+01	PCI/L
1-H4-16	3/15/88	NITRATE		1.7300E+04	PPB
1-H4-16	4/11/88	BETA		1.9300E+01	PCI/L
1-H4-16	4/11/88	NITRATE		2.1400E+04	PPB
1-H4-16	5/04/88	BETA		2.0000E+01	PCI/L
1-H4-16	5/04/88	NITRATE		1.7400E+04	PPB
1-H4-16	9/13/88	BETA		3.5500E+01	PCI/L
1-H4-16	9/13/88	NITRATE		1.2600E+04	PPB
1-H4-16	5/23/89	BETA		1.5400E+01	PCI/L
1-H4-16	5/23/89	NITRATE		1.3900E+04	PPB
1-H4-16	4/20/90	BETA		2.2300E+01	PCI/L
1-H4-16	4/20/90	NITRATE		2.1800E+04	PPB
1-H4-17	6/15/87	BETA		1.5300E+01	PCI/L
1-H4-17	6/15/87	NITRATE		4.3800E+04	PPB
1-H4-17	7/15/87	BETA		-1.6543E+37	PCI/L
1-H4-17	7/15/87	NITRATE		-1.6543E+37	PPB
1-H4-17	8/10/87	BETA		1.6100E+01	PCI/L
1-H4-17	8/10/87	NITRATE		4.7600E+04	PPB
1-H4-17	9/17/87	BETA		1.5900E+01	PCI/L
1-H4-17	9/17/87	NITRATE		4.2200E+04	PPB
1-H4-17	10/14/87	BETA		5.9500E+00	PCI/L
1-H4-17	10/14/87	NITRATE		4.2100E+04	PPB
1-H4-17	12/28/87	BETA		9.4200E+00	PCI/L
1-H4-17	12/28/87	NITRATE		4.8500E+04	PPB
1-H4-17	1/06/88	BETA		1.1500E+01	PCI/L
1-H4-17	1/06/88	NITRATE		5.2000E+04	PPB
1-H4-17	2/09/88	BETA		1.0500E+01	PCI/L
1-H4-17	2/09/88	NITRATE		4.6200E+04	PPB
1-H4-17	3/14/88	BETA		6.3100E+00	PCI/L
1-H4-17	3/14/88	NITRATE		4.4700E+04	PPB
1-H4-17	4/12/88	BETA		1.2800E+01	PCI/L
1-H4-17	4/12/88	NITRATE		4.5300E+04	PPB
1-H4-17	9/13/88	BETA		1.4300E+01	PCI/L
1-H4-17	9/13/88	NITRATE		5.2400E+04	PPB
1-H4-17	5/23/89	BETA		1.0100E+01	PCI/L
1-H4-17	5/23/89	NITRATE		5.1200E+04	PPB
1-H4-17	4/20/90	BETA		1.0200E+01	PCI/L
1-H4-17	4/20/90	NITRATE		5.8800E+04	PPB
1-H4-18	6/15/87	BETA		7.1700E+01	PCI/L
1-H4-18	6/15/87	NITRATE		6.3800E+04	PPB
1-H4-18	7/14/87	BETA		2.0900E+01	PCI/L
1-H4-18	7/14/87	NITRATE		2.5000E+04	PPB
1-H4-18	8/06/87	BETA		2.5400E+01	PCI/L
1-H4-18	8/06/87	NITRATE		2.6600E+04	PPB
1-H4-18	9/15/87	BETA		1.4900E+01	PCI/L
1-H4-18	9/15/87	NITRATE		2.3600E+04	PPB
1-H4-18	10/13/87	BETA		1.7600E+01	PCI/L
1-H4-18	10/13/87	NITRATE		2.3600E+04	PPB
1-H4-18	12/23/87	BETA		1.5100E+01	PCI/L
1-H4-18	12/23/87	NITRATE		2.0100E+04	PPB
1-H4-18	1/05/88	BETA		1.9000E+01	PCI/L
1-H4-18	1/05/88	NITRATE		2.2700E+04	PPB
1-H4-18	2/09/88	BETA		1.8200E+01	PCI/L
1-H4-18	2/09/88	NITRATE		2.0400E+04	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-18	3/14/88	BETA		1.5900E+01	PCI/L
1-H4-18	3/14/88	NITRATE		2.3000E+04	PPB
1-H4-18	4/11/88	BETA		1.1900E+01	PCI/L
1-H4-18	4/11/88	NITRATE		2.0900E+04	PPB
1-H4-18	5/03/88	BETA		1.3300E+01	PCI/L
1-H4-18	5/03/88	NITRATE		1.8600E+04	PPB
1-H4-18	6/10/88	BETA		1.5600E+01	PCI/L
1-H4-18	6/10/88	NITRATE		2.2600E+04	PPB
1-H4-18	7/13/88	BETA		1.6000E+01	PCI/L
1-H4-18	7/13/88	NITRATE		2.1500E+04	PPB
1-H4-18	8/09/88	BETA		8.7100E+00	PCI/L
1-H4-18	8/09/88	NITRATE		2.1000E+04	PPB
1-H4-18	9/07/88	BETA		2.0100E+01	PCI/L
1-H4-18	9/07/88	NITRATE		2.0800E+04	PPB
1-H4-18	10/11/88	BETA		1.3000E+01	PCI/L
1-H4-18	10/11/88	NITRATE		2.0400E+04	PPB
1-H4-18	1/06/89	BETA		1.0800E+01	PCI/L
1-H4-18	1/06/89	NITRATE		2.7600E+04	PPB
1-H4-18	5/23/89	BETA		1.6300E+01	PCI/L
1-H4-18	5/23/89	NITRATE		3.1500E+04	PPB
1-H4-18	8/02/89	BETA		1.0400E+01	PCI/L
1-H4-18	8/02/89	NITRATE		2.7000E+04	PPB
1-H4-18	10/11/89	BETA		9.0500E+00	PCI/L
1-H4-18	10/11/89	NITRATE		2.3500E+04	PPB
1-H4-18	1/18/90	BETA		9.5000E+00	PCI/L
1-H4-18	1/18/90	NITRATE		2.9000E+04	PPB
1-H4-18	4/20/90	BETA		1.8500E+01	PCI/L
1-H4-18	4/20/90	NITRATE		3.7000E+04	PPB
1-H4-2	6/01/55	BETA		3.9000E+01	PCI/L
1-H4-2	7/01/55	BETA		1.4000E+02	PCI/L
1-H4-2	8/01/55	BETA		2.4000E+01	PCI/L
1-H4-2	9/01/55	BETA		8.6000E+01	PCI/L
1-H4-2	10/01/55	BETA		1.6000E+01	PCI/L
1-H4-2	11/01/55	BETA		7.8000E+01	PCI/L
1-H4-2	12/02/55	BETA		1.6000E+01	PCI/L
1-H4-2	2/01/56	BETA		2.6000E+01	PCI/L
1-H4-2	1/18/62	NO3-PDS		9.0000E-03	MG/L
1-H4-2	7/11/62	NO3-PDS		6.8000E+00	MG/L
1-H4-2	5/16/79	BETA		7.5000E+01	PCI/L
1-H4-2	5/16/79	NO3-PDS		4.0000E+00	MG/L
1-H4-3	11/25/74	BETA		7.5000E+01	PCI/L
1-H4-3	11/25/74	NO3-PDS		2.9000E+01	MG/L
1-H4-3	1/27/75	BETA		1.7000E+01	PCI/L
1-H4-3	1/27/75	NO3-PDS		3.3000E+01	MG/L
1-H4-3	3/31/75	BETA		7.5000E+01	PCI/L
1-H4-3	3/31/75	NO3-PDS		3.0000E+01	MG/L
1-H4-3	5/27/75	BETA		8.0000E+01	PCI/L
1-H4-3	5/27/75	NO3-PDS		4.6000E+01	MG/L
1-H4-3	11/24/75	BETA		2.0000E+02	PCI/L
1-H4-3	11/24/75	NO3-PDS		8.6000E+00	MG/L
1-H4-3	1/26/76	BETA		5.0000E+02	PCI/L
1-H4-3	1/26/76	NO3-PDS		2.2000E+02	MG/L
1-H4-3	4/05/76	BETA		6.8000E+02	PCI/L
1-H4-3	4/05/76	NO3-PDS		1.7000E+02	MG/L
1-H4-3	6/03/76	BETA		4.9000E+02	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-3	6/03/76	NO3-PDS		2.3000E+02	MG/L
1-H4-3	3/14/77	BETA		5.0000E+02	PCI/L
1-H4-3	3/14/77	NO3-PDS		1.8000E+02	MG/L
1-H4-3	6/09/77	BETA		5.5000E+02	PCI/L
1-H4-3	6/09/77	NO3-PDS		3.0000E+03	MG/L
1-H4-3	8/02/77	NO3-PDS		1.7000E+03	MG/L
1-H4-3	8/22/77	NO3-PDS		2.7000E+03	MG/L
1-H4-3	9/01/77	BETA		4.4000E+02	PCI/L
1-H4-3	9/01/77	NO3-PDS		2.3000E+03	MG/L
1-H4-3	10/11/77	BETA		7.5000E+01	PCI/L
1-H4-3	10/11/77	NO3-PDS		2.1000E+03	MG/L
1-H4-3	11/02/77	BETA		6.3000E+02	PCI/L
1-H4-3	11/02/77	NO3-PDS		2.1000E+03	MG/L
1-H4-3	11/30/77	BETA		6.0000E+02	PCI/L
1-H4-3	11/30/77	NO3-PDS		1.8000E+03	MG/L
1-H4-3	1/17/78	BETA		5.9000E+02	PCI/L
1-H4-3	1/17/78	NO3-PDS		2.1000E+03	MG/L
1-H4-3	2/28/78	BETA		8.5000E+02	PCI/L
1-H4-3	2/28/78	NO3-PDS		4.4000E+03	MG/L
1-H4-3	3/27/78	BETA		6.9000E+02	PCI/L
1-H4-3	3/27/78	NO3-PDS		4.3000E+03	MG/L
1-H4-3	6/02/78	BETA		1.0000E+03	PCI/L
1-H4-3	6/02/78	NO3-PDS		4.4000E+03	MG/L
1-H4-3	6/23/78	BETA		7.5000E+01	PCI/L
1-H4-3	6/23/78	NO3-PDS		4.7000E+03	MG/L
1-H4-3	7/12/78	BETA		8.8000E+02	PCI/L
1-H4-3	7/12/78	NO3-PDS		8.4000E+03	MG/L
1-H4-3	9/25/78	BETA		1.4000E+03	PCI/L
1-H4-3	9/25/78	NO3-PDS		4.8000E+03	MG/L
1-H4-3	10/11/78	BETA		7.9000E+02	PCI/L
1-H4-3	10/11/78	NO3-PDS		6.2000E+03	MG/L
1-H4-3	11/06/78	BETA		1.5000E+03	PCI/L
1-H4-3	11/06/78	NO3-PDS		3.9000E+03	MG/L
1-H4-3	3/05/79	BETA		1.4000E+03	PCI/L
1-H4-3	3/05/79	NO3-PDS		2.7000E+03	MG/L
1-H4-3	3/26/79	BETA		1.3000E+03	PCI/L
1-H4-3	3/26/79	NO3-PDS		2.3000E+03	MG/L
1-H4-3	5/25/79	BETA		1.1000E+03	PCI/L
1-H4-3	5/25/79	NO3-PDS		1.4000E+03	MG/L
1-H4-3	7/19/79	BETA		6.3000E+02	PCI/L
1-H4-3	7/19/79	NO3-PDS		2.2000E+03	MG/L
1-H4-3	8/23/79	BETA		1.1000E+03	PCI/L
1-H4-3	8/23/79	NO3-PDS		1.5000E+03	MG/L
1-H4-3	9/12/79	BETA		7.2000E+02	PCI/L
1-H4-3	9/12/79	NO3-PDS		1.7000E+03	MG/L
1-H4-3	10/05/79	BETA		1.1000E+03	PCI/L
1-H4-3	10/05/79	NO3-PDS		1.3000E+03	MG/L
1-H4-3	11/01/79	BETA		5.0000E+02	PCI/L
1-H4-3	11/01/79	NO3-PDS		1.0000E+03	MG/L
1-H4-3	1/08/80	BETA		8.4000E+02	PCI/L
1-H4-3	1/25/80	BETA		7.9000E+02	PCI/L
1-H4-3	1/25/80	NO3-PDS		1.7000E+03	MG/L
1-H4-3	3/04/80	BETA		7.5000E+01	PCI/L
1-H4-3	3/04/80	NO3-PDS		1.9000E+03	MG/L
1-H4-3	3/31/80	BETA		9.3000E+02	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-3	3/31/80	NO3-PDS		1.1000E+03	MG/L
1-H4-3	5/15/80	BETA		4.8000E+02	PCI/L
1-H4-3	5/15/80	NO3-PDS		1.2000E+03	MG/L
1-H4-3	6/24/80	BETA		4.2000E+02	PCI/L
1-H4-3	6/24/80	NO3-PDS		7.1000E+02	MG/L
1-H4-3	8/14/80	BETA		6.7000E+02	PCI/L
1-H4-3	8/14/80	NO3-PDS		2.1000E+03	MG/L
1-H4-3	9/11/80	BETA		6.6000E+02	PCI/L
1-H4-3	9/11/80	NO3-PDS		2.1000E+03	MG/L
1-H4-3	9/30/80	BETA		5.5000E+02	PCI/L
1-H4-3	9/30/80	NO3-PDS		6.0000E+01	MG/L
1-H4-3	10/29/80	BETA		4.4000E+02	PCI/L
1-H4-3	10/29/80	NO3-PDS		6.6000E+02	MG/L
1-H4-3	11/04/80	NO3-PDS		6.2000E+02	MG/L
1-H4-3	11/11/80	NO3-PDS		6.3000E+02	MG/L
1-H4-3	11/18/80	NO3-PDS		6.6000E+02	MG/L
1-H4-3	12/01/80	NO3-PDS		7.5000E+02	MG/L
1-H4-3	12/10/80	NO3-PDS		7.4000E+02	MG/L
1-H4-3	12/15/80	NO3-PDS		6.2000E+02	MG/L
1-H4-3	12/31/80	BETA		8.0000E+02	PCI/L
1-H4-3	12/31/80	NO3-PDS		8.2000E+02	MG/L
1-H4-3	1/07/81	NO3-PDS		7.7000E+02	MG/L
1-H4-3	1/12/81	NO3-PDS		8.5000E+02	MG/L
1-H4-3	1/19/81	BETA		8.0000E+02	PCI/L
1-H4-3	1/19/81	NO3-PDS		8.2000E+02	MG/L
1-H4-3	2/04/81	NO3-PDS		5.3000E+02	MG/L
1-H4-3	2/10/81	NO3-PDS		4.3000E+02	MG/L
1-H4-3	2/20/81	NO3-PDS		7.3000E+02	MG/L
1-H4-3	2/26/81	BETA		7.3000E+02	PCI/L
1-H4-3	2/26/81	NO3-PDS		1.2000E+03	MG/L
1-H4-3	3/17/81	BETA		1.1000E+03	PCI/L
1-H4-3	3/17/81	NO3-PDS		2.3000E+03	MG/L
1-H4-3	4/16/81	BETA		5.8000E+02	PCI/L
1-H4-3	4/16/81	NO3-PDS		2.1000E+03	MG/L
1-H4-3	6/19/81	BETA		4.9000E+02	PCI/L
1-H4-3	6/19/81	NO3-PDS		9.8000E+02	MG/L
1-H4-3	7/20/81	BETA		3.7000E+02	PCI/L
1-H4-3	7/20/81	NO3-PDS		9.1000E+02	MG/L
1-H4-3	10/14/81	BETA		4.0000E+02	PCI/L
1-H4-3	10/14/81	NO3-PDS		7.0000E+02	MG/L
1-H4-3	11/09/81	BETA		7.5000E+01	PCI/L
1-H4-3	1/05/82	NO3-PDS		7.2000E+02	MG/L
1-H4-3	2/26/82	NO3-PDS		9.5000E+02	MG/L
1-H4-3	5/20/82	NO3-PDS		1.4000E+03	MG/L
1-H4-3	10/27/82	NO3-PDS		1.8000E+03	MG/L
1-H4-3	2/16/83	NO3-PDS		7.3000E+02	MG/L
1-H4-3	5/16/83	NO3-PDS		2.1000E+03	MG/L
1-H4-3	8/11/83	NO3-PDS		8.4000E+02	MG/L
1-H4-3	12/13/83	NO3-PDS		3.4000E+02	MG/L
1-H4-3	2/22/84	NO3-PDS		1.2000E+03	MG/L
1-H4-3	5/23/84	NO3-ION		9.6000E+02	MG/L
1-H4-3	9/19/84	NO3-ION		6.1000E+02	MG/L
1-H4-3	12/06/84	NO3-ION		4.5000E+02	MG/L
1-H4-3	2/15/85	NO3-ION		2.2000E+02	MG/L
1-H4-3	4/18/85	NO3-ION		1.4400E+03	MG/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-3	6/19/85	BETA		7.8300E+02	PCI/L
1-H4-3	6/19/85	NITRATE		1.3500E+06	PPB
1-H4-3	7/13/85	NO3-ION		9.8000E+02	MG/L
1-H4-3	8/01/85	BETA		4.1200E+02	PCI/L
1-H4-3	8/01/85	NITRATE		6.2100E+05	PPB
1-H4-3	8/27/85	BETA		5.1600E+02	PCI/L
1-H4-3	8/27/85	NITRATE		4.2700E+05	PPB
1-H4-3	10/01/85	BETA		5.1000E+02	PCI/L
1-H4-3	10/01/85	BETA		5.3000E+02	PCI/L
1-H4-3	10/01/85	NITRATE		4.1800E+05	PPB
1-H4-3	10/01/85	NO3-ION		5.0000E+02	MG/L
1-H4-3	11/01/85	BETA		6.4400E+02	PCI/L
1-H4-3	11/01/85	NITRATE		1.0400E+06	PPB
1-H4-3	12/13/85	BETA		1.0900E+03	PCI/L
1-H4-3	12/13/85	NITRATE		8.1600E+05	PPB
1-H4-3	1/22/86	BETA		9.7500E+02	PCI/L
1-H4-3	1/22/86	NITRATE		2.8300E+06	PPB
1-H4-3	2/03/86	BETA		4.7000E+02	PCI/L
1-H4-3	2/24/86	BETA		8.3600E+02	PCI/L
1-H4-3	2/24/86	NITRATE		1.0000E+06	PPB
1-H4-3	3/24/86	BETA		9.7700E+02	PCI/L
1-H4-3	3/24/86	NITRATE		1.9400E+06	PPB
1-H4-3	4/24/86	BETA		6.6000E+02	PCI/L
1-H4-3	4/24/86	BETA		9.8700E+02	PCI/L
1-H4-3	4/24/86	NITRATE		1.5900E+06	PPB
1-H4-3	5/28/86	BETA		1.1600E+03	PCI/L
1-H4-3	5/28/86	NITRATE		2.8900E+06	PPB
1-H4-3	6/25/86	BETA		1.9200E+03	PCI/L
1-H4-3	6/25/86	NITRATE		3.1500E+06	PPB
1-H4-3	7/23/86	BETA		1.6000E+03	PCI/L
1-H4-3	7/23/86	NITRATE		3.1200E+06	PPB
1-H4-3	7/28/86	BETA		7.2000E+02	PCI/L
1-H4-3	8/20/86	BETA		1.1800E+03	PCI/L
1-H4-3	8/20/86	NITRATE		1.8400E+06	PPB
1-H4-3	9/15/86	BETA		5.4700E+02	PCI/L
1-H4-3	9/15/86	NITRATE		1.1200E+06	PPB
1-H4-3	10/24/86	BETA		1.6000E+02	PCI/L
1-H4-3	10/24/86	BETA		3.1800E+02	PCI/L
1-H4-3	10/24/86	NITRATE		4.7600E+05	PPB
1-H4-3	11/17/86	BETA		2.3800E+02	PCI/L
1-H4-3	11/17/86	NITRATE		4.2700E+05	PPB
1-H4-3	12/12/86	BETA		6.3000E+02	PCI/L
1-H4-3	12/12/86	NITRATE		5.6200E+05	PPB
1-H4-3	1/12/87	BETA		9.0800E+02	PCI/L
1-H4-3	1/12/87	NITRATE		7.1700E+05	PPB
1-H4-3	2/18/87	BETA		7.2200E+02	PCI/L
1-H4-3	2/18/87	NITRATE		1.0100E+06	PPB
1-H4-3	3/10/87	BETA		7.1100E+02	PCI/L
1-H4-3	3/10/87	NITRATE		9.0100E+05	PPB
1-H4-3	4/09/87	BETA		5.6700E+02	PCI/L
1-H4-3	4/09/87	NITRATE		4.6500E+05	PPB
1-H4-3	5/15/87	BETA		2.3600E+02	PCI/L
1-H4-3	5/15/87	NITRATE		3.2300E+05	PPB
1-H4-3	6/15/87	BETA		3.4400E+02	PCI/L
1-H4-3	6/15/87	NITRATE		4.2900E+05	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-3	7/10/87	BETA		8.1100E+02	PCI/L
1-H4-3	7/10/87	NITRATE		1.0200E+06	PPB
1-H4-3	8/11/87	BETA		6.0300E+02	PCI/L
1-H4-3	8/11/87	BETA		7.8000E+02	PCI/L
1-H4-3	8/11/87	NITRATE		7.4800E+05	PPB
1-H4-3	8/11/87	NITRATE		7.5000E+05	PPB
1-H4-3	9/21/87	BETA		2.1900E+02	PCI/L
1-H4-3	9/21/87	NITRATE		3.8400E+05	PPB
1-H4-3	9/21/87	NITRATE		4.0300E+05	PPB
1-H4-3	10/06/87	BETA		1.6600E+02	PCI/L
1-H4-3	10/06/87	NITRATE		3.0500E+05	PPB
1-H4-3	12/18/87	BETA		1.9800E+02	PCI/L
1-H4-3	12/18/87	NITRATE		2.4600E+05	PPB
1-H4-3	1/07/88	BETA		1.9000E+02	PCI/L
1-H4-3	1/07/88	NITRATE		2.7300E+05	PPB
1-H4-3	2/11/88	BETA		4.6900E+02	PCI/L
1-H4-3	2/11/88	NITRATE		6.1900E+05	PPB
1-H4-3	3/09/88	BETA		7.3300E+02	PCI/L
1-H4-3	3/09/88	NITRATE		6.6300E+05	PPB
1-H4-3	4/14/88	BETA		2.3000E+02	PCI/L
1-H4-3	4/14/88	NITRATE		3.0200E+05	PPB
1-H4-3	4/15/88	BETA		2.6600E+02	PCI/L
1-H4-3	5/04/88	BETA		1.9800E+02	PCI/L
1-H4-3	5/04/88	NITRATE		2.2700E+05	PPB
1-H4-3	6/07/88	BETA		1.7500E+02	PCI/L
1-H4-3	6/07/88	NITRATE		2.1800E+05	PPB
1-H4-3	6/10/88	NITRATE		2.0700E+05	PPB
1-H4-3	7/14/88	BETA		3.5000E+02	PCI/L
1-H4-3	7/14/88	NITRATE		4.8000E+05	PPB
1-H4-3	8/10/88	BETA		2.8300E+02	PCI/L
1-H4-3	8/10/88	BETA		3.2400E+02	PCI/L
1-H4-3	8/10/88	NITRATE		3.6400E+05	PPB
1-H4-3	9/07/88	BETA		2.0200E+02	PCI/L
1-H4-3	9/07/88	NITRATE		2.6500E+05	PPB
1-H4-3	10/12/88	BETA		1.4600E+02	PCI/L
1-H4-3	10/12/88	BETA		1.5000E+02	PCI/L
1-H4-3	10/12/88	NITRATE		1.6900E+05	PPB
1-H4-3	10/12/88	NITRATE		1.7000E+05	PPB
1-H4-3	12/06/88	BETA		1.5800E+02	PCI/L
1-H4-3	1/09/89	BETA		9.5700E+01	PCI/L
1-H4-3	1/09/89	NITRATE		1.9100E+05	PPB
1-H4-3	5/25/89	BETA		2.5000E+02	PCI/L
1-H4-3	5/25/89	NITRATE		5.2400E+05	PPB
1-H4-3	8/03/89	BETA		2.0700E+02	PCI/L
1-H4-3	8/03/89	NITRATE		4.7400E+05	PPB
1-H4-3	9/29/89	BETA		1.3300E+02	PCI/L
1-H4-3	9/29/89	NITRATE		2.4200E+05	PPB
1-H4-3	10/11/89	BETA		8.3000E+01	PCI/L
1-H4-3	10/11/89	BETA		8.5000E+01	PCI/L
1-H4-3	10/11/89	NITRATE		1.7200E+05	PPB
1-H4-3	10/11/89	NITRATE		1.7600E+05	PPB
1-H4-3	11/28/89	BETA		6.2200E+01	PCI/L
1-H4-3	11/28/89	NITRATE		1.2700E+05	PPB
1-H4-3	12/27/89	BETA		6.9300E+01	PCI/L
1-H4-3	12/27/89	NITRATE		1.5800E+05	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-3	1/17/90	BETA		7.0300E+01	PCI/L
1-H4-3	1/17/90	NITRATE		1.4800E+05	PPB
1-H4-3	2/08/90	BETA		8.0600E+01	PCI/L
1-H4-3	2/08/90	NITRATE		1.6800E+05	PPB
1-H4-3	3/14/90	BETA		8.3900E+01	PCI/L
1-H4-3	3/14/90	NITRATE		1.8200E+05	PPB
1-H4-3	4/23/90	BETA		1.0800E+02	PCI/L
1-H4-3	4/23/90	NITRATE		2.3100E+05	PPB
1-H4-3	5/06/90	BETA		1.1300E+02	PCI/L
1-H4-3	5/06/90	NITRATE		2.4000E+05	PPB
1-H4-4	12/13/83	NO3-PDS		3.8000E+02	MG/L
1-H4-4	2/22/84	NO3-PDS		8.5000E+01	MG/L
1-H4-4	5/23/84	NO3-ION		2.2000E+02	MG/L
1-H4-4	9/19/84	NO3-ION		6.2000E+02	MG/L
1-H4-4	12/31/84	BETA		3.6000E+02	PCI/L
1-H4-4	5/21/85	NO3-ION		2.8000E+02	MG/L
1-H4-4	6/19/85	BETA		2.9400E+02	PCI/L
1-H4-4	6/19/85	NITRATE		1.3000E+06	PPB
1-H4-4	7/13/85	NO3-ION		5.9000E+01	MG/L
1-H4-4	8/01/85	BETA		3.4000E+02	PCI/L
1-H4-4	8/01/85	NITRATE		5.1000E+05	PPB
1-H4-4	8/26/85	BETA		3.8400E+02	PCI/L
1-H4-4	8/26/85	NITRATE		4.4400E+05	PPB
1-H4-4	10/01/85	BETA		2.5700E+02	PCI/L
1-H4-4	10/01/85	BETA		4.4000E+02	PCI/L
1-H4-4	10/01/85	NITRATE		3.7800E+05	PPB
1-H4-4	10/01/85	NO3-ION		5.6000E+02	MG/L
1-H4-4	11/01/85	BETA		2.8900E+02	PCI/L
1-H4-4	11/01/85	NITRATE		3.9200E+05	PPB
1-H4-4	12/12/85	BETA		1.8900E+01	PCI/L
1-H4-4	12/12/85	NITRATE		2.3300E+04	PPB
1-H4-4	1/21/86	BETA		2.4900E+02	PCI/L
1-H4-4	1/21/86	NITRATE		2.2500E+05	PPB
1-H4-4	2/03/86	BETA		3.1000E+02	PCI/L
1-H4-4	2/24/86	BETA		2.3700E+02	PCI/L
1-H4-4	2/24/86	NITRATE		2.5900E+05	PPB
1-H4-4	3/21/86	BETA		1.7300E+02	PCI/L
1-H4-4	3/21/86	NITRATE		2.0000E+05	PPB
1-H4-4	4/24/86	BETA		2.9100E+01	PCI/L
1-H4-4	4/24/86	BETA		5.4000E+01	PCI/L
1-H4-4	4/24/86	NITRATE		3.8700E+04	PPB
1-H4-4	5/28/86	BETA		1.5900E+02	PCI/L
1-H4-4	5/28/86	NITRATE		1.2500E+05	PPB
1-H4-4	6/25/86	BETA		2.4200E+02	PCI/L
1-H4-4	6/25/86	NITRATE		2.0200E+05	PPB
1-H4-4	7/23/86	BETA		1.4700E+01	PCI/L
1-H4-4	7/23/86	NITRATE		1.7500E+04	PPB
1-H4-4	7/28/86	BETA		5.3000E+01	PCI/L
1-H4-4	8/20/86	BETA		3.5900E+02	PCI/L
1-H4-4	8/20/86	NITRATE		3.8900E+05	PPB
1-H4-4	9/15/86	BETA		4.5800E+02	PCI/L
1-H4-4	9/15/86	NITRATE		5.7500E+05	PPB
1-H4-4	10/24/86	BETA		4.1700E+02	PCI/L
1-H4-4	10/24/86	BETA		4.4000E+02	PCI/L
1-H4-4	10/24/86	NITRATE		5.2800E+05	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-4	11/19/86	BETA		3.5700E+02	PCI/L
1-H4-4	11/19/86	NITRATE		3.2600E+05	PPB
1-H4-4	12/12/86	BETA		3.7700E+02	PCI/L
1-H4-4	12/12/86	NITRATE		4.3500E+05	PPB
1-H4-4	1/14/87	BETA		1.2600E+02	PCI/L
1-H4-4	1/14/87	NITRATE		1.1200E+05	PPB
1-H4-4	2/12/87	BETA		4.0400E+02	PCI/L
1-H4-4	2/12/87	NITRATE		4.9200E+05	PPB
1-H4-4	3/09/87	BETA		4.8100E+02	PCI/L
1-H4-4	3/09/87	NITRATE		4.9300E+05	PPB
1-H4-4	4/10/87	BETA		4.3100E+02	PCI/L
1-H4-4	4/10/87	NITRATE		4.5200E+05	PPB
1-H4-4	5/14/87	BETA		6.8800E+00	PCI/L
1-H4-4	5/14/87	NITRATE		9.7200E+03	PPB
1-H4-4	6/16/87	BETA		1.5300E+02	PCI/L
1-H4-4	6/16/87	NITRATE		1.8000E+05	PPB
1-H4-4	7/08/87	BETA		3.3500E+02	PCI/L
1-H4-4	7/08/87	NITRATE		2.9600E+05	PPB
1-H4-4	8/11/87	BETA		3.9700E+02	PCI/L
1-H4-4	8/11/87	BETA		4.3000E+02	PCI/L
1-H4-4	8/11/87	NITRATE		3.6900E+05	PPB
1-H4-4	8/11/87	NITRATE		3.7400E+05	PPB
1-H4-4	9/22/87	BETA		3.1100E+02	PCI/L
1-H4-4	9/22/87	NITRATE		4.9900E+05	PPB
1-H4-4	9/22/87	NITRATE		5.1200E+05	PPB
1-H4-4	10/16/87	BETA		2.2000E+02	PCI/L
1-H4-4	10/16/87	BETA		2.2700E+02	PCI/L
1-H4-4	10/16/87	NITRATE		2.3100E+05	PPB
1-H4-4	12/17/87	BETA		1.7400E+02	PCI/L
1-H4-4	12/17/87	BETA		1.8300E+02	PCI/L
1-H4-4	12/17/87	NITRATE		1.3900E+05	PPB
1-H4-4	1/06/88	BETA		1.3900E+02	PCI/L
1-H4-4	1/06/88	BETA		1.4900E+02	PCI/L
1-H4-4	1/06/88	NITRATE		1.6100E+05	PPB
1-H4-4	1/06/88	NITRATE		1.6200E+05	PPB
1-H4-4	2/11/88	BETA		2.0800E+02	PCI/L
1-H4-4	2/11/88	BETA		2.1000E+02	PCI/L
1-H4-4	2/11/88	NITRATE		2.8100E+05	PPB
1-H4-4	2/11/88	NITRATE		2.8800E+05	PPB
1-H4-4	3/10/88	BETA		2.4800E+02	PCI/L
1-H4-4	3/10/88	BETA		2.7200E+02	PCI/L
1-H4-4	3/10/88	NITRATE		3.0500E+05	PPB
1-H4-4	3/10/88	NITRATE		3.2000E+05	PPB
1-H4-4	4/13/88	BETA		2.5300E+02	PCI/L
1-H4-4	4/13/88	BETA		2.5700E+02	PCI/L
1-H4-4	4/13/88	NITRATE		2.9700E+05	PPB
1-H4-4	4/13/88	NITRATE		2.9900E+05	PPB
1-H4-4	5/03/88	BETA		2.4600E+02	PCI/L
1-H4-4	5/03/88	BETA		2.5200E+02	PCI/L
1-H4-4	5/03/88	NITRATE		2.7400E+05	PPB
1-H4-4	5/03/88	NITRATE		2.7800E+05	PPB
1-H4-4	6/07/88	BETA		7.6100E+01	PCI/L
1-H4-4	6/07/88	BETA		7.8300E+01	PCI/L
1-H4-4	6/07/88	BETA		8.0600E+01	PCI/L
1-H4-4	6/07/88	NITRATE		7.9300E+04	PPB

