FINAL

FEASIBILITY STUDY REPORT

OPERABLE UNIT B POLELINE ROAD DISPOSAL AREA FORT RICHARDSON, ALASKA

Contract No. DACA-85-94-D-0005
Delivery Order No. 017

Prepared for

U.S. Army Corps of Engineers
Alaska District
Anchorage, Alaska

JANUARY 1997

Prepared By

Woodward-Clyde

3501 Denali Street, Suite 101
Anchorage, Alaska 99503

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OUB 0023568

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EXECUTIVE SUMMARY

Woodward-Clyde conducted a Feasibility Study (FS) at Operable Unit B (OUB), the Poleline Road Disposal Area (PRDA), at Fort Richardson, Alaska. This FS was based on a Remedial Investigation (RI) conducted in 1995 and on previous investigations and a removal action. Previous investigations identified four disposal areas that were used between 1950 and 1972 for the disposal of chemical warfare training materials and halogenated solvents. Two of the disposal areas (Areas A-3 and A-4) were excavated in 1993 and 1994 and were backfilled with soil meeting removal action levels. The other two areas (Areas A-1 and A-2) have not been excavated and potentially contain unexploded ordnance.

The RI field work was performed in August and September 1995 and involved the collection and analysis of soil, groundwater, sediment and surface water samples from the site and background areas. Samples were analyzed for volatile organic compounds (VOCs), metals, explosives, and chemical warfare materials and their breakdown products.

Soil samples were collected from borings drilled around the former disposal areas and through the backfill at Areas A-3 and A-4. Concentrations of contaminants in soils are generally well below regulatory levels outside of the disposal areas. None of the samples collected from the backfilled soil in Areas A-3 and A-4 exceeded the cleanup criteria used during the excavation (1,1,2,2-tetrachloroethane, 30 mg/kg; tetrachloroethene [PCE], 100 mg/kg; and trichloroethene [TCE], 600 mg/kg). However, soil samples collected beneath the previous excavation (beneath the perched water table) in Area A-3 had concentrations of 1,1,2,2-tetrachloroethane (79 mg/kg) which exceeded the cleanup criterion used during the excavation.

Halogenated solvents were found in groundwater samples from both the shallow and deep water bearing intervals. Two solvents, 1,1,2,2-tetrachloroethane and TCE, were found at concentrations significantly higher than any other VOCs detected at the site. The Alaska MCL for TCE in water (0.005 mg/L) was exceeded in 10 of the 14 monitoring wells sampled for VOCs. There is no Alaska MCL for 1,1,2,2-tetrachloroethane. A groundwater model performed using MODFLOW and MT3D estimated that the solvents would take over 100 years to reach the Eagle River.

A risk assessment was performed and is provided as a separate document. The risk assessment concluded that the site poses no imminent threat to human health or the environment under current and probable future use scenarios, based on a lack of complete exposure pathways. However, if groundwater were to be used as a drinking water supply and if buildings were constructed with basements on the site, groundwater (ingestion) and soil gas (inhalation of contaminated vapors seeping into basements) may pose unacceptable risks.

Based on the results of the RI, TCE and 1,1,2,2-tetrachloroethane were selected as the chemicals of concern for the FS. These two chemicals were found in higher concentrations and over a larger area than the other chemicals detected. The following Remedial Action Objectives were developed for the FS:

1. Reduce contaminant levels in the groundwater to comply with drinking water standards
2. Prevent the soil from continuing to act as a source of groundwater contamination
3. Prevent the contaminated groundwater from adversely affecting the Eagle River surface water and sediments
4. Minimize degradation of the State of Alaska's groundwater resources at the site as a result of past disposal practices.

After identifying and screening potential process options that may be effective and implementable at the site, the following alternatives were developed:

- Alternative 1 - No Action. The No Action Alternative involves no additional costs or actions at the site. This alternative is required by the NCP.
- Alternative 2 - Natural Attenuation. Interim U.S. Army policy requires the inclusion of "Natural Attenuation" for evaluation as a remedial action alternative through the preparation of the Proposed Plan. Natural attenuation relies on biological, physical, and chemical processes that are occurring in the environment without artificial stimulus. Groundwater monitoring would include intrinsic remediation parameters and VOCs.