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-4	6/07/88	NITRATE		7.9800E+04	PPB
1-H4-4	7/14/88	BETA		1.5800E+02	PCI/L
1-H4-4	7/14/88	BETA		1.8700E+02	PCI/L
1-H4-4	7/14/88	NITRATE		1.9700E+05	PPB
1-H4-4	7/14/88	NITRATE		2.0200E+05	PPB
1-H4-4	8/09/88	BETA		1.9900E+02	PCI/L
1-H4-4	8/09/88	BETA		2.4100E+02	PCI/L
1-H4-4	8/09/88	BETA		2.5700E+02	PCI/L
1-H4-4	8/09/88	NITRATE		2.5500E+05	PPB
1-H4-4	8/09/88	NITRATE		2.7100E+05	PPB
1-H4-4	9/06/88	BETA		2.2400E+02	PCI/L
1-H4-4	9/06/88	BETA		2.6400E+02	PCI/L
1-H4-4	9/06/88	NITRATE		2.5400E+05	PPB
1-H4-4	9/06/88	NITRATE		2.5800E+05	PPB
1-H4-4	10/12/88	BETA		2.1400E+02	PCI/L
1-H4-4	10/12/88	NITRATE		2.6600E+05	PPB
1-H4-4	12/06/88	BETA		8.4400E+01	PCI/L
1-H4-4	1/09/89	BETA		8.3700E+00	PCI/L
1-H4-4	1/09/89	NITRATE		2.6300E+04	PPB
1-H4-4	5/25/89	BETA		6.8600E+00	PCI/L
1-H4-4	5/25/89	HNITRAT		9.7000E+03	PPB
1-H4-4	5/25/89	NITRATE		1.0400E+04	PPB
1-H4-4	8/03/89	BETA		1.6800E+02	PCI/L
1-H4-4	8/03/89	NITRATE		3.9200E+05	PPB
1-H4-4	10/11/89	BETA		2.0200E+02	PCI/L
1-H4-4	10/11/89	NITRATE		3.6800E+05	PPB
1-H4-4	11/28/89	BETA		1.3400E+02	PCI/L
1-H4-4	11/28/89	NITRATE		2.5300E+05	PPB
1-H4-4	12/27/89	BETA		1.3100E+02	PCI/L
1-H4-4	12/27/89	NITRATE		1.8500E+05	PPB
1-H4-4	1/17/90	BETA		1.0200E+02	PCI/L
1-H4-4	1/17/90	NITRATE		1.9200E+05	PPB
1-H4-4	2/08/90	BETA		2.0300E+01	PCI/L
1-H4-4	2/08/90	NITRATE		3.5900E+04	PPB
1-H4-4	3/14/90	BETA		3.9400E+01	PCI/L
1-H4-4	3/14/90	NITRATE		8.3100E+04	PPB
1-H4-4	4/23/90	BETA		5.7500E+01	PCI/L
1-H4-4	4/23/90	NITRATE		9.8300E+04	PPB
1-H4-4	5/06/90	BETA		7.2800E+00	PCI/L
1-H4-4	5/06/90	NITRATE		1.6900E+04	PPB
1-H4-5	12/13/83	NO3-PDS		3.1000E+00	MG/L
1-H4-5	2/22/84	NO3-PDS		4.8000E-01	MG/L
1-H4-5	5/23/84	NO3-ION		1.5000E+01	MG/L
1-H4-5	9/19/84	NO3-ION		5.7000E+01	MG/L
1-H4-5	1/02/85	NO3-ION		4.7000E+00	MG/L
1-H4-5	5/21/85	NO3-ION		1.5000E+01	MG/L
1-H4-5	6/24/85	BETA		5.4200E+00	PCI/L
1-H4-5	6/24/85	BETA		5.5300E+00	PCI/L
1-H4-5	6/24/85	BETA		6.8400E+00	PCI/L
1-H4-5	6/24/85	NITRATE		1.4500E+04	PPB
1-H4-5	6/24/85	NITRATE		1.5000E+04	PPB
1-H4-5	6/24/85	NITRATE		1.5800E+04	PPB
1-H4-5	7/13/85	NO3-ION		3.6000E+00	MG/L
1-H4-5	7/25/85	BETA		5.4200E+00	PCI/L
1-H4-5	7/25/85	BETA		7.7300E+00	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-5	7/25/85	BETA		8.8400E+00	PCI/L
1-H4-5	7/25/85	BETA		2.2200E+01	PCI/L
1-H4-5	7/25/85	NITRATE		2.2500E+04	PPB
1-H4-5	7/25/85	NITRATE		2.3000E+04	PPB
1-H4-5	7/25/85	NITRATE		2.4500E+04	PPB
1-H4-5	7/25/85	NITRATE		2.5100E+04	PPB
1-H4-5	8/26/85	BETA		6.2900E+00	PCI/L
1-H4-5	8/26/85	BETA		7.0500E+00	PCI/L
1-H4-5	8/26/85	BETA		9.1400E+00	PCI/L
1-H4-5	8/26/85	BETA		1.0200E+01	PCI/L
1-H4-5	8/26/85	NITRATE		2.3000E+04	PPB
1-H4-5	8/26/85	NITRATE		2.3900E+04	PPB
1-H4-5	8/26/85	NITRATE		2.5900E+04	PPB
1-H4-5	8/26/85	NITRATE		2.6000E+04	PPB
1-H4-5	10/01/85	BETA		6.4100E+00	PCI/L
1-H4-5	10/01/85	BETA	<	1.3000E+01	PCI/L
1-H4-5	10/01/85	NITRATE		2.1000E+04	PPB
1-H4-5	10/01/85	NO3-ION		5.6000E+01	MG/L
1-H4-5	10/31/85	BETA		7.7200E+00	PCI/L
1-H4-5	10/31/85	NITRATE		1.9300E+04	PPB
1-H4-5	12/12/85	BETA		6.3600E+01	PCI/L
1-H4-5	12/12/85	NITRATE		1.9600E+04	PPB
1-H4-5	1/21/86	BETA		1.1200E+01	PCI/L
1-H4-5	1/21/86	NITRATE		1.9900E+04	PPB
1-H4-5	1/31/86	BETA	<	1.2000E+01	PCI/L
1-H4-5	1/31/86	NO3-ION		5.6000E+01	MG/L
1-H4-5	2/25/86	BETA		7.2900E+00	PCI/L
1-H4-5	2/25/86	NITRATE		2.1600E+04	PPB
1-H4-5	3/25/86	BETA		4.5900E+00	PCI/L
1-H4-5	3/25/86	NITRATE		2.2300E+04	PPB
1-H4-5	4/24/86	BETA		5.7000E+00	PCI/L
1-H4-5	4/24/86	BETA	<	9.0000E+00	PCI/L
1-H4-5	4/24/86	NITRATE		2.2400E+04	PPB
1-H4-5	4/24/86	NO3-ION		4.3000E+01	MG/L
1-H4-5	5/28/86	BETA		2.3400E+01	PCI/L
1-H4-5	5/28/86	NITRATE		2.6000E+04	PPB
1-H4-5	6/26/86	BETA		8.0100E+00	PCI/L
1-H4-5	6/26/86	NITRATE		2.7900E+04	PPB
1-H4-5	7/25/86	BETA		6.5700E+00	PCI/L
1-H4-5	7/25/86	NITRATE		2.6800E+04	PPB
1-H4-5	7/28/86	BETA	<	8.7000E+00	PCI/L
1-H4-5	7/28/86	NITRATE		2.6400E+04	PPB
1-H4-5	8/20/86	BETA		1.2500E+01	PCI/L
1-H4-5	8/20/86	NITRATE		2.9200E+04	PPB
1-H4-5	9/16/86	BETA		1.3000E+01	PCI/L
1-H4-5	9/16/86	NITRATE		3.2200E+04	PPB
1-H4-5	10/27/86	BETA		1.1200E+01	PCI/L
1-H4-5	10/27/86	BETA	<	6.5000E+00	PCI/L
1-H4-5	10/27/86	NITRATE		2.9800E+04	PPB
1-H4-5	10/27/86	NITRATE		3.2800E+04	PPB
1-H4-5	11/19/86	BETA		6.8700E+00	PCI/L
1-H4-5	11/19/86	NITRATE		3.3100E+04	PPB
1-H4-5	12/11/86	BETA		7.2200E+00	PCI/L
1-H4-5	12/11/86	NITRATE		2.9700E+04	PPB
1-H4-5	1/13/87	BETA		1.1200E+01	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-5	1/13/87	NITRATE		3.0200E+04	PPB
1-H4-5	2/18/87	BETA		1.4300E+01	PCI/L
1-H4-5	2/18/87	NITRATE		2.9900E+04	PPB
1-H4-5	3/10/87	BETA		1.0200E+01	PCI/L
1-H4-5	3/10/87	NITRATE		3.3000E+04	PPB
1-H4-5	4/10/87	BETA		8.7100E+00	PCI/L
1-H4-5	4/10/87	NITRATE		2.8700E+04	PPB
1-H4-5	5/19/87	BETA		5.7500E+00	PCI/L
1-H4-5	5/19/87	NITRATE		2.9600E+04	PPB
1-H4-5	6/16/87	BETA	<	3.1700E+00	PCI/L
1-H4-5	6/16/87	NITRATE		3.0300E+04	PPB
1-H4-5	7/08/87	BETA		1.1700E+01	PCI/L
1-H4-5	7/08/87	NITRATE		2.9500E+04	PPB
1-H4-5	8/11/87	BETA		1.6400E+01	PCI/L
1-H4-5	8/11/87	NITRATE		3.6800E+04	PPB
1-H4-5	9/21/87	BETA		7.7400E+00	PCI/L
1-H4-5	9/21/87	NITRATE		3.9900E+04	PPB
1-H4-5	12/17/87	BETA		8.5900E+00	PCI/L
1-H4-5	12/17/87	NITRATE		3.6200E+04	PPB
1-H4-5	3/16/88	BETA		5.8100E+00	PCI/L
1-H4-5	3/16/88	NITRATE		4.0800E+04	PPB
1-H4-5	6/13/88	BETA		7.2300E+00	PCI/L
1-H4-5	6/13/88	NITRATE		3.9500E+04	PPB
1-H4-5	9/07/88	BETA		6.1300E+00	PCI/L
1-H4-5	9/07/88	NITRATE		3.7500E+04	PPB
1-H4-5	10/13/88	BETA		1.2100E+01	PCI/L
1-H4-5	10/13/88	NITRATE		3.7400E+04	PPB
1-H4-5	1/06/89	BETA		5.9300E+00	PCI/L
1-H4-5	1/06/89	BETA		7.0200E+00	PCI/L
1-H4-5	1/06/89	NITRATE		3.9500E+04	PPB
1-H4-5	1/06/89	NITRATE		4.0600E+04	PPB
1-H4-5	6/20/89	BETA		8.9700E+00	PCI/L
1-H4-5	6/20/89	NITRATE		4.4800E+04	PPB
1-H4-5	10/11/89	NITRATE		3.9000E+04	PPB
1-H4-5	1/18/90	BETA		3.3800E+00	PCI/L
1-H4-5	1/18/90	BETA		4.4400E+00	PCI/L
1-H4-5	1/18/90	NITRATE		4.5400E+04	PPB
1-H4-5	1/18/90	NITRATE		4.5900E+04	PPB
1-H4-5	4/18/90	BETA		4.9300E+00	PCI/L
1-H4-5	4/18/90	NITRATE		4.9700E+04	PPB
1-H4-6	12/13/83	NO3-PDS		2.5000E+01	MG/L
1-H4-6	2/22/84	NO3-PDS		1.7000E+01	MG/L
1-H4-6	5/23/84	NO3-ION		2.6000E+01	MG/L
1-H4-6	9/19/84	NO3-ION		3.2000E+01	MG/L
1-H4-6	1/02/85	NO3-ION		4.3000E+01	MG/L
1-H4-6	5/21/85	NO3-ION		4.5000E+01	MG/L
1-H4-6	6/19/85	BETA		7.0800E+00	PCI/L
1-H4-6	6/19/85	NITRATE		1.5000E+04	PPB
1-H4-6	7/13/85	NO3-ION		3.2000E+01	MG/L
1-H4-6	7/25/85	BETA		7.8100E+00	PCI/L
1-H4-6	7/25/85	NITRATE		2.0100E+04	PPB
1-H4-6	8/26/85	BETA		7.7000E+00	PCI/L
1-H4-6	8/26/85	NITRATE		1.9300E+04	PPB
1-H4-6	10/03/85	BETA		7.7900E+00	PCI/L
1-H4-6	10/03/85	BETA	<	-6.2000E-01	PCI/L

Beta and Nitrate data, 100-H Wells

WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-6	10/03/85	NITRATE		1.8800E+04	PPB
1-H4-6	10/03/85	NO3-ION		4.7000E+01	MG/L
1-H4-6	10/31/85	BETA		8.9300E+00	PCI/L
1-H4-6	10/31/85	NITRATE		2.2900E+04	PPB
1-H4-6	12/12/85	BETA		6.8100E+00	PCI/L
1-H4-6	12/12/85	NITRATE		2.9200E+04	PPB
1-H4-6	1/21/86	BETA		7.1400E+00	PCI/L
1-H4-6	1/21/86	NITRATE		2.7100E+04	PPB
1-H4-6	1/31/86	BETA	<	-2.0000E+00	PCI/L
1-H4-6	1/31/86	NO3-ION		6.4000E+01	MG/L
1-H4-6	2/25/86	BETA		7.4500E+00	PCI/L
1-H4-6	2/25/86	NITRATE	<	2.9500E+04	PPB
1-H4-6	3/24/86	BETA		1.0000E+01	PCI/L
1-H4-6	3/24/86	NITRATE		3.1100E+04	PPB
1-H4-6	4/25/86	BETA		9.5200E+00	PCI/L
1-H4-6	4/25/86	BETA	<	5.0000E+00	PCI/L
1-H4-6	4/25/86	NITRATE		2.8100E+04	PPB
1-H4-6	4/25/86	NO3-ION		5.2000E+01	MG/L
1-H4-6	5/28/86	BETA		2.2400E+01	PCI/L
1-H4-6	5/28/86	NITRATE		3.0100E+04	PPB
1-H4-6	6/26/86	BETA		1.1900E+01	PCI/L
1-H4-6	6/26/86	NITRATE		2.9600E+04	PPB
1-H4-6	7/25/86	BETA		1.2600E+01	PCI/L
1-H4-6	7/25/86	NITRATE		3.3000E+04	PPB
1-H4-6	7/28/86	BETA	<	1.1000E+01	PCI/L
1-H4-6	7/28/86	NITRATE		3.3400E+04	PPB
1-H4-6	8/21/86	BETA		9.1700E+00	PCI/L
1-H4-6	8/21/86	NITRATE		3.6300E+04	PPB
1-H4-6	9/15/86	BETA		1.1900E+01	PCI/L
1-H4-6	9/15/86	NITRATE		3.6300E+04	PPB
1-H4-6	10/29/86	BETA		1.2800E+01	PCI/L
1-H4-6	10/29/86	BETA	<	-2.2000E+00	PCI/L
1-H4-6	10/29/86	NITRATE		2.9200E+04	PPB
1-H4-6	10/29/86	NITRATE		3.0000E+04	PPB
1-H4-6	11/17/86	BETA		8.8300E+00	PCI/L
1-H4-6	11/17/86	NITRATE		3.5000E+04	PPB
1-H4-6	12/11/86	BETA		1.1900E+01	PCI/L
1-H4-6	12/11/86	NITRATE		3.7300E+04	PPB
1-H4-6	1/13/87	BETA		5.9000E+00	PCI/L
1-H4-6	1/13/87	NITRATE		3.4400E+04	PPB
1-H4-6	2/18/87	BETA		1.4700E+01	PCI/L
1-H4-6	2/18/87	NITRATE		3.7800E+04	PPB
1-H4-6	3/11/87	BETA		7.8600E+00	PCI/L
1-H4-6	3/11/87	NITRATE		3.8100E+04	PPB
1-H4-6	4/14/87	BETA		8.7500E+00	PCI/L
1-H4-6	4/14/87	NITRATE		3.7000E+04	PPB
1-H4-6	5/15/87	BETA		7.8300E+00	PCI/L
1-H4-6	5/15/87	NITRATE		3.1500E+04	PPB
1-H4-6	6/16/87	BETA		1.0400E+01	PCI/L
1-H4-6	6/16/87	NITRATE		3.8500E+04	PPB
1-H4-6	7/08/87	BETA		1.2700E+01	PCI/L
1-H4-6	7/08/87	NITRATE		3.8200E+04	PPB
1-H4-6	8/12/87	BETA		2.8300E+01	PCI/L
1-H4-6	8/12/87	NITRATE		3.8400E+04	PPB
1-H4-6	9/22/87	BETA		8.0400E+00	PCI/L

Beta and Nitrate data, 100-H Wells

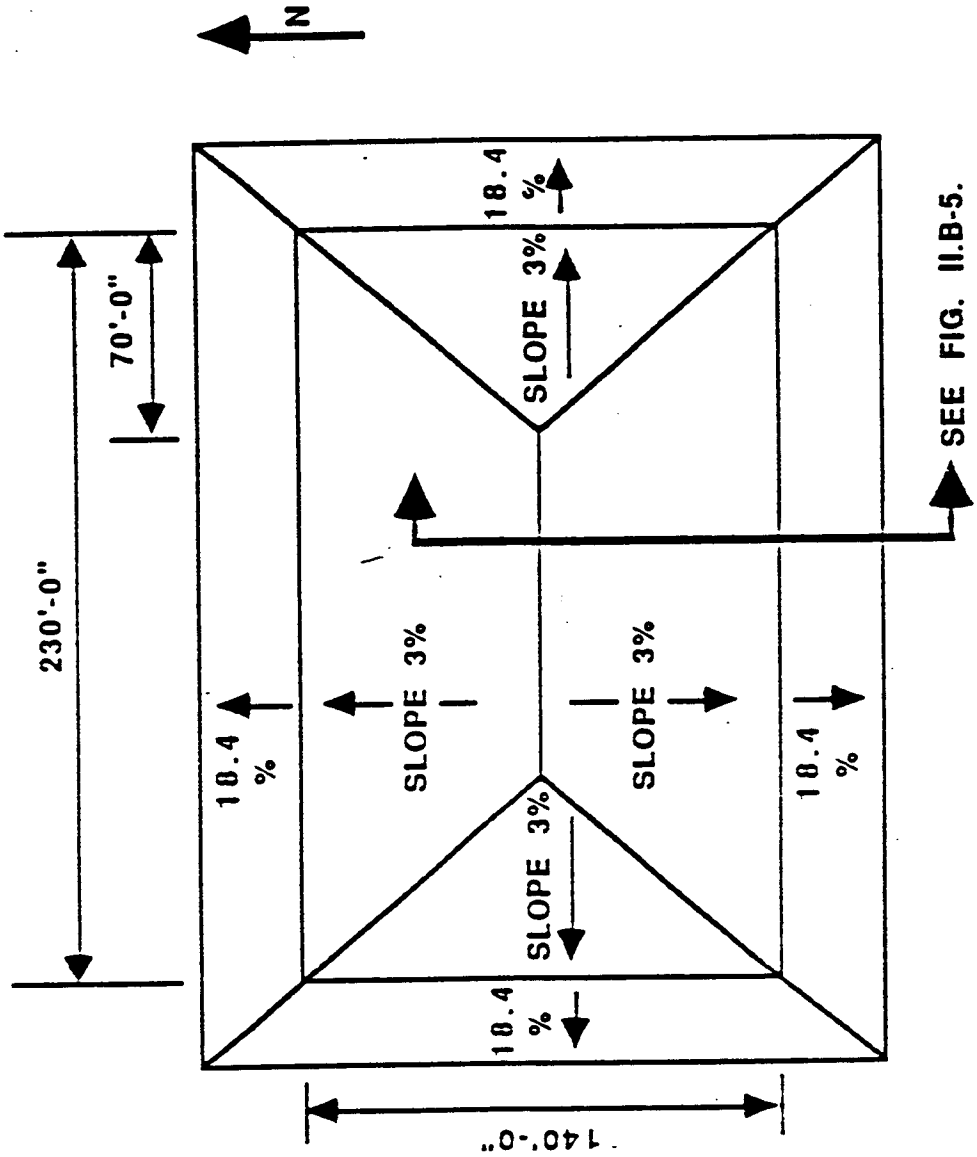
WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-6	9/22/87	NITRATE		4.0700E+04	PPB
1-H4-6	12/18/87	BETA		1.0100E+01	PCI/L
1-H4-6	12/18/87	NITRATE		3.8000E+04	PPB
1-H4-6	3/16/88	BETA		7.9000E+00	PCI/L
1-H4-6	3/16/88	NITRATE		4.0000E+04	PPB
1-H4-6	6/15/88	BETA		8.2800E+00	PCI/L
1-H4-6	6/15/88	NITRATE		3.8900E+04	PPB
1-H4-6	9/12/88	BETA		1.7300E+01	PCI/L
1-H4-6	9/12/88	NITRATE		3.8600E+04	PPB
1-H4-6	10/13/88	BETA		9.0500E+00	PCI/L
1-H4-6	10/13/88	NITRATE		3.9000E+04	PPB
1-H4-6	1/09/89	BETA		7.4900E+00	PCI/L
1-H4-6	1/09/89	NITRATE		3.9100E+04	PPB
1-H4-6	5/24/89	BETA		4.4300E+00	PCI/L
1-H4-6	5/24/89	NITRATE		3.6700E+04	PPB
1-H4-6	8/04/89	BETA		6.9700E+00	PCI/L
1-H4-6	8/04/89	BETA		7.6000E+00	PCI/L
1-H4-6	8/04/89	NITRATE		3.8000E+04	PPB
1-H4-6	10/11/89	BETA		9.1800E+00	PCI/L
1-H4-6	10/11/89	NITRATE		3.8000E+04	PPB
1-H4-6	1/17/90	BETA		5.0500E+00	PCI/L
1-H4-6	1/17/90	NITRATE		3.9100E+04	PPB
1-H4-6	4/23/90	BETA		7.6000E+00	PCI/L
1-H4-6	4/23/90	NITRATE		3.7000E+04	PPB
1-H4-7	12/18/86	BETA		9.1700E+00	PCI/L
1-H4-7	12/18/86	NITRATE		2.7100E+04	PPB
1-H4-7	1/13/87	BETA		7.3000E+00	PCI/L
1-H4-7	1/13/87	NITRATE		2.6600E+04	PPB
1-H4-7	2/11/87	BETA		1.0500E+01	PCI/L
1-H4-7	2/11/87	NITRATE		2.8400E+04	PPB
1-H4-7	3/04/87	BETA		6.8000E+00	PCI/L
1-H4-7	3/04/87	NITRATE		2.7600E+04	PPB
1-H4-7	4/06/87	BETA		4.0500E+00	PCI/L
1-H4-7	4/06/87	NITRATE		2.3900E+04	PPB
1-H4-7	5/18/87	BETA		1.2300E+01	PCI/L
1-H4-7	5/18/87	NITRATE		4.4700E+04	PPB
1-H4-7	6/15/87	BETA		4.5400E+00	PCI/L
1-H4-7	6/15/87	NITRATE		3.9500E+04	PPB
1-H4-7	7/07/87	BETA		6.1400E+00	PCI/L
1-H4-7	7/07/87	NITRATE		2.9800E+04	PPB
1-H4-7	8/10/87	BETA	<	3.3900E+00	PCI/L
1-H4-7	8/10/87	NITRATE		2.9500E+04	PPB
1-H4-7	9/15/87	BETA		8.3200E+00	PCI/L
1-H4-7	9/15/87	NITRATE		2.9700E+04	PPB
1-H4-7	10/14/87	BETA		8.1500E+00	PCI/L
1-H4-7	10/14/87	BETA		1.0200E+01	PCI/L
1-H4-7	10/14/87	NITRATE		3.1200E+04	PPB
1-H4-7	3/14/88	BETA		7.1600E+00	PCI/L
1-H4-7	3/14/88	NITRATE		3.0300E+04	PPB
1-H4-7	6/13/88	BETA		1.2900E+01	PCI/L
1-H4-7	6/13/88	NITRATE		3.6600E+04	PPB
1-H4-7	9/08/88	BETA		7.8600E+00	PCI/L
1-H4-7	9/08/88	NITRATE		3.5000E+04	PPB
1-H4-7	6/06/89	BETA		3.1800E+00	PCI/L
1-H4-7	6/06/89	NITRATE		5.6800E+04	PPB

Beta and Nitrate data, 100-H Wells

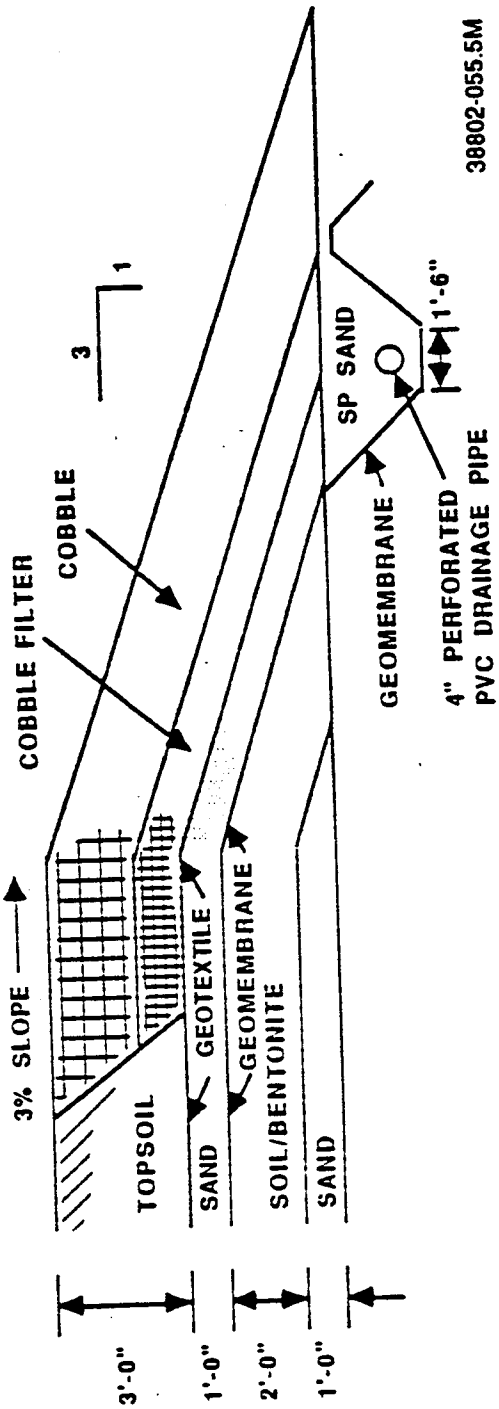
WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-7	10/18/89	BETA		4.4500E+00	PCI/L
1-H4-7	10/18/89	NITRATE		3.6000E+04	PPB
1-H4-7	11/30/89	BETA		6.3700E+00	PCI/L
1-H4-7	11/30/89	NITRATE		3.5300E+04	PPB
1-H4-7	4/23/90	BETA		8.8900E+00	PCI/L
1-H4-7	4/23/90	NITRATE		3.5200E+04	PPB
1-H4-8	12/31/86	BETA		6.9800E+00	PCI/L
1-H4-8	12/31/86	NITRATE		2.9200E+04	PPB
1-H4-8	1/09/87	BETA		1.0500E+01	PCI/L
1-H4-8	1/09/87	NITRATE		2.9200E+04	PPB
1-H4-8	2/06/87	BETA		5.4900E+00	PCI/L
1-H4-8	2/06/87	NITRATE		2.9800E+04	PPB
1-H4-8	3/04/87	BETA		1.0700E+01	PCI/L
1-H4-8	3/04/87	NITRATE		2.9700E+04	PPB
1-H4-8	4/09/87	BETA		8.7100E+00	PCI/L
1-H4-8	4/09/87	NITRATE		2.7800E+04	PPB
1-H4-8	5/18/87	BETA		1.1600E+01	PCI/L
1-H4-8	5/18/87	NITRATE		2.9900E+04	PPB
1-H4-8	6/12/87	BETA		6.1800E+00	PCI/L
1-H4-8	6/12/87	NITRATE		3.6800E+04	PPB
1-H4-8	7/07/87	BETA		7.2400E+00	PCI/L
1-H4-8	7/07/87	NITRATE		3.1000E+04	PPB
1-H4-8	8/10/87	BETA		8.4700E+00	PCI/L
1-H4-8	8/10/87	NITRATE		3.4700E+04	PPB
1-H4-8	9/18/87	BETA		8.4600E+00	PCI/L
1-H4-8	9/18/87	NITRATE		3.5900E+04	PPB
1-H4-8	10/14/87	BETA		8.6700E+00	PCI/L
1-H4-8	10/14/87	NITRATE		3.4600E+04	PPB
1-H4-8	3/11/88	BETA		4.2800E+00	PCI/L
1-H4-8	3/11/88	NITRATE		3.7100E+04	PPB
1-H4-8	6/13/88	BETA		1.0000E+01	PCI/L
1-H4-8	6/13/88	NITRATE		3.8400E+04	PPB
1-H4-8	9/07/88	BETA		1.1400E+01	PCI/L
1-H4-8	9/07/88	NITRATE		3.9100E+04	PPB
1-H4-8	5/12/89	BETA		7.0600E+00	PCI/L
1-H4-8	5/12/89	NITRATE		3.9400E+04	PPB
1-H4-8	4/25/90	BETA		1.2500E+01	PCI/L
1-H4-8	4/25/90	NITRATE		3.9800E+04	PPB
1-H4-9	1/30/87	BETA		3.7200E+01	PCI/L
1-H4-9	1/30/87	NITRATE		5.1800E+04	PPB
1-H4-9	2/19/87	BETA		2.1600E+02	PCI/L
1-H4-9	2/19/87	NITRATE		1.8600E+05	PPB
1-H4-9	3/05/87	BETA		1.7600E+02	PCI/L
1-H4-9	3/05/87	NITRATE		2.3900E+05	PPB
1-H4-9	4/08/87	BETA		1.2600E+02	PCI/L
1-H4-9	4/08/87	NITRATE		1.1600E+05	PPB
1-H4-9	5/18/87	BETA		1.8400E+02	PCI/L
1-H4-9	5/18/87	NITRATE		1.4500E+05	PPB
1-H4-9	6/15/87	BETA		4.0200E+01	PCI/L
1-H4-9	6/15/87	NITRATE		6.2000E+04	PPB
1-H4-9	7/07/87	BETA		1.8100E+02	PCI/L
1-H4-9	7/07/87	NITRATE		2.0200E+05	PPB
1-H4-9	8/10/87	BETA		3.0500E+02	PCI/L
1-H4-9	8/10/87	NITRATE		2.5300E+05	PPB
1-H4-9	9/15/87	BETA		7.6000E+01	PCI/L

Beta and Nitrate data, 100-H Wells

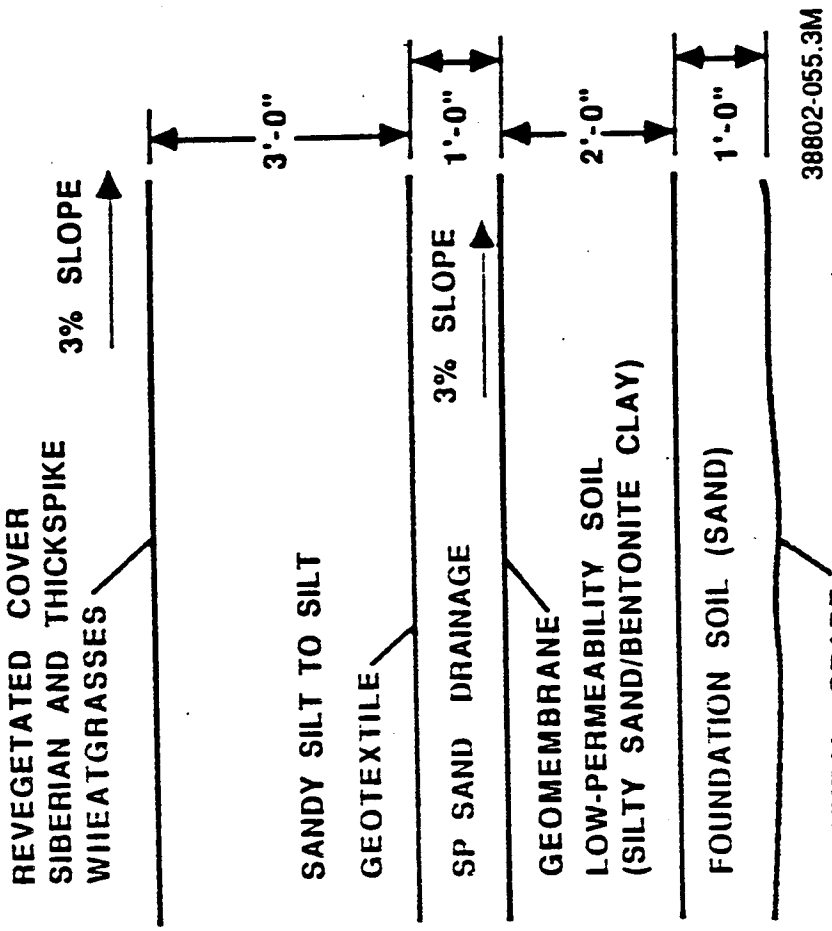
WELL NAME	COLLECTION DATE	CONSTITUENT NAME	LESS THAN FLAG	ANALYSIS VALUE	ANALYSIS UNITS
1-H4-9	9/15/87	NITRATE		1.1900E+05	PPB
1-H4-9	10/06/87	BETA		6.4900E+01	PCI/L
1-H4-9	10/06/87	NITRATE		1.0200E+05	PPB
1-H4-9	12/28/87	BETA		1.2800E+02	PCI/L
1-H4-9	12/28/87	BETA		1.6400E+02	PCI/L
1-H4-9	12/28/87	NITRATE		1.9800E+05	PPB
1-H4-9	1/07/88	BETA		1.5900E+02	PCI/L
1-H4-9	1/07/88	NITRATE		2.0600E+05	PPB
1-H4-9	2/10/88	BETA		2.2300E+02	PCI/L
1-H4-9	2/10/88	NITRATE		1.3100E+05	PPB
1-H4-9	3/11/88	BETA		2.0300E+02	PCI/L
1-H4-9	3/11/88	BETA		2.2700E+02	PCI/L
1-H4-9	3/11/88	NITRATE		2.5600E+05	PPB
1-H4-9	6/07/88	BETA		4.1500E+01	PCI/L
1-H4-9	6/07/88	BETA		5.0200E+01	PCI/L
1-H4-9	6/07/88	NITRATE		6.2800E+04	PPB
1-H4-9	6/07/88	NITRATE		6.3600E+04	PPB
1-H4-9	7/13/88	BETA		9.2900E+01	PCI/L
1-H4-9	7/13/88	NITRATE		1.2700E+05	PPB
1-H4-9	8/10/88	BETA		9.1400E+01	PCI/L
1-H4-9	8/10/88	NITRATE		1.1300E+05	PPB
1-H4-9	9/02/88	BETA		7.1600E+01	PCI/L
1-H4-9	9/02/88	BETA		7.3400E+01	PCI/L
1-H4-9	9/02/88	NITRATE		9.8000E+04	PPB
1-H4-9	9/02/88	NITRATE		1.0200E+05	PPB
1-H4-9	10/12/88	BETA		5.6300E+01	PCI/L
1-H4-9	10/12/88	NITRATE		7.6900E+04	PPB
1-H4-9	1/06/89	BETA		2.1500E+01	PCI/L
1-H4-9	1/06/89	NITRATE		5.8000E+04	PPB
1-H4-9	5/15/89	BETA		2.7600E+01	PCI/L
1-H4-9	5/15/89	NITRATE		6.9300E+04	PPB
1-H4-9	12/27/89	BETA		2.6400E+01	PCI/L
1-H4-9	12/27/89	NITRATE		6.8500E+04	PPB
1-H4-9	1/18/90	BETA		2.9400E+01	PCI/L
1-H4-9	1/18/90	NITRATE		7.0500E+04	PPB
1-H4-9	2/07/90	BETA		2.7900E+01	PCI/L
1-H4-9	2/07/90	NITRATE		6.4000E+04	PPB
1-H4-9	3/14/90	BETA		5.5100E+00	PCI/L
1-H4-9	3/14/90	NITRATE		4.4900E+04	PPB
1-H4-9	4/20/90	BETA		9.6200E+00	PCI/L
1-H4-9	4/20/90	NITRATE		4.2000E+03	PPB
1-H4-9	5/06/90	BETA		1.1000E+01	PCI/L
1-H4-9	5/06/90	NITRATE		4.4500E+04	PPB


N
18.4 %
SLOPE 3%
70'-0"
230'-0"
SEE FIG. II.B-5.
38802-055.4M
SLOPE 3%
SLOPE 3%
18.4 %
18.4 %
SLOPE 3%
18.4 %
140'-0"

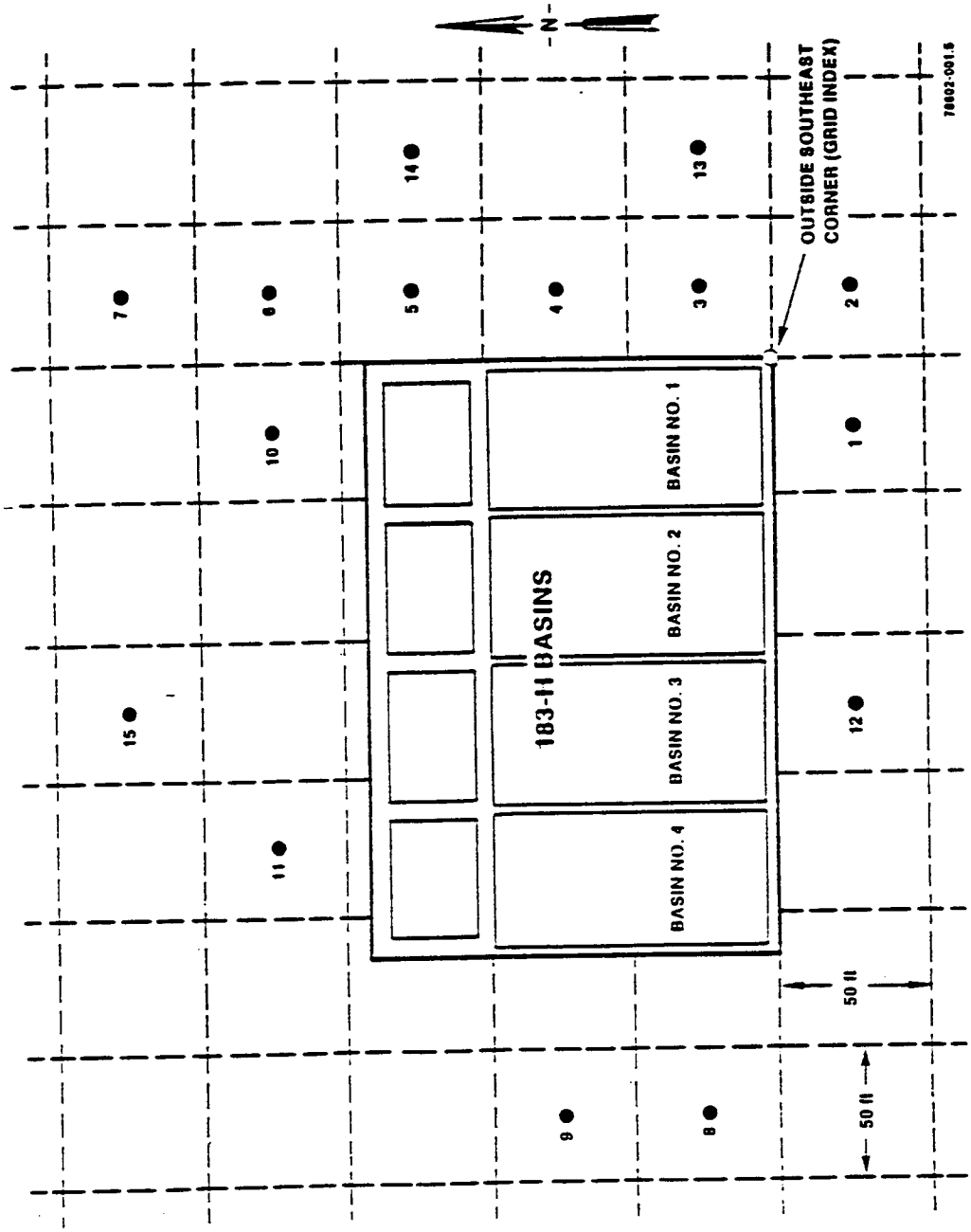
Cover Plan.



Cover Embankment Cross Section.


COMPONENT SATURATED HYDRAULIC CONDUCTIVITY
REVEGETATED COVER SIBERIAN AND THICKSPIKE WHEATGRASSES
3% SLOPE
3'-0"
SANDY SILT TO SILT
GEOTEXTILE
SP SAND DRAINAGE
3% SLOPE
1'-0"
GEOMEMBRANE
LOW-PERMEABILITY SOIL (SILTY SAND/BENTONITE CLAY)
2'-0"
FOUNDATION SOIL (SAND)
1'-0"
NATURAL GRADE
K ≤ 2.4 x 10⁻⁴ cm/s
VI
K ≥ 1 x 10⁻² cm/s
IV
K ≤ 1 x 10⁻⁷ cm/s
VI
K ≥ 1 x 10⁻² cm/s
IV
38802-055.3M

APPENDIX A-2

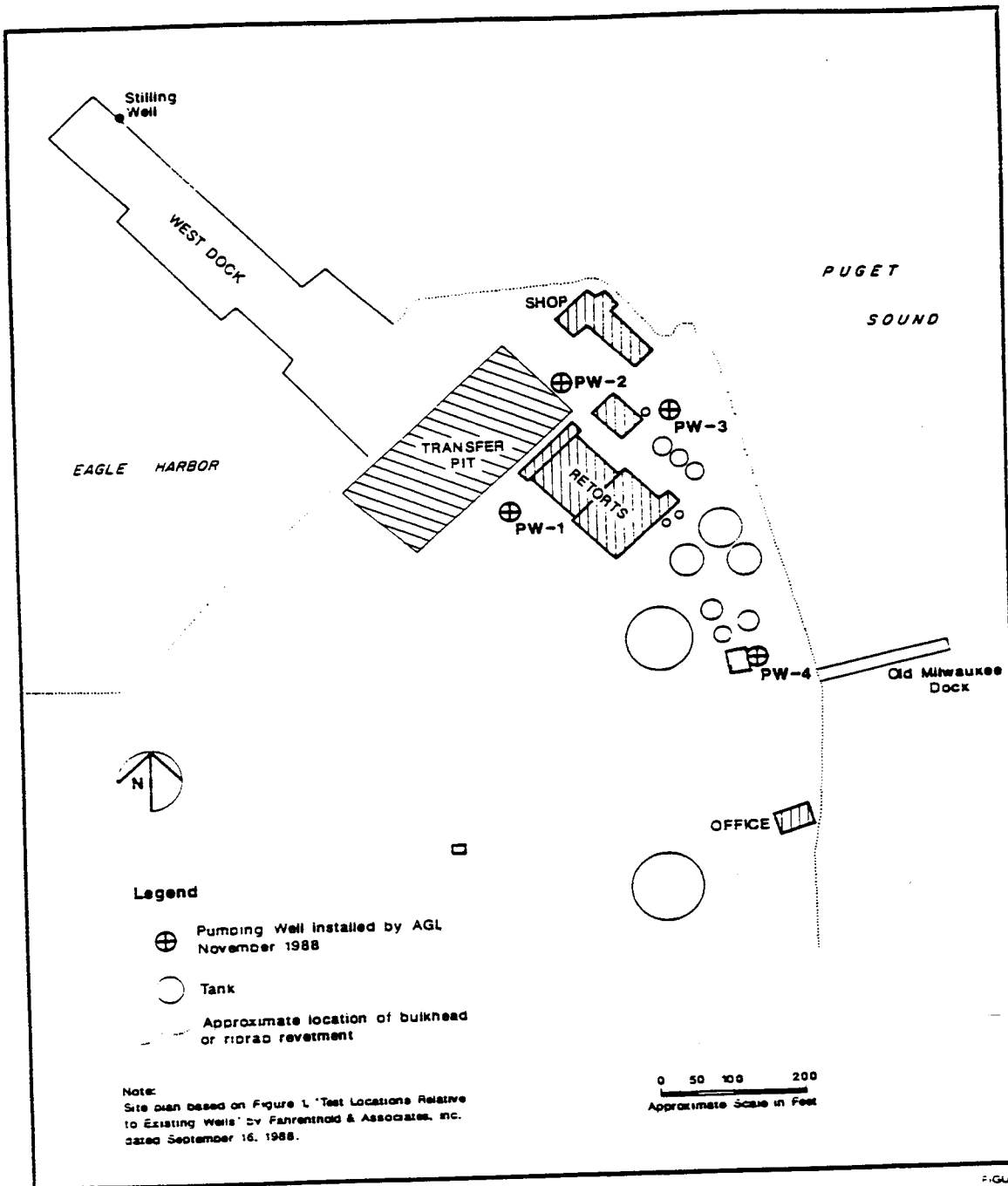


Soil Sample Locations.