- Alternative 3 - Containment. The containment alternative involves a synthetic liner with soil cover as a cap and a bentonite slurry wall to 25 feet bgs as a vertical barrier to prevent recharge of the groundwater from the wetland.

- Alternative 4 - Interception Trench, Air Stripping, and Soil Vapor Extraction. Groundwater is collected in drainage trenches and treated in an air stripper. The treated groundwater is discharged outside the capture zone of the interception trenches and soil vapor extraction is used to remediate contaminated soils above the lowered water table.

- Alternative 5 - Air Sparging and Soil Vapor Extraction of the "Hot Spot" and Natural Attenuation. Groundwater in the "hot spot" area is treated using air sparging, and unsaturated "hot spot" soils are treated with soil vapor extraction. Groundwater is monitored for intrinsic remediation parameters and VOCs.

Woodward-Clyde performed a treatability study in October and November 1996. The treatability study included air sparging and soil vapor extraction pilot tests, groundwater sampling for intrinsic remediation parameters, and aquifer tests. Based on results of the treatability study, an additional alternative was developed:

- Alternative 6 - Soil Vapor Extraction of the "Hot Spot." Soil in the hot spot is treated with soil vapor extraction. Groundwater is extracted via a knockout tank in the SVE system, treated in an air stripper, and discharged to an infiltration system. DNAPLS are treated with a bubble tube.

The following costs were estimated for the alternatives: Alternative 1 ($0), Alternative 2 ($1,300,000), Alternative 3 ($2,500,000), Alternative 4 ($7,500,000), Alternative 5 ($5,500,000), and Alternative 6 ($4,000,000).

1.0
INTRODUCTION

The United States Army Corps of Engineers (USACE), Alaska District, retained Woodward-Clyde Federal Services (Woodward-Clyde) to perform a Feasibility Study (FS) at Operable Unit B (OUB) at the Fort Richardson United States (U.S.) Army post near Anchorage, Alaska. OUB consists of one site, the Poleline Road Disposal Area (PRDA). Fort Richardson is on the United States Environmental Protection Agency (USEPA) National Priority List (NPL), and all work performed for the PRDA was in compliance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Work also was conducted in compliance with the draft Federal Facilities Agreement (FFA) negotiated among the U.S. Army, the USEPA, and the Alaska Department of Environmental Conservation (ADEC). The OUB FS project was assigned Delivery Order Number 017, under terms of USACE contract number DACA85-94-D-0005. The scope of the FS was provided by the USACE in a Statement of Work (SOW) dated December 6, 1995.

1.1 PURPOSE OF FEASIBILITY STUDY

The purpose of the FS is to evaluate potential remedial alternatives. The FS report is intended to provide information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for the PRDA site. The FS is based on data collected during previous investigations and will be used during preparation of the Proposed Plan and, following public comment on the Proposed Plan, the Record of Decision for the site remedy.

1.2 FEASIBILITY STUDY APPROACH AND ORGANIZATION

1.2.1 Approach

The FS was conducted in four phases. The first phase involved the development of remedial action objectives (RAOs); the identification and screening of general response actions, remedial technologies, and process options; and the development of remedial alternatives. The results of the first phase were presented in the First Technical Memorandum submitted April 22, 1996 (Woodward-Clyde 1996a). Comments to the First Technical Memorandum guided the second phase of the FS, which was a detailed analysis and comparison of alternatives. The results of the second phase were presented in the Second Technical Memorandum submitted June 17, 1996 (Woodward-Clyde 1996b). Comments to both memoranda were incorporated into the Draft Final FS Report (Woodward-Clyde 1996e). The third phase consisted of a final review by the Remedial Project Managers (RPMs) and the subsequent deletion and combination of proposed alternatives, which were presented in the Draft Final FS report (Woodward-Clyde 1996f). The fourth phase consisted of a review of results of the fall 1996 treatability study and development of a new alternative, which is presented in this Second Draft Final FS report as Alternative 6.

1.2.2 Organization

This Final FS report is organized as follows. Section 1.0, *Introduction*, presents the purpose and the approach of the FS and a summary of previous investigations, a removal action, a remedial investigation (RI), a risk assessment, and a treatability study. Section 2.0, *Identification and Screening of Remedial Technologies and Process Options*, contains remedial action objectives; the identification of general response actions, remedial technologies and process options; and screening of remedial technologies and process options. Section 3.0, *Development of Alternatives*, is a summary of the development of each of the six alternatives chosen for the PRDA. Section 4.0, *Analysis of Alternatives*, includes a detailed analysis of alternatives; a comparative analysis of remedial alternatives; and conclusions. Section 5.0, *References*, contains a list of documents used in preparation of the FS. Appendix A contains applicable or relevant and appropriate requirements (ARARs), and Appendix B presents the groundwater modeling for conceptual design development.

1.3 SITE DESCRIPTION AND HISTORY

1.3.1 Site Description

This section presents a brief description of the PRDA site. Additional details are provided in the Final RI Report (Woodward-Clyde 1996c).

Location

The PRDA is located on the Fort Richardson U.S. Army Post, approximately 10 miles northeast of Anchorage, Alaska (Figure 1-1). The site is approximately 1 mile south of the Eagle River and 0.6 miles north of the Anchorage Regional Landfill (Figure 1-2). Access to the area is by Poleline Road, a major gravel road that runs northeast-southwest along a power line route and the Eklutna Water Line. The PRDA is bisected by Barrs Boulevard, a gravel road extending from the Glenn Highway to Poleline Road.

Topography

The PRDA is a low-lying, relatively flat area which is bordered by wooded hills to the northwest and southeast. Wetlands are located directly south and southwest of disposal areas A-1 through A-4 (Figure 1-3). The remaining area bordering the PRDA is relatively flat and wooded.

Geology

The surficial deposits of the region are fluvially reworked glacial sediments and glacial tills. These deposits appear to be up to 30 feet thick at the site and consist of unstratified to poorly stratified clays, silts, sands, gravels, and boulders. A basal till lies below the surficial deposits and overlies an advance moraine/till complex. Underlying the glacial sediments is bedrock composed of a hard black fissile claystone.

A 1979 Soil Survey described most of the soils at PRDA as a Homestead silt loam (USACE 1979). The Homestead silt loam is described as a well-drained soil formed over very gravely till. The underlying till varies in compactness, and in some areas is very firm. The Homestead occurs on moraines with slopes ranging from 0 to 75 percent. Soils matching the Homestead series are found over most of the site, except for the wetland areas, which were included in the Salamatof series. The Salamatof is a nearly level, very poorly drained soil consisting of fibrous peat materials that occurs in broad basins and depressions on terraces and moraines. Salamatof series soils are found in the wetlands to the southwest of the site and a small area immediately northeast of Area A-1.

The subsurface soils collected during the 1995 field investigation were glacial tills, generally described as silty sands with some gravel. These three grain sizes (silt, sand and gravel) were observed in nearly every sample at various percentages. Clay sized particles were observed in very few samples. The soils at PRDA were difficult to drill through and sample because of the high density. The effect of the density can be seen in the blow counts recorded during drilling. It was not unusual for blow counts to exceed 50 blows per 6 inches. Few lithological changes were noted during drilling.

Hydrogeology

Four water bearing intervals have been identified at the PRDA (Figure 1-4). The four water bearing intervals are a perched interval, a shallow interval, an intermediate interval, and a deep aquifer. The detection of contaminants in all four intervals suggests that they are interconnected to some degree. Observations made while drilling indicate that the saturated intervals are separated by zones of very dense, low porosity, compact tills. The compact tills are dry or slightly moist.

The perched interval was observed in borings drilled between Area A-2 and the wetlands, and in Area A-3. The top of the perched interval was encountered at 4 to 10 feet below ground surface (bgs), and the bottom was found at 6 to 12 feet bgs. The average thickness of the perched interval is approximately 5 feet. The perched interval is recharged mainly by surface water from the wetlands, although some recharge also occurs from precipitation. The only well installed in the perched interval is MW-14.

The shallow saturated interval is an average of 10 feet thick; the top was encountered at 20 to 25 feet bgs, and the bottom was found at 28 to 36 feet bgs. Groundwater elevations indicate that shallow groundwater is flowing in a north-northeast direction. There are 11 monitoring wells screened in the shallow interval, including the background well. Additional wells and piezometers were installed in the shallow zone during the treatability study as described in Section 1.4.6. Because of the localized nature of water-bearing zones in this typical glacio-fluvial geologic setting, it is difficult to tell whether the water-bearing units are hydraulically connected between wells. The shallow interval is recharged by water from the perched interval and by infiltration of precipitation.