APPENDIX A-2

APPENDIX: B

B-1: Pumping Well Location Maps
B-2: Soil Boring Data
B-3: Product Level Measurements
B-4: Evaluation Summary of Remediation Alternatives



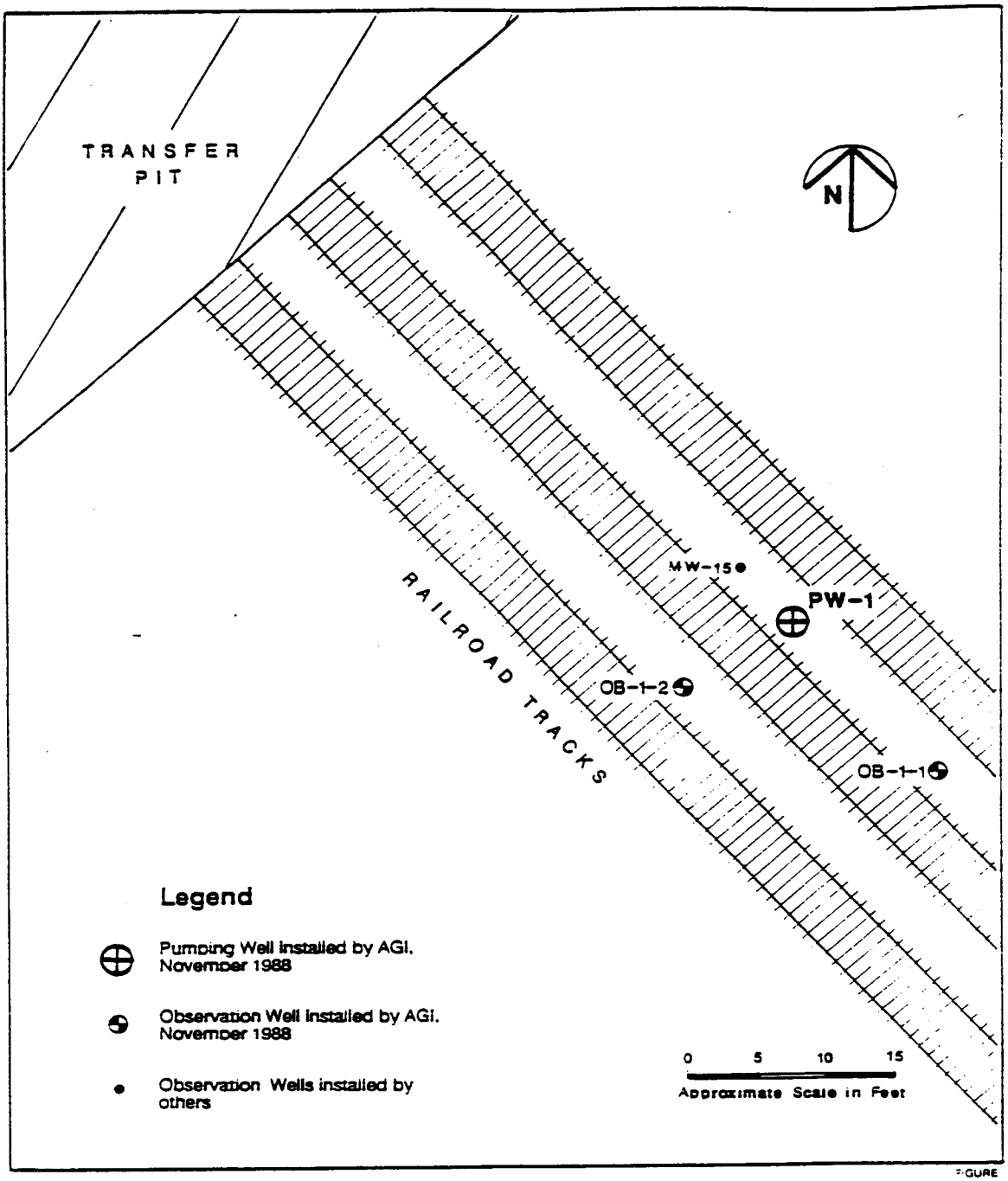
Applied Geotechnology Inc.
Geotechnical Engineering
Geology & Hydrogeology

Site Plan
Wyckoff Company
Eagle Harbor Facility

FIGURE **1**

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15,347.001	MB		13. December 88		

APPENDIX B-1



FIGURE

Applied Geotechnology Inc.
Geotechnical Engineering
Geology & Hydrogeology

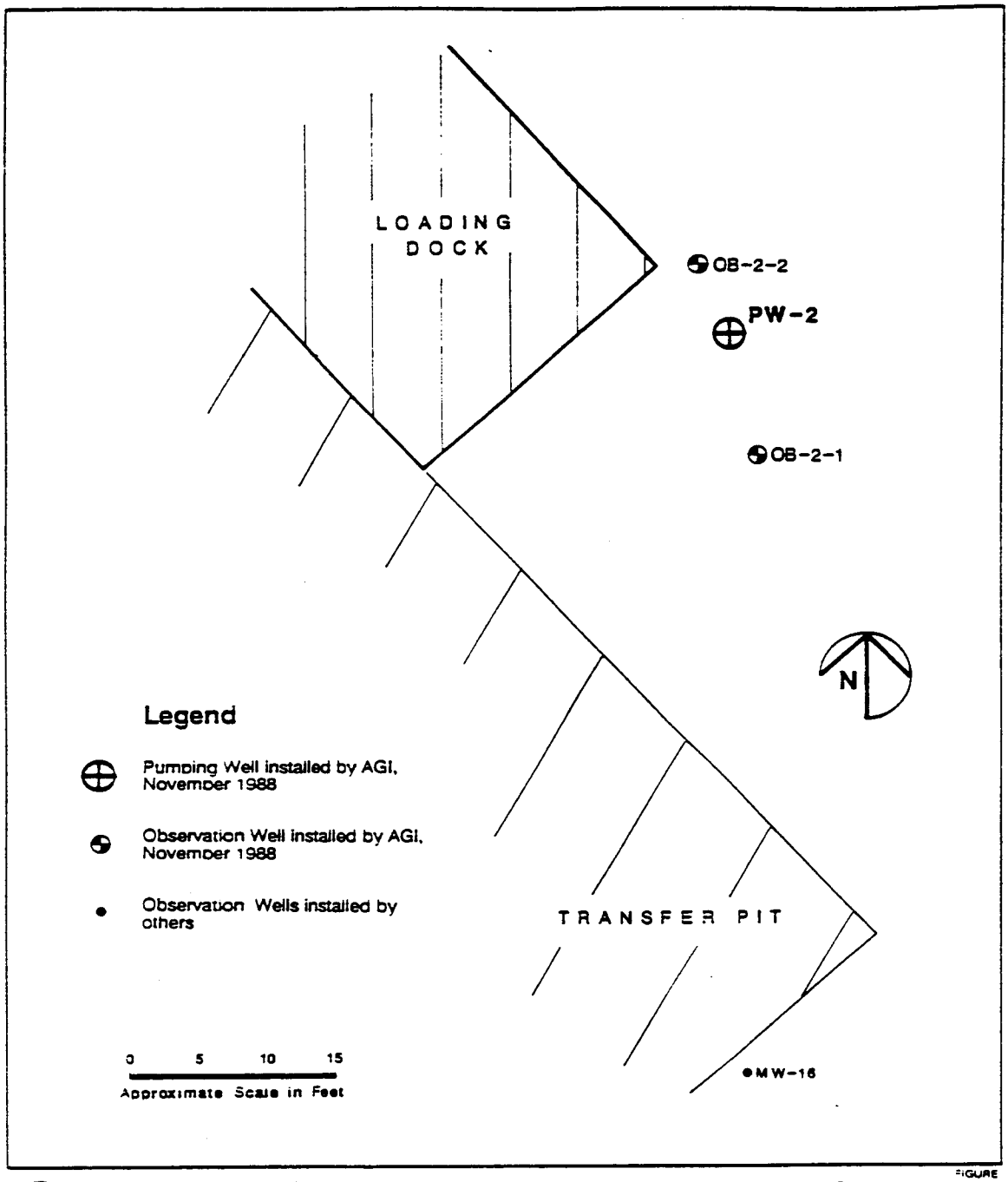
Pumping Well PW-1 Location Map

Wyckoff Company
Eagle Harbor Facility

2

JOB NUMBER	DRAWN		REVISED
15.347.001	NB		13 December 88

APPENDIX B-1



Applied Geotechnology Inc.
Geotechnical Engineering
Geology & Hydrogeology

Pumping Well PW-2 Location Map
Wyckoff Company
Eagle Harbor Facility

FIGURE
3

Job Number	Drawn	Approved	Date	Rev. Dec	Date
15.347.001	NB		13 December 88		

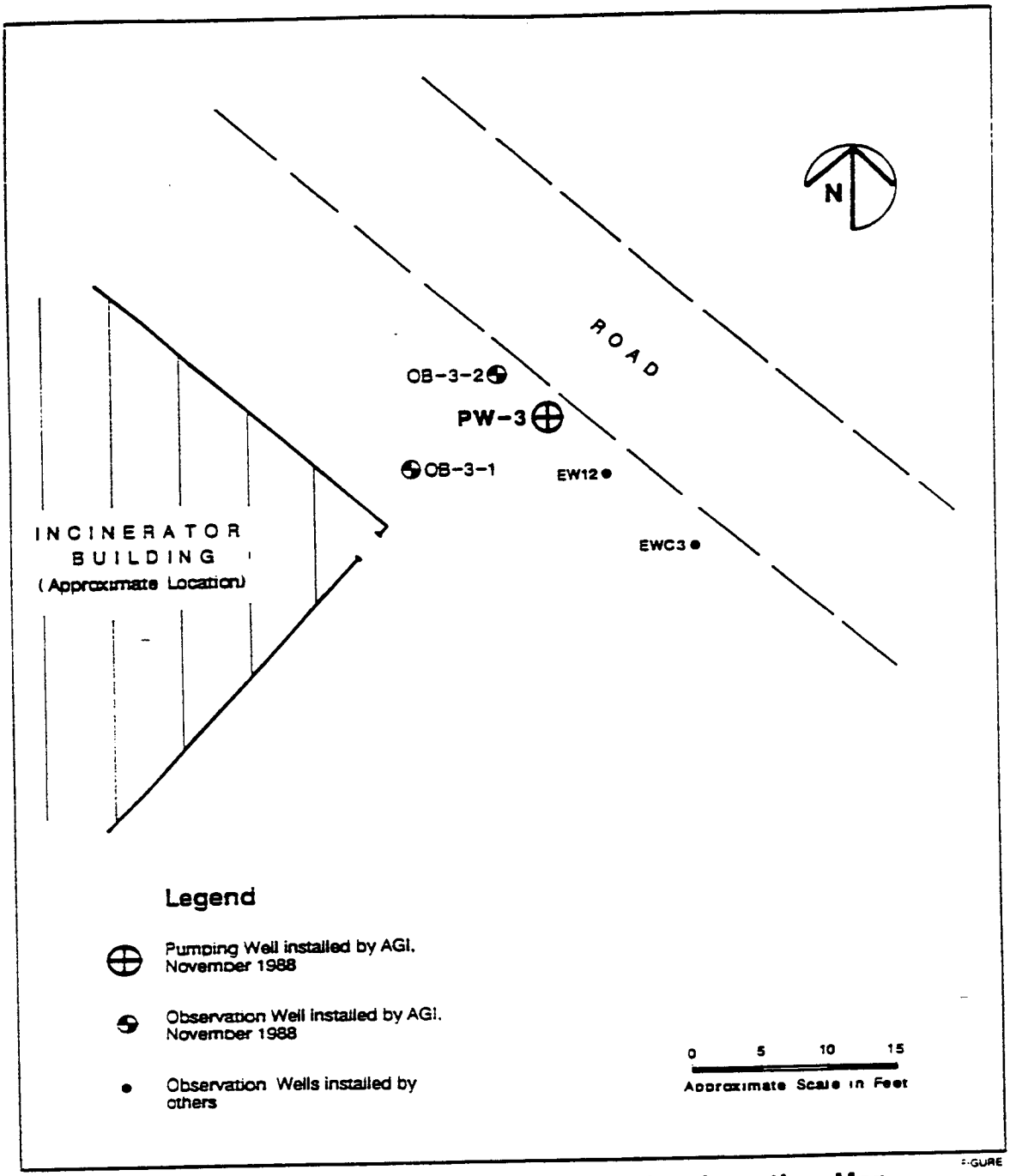


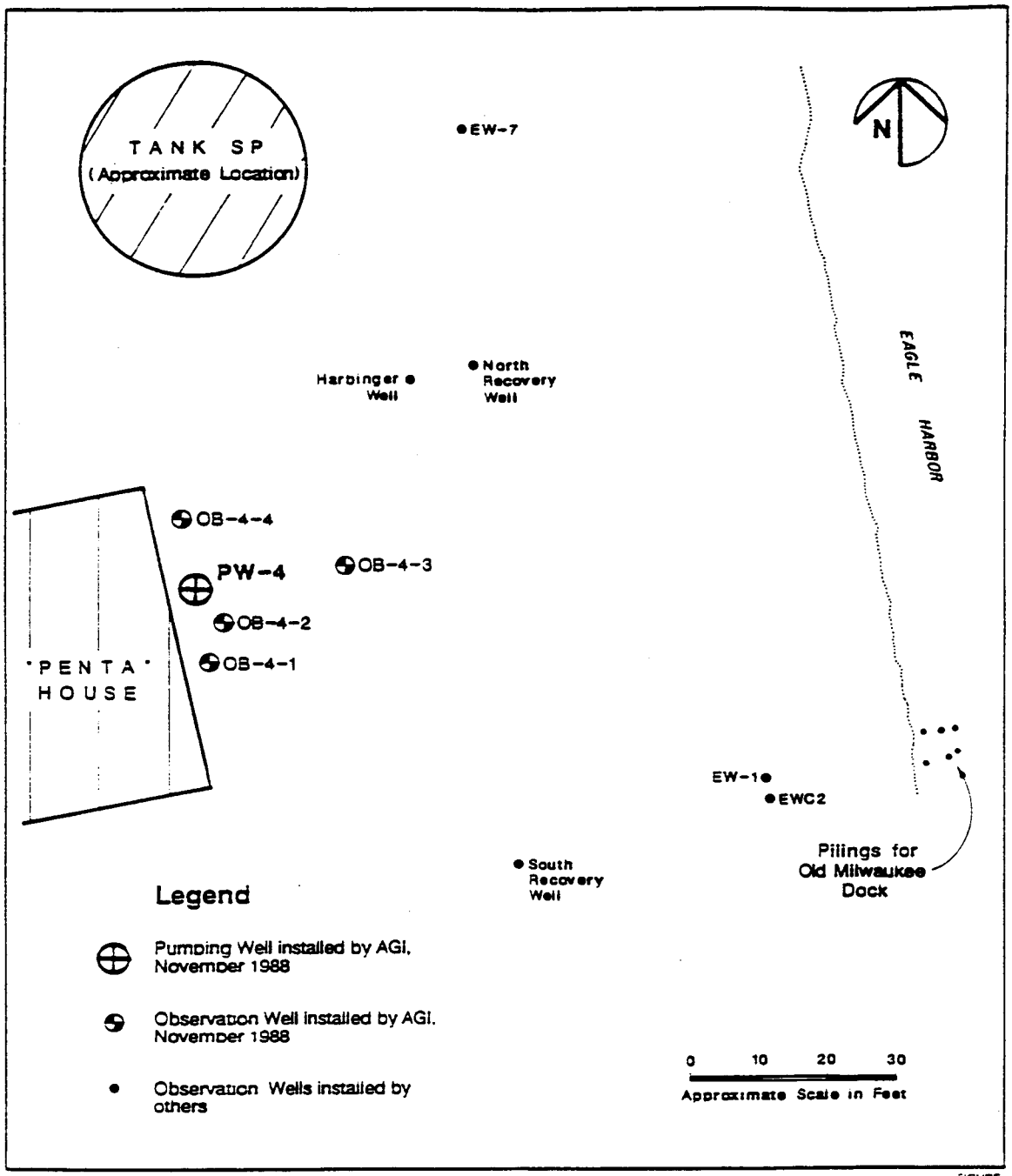
FIGURE 4

Applied Geotechnology Inc.
Geotechnical Engineering
Geology & Hydrogeology

Pumping Well PW-3 Location Map
Wyckoff Company
Eagle Harbor Facility

JOB NUMBER	DRAWN	DESIGNED	DATE	REVISED	DATE
15.347.001	MB		13 December 88		

APPENDIX B-1



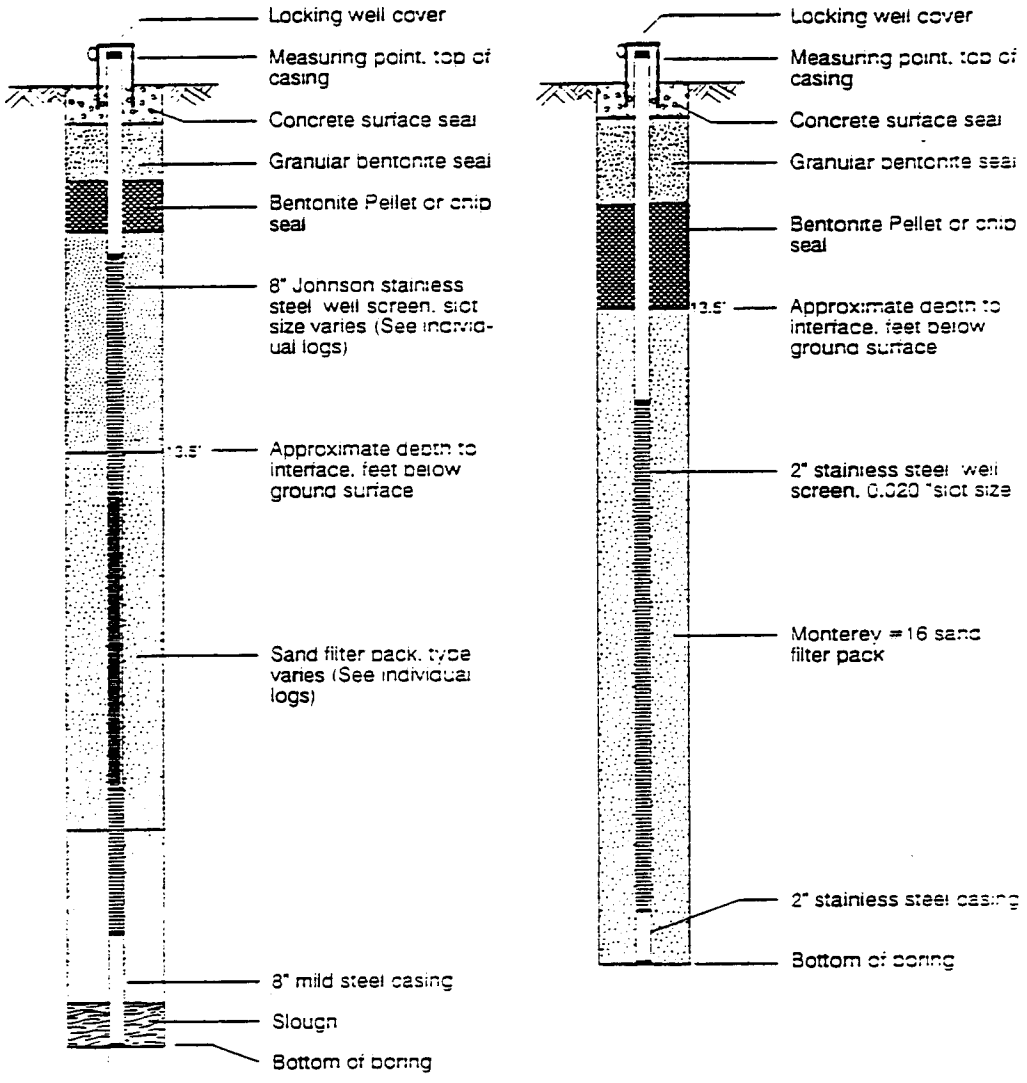
Applied Geotechnology Inc.
Geotechnical Engineering
Geology & Hydrogeology

Pumping Well PW-4 Location Map
Wyckoff Company
Eagle Harbor Facility

FIGURE 5

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	NB		13 December 88		

APPENDIX B-1



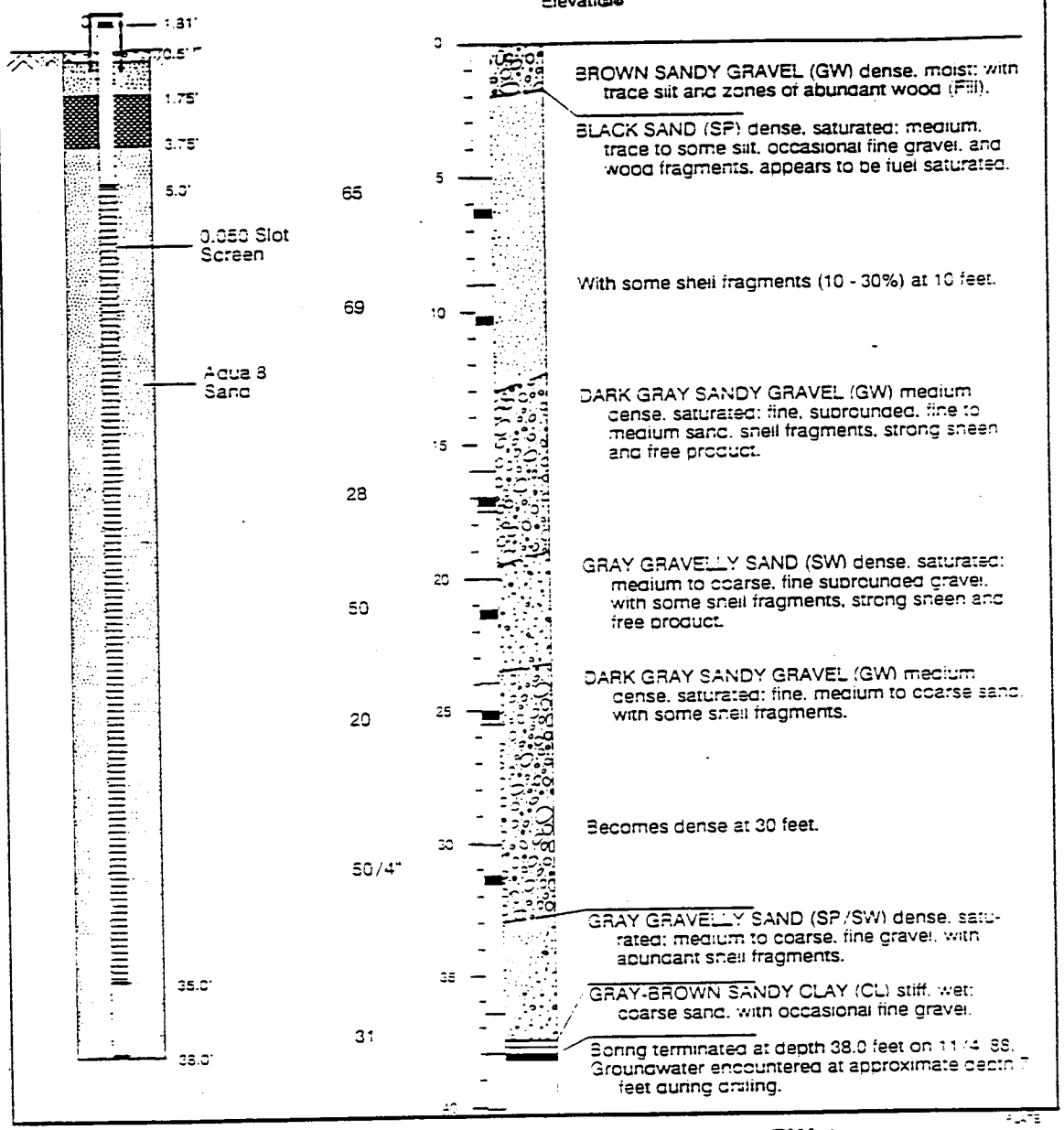
Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Well Construction Legend
Wyckoff Company
Eagle Harbor Facility

PLATE
B2

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.047.001	MB		15 December 88		

APPENDIX B-2



PLATE

Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring PW-1

Wyckoff Company
Eagle Harbor Facility

B3

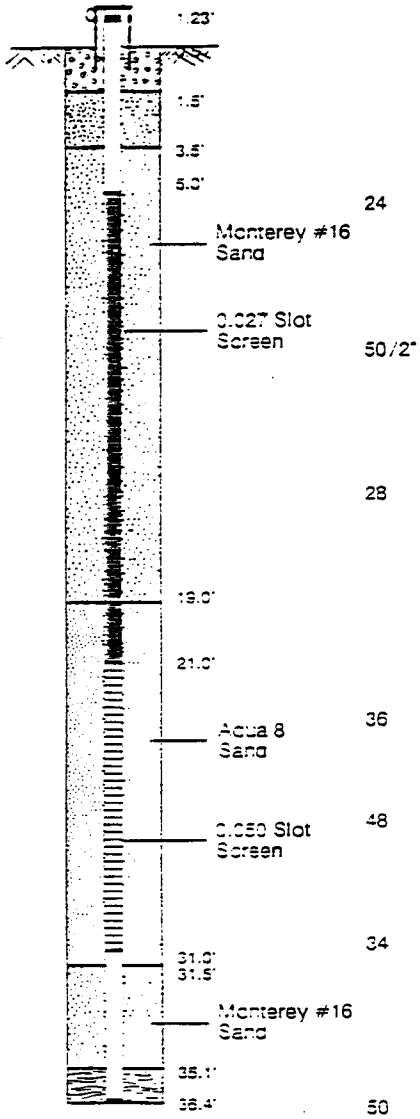
JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS NB		12 December 88		

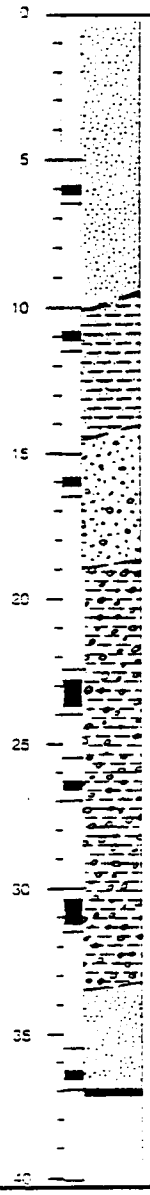
APPENDIX B-2

Well Installation

Equipment Bucyrus - Erie Cable Tool Rig

Land Surface Elevation Not Available Date 11/14/88





BROWN SAND (SP) medium dense, moist; medium, with silt, micaceous, occasional wood fragments and fine gravel.

Becomes black at approximate depth 2.5 feet.

Becomes saturated at depth 4 feet.

DARK GRAY SILTY SAND (SM) dense, saturated; medium, with trace fine to coarse gravel, shell fragments, and wood fragments, strong odor, small blebs of products.

DARK GRAY GRAVELLY SAND (SW) dense, saturated; medium, fine to coarse gravel, trace silt and shell fragments, strong odor, some apparent fuel product.

GRAY SILTY GRAVEL (GM) dense, saturated; fine to coarse, with trace clay and shell fragments, slight sheen.

Grades to trace silt, strong sheen at depth 26 feet.

GRAY SAND (SP) dense, saturated; medium to coarse, with fine gravel, trace silt and shell fragments, oily sheen.

Boring terminated at depth 37.3 feet on 11/[illegible]/88.

Groundwater encountered at approximate depth 4 feet during drilling.

PLATE

Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring PW-2

Wyckoff Company
Eagle Harbor Facility

B4

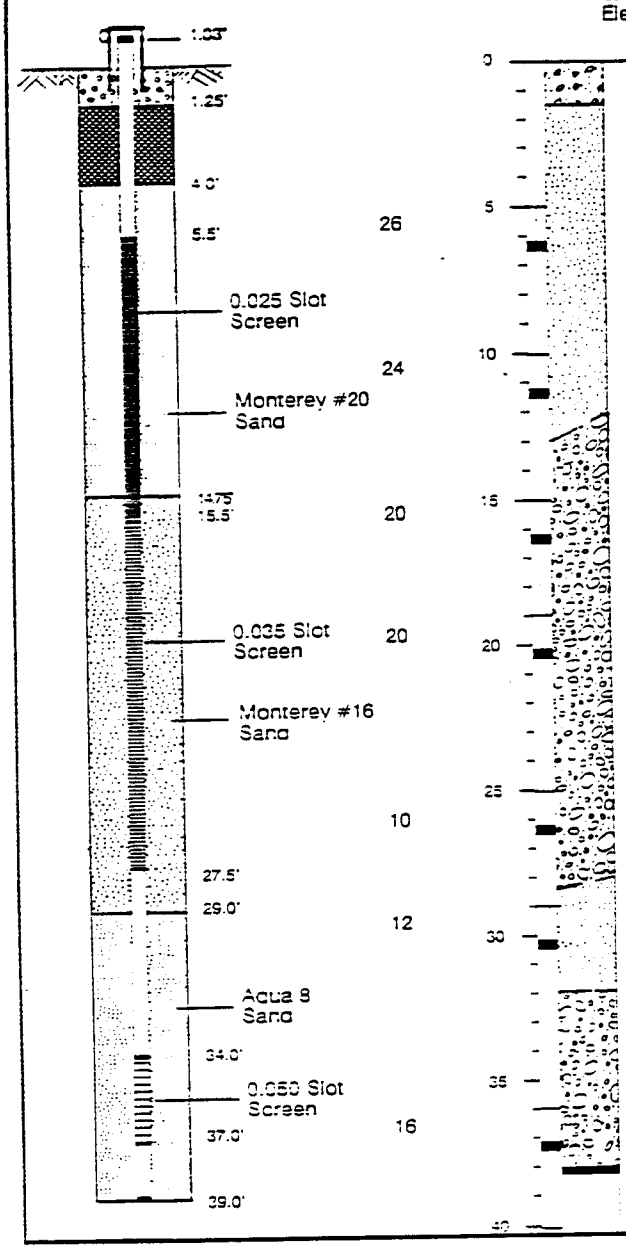
JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2

Well Installation

Equipment Bucyrus - Erie Cable Tool Rig

Land Surface Elevation Not Available Date 11/18/88



GRAY SANDY GRAVEL (GP)

GRAY SAND (SP) medium dense, saturated: fine to medium, strong odor, heavy sheen.

GRAY SANDY GRAVEL (GW) medium dense, saturated: fine to coarse, with medium to coarse sand, some shells, heavy product odor and sheen.

GRAY SAND (SP) medium dense, saturated: fine to medium, with some gravel, some shells, heavy product odor and sheen.

GRAY SANDY GRAVEL (GW) medium dense, saturated: medium to coarse sand, slight odor and sheen.

Boring terminated at depth 38.0 feet on 11/12/88. Groundwater encountered at approximate depth 6 feet during drilling.

Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring PW-3
Wyckoff Company
Eagle Harbor Facility

B5

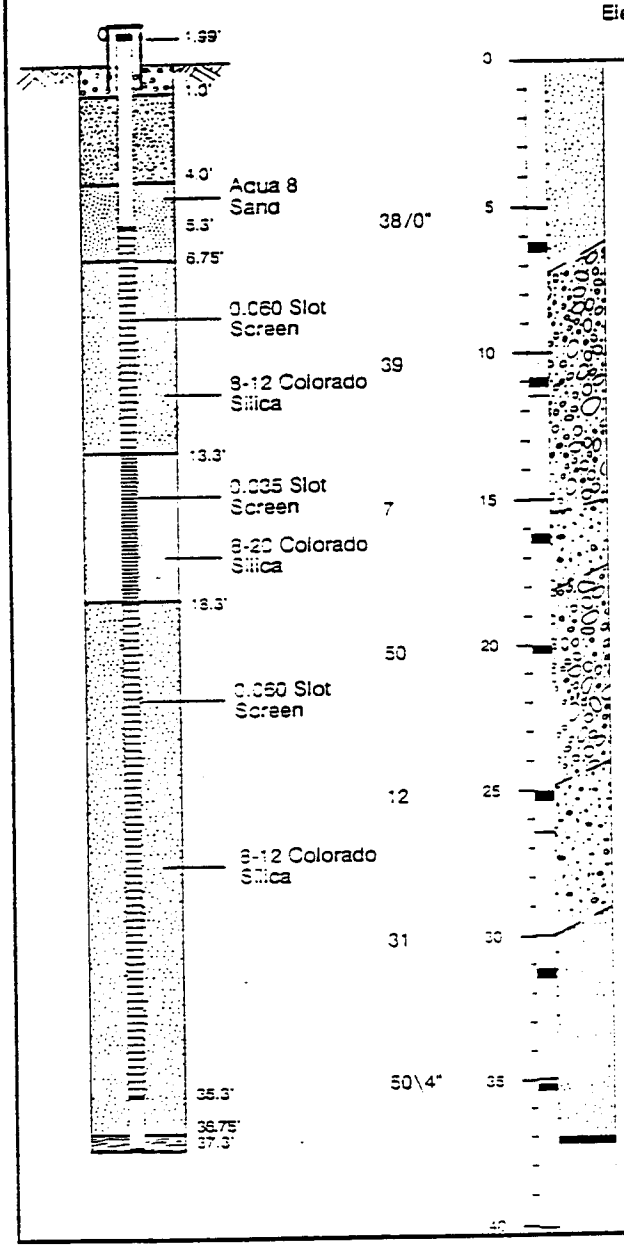
JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS, NB		12 December 88		

APPENDIX B-2

Well Installation

Equipment Bucyrus - Erie Cable Tool Rig

Land Surface Elevation Not Available Date 11/23/88



BROWN-GRAY SAND (SP) medium dense, wet; fine to medium, with trace shells and silt.

Becomes gravelly at depth 6 feet.

Free product noted at approximate depth 7.5 feet.

GRAY SANDY GRAVEL (GW) loose, saturated; rounded gravel, fine to coarse sand, trace silt, with some shells.

BLACK SAND (SW) loose, saturated; fine to coarse, with some fine gravel and trace shells, occasional free product blebs.

GRAY SANDY GRAVEL (GW) medium dense, saturated; rounded gravel, with trace silt, trace shells, moderate creosote odor and occasional product, belbs and sheen.

GRAY GRAVELLY SAND (SW) medium dense, saturated; fine to coarse, with zones of sandy fine to coarse gravel.

GRAY SAND (SP) medium dense, saturated; fine to medium, with trace silt, trace to some gravel, slight odor noted.

Boring terminated at depth 37 feet on 11/16/88.

Groundwater encountered at approximate depth 6 feet during drilling.

PLATE

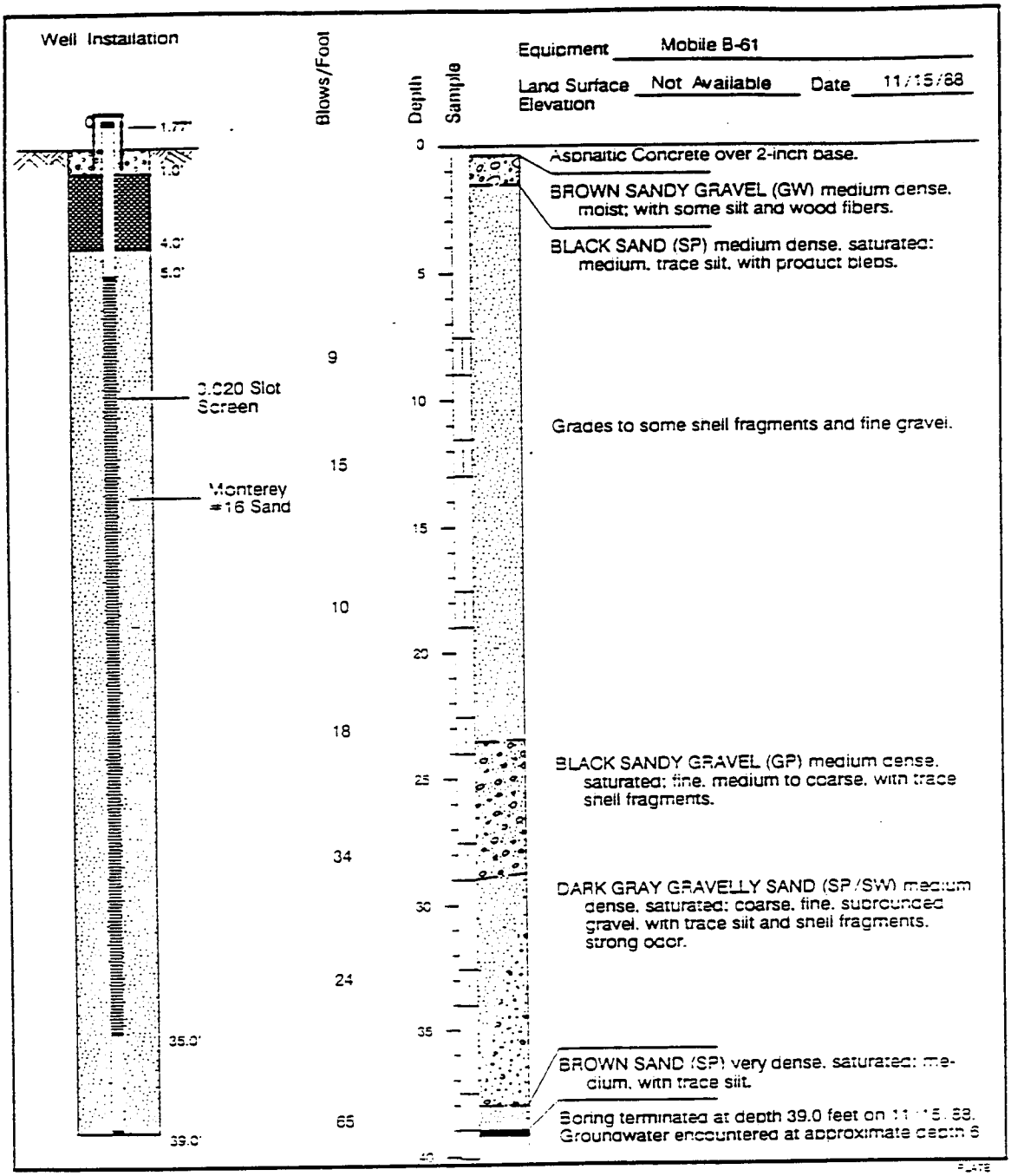
Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring PW-4
Wyckoff Company
Eagle Harbor Facility

B6

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



PLATE

Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

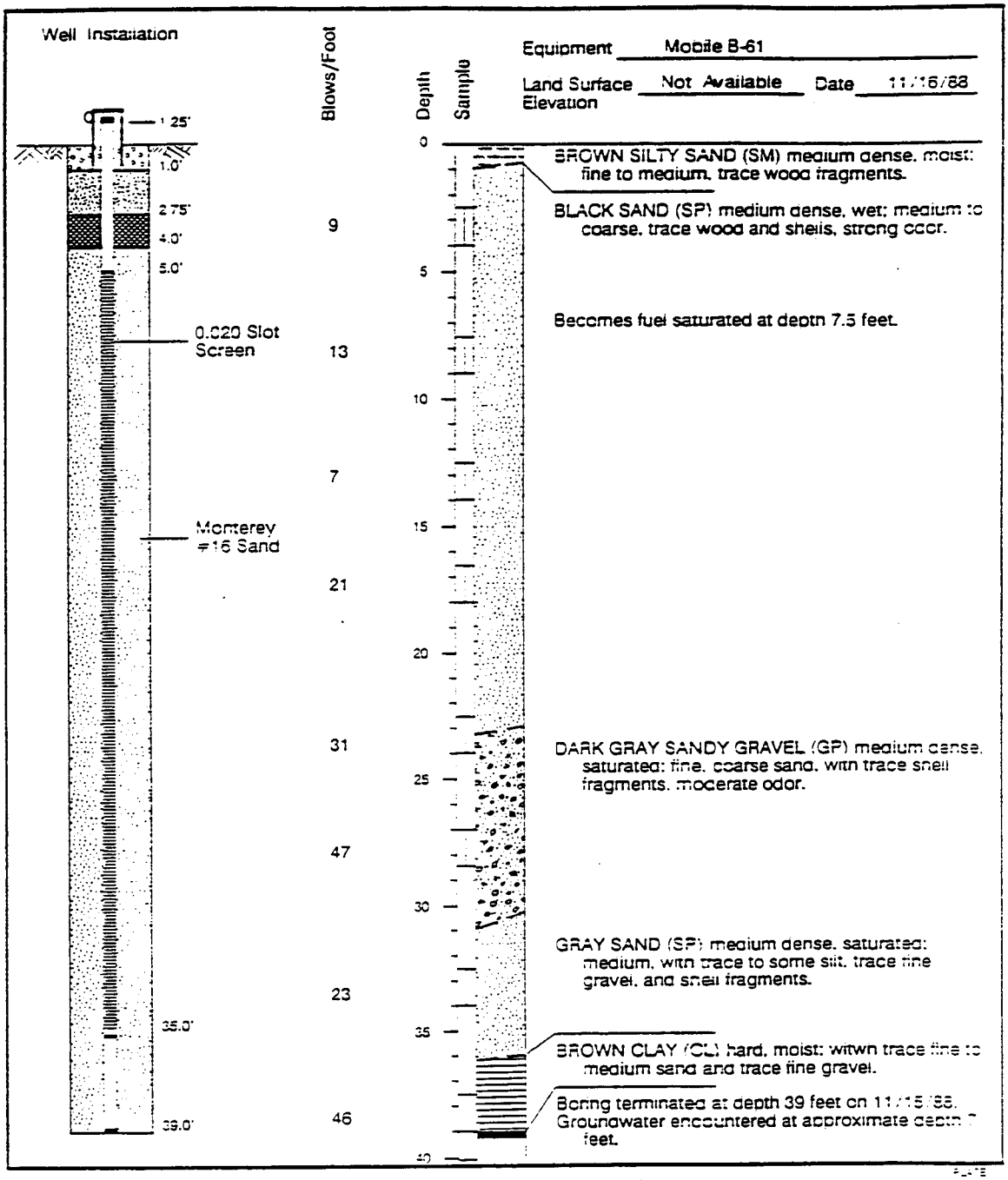
Log of Boring OB-1-1

Wyckoff Company
Eagle Harbor Facility

B7

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

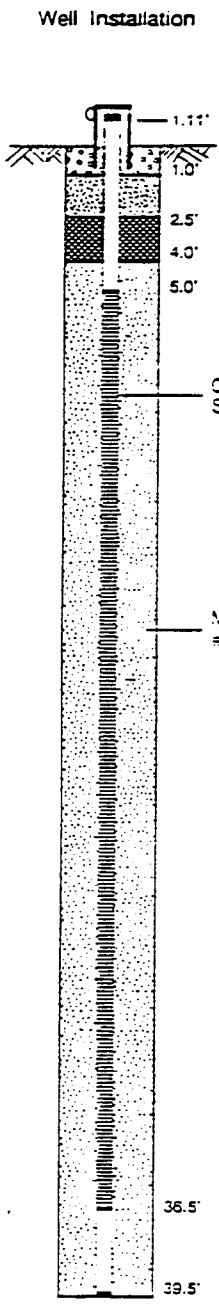
Log of Boring OB-1-2

Wyckoff Company
Eagle Harbor Facility

B8

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



Blows/Foot: 17, 10, 7, 38, 50, 32

Depth: 0, 5, 10, 15, 20, 25, 30, 35, 40

Sample

Equipment: Mobile B-61

Land Surface Elevation: Not Available Date: 11/16/88

Wood/Bark.

GRAY SAND (SP) medium dense, wet; fine to medium, with trace silt.

Grades with trace shell fragments at depth 18 feet.

GRAY SANDY GRAVEL (GW) very dense, saturated; fine, medium to coarse sand, with trace to some silt and shell fragments, with some free product.

Boring terminated at depth 39 feet on 11/16/88. Groundwater encountered at approximate depth 6 feet during drilling.

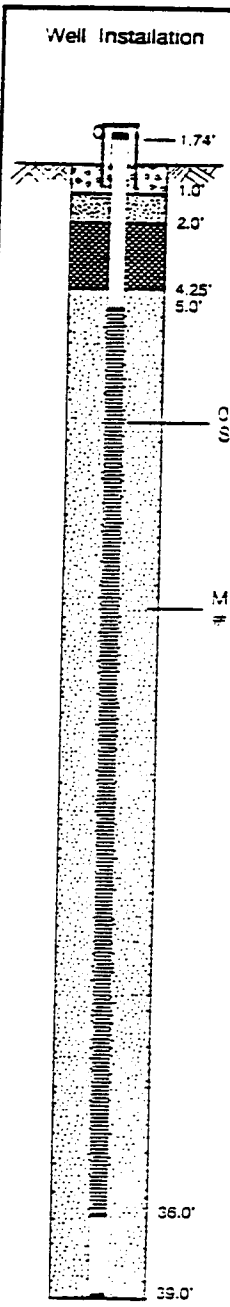
Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring OB-2-1
Wyckoff Company
Eagle Harbor Facility

PLATE B9

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
5.347.001	BS/NB		12 December 88		

APPENDIX B-2



Blows/Foot: 7, 15, 10, 31, 24, 58, 49

Depth / Sample

Equipment Mobile B-61

Land Surface Elevation Not Available Date 11/16.88

0 — BROWN SAND (SP) medium dense, moist; medium, with trace silt and subrounded gravels.

5

Becomes saturated with some product at depth 8 feet.

10

Product in discrete zones at depth 13 feet.

15 — DARK GRAY GRAVELLY SAND TO SANDY GRAVEL (SW/GP) medium dense, saturated; medium to coarse sand, fine gravel, with trace silt and shell fragments, some free product, strong sheen.

20

25

30 — Becomes very dense at depth 33 feet.

35

40 — Boring terminated at depth 39 feet on 11/16/88. Groundwater encountered at approximate depth 8.5 feet during drilling.

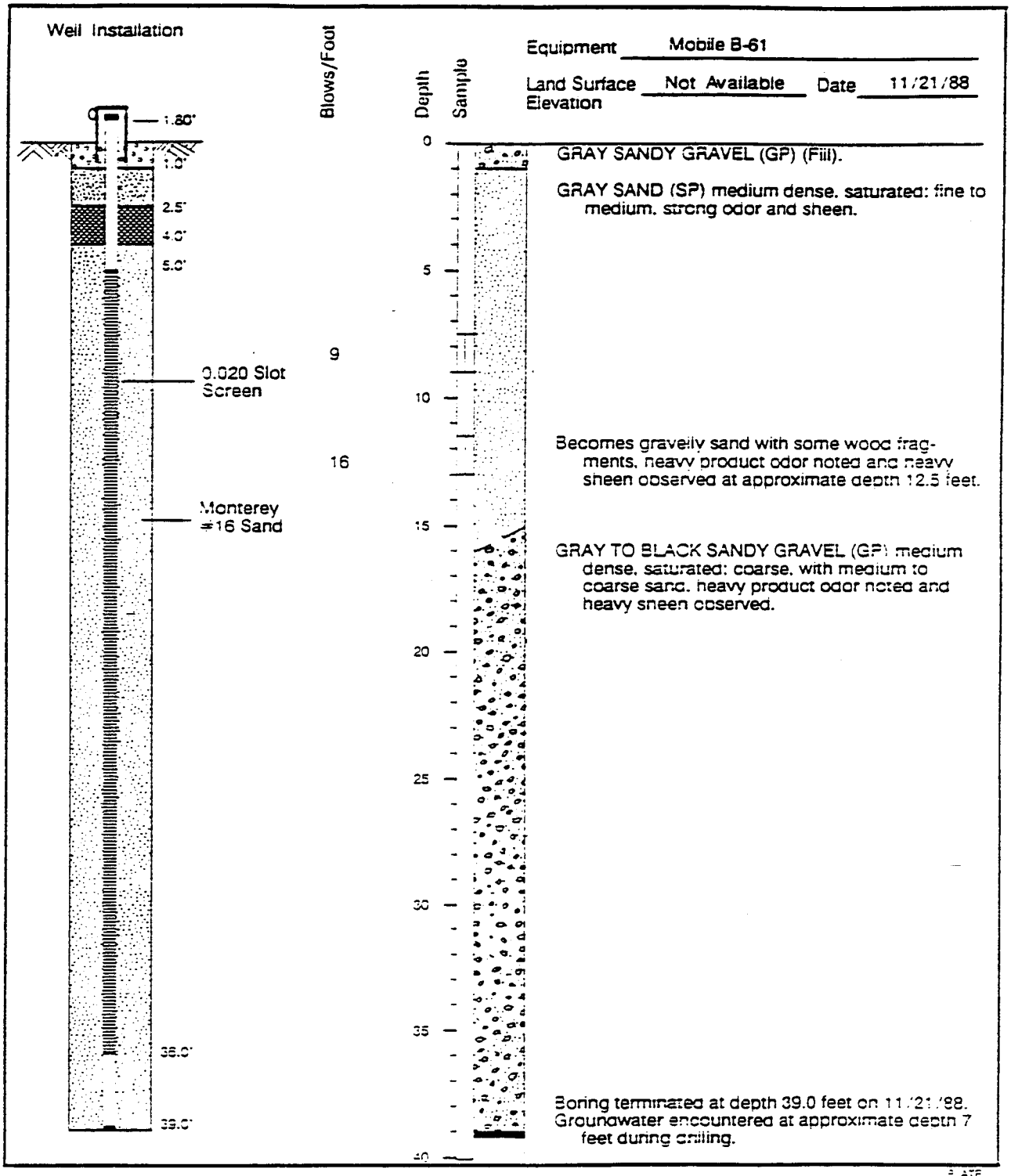
Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring OB-2-2
Wyckoff Company
Eagle Harbor Facility

B10

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

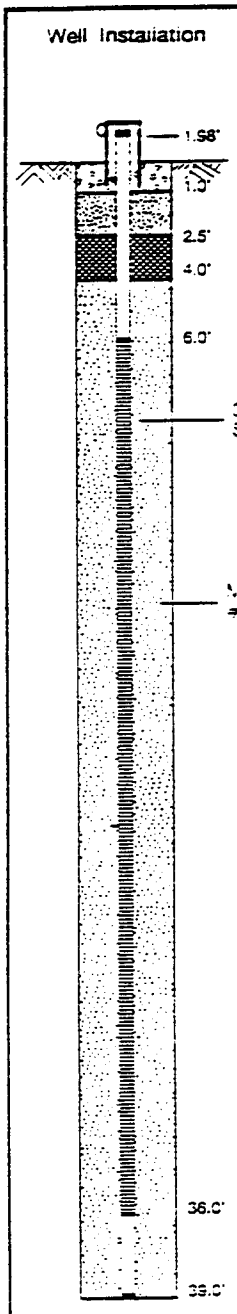
Log of Boring OB-3-1

Wyckoff Company
Eagle Harbor Facility

PLATE
B11

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



Blows/Foot: 11, 9, 20, 34, 14, 30, 36

Depth: 0, 5, 10, 15, 20, 25, 30, 35, 40

Sample

Equipment 4-inch Hollow Stem Auger

Land Surface Elevation Not Available Date 11/21/88

GRAY SANDY GRAVEL (GP) (Fill).

GRAY SAND (SP) loose, saturated; fine to medium, with heavy product odor noted and heavy sheen observed.

With trace organics (sawdust) at approximate depth 12.5 feet.

GRAY TO BLACK SANDY GRAVEL (GP) loose, saturated; with some shells, coarse, medium to coarse sand, heavy product odor noted and heavy sheen observed.

Boring terminated at depth 39.0 feet on 11/21/88. Groundwater encountered at approximate depth 7 feet during drilling.

PLATE

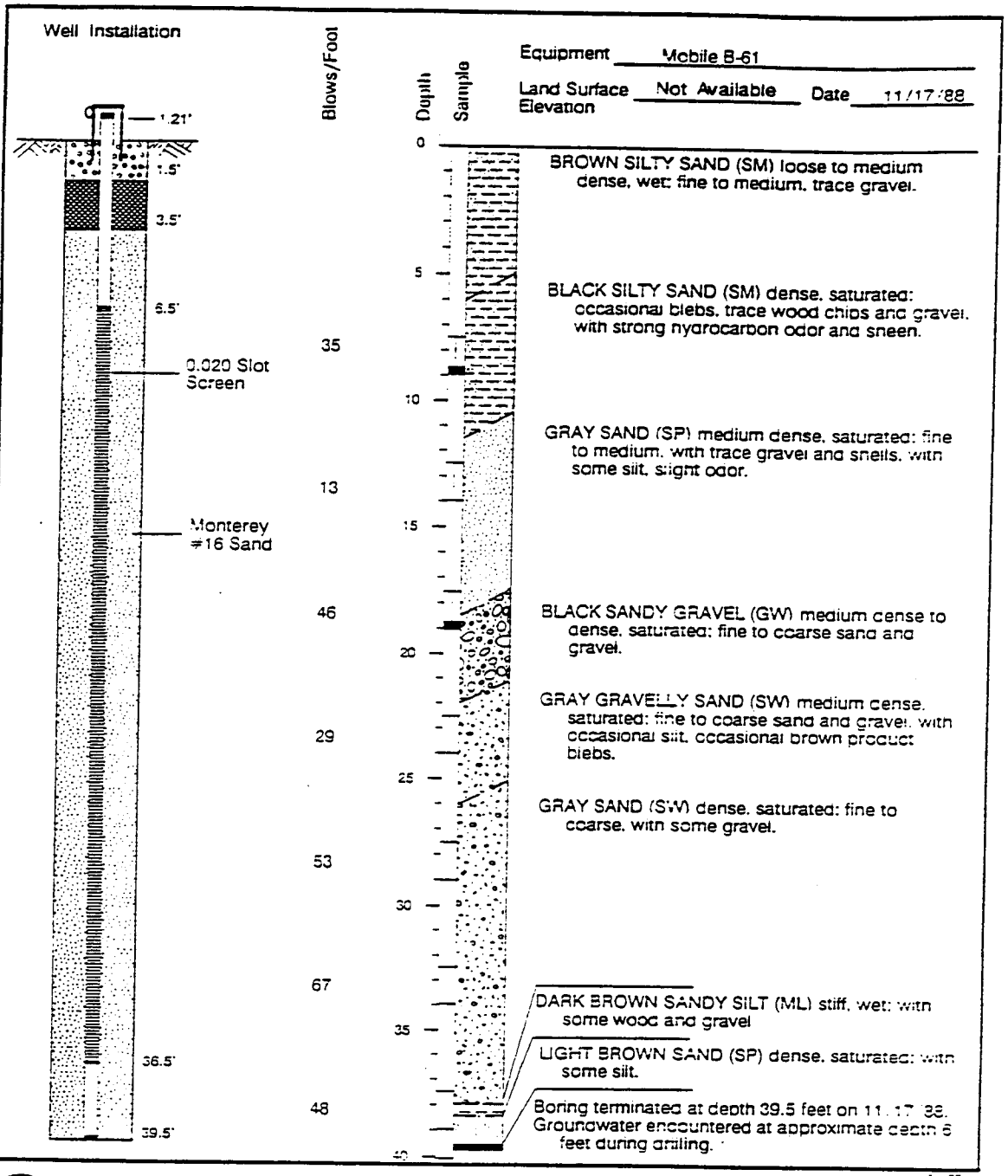
Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring OB-3-2
Wyckoff Company
Eagle Harbor Facility

B12

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



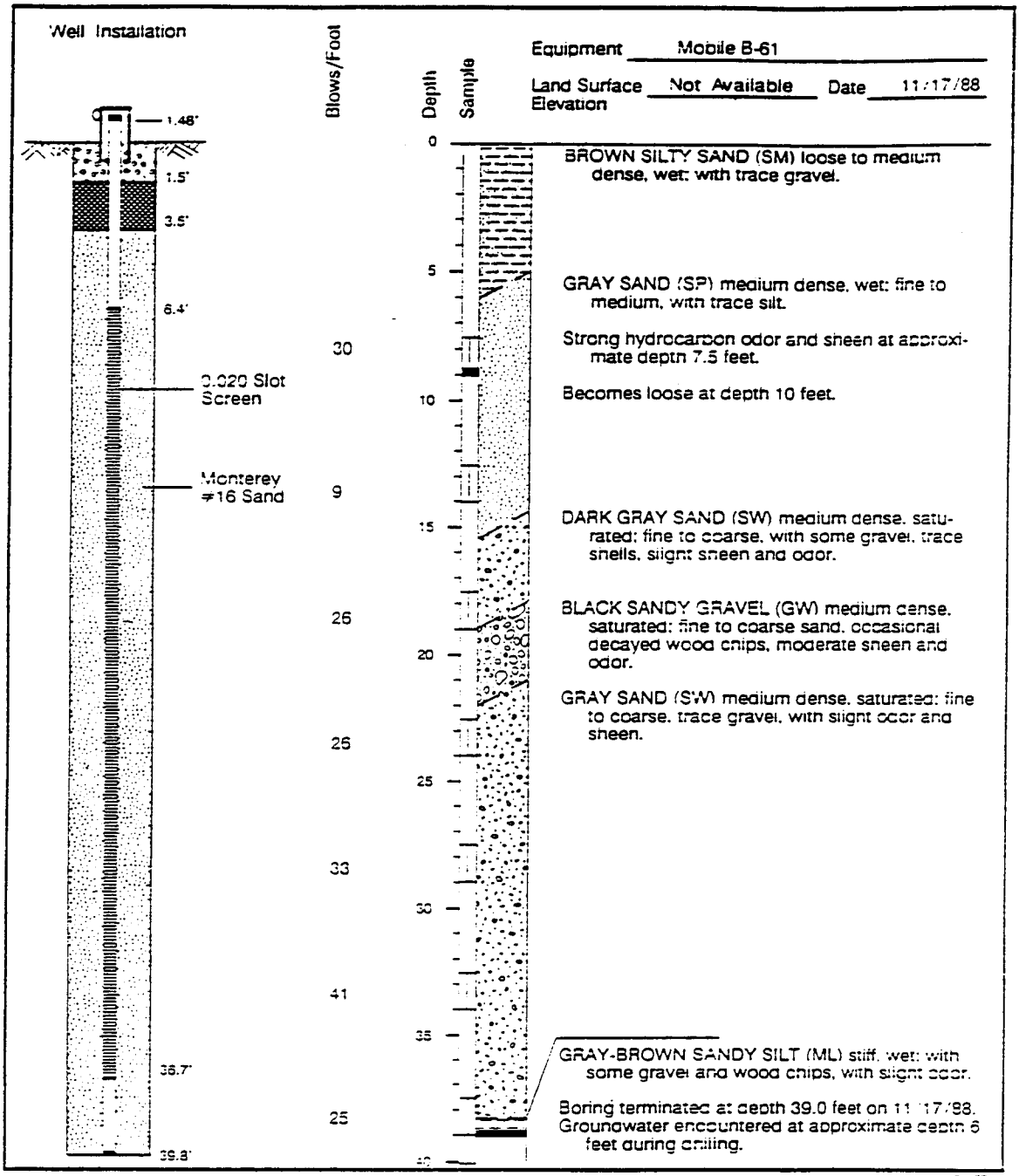
Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring OB-4-1
Wyckoff Company
Eagle Harbor Facility

B13

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
5347 001	PS/NB		12 December 88		

APPENDIX B-2



Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

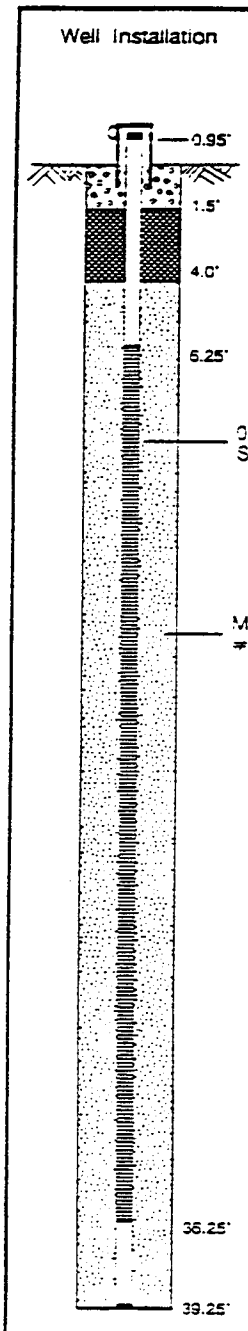
Log of Boring OB-4-2

Wyckoff Company
Eagle Harbor Facility

PLATE **B14**

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



Blows/Foot: 29, 19, 41, 34, 44, 50, 61

Depth: 0, 5, 10, 15, 20, 25, 30, 35, 40

Sample

Equipment Mobile B-61

Land Surface Elevation Not Available Date 11/18/88

BROWN SAND (SP) loose to medium dense, wet; with some silt.

GRAY SAND (SP) medium dense, wet; fine to medium, with trace silt, moderate odor and sheen.

BLACK GRAVELLY SAND (SW) medium dense, saturated; fine to coarse, with trace shells, strong hydrocarbon odor and sheen.

GRAY SAND (SW) medium dense, saturated; fine to coarse, trace gravel.

GRAY SILTY SAND (SM) dense, saturated; fine to coarse, with some fine to coarse gravel, trace shells, slight to moderate odor.

GRAY SAND (SW) very dense, saturated; fine to coarse, trace to some gravel,trace shells, slight odor.

Boring terminated at depth 39.3 feet on 11/18/88. Groundwater encountered at approximate depth 7 feet during drilling.

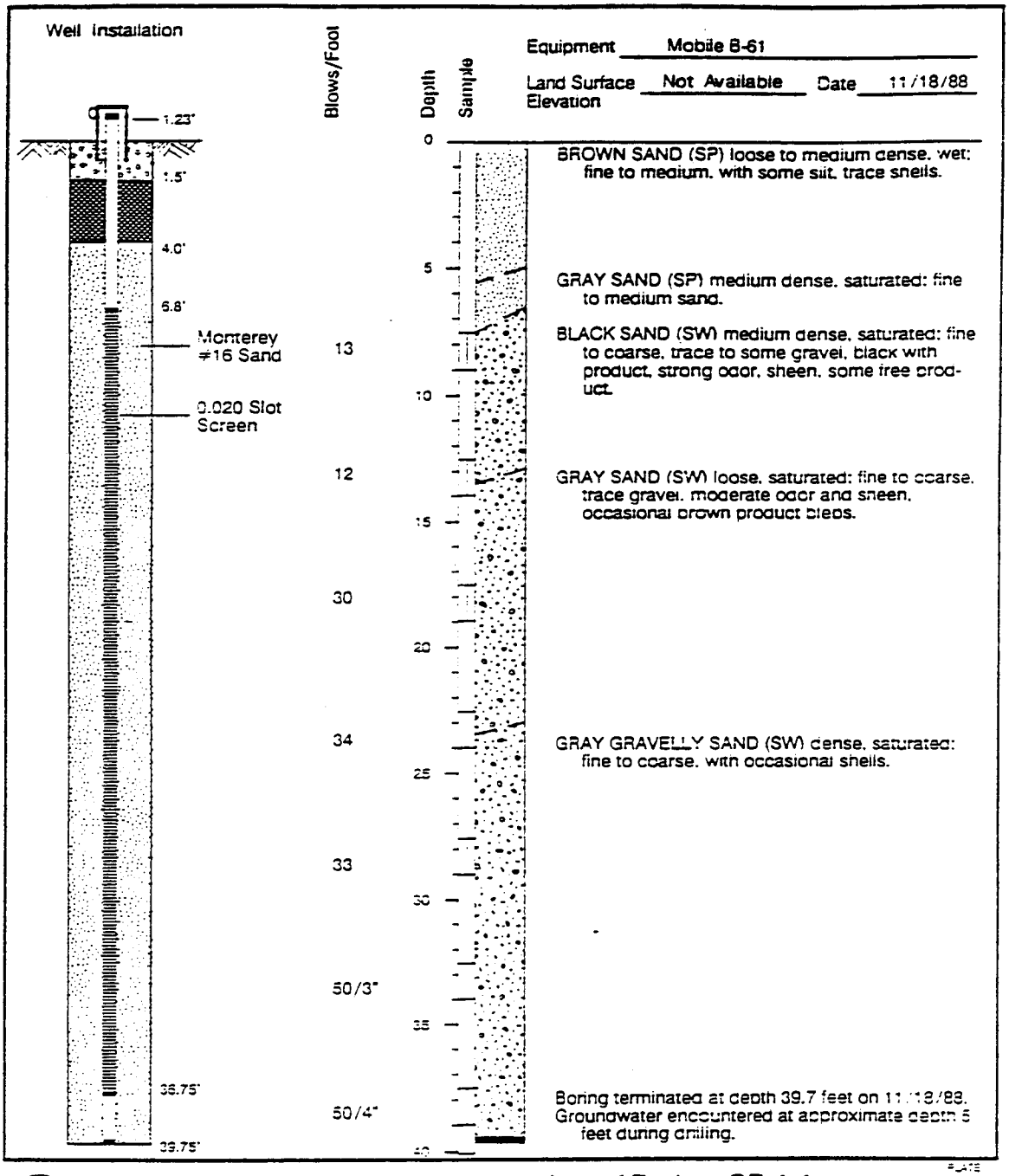
Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring OB-4-3
Wyckoff Company
Eagle Harbor Facility

PLATE B15

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2



Applied Geotechnology Inc.
Geological Engineering
Geology & Hydrogeology

Log of Boring OB-4-4

Wyckoff Company
Eagle Harbor Facility

PLATE **B16**

JOB NUMBER	DRAWN	APPROVED	DATE	REVISED	DATE
15.347.001	PS/NB		12 December 88		

APPENDIX B-2

Product Level Measurements
Wyckoff Company
Eagle Harbor Plant

Well	Date	Time	Depth to Fluid (feet)	Depth to Water (feet)	Product Thickness (feet)
PW-1	11-11-88	07:25	7.02	9.30	2.28
		12:15	7.35	9.90	2.55
		15:11	23.08	28.62	5.54
	11-14-88	08:04	7.2	9.65	2.45
	11-28-88	12:10	8.58	11.78	3.2
	11-29-88	13:45	8.95	13.63	4.68
	11-30-88	08:30	9.07	21.24	12.17
		11:30	20.72	30.67	9.95
		13:40	21.75	32.72	10.97
		14:40	22.4	30.56	8.16
		15:40	22.95	31.4	8.45
		19:00	23.66	31.55	7.89
OB-1-1	11-28-88	12:10	8.76	9	0.24
	11-29-88	13:45	8.56	8.73	0.17
	11-30-88	08:41	9.26	13	3.74
		11:30	12.26	13.76	1.5
		13:40	12.74	14.74	2
		14:40	13.03	15.42	2.39
		15:40	13.34	16.14	2.8
		19:00	13.68	17.51	3.83
OB-1-2	11-28-88	12:10	8.26	8.7	0.44
	11-29-88	13:45	9.14	9.21	0.07
	11-30-88	08:45	8.8	8.98	0.18
		11:30	13.15	13.3	0.15
		13:40	13.64	13.95	0.31
		14:40	13.95	14.51	0.56
		15:40	14.24	15.05	0.81
		19:00	14.63	17.33	2.7
MW-15	11-11-88	08:10	6.21	6.21	0.00
		12:15	6.20	6.22	0.02
	11-14-88	08:06	6.19	6.21	0.02
		10:00	8.84	8.90	0.06
	11-29-88	13:45	6.01	6.08	0.07
	11-30-88	08:50	6.25	6.40	0.15
		11:30	9.08	9.15	0.07
		13:40	9.35	9.74	0.39
		14:40	9.92	10.58	0.66
		15:40	9.68	10.65	0.81
		19:00	9.95	11.49	1.53

Product Level Measurements (Cont.)
Wyckoff Company
Eagle Harbor Plant

Well	Date	Time	Depth to Fluid (feet)	Depth to Water (feet)	Product Thickness (feet)
PW-2	11-17-88	11:00	4.32	4.32	0
		14:25	10.98	10.98	0
	11-28-88	11:36	4.84	4.85	0.01
	12-1-88	16:29	8.22	<8.22	<0.01
	12-9-88	10:35	7.25	7.26	0.01
08-2-1	11-17-88	11:12	4.47	4.47	0
		14:25	8.5	8.5	0
	11-28-88	11:36	6.35	6.35	0
	12-1-88	16:27	9.7	9.7	0
	12-9-88	10:43	8.78	8.78	sheen
08-2-2	11-17-88	11:05	4.91	4.95	0.04
		14:25	9.09	9.16	0.07
	11-28-88	11:36	6.22	9.62	3.4
	12-1-88	16:32	9.71	12.2	2.49
	12-9-88	10:32	8.62	10.5	1.98
PW-3	11-21-88	16:46	7.97	7.97	0
	11-28-88	11:10	7.65	7.65	sheen
	12-8-88	08:10	9.09	9.09	sheen
	12-9-88	09:31	17.32	<17.32	<0.01
08-3-1	11-21-88	16:47	7.52	7.52	0
	11-28-88	11:10	6.88	<6.88	<0.01
	12-8-88	08:07	7.89	7.89	0
	12-9-88	09:30	10.2	10.2	0
08-3-2	11-21-88	16:48	7.72	7.72	0
	11-28-88	11:10	6.65	6.65	0
	12-8-88	08:08	8.04	8.04	0
	12-9-88	09:32	11.38	11.38	0

Product Level Measurements (Cont.)
Wyckoff Company
Eagle Harbor Plant

Well	Date	Time	Depth to Fluid (feet)	Depth to Water (feet)	Product Thickness (feet)
PW-6	11-28-88	10:30	7.12	7.12	0
	12-5-88	16:32	9.6	9.6	0
	12-6-88	09:10	12.52	12.52	0
		10:20	12.73	<12.73	<0.01
		16:10	12.23	12.27	0.04
	12-9-88	09:54	9.23	9.23	sheen
OB-4-1	11-28-88	10:30	6.17	6.17	0
	12-5-88	16:38	8.95	9.80	0.95
	12-6-88	09:10	10.94	11.45	0.51
		10:20	11.18	11.69	0.51
		16:10	10.57	11.11	0.54
	12-9-88	09:58	8.57	8.88	0.31
OB-4-2	11-28-88	10:30	5.62	5.88	0.26
	12-5-88	16:40	8.93	9.00	0.07
	12-6-88	09:10	11.26	11.27	0.01
		10:20	11.46	11.48	0.02
		16:10	10.91	10.91	0.00
	12-9-88	09:56	8.44	8.44	0.00
OB-4-3	11-28-88	10:30	6.39	6.80	0.41
	12-5-88	16:36	8.89	8.89	0.00
	12-6-88	09:10	10.32	<10.32	<0.01
		10:20	10.48	<10.48	<0.01
		16:10	9.87	9.87	0.00
	12-9-88	10:02	8.44	8.44	0.00
OB-4-4	11-28-88	10:30	6.70	6.70	0.00
	12-5-88	16:34	9.35	9.46	0.11
	12-6-88	09:10	11.09	11.19	0.10
		10:20	11.24	11.32	0.08
		16:10	10.66	10.73	0.07
	12-9-88	9:52	8.92	8.92	0.00

EVALUATION OF REMEDIAL ALTERNATIVES FOR EE/CA SCREENING FACTORS

Alternative	Timeliness	Screening Factors Protect Public Health	Protect Environment	Retained for Evaluation
Alternative 1 No action	No implementation required	Unacceptable public health risks are not reduced or eliminated	Contaminant migration offsite is uncontrolled. Unacceptable ecological risks not reduced or eliminated	No
Alternative 2 Active product recovery and groundwater treatment	Can be implemented within 1 yr	Public health risks associated with Extremely Hazardous Waste are reduced but not eliminated	Intermediate source of contamination is reduced. Contaminant migration offsite is uncontrolled	No
Alternative 3 Slurry wall, active product recovery, and groundwater treatment	Can be implemented within 1 yr	Public health risks associated with Extremely Hazardous Waste are reduced Exposure of public to seepage in intertidal area is greatly reduced	Nearly all seepage stopped. Exposure to marine organisms in the intertidal area is reduced. Sediment contamination will be continuing threat to shellfish	Yes
Alternative 4 Sheet piling, active product recovery, and groundwater treatment	Can be implemented within 1 yr	Public health risks associated with Extremely Hazardous Waste are reduced Exposure of public to seepage in intertidal area is greatly reduced Restricted beach access reduces exposure to public	Seepage will be stopped and sediments in intertidal area will be contained, greatly reducing environmental risks	Yes
Alternative 5 Barrier wells, active product recovery, and groundwater treatment	Can be implemented within 1 yr	Public health risks associated with Extremely Hazardous Waste are reduced Exposure of public to seepage in intertidal area is greatly reduced	Nearly all seepage will be stopped. Environmental risks will be reduced by decreasing source of sediment contamination Exposure to marine organisms in the intertidal area is reduced. Some backflushing of marine sediments achieved, reducing sediment contamination as threat	Yes

EVALUATION OF REMEDIAL ALTERNATIVES
EE/CA SELECTION CRITERIA

Criteria	Alternative 3 Slurry Wall, Product Recovery, and Groundwater Treatment	Alternative 4 Sheet Piling, Product Recovery, and Groundwater Treatment	Alternative 5 Barrier Wells, Product Recovery, and Groundwater Treatment
RELIABILITY/TECHNICAL FEASIBILITY			
Effectiveness	Effective physical wall, stops majority of seepage Reduction in floating and sinking product Sediments in the intertidal area are not affected Acceptable discharge of treated groundwater	Potentially effective physical wall, integrity at depth is uncertain Reduction in floating and sinking product Provides containment of contaminated sediments in the intertidal area Acceptable discharge of treated groundwater	Effective hydraulic barrier Enhanced reduction in floating and sinking product Potential conversion of floating product into sinking product May draw contaminants from nearshore sediments Acceptable discharge of treated groundwater

(Continued)

Criteria	Alternative 3 Slurry Wall, Product Recovery, and Groundwater Treatment	Alternative 4 Sheet Piling, Product Recovery, and Groundwater Treatment	Alternative 5 Barrier Wells, Product Recovery, and Groundwater Treatment
Constructability	Poor accessibility in the proposed construction area Requires excavation and disposal of large volume of contaminated soils Requires imported soil and attapulgite clay Requires pilot compatibility testing	Good accessibility in the intertidal area Installation from a barge Need product release control during construction Cobbles, boulders, riprap may affect integrity	Easy to install, good accessibility Requires disposal of small quantity of soils from drilling
Environmental Impacts	Short term exposure to inhalation of fugitive dusts and direct contact during construction Possible impacts due to disposal of contaminated soil	Minor short term exposure by direct contact during construction Product release from sediments during construction	Minimal environmental impacts
Reliability	Product recovery and groundwater treatment are proven technologies Slurry walls have been used for containing creosote seepage at other sites	Product recovery and groundwater treatment are proven technologies Reliability is uncertain under tidal influence	Product recovery and groundwater treatment are proven technologies Barrier wells are proven technology for leachate plume control

(Continued)

Criteria	Alternative 3 Slurry Wall, Product Recovery, and Groundwater Treatment	Alternative 4 Sheet Piling, Product Recovery, and Groundwater Treatment	Alternative 5 Barrier Wells, Product Recovery, and Groundwater Treatment
Useful life	Several years to several decades	Up to 40 yr with appropriate protection	Several years to several decades
ADMINISTRATIVE/MANAGERIAL FEASIBILITY	Noise and fugitive dust pose public nuisance during construction Requires health and safety protection for offsite disposal	Noise and product release pose public nuisance during construction Construction in intertidal area possibly subject to regulation of the Shoreline Management Act	Noise during well drilling poses public nuisance
REASONABLE COST	Capital cost $2,158K; O&M costs $691K[a] Exceeds the ERA budget	Capital cost $2,024K; O&M costs $700K[a] Exceeds the ERA budget	Capital cost $895K; O&M costs $3,012K[a] Under the ERA budget

[a] Present worth value based on 5 yr operation and a 10 percent interest rate.

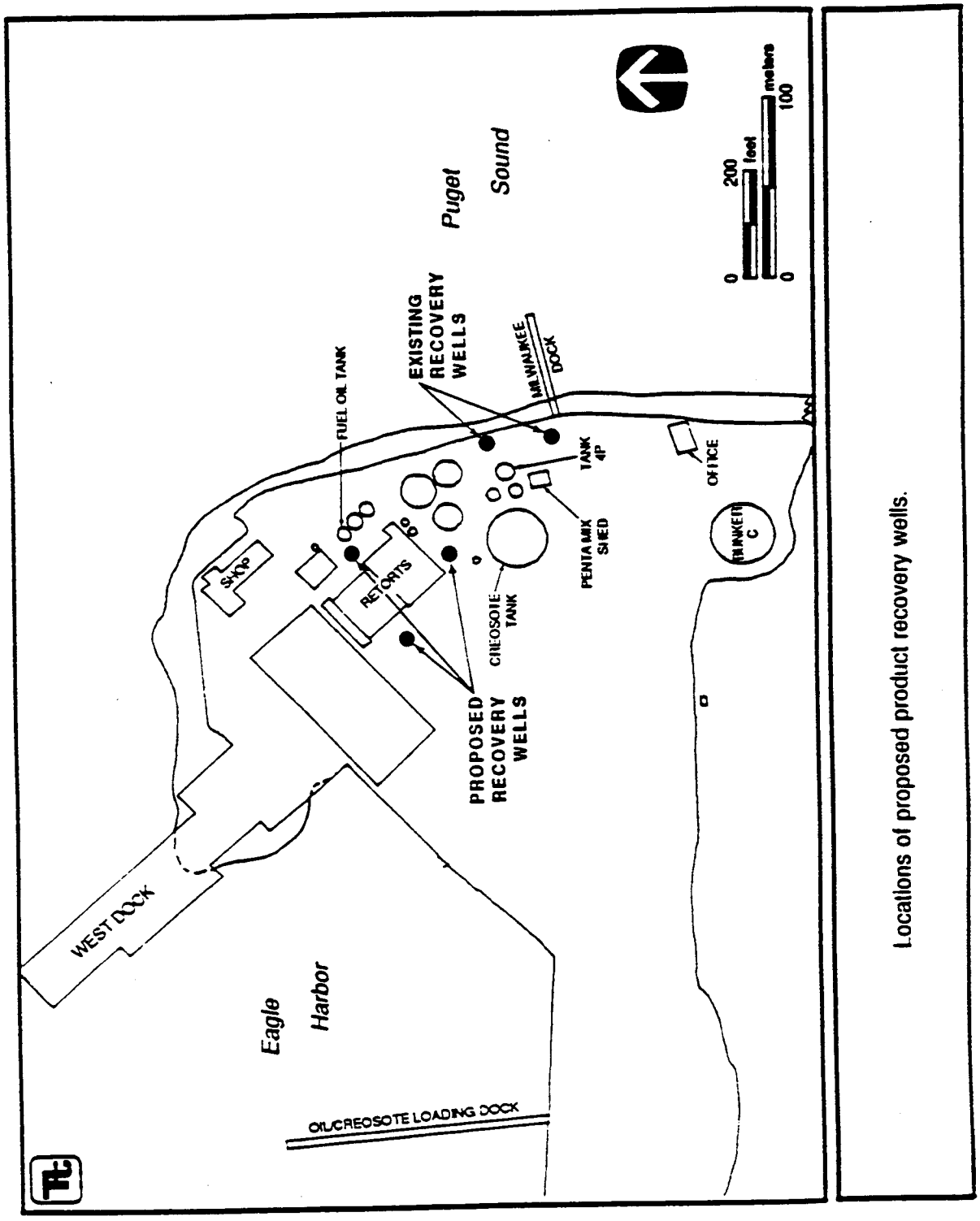
TABLE 36. SUMMARY OF REMEDIAL ALTERNATIVE COST ESTIMATES[a]

	Capital Cost	O&M Costs[b]	Total Cost
Alternative 3			
Slurry wall, product recovery, and groundwater treatment	$2,158K	$691K	$2,849K
Alternative 4			
Sheet piling, product recovery, and groundwater treatment	$2,024K	$700K	$2,724K
Alternative 5			
Barrier wells, product recovery, and groundwater treatment	$895K	$3,012K	$3,907K[c]

[a] Based on 5 yr operation.

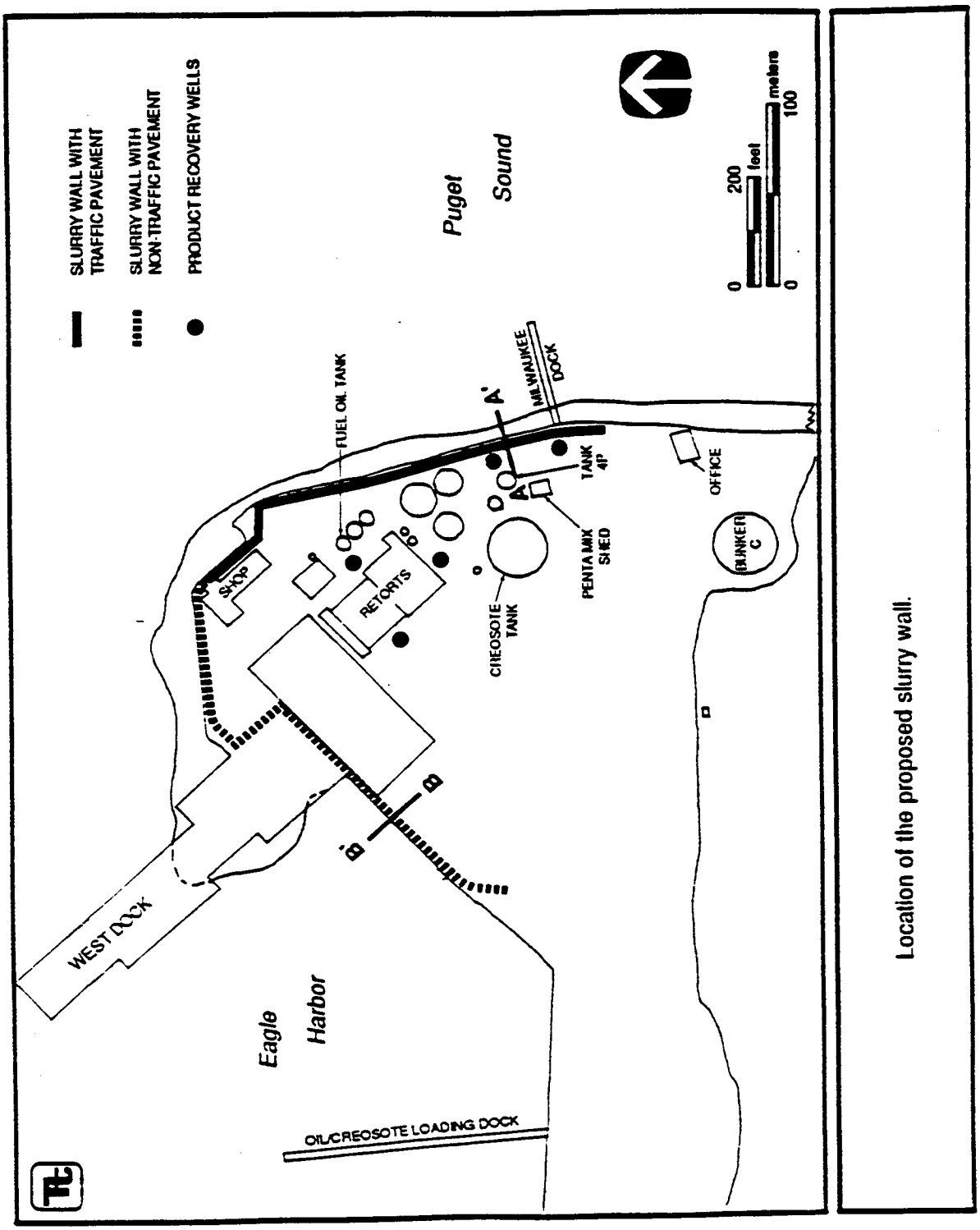
[b] Present worth based on 5 yr operation and 10 percent discount rate.

[c] Based on very conservative O&M costs. Actual costs may be significantly lower.



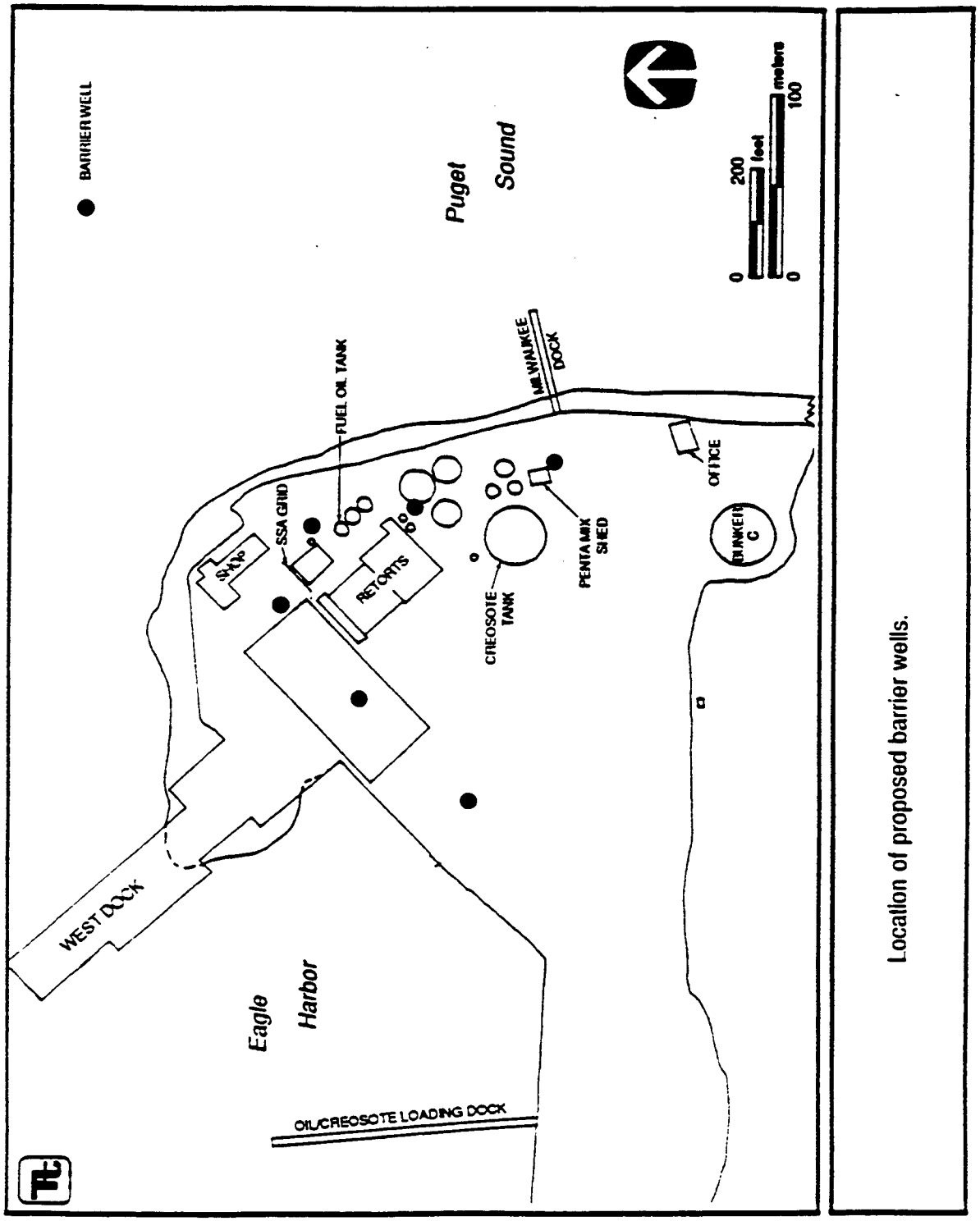
Locations of proposed product recovery wells.

APPENDIX B-4



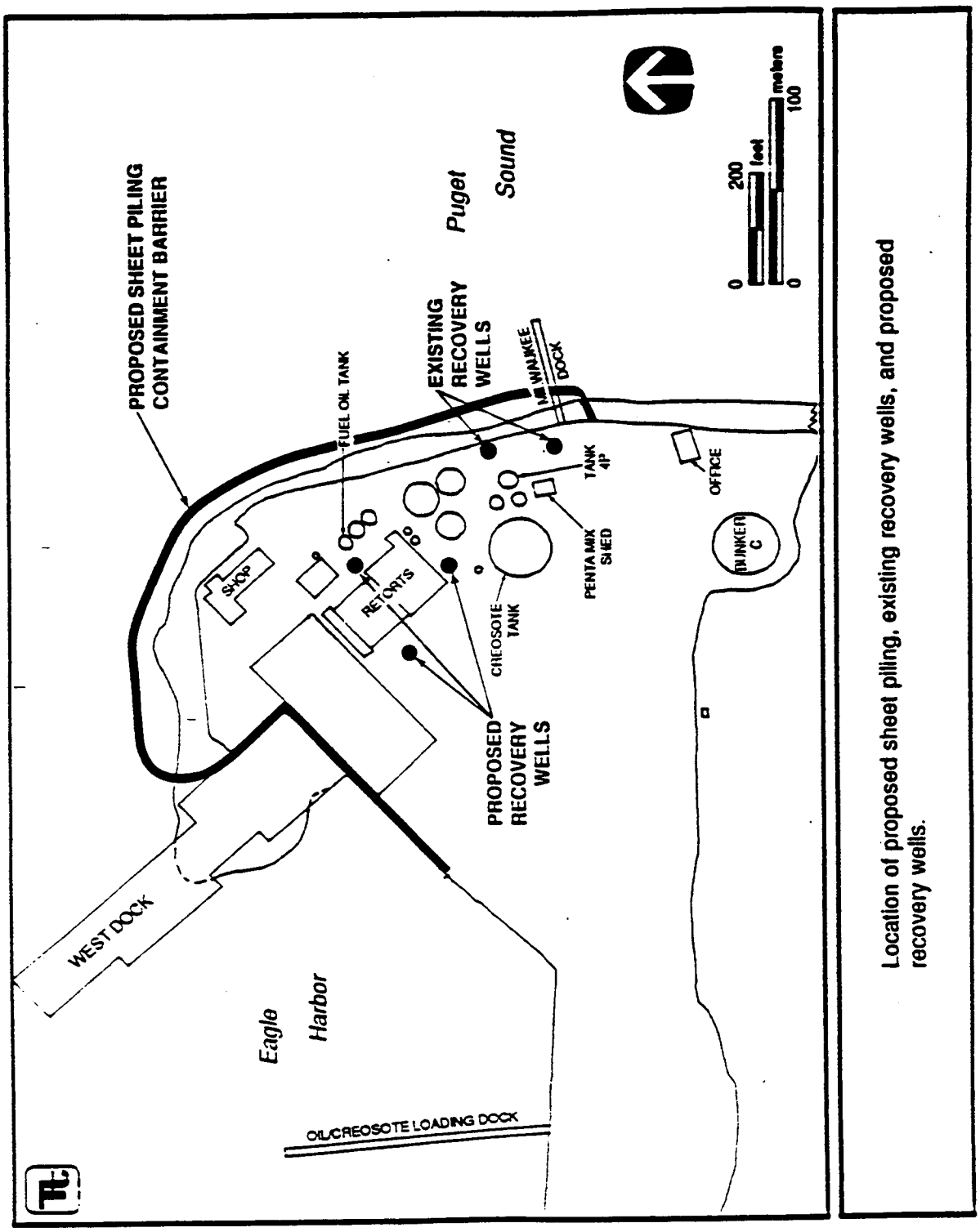
Location of the proposed slurry wall.

APPENDIX B-4



Location of proposed barrier wells.

APPENDIX B-4



Location of proposed sheet piling, existing recovery wells, and proposed recovery wells.

APPENDIX: C

C-1: Tacoma Landfill RI Gas Samples
C-2: Tacoma Landfill RI Groundwater Samples
C-3: Summary of Remedial Technology Screening
C-4: Summary of Detailed Evaluation of Remedial Alternatives
C-5: Summary of Environmental Impacts

TACOMA LANDFILL REMEDIAL INVESTIGATION
LANDFILL GAS SAMPLES
VOLATILE ORGANIC COMPOUNDS
Concentrations in ug/m3

Sample Number	Date	Acrolein	Acrylo-nitrile	Benzene	Bromo-dichloro-methane	Bromo-methane	Bromo-form	Carbon Tetra-chloride	Chloro-benzene	Chloro-ethane
GS-001	06/25/86	N/A	N/A	2600	500U	1000U	500U	500U	1600	1400
GS-002	06/25/86	N/A	N/A	700	500U	1000U	500U	500U	500U	1000U
GS-003	06/25/86	N/A	N/A	3200	125U	250U	125U	125U	125U	300
GS-004	06/25/86	N/A	N/A	2400	125U	250U	125U	125U	980	250U
GS-005	06/25/86	N/A	N/A	2900	125U	250U	125U	125U	950	250U
GS-006	06/25/86	N/A	N/A	1800	500U	1000U	500U	500U	1400	1000U
GS-007	06/25/86	N/A	N/A	1800	500U	1000U	500U	500U	500U	6300
GS-008	06/25/86	N/A	N/A	3000	500U	1000U	500U	500U	1100	1000U
GS-009	06/25/86	N/A	N/A	1300	500U	1000U	500U	500U	1600	1000U
GS-010	06/25/86	N/A	N/A	1800	500U	1000U	500U	500U	500U	TR
GS-011	06/25/86	N/A	N/A	2000	500U	1000U	500U	500U	1200	TR
GS-012	06/25/86	N/A	N/A	4800	500U	1000U	500U	500U	800	1400
GS-013	08/26/86	N/A	N/A	35.5U	35.5U	71U	35.5U	35.5U	35.5U	71U
GS-014	08/26/86	N/A	N/A	2200	25U	50U	25U	25U	25U	450

Sample Number	Date	2-Chloro-ethyl vinyl ether	Chloro-form	Chloro-methane	Dibromo-chloro-methane	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	1,1-Di-chloro-ethene	Trans-1,2-Di-chloro ethene	1,2-Di-chloro-propane	Cis-1,3-dichloro-propane
GS-001	06/25/86	1000U	500U	1000U	500U	TR	500U	500U	2500	500U	500U
GS-002	06/25/86	1000U	500U	1000U	500U	500U	500U	500U	TR	500U	500U
GS-003	06/25/86	250U	125U	250U	125U	125U	125U	125U	500	125U	125U
GS-004	06/25/86	250U	125U	250U	125U	125U	125U	125U	130	125U	125U
GS-005	06/25/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U
GS-006	06/25/86	1000U	500U	1000U	500U	500U	500U	500U	700	500U	500U
GS-007	06/25/86	1000U	500U	1000U	500U	500U	500U	17000	12000	500U	500U
GS-008	06/25/86	1000U	500U	1000U	500U	500U	500U	500U	500U	500U	500U
GS-009	06/25/86	1000U	500U	1000U	500U	500U	500U	500U	500U	500U	500U
GS-010	06/25/86	1000U	500U	1000U	500U	900	TR	TR	23000	500U	500U
GS-011	06/25/86	1000U	500U	1000U	500U	500U	500U	1000	16000	500U	500U
GS-012	06/25/86	1000U	500U	1000U	500U	3700	12000	TR	120000	TR	500U
GS-013	08/26/86	71U	35.5U	71U	35.5U	35.5U	35.5U	35.5U	35.5U	35.5U	35.5U
GS-014	08/26/86	50U	25U	50U	25U	1600	25U	45	1200	25U	25U

TACOMA LANDFILL REMEDIAL INVESTIGATION
LANDFILL GAS SAMPLES
VOLATILE ORGANIC COMPOUNDS
Concentrations in ug/m3

Sample Number	Date	Trans-1,3-Di-Chloro-propene	Ethyl Benzene	Methy-lene Chloride	1,1,2,2-Tetra-chloro-ethane	Tetra-chloro-ethene	Toluene	1,1,1-Tri-chloro-ethane	1,1,2-Tri-chloro-ethane	Tri-chloro-ethene	Vinyl Chlor-ide	Acetone
GS-001	06/25/86	500U	68000	1700B	500U	1300	61000	500U	500U	1100	52000	1000U
GS-002	06/25/86	500U	4300	2500B	500U	TR	1600	500U	500U	TR	TR	1000U
GS-003	06/25/86	125U	18000	TRB	125U	300	11000	125U	125U	125U	26000	3200B
GS-004	06/25/86	125U	8100	200B	125U	TR	530	125U	125U	125U	530	250U
GS-005	06/25/86	125U	8000	300B	125U	TR	630	125U	125U	125U	630	250U
GS-006	06/25/86	500U	39000	TRB	500U	TR	3300	500U	500U	500U	1800	1000U
GS-007	06/25/86	500U	21700	73000	500U	25000	89000	900	500U	3800	39000	1000U
GS-008	06/25/86	500U	30000	500U	500U	TR	1400	500U	500U	500U	TR	1000U
GS-009	06/25/86	500U	36000	TRB	500U	500U	500U	500U	500U	500U	2000	100U
GS-010	06/25/86	500U	50000	2000B	500U	20000	860000	500U	500U	13000	28000	3700B
GS-011	06/25/86	500U	77000	2500B	500U	4700	210000	500U	500U	5800	47000	10000
GS-012	06/25/86	500U	28000	33000B	500U	24000	84000	TR	500U	25000	38000	1000U
GS-013	08/26/86	35.5U	TRB	250B	35.5U	35.5U	130B	35.5U	35.5U	35.5U	71U	160B
GS-014	08/26/86	25U	1200	1600B	25U	2000	26000	900	25U	1100	2900	50U

Sample Number	Date	2-Butanone	Carbon Disulfide	2-Hexanone	4-Methyl-2-Pentanone	Styrene	Vinyl Acetate	Total Xylenes
GS-001	06/25/86	2000	500U	1800	1000U	2000	1000U	61000
GS-002	06/25/86	1000U	TR	1000U	1000U	500U	1000U	8400
GS-003	06/25/86	250U	800	250U	250U	125U	250U	20000
GS-004	06/25/86	250U	125U	TR	250U	125U	250U	13000
GS-005	06/25/86	250U	100	TR	250U	125U	250U	11000
GS-006	06/25/86	1000U	500U	1000U	1000U	500U	1000U	9000
GS-007	06/25/86	2800	500U	1000U	1000U	500U	1000U	24000
GS-008	06/25/86	1000U	500U	1000U	1000U	500U	1000U	36000
GS-009	06/25/86	100U	TR	1000U	1000U	500U	1000U	11000
GS-010	06/25/86	6000	2000	8000	1000U	9000	1000U	71000
GS-011	06/25/86	25000	900	8200	1000U	1000U	1000U	170000
GS-012	06/25/86	1000U	TR	TR	1000U	900	1000U	44000
GS-013	08/26/86	71U	130B	71U	71U	35.5U	71U	55B
GS-014	08/26/86	50U	180B	50U	50U	25U	50U	25U

TACOMA LANDFILL REMEDIAL INVESTIGATION
GROUND WATER SAMPLES
VOLATILE ORGANIC COMPOUNDS
Concentrations in ug/l

Sample Number	Date	Acrolein	Acrylo-nitrile	Benzene	Bromo-dichloro-methane	Bromo-methane	Bromo-form	Carbon Tetra-chloride	Chloro-benzene	Chloro-ethane
GW-001	08/07/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-003	08/04/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-005	08/07/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-007	08/05/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-008	08/04/86	N/A	N/A	5U	5U	10U	5U	5U	5U	TR
GW-009	08/05/86	N/A	N/A	5U	5U	10U	5U	5U	5U	12
GW-010	08/05/86	N/A	N/A	5U	5U	10U	5U	5U	5U	15
GW-011	08/04/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-012	08/05/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-013	08/04/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-014	08/04/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-015	08/05/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-016	08/04/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-017	10/21/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-018	10/21/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-019	10/21/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-020	11/18/86	N/A	N/A	9	1U	10U	5U	1U	3	1U
GW-021	10/21/86	N/A	N/A	6	1U	10U	5U	1U	1U	9
GW-022	10/21/86	N/A	N/A	1U	1U	10U	5U	1U	1U	3
GW-023	10/21/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-024	10/23/86	N/A	N/A	1U	1U	10U	5U	1U	1U	3
GW-025	10/23/86	N/A	N/A	1U	1U	10U	5U	1U	1U	3
GW-026	10/23/86	N/A	N/A	1U	1U	10U	5U	1U	1U	3
GW-027	10/22/86	N/A	N/A	4	1U	10U	5U	1U	1U	31
GW-028	10/22/86	N/A	N/A	1U	1U	10U	5U	1U	1U	7
GW-029	10/22/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-030	10/22/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-031	10/22/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-032	10/22/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-033	10/22/86	N/A	N/A	1U	2	10U	5U	1U	1U	1U
GW-034	/ /	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-051	12/16/86	N/A	N/A	1U	1U	10U	5U	1U	1U	1U
GW-100	08/07/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-101	08/07/86	N/A	N/A	5U	5U	10U	5U	5U	5U	10U
GW-102	10/27/86	N/A	N/A	1U	1U	10U	5U	1U	1U	6

TACOMA LANDFILL REMEDIAL INVESTIGATION
GROUND WATER SAMPLES
VOLATILE ORGANIC COMPOUNDS
Concentrations in ug/L

Sample Number	Date	2-Chloro-ethyl vinyl ether	Chloro-form	Chloro-methane	Dibromo-chloro-methane	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	1,1-Di-chloro-ethene	Trans-1,2-Di-chloro ethene	1,2-Di-chloro-propane	Cis-1,3-dichloro-propane
GW-001	08/07/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-003	08/04/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-005	08/07/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-007	08/05/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-008	08/04/86	10U	5U	10U	5U	TR	5U	5U	5U	5U	5U
GW-009	08/05/86	10U	5U	10U	5U	TR	5U	5U	5U	5U	5U
GW-010	08/05/86	10U	5U	10U	5U	TR	5U	5U	5U	5U	5U
GW-011	08/04/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-012	08/05/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-013	08/04/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-014	08/04/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-015	08/05/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-016	08/04/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-017	10/21/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-018	10/21/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-019	10/21/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-020	11/18/86	10U	1U	10U	1U	1U	1U	1U	110	1U	1U
GW-021	10/21/86	10U	1U	10U	1U	18	1U	1U	86	3	1U
GW-022	10/21/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-023	10/21/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-024	10/23/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-025	10/23/86	10U	1U	10U	1U	2	1U	1U	1U	1U	1U
GW-026	10/23/86	10U	1U	10U	1U	2	1U	1U	1U	1U	1U
GW-027	10/22/86	10U	1U	10U	1U	56	4	1	9	1	1U
GW-028	10/22/86	10U	7	10U	1U	1	1U	1U	1U	1U	1U
GW-029	10/22/86	10U	3	10U	1U	1U	1U	1U	1U	1U	1U
GW-030	10/22/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-031	10/22/86	10U	5	10U	1U	1U	1U	1U	1U	1U	1U
GW-032	10/22/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-033	10/22/86	10U	21	10U	1U	1U	1U	1U	1U	1U	1U
GW-034	/ /	10U	1	10U	1U	1U	1U	1U	1U	1U	1U
GW-051	12/16/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U
GW-100	08/07/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-101	08/07/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U
GW-102	10/27/86	10U	1U	10U	1U	4	1U	1U	1U	1U	1U

TACOMA LANDFILL REMEDIAL INVESTIGATION
GROUND WATER SAMPLES
VOLATILE ORGANIC COMPOUNDS
Concentrations in ug/l

Sample Number	Date	Trans-1,3-Di-Chloro-propene	Ethyl Benzene	Methy-lene Chloride	1,1,2,2-Tetra-chloro-ethane	Tetra-chloro-ethene	Toluene	1,1,1-Tri-chloro-ethane	1,1,2-Tri-chloro-ethane	Tri-chloro-ethene	Vinyl Chlor-ide	Acetone
GW-001	08/07/86	5U	5U	5U	5U	5U	5U	5U	5U	5U	10U	10U
GW-003	08/04/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	10U	10U
GW-005	08/07/86	5U	5U	5U	5U	5U	5U	5U	5U	5U	10U	10U
GW-007	08/05/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	10U	10U
GW-008	08/04/86	5U	5U	5UJ	5U	5U	5U	48	5U	5U	10U	10U
GW-009	08/05/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	9	10U
GW-010	08/05/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	15	10U
GW-011	08/04/86	5U	5U	5U	5U	5U	5U	5U	5U	5U	10U	10U
GW-012	08/05/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	10U	10U
GW-013	08/04/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	10U	10U
GW-014	08/04/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	10U	10U
GW-015	08/05/86	5U	5U	5UJ	5U	5U	5U	5U	5U	5U	10U	10U
GW-016	08/04/86	5U	5U	5U	5U	5U	5U	5U	5U	5U	10U	10UJ
GW-017	10/21/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-018	10/21/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-019	10/21/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-020	11/18/86	1U	9	5U	1U	1U	34	1U	1U	1	23	100*
GW-021	10/21/86	1U	1U	5UJ	1U	1U	2	1	1U	8	5	10U
GW-022	10/21/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-023	10/21/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-024	10/23/86	1U	1U	5U	1U	1U	1U	16	1U	1U	1	10U
GW-025	10/23/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1	10U
GW-026	10/23/86	1U	1U	5U	1U	1U	1U	1	1U	1U	1	10U
GW-027	10/22/86	1U	2	160B	1U	8	18	10	1U	11	44	10U
GW-028	10/22/86	1U	1U	36B	1U	1U	1U	1U	1U	1U	4	10U
GW-029	10/22/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-030	10/22/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-031	10/22/86	1U	1U	5U	1U	1U	1U	1	1U	1U	4	10U
GW-032	10/22/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10U
GW-033	10/22/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	1U	10UJ
GW-034	/ /	1U	1U	5UJ	1U	1U	1U	1U	1U	1U	1U	10U
GW-051	12/16/86	1U	1U	5U	1U	1U	1U	63	1U	1U	1U	10U
GW-100	08/07/86	5U	5U	5U	5U	5U	5U	5U	5U	5U	10U	10U
GW-101	08/07/86	5U	5U	5U	5U	5U	5U	5U	5U	5U	10U	10U
GW-102	10/27/86	1U	1U	5U	1U	1U	1U	1U	1U	1U	7	10U

TACOMA LANDFILL REMEDIAL INVESTIGATION
GROUND WATER SAMPLES
VOLATILE ORGANIC COMPOUNDS
Concentrations in ug/L

Sample Number	Date	2-Butanone	Carbon Disulfide	2-Hexanone	4-Methyl-2-Pentanone	Styrene	Vinyl Acetate	Total Xylenes
GW-001	08/07/86	10U	5U	10U	10U	5U	10U	5U
GW-003	08/04/86	10U	5U	10U	10U	5U	10U	5U
GW-005	08/07/86	10U	5U	10U	10U	5U	10U	5U
GW-007	08/05/86	10U	5U	10U	10U	5U	10U	5U
GW-008	08/04/86	10U	5U	10U	10U	5U	10U	5U
GW-009	08/05/86	10U	5U	10U	10U	5U	10U	5U
GW-010	08/05/86	10U	5U	10U	10U	5U	10U	5U
GW-011	08/04/86	10U	5U	10U	10U	5U	10U	5U
GW-012	08/05/86	10U	5U	10U	10U	5U	10U	5U
GW-013	08/04/86	10U	5U	10U	10U	5U	10U	5U
GW-014	08/04/86	10U	5U	10U	10U	5U	10U	5U
GW-015	08/05/86	10U	5U	10U	10U	5U	10U	5U
GW-016	08/04/86	10U	5U	10U	10U	5U	10U	5U
GW-017	10/21/86	10U	1U	10U	10U	1U	10U	1U
GW-018	10/21/86	10U	1U	10U	10U	1U	10U	1U
GW-019	10/21/86	10U	1U	10U	10U	1U	10U	1U
GW-020	11/18/86	280*	1U	10U	130	1U	10U	28
GW-021	10/21/86	10U	1U	10U	10U	1U	10U	6
GW-022	10/21/86	10U	1U	10U	10U	1U	10U	1U
GW-023	10/21/86	10U	1U	10U	10U	1U	10U	1U
GW-024	10/23/86	10U	1U	10U	10U	1U	10U	1U
GW-025	10/23/86	10U	1U	10U	10U	1U	10U	1U
GW-026	10/23/86	10U	1U	10U	10U	1U	10U	1U
GW-027	10/22/86	10U	1U	10U	10U	1U	10U	2
GW-028	10/22/86	10U	1U	10U	10U	1U	10U	1U
GW-029	10/22/86	10U	1U	10U	10U	1U	10U	1U
GW-030	10/22/86	10U	1U	10U	10U	1U	10U	1U
GW-031	10/22/86	10U	1U	10U	10U	1U	10U	1U
GW-032	10/22/86	10U	1U	10U	10U	1U	10U	1U
GW-033	10/22/86	10U	1U	10U	10U	1U	10U	1U
GW-034	/ /	10U	1U	10U	10U	1U	10U	1U
GW-051	12/16/86	10U	1U	10U	10U	1U	10U	1U
GW-100	08/07/86	10U	5U	10U	10U	5U	10U	5U
GW-101	08/07/86	10U	5U	10U	10U	5U	10U	5U
GW-102	10/27/86	10U	1U	10U	10U	1U	10U	1U

TACOMA LANDFILL REMEDIAL INVESTIGATION
GROUND WATER SAMPLES
HALOGENATED ORGANIC COMPOUNDS
Concentrations in ug/L

Sample Number	Well Number	Date	Bromo-dichloro-methane	Bromo-methane	Bromo-form	Carbon Tetra-chloride	Chloro-benzene	Chloro-ethane	2-Chloro-ethyl vinyl ether	Chloro-form	Chloro-methane	Dibromo chloro-methane
GW-051	EW-08	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
GW-052	EW-08(DUP)	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
GW-053	EW-17	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
GW-054	EW-18	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
GW-055	EW-11	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
GW-069	EW-13	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
GW-074	BLANK	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.44	0.2U	0.2U

Sample Number	Well Number	Date	1,1-Di-chloro-ethene	1,2-Di-chloro-ethane	1,1-Di-chloro-ethane	Trans-1,2-Di-chloro-ethene	1,2-Di-chloro-propane	Cis-1,3-dichloro-propane	Trans-1,3-Di-chloro-propene	Methy-lene Chloride	1,1,2,2-Tetra-chloro-ethane	Tetra-chloro-ethene
GW-051	EW-08	12/16/86	0.2U	0.6	0.2U	0.28	0.2U	0.2U	0.2U	2.0U	0.2U	0.2U
GW-052	EW-08(DUP)	12/16/86	0.2U	0.2U	2.5	0.32	0.2U	0.2U	0.2U	2.0U	0.2U	0.2U
GW-053	EW-17	12/16/86	0.2U	0.2U	3.7	0.23	0.2U	0.2U	0.2U	2.0U	0.2U	0.2U
GW-054	EW-18	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	2.0U	0.2U	0.2U
GW-055	EW-11	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	2.0U	0.2U	0.2U
GW-069	EW-13	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	2.0U	0.2U	0.2U
GW-074	BLANK	12/16/86	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	2.0U	0.2U	0.2U

Sample Number	Well Number	Date	1,1,1-Tri-chloro-ethane	1,1,2-Tri-chloro-ethane	Vinyl Chloride	1,2-Di-chloro-benzene	1,3-Di-chloro-benzene	1,4-Di-chloro-benzene	Dichloro-difluoro-methane	Tri-chloro-fluoro-methane	Tri-chloro-ethene
GW-051	EW-08	12/16/86	65	0.2U	0.2U	0.5U	0.5U	0.5U	0.2U	2.0U	0.2U
GW-052	EW-08(DUP)	12/16/86	59	0.2U	0.2U	0.5U	0.5U	0.5U	0.2U	2.0U	0.2U
GW-053	EW-17	12/16/86	0.99	0.2U	0.2U	0.5U	0.5U	0.5U	0.2U	2.0U	0.2U
GW-054	EW-18	12/16/86	0.2U	0.2U	0.2U	0.5U	0.5U	0.5U	0.2U	2.0U	0.2U
GW-055	EW-11	12/16/86	0.2U	0.2U	0.2U	0.5U	0.5U	0.5U	0.2U	2.0U	0.2U
GW-069	EW-13	12/16/86	0.32	0.2U	0.2U	0.5U	0.5U	0.5U	0.2U	2.0U	0.2U
GW-074	BLANK	12/16/86	0.2U	0.2U	0.2U	0.5U	0.5U	0.5U	0.2U	2.0U	0.2U

SUMMARY OF
REMEDIAL TECHNOLOGY SCREENING

Contaminant Pathway	General Response Category	Remedial Technologies	Process Options	Retained	Rejected	Comments
Groundwater	No Action	None	None	X		Required by NCP.
	Institutional Controls	Groundwater Use Restrictions		X		Potentially viable.
		Groundwater Monitoring		X		Potentially viable.
		Surface Water Monitoring		X		Potentially viable.
	Containment	Capping	Native Soil		X	Does not meet permeability requirements.
			Clay		X	No clay readily available, not cost-effective
			Sprayed Asphalt		X	High maintenance requirement due to poor weathering characteristics, brittleness with age, photosensitivity, and cracking.
			Concrete		X	Potential for cracking.
			Soil-Bentonite		X	Not enough soil at the Tacoma Landfill that is suitable for mixing with bentonite.
			Soil-Synthetic Membrane	X		Potentially viable.
		Vertical Barriers	Soil-Bentonite Slurry Wall		X	Depth to impervious layer is too deep for construction techniques.
			Cement-Bentonite Slurry Wall		X	Depth to impervious layer is too deep for construction techniques.
			Grout Curtain		X	Does not attain low permeabilities and historically has not proven effective.
			Sheet Piling		X	Depth to impervious layer is too deep, leakage may occur at joints, and granular soils with cobbles would make for difficult installations.
			Vibrating Beam		X	Depth to impervious layer is too deep and granular soils with cobbles would make for difficult installation.

SUMMARY OF
REMEDIAL TECHNOLOGY SCREENING

Contaminant Pathway	General Response Category	Remedial Technologies	Process Options	Retained	Rejected	Comments
Groundwater	Containment	Horizontal Barriers			X	Cannot verify continuity and effectiveness of the barrier.
		Surface Controls	Grading	X		Included in capping.
			Revegetation	X		Included in capping.
			Drainage Control	X		Included in capping.
		Gradient Controls	French Drains		X	Technology is limited to shallow depths.
			Pipe & Media Drains		X	Technology is limited to shallow depths.
			Extraction/ Injection Wells	X		Potentially viable.
			Extraction Wells	X		Potentially viable.
	Removal	Groundwater Wells	Extraction Wells	X		Potentially viable.
			Extraction/ Injection Wells	X		Potentially viable.
		Subsurface Drains	French Drains		X	Technology is limited to shallow depths.
			Pipe and Media Drains		X	Technology is limited to shallow depths.
		Enhanced Removal Process			X	Not suited to contaminants found at Tacoma Landfill.
	Onsite Treatment Discharge	Equalization/ Detention	Surface Impoundment	X		Potentially viable.
			Tank	X		Potentially viable.
		Physical Treatment	Dissolved Air Flotation		X	The amount of suspended solids, oils, and greases is minimal.
			Sedimentation		X	The amount of suspended solids is minimal.
			Coagulation and Flocculation		X	The amount of suspended solids is minimal.
			Filtration		X	The amount of suspended solids is minimal.

SUMMARY OF
REMEDIAL TECHNOLOGY SCREENING

Contaminant Pathway	General Response Category	Remedial Technologies	Process Options	Retained	Rejected	Comments
Groundwater	Onsite Treatment/ Discharge	Physical Treatment	Reverse Osmosis		X	Technology will not remove contaminants of concern.
			Air Stripping	X		Potentially viable.
			Steam Stripping		X	Technology has high costs compared to similar technology (air stripping).
			Carbon Adsorption	X		Potentially viable.
		Chemical Treatment	Neutralization		X	Not required because groundwater pH averages 6.5.
			Chemical Reduction		X	Not effective because the heavy metal content is relatively low.
			Wet Air Oxidation		X	Technology was developed for higher strength wastes than those under consideration.
			Super Critical Water Oxidation		X	Capital and operational costs associated with this process are very high with no substantial increase in effectiveness.
			Chlorination		X	Technology will not be considered because of the low concentrations of cyanides and metals.
			Ozone/Ultraviolet		X	Technology will not be considered due to its corrosiveness and toxicity.
			Precipitation		X	Technology is not appropriate because of the low concentrations of metals and suspended solid particles.
			Ion Exchange		X	Technology is not appropriate because of the low concentration of ions to be exchanged.
		Biological Treatment	Activated Sludge		X	Technology is not practical since a high purity activated sludge unit exists at the POTW.
			Rotating Biological Contactors		X	Technology is not appropriate because it has not been proven reliable in treating heavily chlorinated compounds.

SUMMARY OF
REMEDIAL TECHNOLOGY SCREENING

Contaminant Pathway	General Response Category	Remedial Technologies	Process Options	Retained	Rejected	Comments
Groundwater	Onsite Treatment/ Discharge	Biological Treatment	Trickling Filters		X	Technology is not appropriate because the heavily chlorinated molecules remain somewhat resistant to microbial contact.
			Waste Stabilization Ponds		X	Technology is not appropriate because treatment efficiences are relatively poor.
		Thermal Treatment	Liquid Injection	X		Potentially viable.
			Molten Salt		X	Technology will not be used due to materials with a high chlorine content.
		Insitu Treatment	Permeable Treatment Bed		X	Depth of trenching is too great.
			Bioreclamation		X	Technology is not appropriate because not all contaminants are biodegraded.
			Vitrification		X	Technology produces undesirable off-gases and not applicable for the waste streams present.
		Surface Discharge		X		Potentially viable.
		Onsite Subsurface Discharge	Recharge Wells	X		Potentially viable.
			Seepage Channel	X		Potentially viable.
		Publicly Owned Treatment Works		X		Potentially viable.
		Water Treatment Facility		X		Potentially viable.
		Onsite Solids Disposal		X		Potentially viable.

SUMMARY OF
REMEDIAL TECHNOLOGY SCREENING

Contaminant Pathway	General Response Category	Remedial Technologies	Process Options	Retained	Rejected	Comments
Groundwater	Offsite Treatment/Disposal	RCRA Incineration Facility			X	Cost much higher than conventional physical, chemical or biological treatment.
		RCRA Treatment Facility		X		Retained only for treatment byproducts, (i.e., spent carbon).
		RCRA Deep Well Injection Well			X	Cost much higher than conventional physical, chemical, or biological treatment.
		Publicly Owned Treatment Works		X		Potentially viable.
		Reusable Products			X	Impractical because of the low concentrations of reusable materials.
		RCRA Disposal Facility		X		Potentially viable.
	Other Management Options	Alternative Water Supplies	Bottled Water	X		Potentially viable for temporary use.
			Bulk Water		X	Not practical since other sources of drinking water are available.
			Municipal Water Supply	X		Potentially viable.
		Individual Treatment Units			X	Not practical when other sources of drinking water are available. High maintenance costs.
Gas Migration/Air Quality	No Action	None	None	X		Required by NCP.
	Institutional Control	Air Quality Monitoring		X		Potentially viable.
		Subsurface Gas Monitoring		X		Potentially viable.
	Containment	Capping	Native		X	Does not limit infiltration and leachate production.
			Clay		X	No clay readily available. Not cost-effective.

SUMMARY OF
REMEDIAL TECHNOLOGY SCREENING

Contaminant Pathway	General Response Category	Remedial Technologies	Process Options	Retained	Rejected	Comments
Gas Migration/Air Quality	Containment	Capping	Sprayed Asphalt		X	High maintenance requirement due to poor weathering characteristics, brittleness with age, photosensitivity and cracking.
			Concrete		X	Potential for cracking.
			Soil-Bentonite		X	Not enough soil at the Tacoma Landfill that is suitable for mixing with bentonite.
			Soil-Synthetic Membrane	X		Potentially viable.
		Vertical Barriers	Soil-Bentonite Slurry Wall		X	Depth to impervious layer is too deep for construction techniques.
			Cement-Bentonite Slurry Wall		X	Depth to impervious layer is too deep for construction techniques.
			Grout Curtain		X	Does not attain low permeabilities and historically has not proven effective.
			Sheet Piling		X	Depth to impervious layer is too deep, leakage may occur at joints, and granular soils with cobbles would make for difficult installation.
			Vibrating Beam		X	Depth to impervious layer is too deep and granular soils with cobbles would make for difficult installation.
	Removal	Passive Trench Vents	Low Permeability		X	Installation depth is too great. Does not stop diffuse gas flow.
			High Permeability		X	Installation depth is too great.
			Combined low and high permeability		X	Installation depth is too great.
		Gas Extraction Wells		X		Potentially viable.

SUMMARY OF
REMEDIAL TECHNOLOGY SCREENING

Contaminant Pathway	General Response Category	Remedial Technologies	Process Options	Retained	Rejected	Comments
Gas Migration/Air Quality	Onsite Treatment	Physical Treatment	Carbon Adsorption		X	Not cost-effective because gas extraction wells and flares already operational at Tacoma landfill.
		Thermal Treatment	Flaring	X		Potentially viable.
		Gas Utilization	Electrical Generation		X	Technology is not economically feasible to produce electrical generation for sale either to City Light Division or Puget Power.
			Direct Sale		X	Not viable because there are no large users within a two mile radius of the landfill and a medium user would only be able to utilize about half the volume of gas available.
			Upgrading Gas		X	Not cost-effective.
	Other Management Options	Evacuation or Relocation of Residents and Businesses		X		May be required as a temporary precaution during remedial action implementation.

SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

Alternative	Cost ($1,000) Capital	Present Worth	Public Health Impacts	Environmental Impacts	Technical Feasibility	Institutional Requirements	Community Concerns
1 No Action	--	--	o Contaminant releases uncontrolled. o Potential ingestion of contaminated water as plume migrates to wells which have not already been taken out of service. o Contaminants remain in groundwater for a long time period.	o Confaminants remain in groundwater. o Continued migration of plume in aquifer. o Potential for discharge of contaminants into Leach Creek as plume continues to migrate.	N/A	o Does not meet ARARs.	o Exposure to contaminated well water. o Not acceptable to public.
2 Containment by Pumping, POTW Discharge	17,932	23,418	o Contaminants in groundwater which migrate to close-in and distant wells are below the threshold limits for the protection of public health. o Contaminated groundwater upgradient of the extraction wells on Orchard Street is removed from the aquifer and treated to ARARs. o Some contamination remains after 25-35 years. o No exposure to contaminated groundwater due to provision of alternate supply to affected well owners.	o Removes contaminated groundwater from aquifer. o Reduces the duration and concentration of contaminants downgradient of the extraction wells. o Prevents measurable impacts on water quality in Leach Creek.	o Effective and proven technologies.		o Acceptable alternative.

SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES (Continued)

Alternative	Cost ($1,000) Capital	Cost ($1,000) Present Worth	Public Health Impacts	Environmental Impacts	Technical Feasibility	Institutional Requirements	Community Concerns
8 Containment by Pumping, Onsite Carbon Adsorption, Surface Discharge	19,266	23,417	o Same as Alternative 4.	o Same as Alternative 4.	o Highly effective. o Well established technology. o Accomodates fluctuations in effluents.	o Same as Alternative 4.	o Acceptable alternative.
12 Containment by Pumping, Onsite Air Stripping, Surface Discharge	18,971	21,015	o Same as Alternative 4.	o Same as Alternative 4.	o Highly effective. o Well established technology. o Air stripper must be overdesigned to guarantee efficient removal. o Pilot plant testing is recommended determine to design paramaters.	o Same as Alternative 4.	o Acceptable alternative.

SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES (continued)

Alternative	Cost ($1,000) Capital	Cost ($1,000) Present Worth	Public Health Impacts	Environmental Impacts	Technical Feasibility	Institutional Requirements	Community Concerns
3 Alternate Water Supply, Groundwater Use Restrictions	16,423	18,376	o Safe drinking water supply is provided. o Water use restrictions must be enforced throughout entire area. o No exposure from ingested groundwater but potential exposure to contaminants in Leach Creek.	o Reduces the duration and concentration of contaminants in aquifer. o Continued migration of contaminant plume. o Potential for discharge of contaminants into Leach Creek as plume continues to migrate.	o Effectively and reliably provides safe drinking water supply. o Installed, operated and maintained by City of Tacoma.	o Does not meet ARARs.	o Residents must pay for water.
4 Containment by Pumping, Onsite Air Stripping/ Carbon Adsorption, Surface Discharge	19,532	22,717	o Contaminants in groundwater which migrate to close-in and distant wells are below the threshold limits for the protection of public health. o Contaminated groundwater, upgradient of extraction wells on Orchard Street, is removed from aquifer and treated to ARARs. o Some contamination remains after 25-35 years. o No exposure to contaminated groundwater due to alternate supply to affected well owners.	o Removes large portion of contaminated groundwater from aquifer. o Reduces the duration and concentration of contaminants downgradeint of extraction wells. o Prevents measurable impact on Leach Creek water quality.	o Effective, well established technologies. o Technologies accomodate fluctuations in influent characteristics.	o NPDES permit required to discharge treated effluent. o ARARs attained for treated water.	o Acceptable alternative.

SUMMARY OF ENVIRONMENTAL IMPACTS

Criteria

Remedial Action Alternatives	BENEFICIAL EFFECTS: Final Environmental Conditions	BENEFICIAL EFFECTS: Improvements in Biological Environment	BENEFICIAL EFFECTS: Improvements in Human Use Resources	ADVERSE EFFECTS
1 No Action	Continued generation of leachate, continued contamination of groundwater, no significant impacts to air or surface water.	None.	None.	Continued Contamination of Groundwater.
	Environmental Impacts Rating 4			
2 Containment by Pumping, POTW Discharge	Leachate production is eliminated, contaminated groundwater is removed, duration and concentration of contaminants discharged to surface water are reduced, no significant impacts to air.	Contains and removes portion of contaminated groundwater.	Minimizes further leachate production and removes majority of contaminated groundwater. Reduces duration and concentration of contaminants not removed.	Reduces flow to Leach Creek.
	Environmental Impacts Rating 2			
3 Alternate Water Supply, Groundwater Use Restrictions	Leachate production is eliminated, duration and concentration of contaminants discharged to surface water are reduced, no significant impacts to air.	Reduces concentration and duration of contaminants in aquifer.	Safe drinking water is supplied to residents.	Contaminated groundwater is not removed.
	Environmental Impacts Rating 3			

SUMMARY OF ENVIRONMENTAL IMPACTS

Remedial Action Alternatives	Criteria: BENEFICIAL EFFECTS — Final Environmental Conditions	Criteria: BENEFICIAL EFFECTS — Improvements in Biological Environment	Criteria: BENEFICIAL EFFECTS — Improvements in Human Use Resources	Criteria: ADVERSE EFFECTS
4 Containment by Pumping, Onsite Air Stripping/ Carbon Adsorption, Surface Discharge	Same as Alternative 2 plus treated water discharged to Flett Creek.	Discharge clean effluent to Flett Creek; contains and removes portion of contaminated groundwater; minimizes leachate production.	Same as Alternative 2.	Potential for spillage of spent carbon during transport offsite and minimal emissions of volatile organics to the atmosphere.
	Environmental Impacts Rating 2			
8 Containment by Pumping, Onsite Carbon Adsorption, Surface Discharge	Same as Alternative 4.	Same as Alternative 4.	Same as Alternative 2.	Potential for spillage of spent carbon during transport offsite for regeneration, reduces flow to Leach Creek.
	Environmental Impacts Rating 2			
12 Containment by Pumping, Onsite Air Stripping, Surface Discharge	Same as Alternative 4.	Same as Alternative 4.	Same as Alternative 2.	Potential for minimal emissions of volatile organics to the atmosphere, reduces flow to Leach Creek.
	Environmental Impacts Rating 2			

Appendix D: Data Diskette Description

The floppy disk attached to the back cover contains selected data files for the Hanford 183-H and Wyckoff sites. All files are ASCII. File 100.ASC contains all of the raw data for the monitoring wells shown in Figures II-2, II-5, and II-10. Files TBLIII-1.ASC, TBLIII-2.ASC, TBLIII-3.ASC, and TBLIII-4.ASC, respectively, are ASCII versions of Tables III-1 through III-4 in Chapter III.