The intermediate interval was observed while drilling deep monitoring well MW-16. The saturated portion of the intermediate interval was encountered at approximately 65 to 95 feet bgs in MW-16. The intermediate saturated interval does not correlate with the other deep wells on site, suggesting that it is an isolated lens with limited continuity. There may be several isolated lenses of saturated material within the intermediate interval.

The five deep monitoring wells at the PRDA penetrate the deep aquifer, the top of which was encountered from approximately 80 to 125 feet bgs. The deep aquifer is an advance moraine/till complex with a thickness of between 3 and 40 feet. Groundwater elevations indicate that the flow direction in the deep aquifer is locally to the northeast and regionally to the northwest. The available data indicate that the deep aquifer below the PRDA is not connected with the aquifers used for drinking water in the community of Eagle River (over one mile to the northeast).

The deep aquifer overlies a claystone bedrock unit with unknown thickness. Four of the five deep wells at the PRDA penetrate the bedrock unit and the well screens extend slightly into the bedrock. The top of bedrock was encountered from 120 to 170 feet beneath the PRDA.

Hydraulic conductivities were estimated from existing site data (slug tests performed by Environmental Science and Engineering, Inc. [ESE], and grain size analyses conducted during the RI) and from literature values documenting hydraulic conductivities in similar hydrogeologic intervals in the Eagle River area (Munter and Allely, 1992):

Saturated Interval	Estimated Hydraulic Conductivity
Perched	0.5 feet per day (ft/day)
Shallow	0.5 ft/day
Intermediate	0.05 ft/day
Deep	0.3 ft/day

Five single well pump tests were completed during the fall of 1996. The hydraulic conductivities calculated from the pump test data ranged from 0.7 to 3.4 ft/day. Only wells installed in the shallow groundwater interval were pump tested. The hydraulic conductivity values calculated from the pump tests generally agree with the previous estimated values.

The ultimate discharge of the water-bearing intervals at the PRDA is probably the Eagle River, approximately 1 mile north of the PRDA. The Eagle River flows into the Knik Arm of Cook Inlet approximately 5 miles northwest of the PRDA. The river is not used as a drinking water supply.

Land Use

The land surrounding the PRDA currently is used for U.S. Army training activities and for recreational purposes. It is unlikely that groundwater beneath the PRDA ever would be used for a drinking water supply. Yield from the intermediate, shallow, and perched saturated intervals may be too low to supply an average household, and the installation of septic systems would preclude use of the shallow or perched intervals for drinking water. The deep aquifer may provide sufficient yield but the installation of drinking water wells in the deep aquifer is unlikely. The Eklutna Water Line, a pipeline which supplies Anchorage and the community of Eagle River with drinking water from Eklutna Lake (over 15 miles from the site), runs immediately west of the PRDA and would provide a relatively inexpensive and reliable source of drinking water.

1.3.2 Waste Disposal History

The PRDA was identified in 1990 through interviews conducted by the U.S. Army with two ex-soldiers who were stationed at Fort Richardson in the 1950s and who recalled the disposal of chemicals and other materials in the area (ESE 1991). The disposal location was corroborated by a USACE map dated 1954 showing a "Chemical Disposal Area" at the PRDA, and by 1957 aerial photography showing trenches in the area. A 1965 aerial photograph shows that a portion of the hill west of the PRDA was cut back.

The disposal area was active from approximately 1950 to 1972. At this time, standard military practice was to dispose of suspected chemical weapons in the following manner (OHM Remediation Services, Inc. [OHM] 1993). A layer of "bleach/lime" was laid down in the bottom of the trench, and then the materials contaminated with chemical weapons were placed on a pallet in the trench. Diesel fuel was poured on the agent and then ignited with thermal grenades. After burning was complete, a mixture of either bleach or lime, combined with chlorinated solvent carrier (trichloroethene [TCE], tetrachloroethene [PCE], and 1,1,2,2-tetrachloroethane) was poured over the materials.

Information provided by the ex-soldiers indicated that disposed materials may have included solvents and other decontaminants (such as bleach) that were used to neutralize chemical warfare agents, smoke bombs, and Japanese cluster bombs (ESE 1991). Both types of bombs were detonated in pits prior to burial, but there may have been many duds dispersed over the area that were not recovered.

1.4 SUMMARY OF PREVIOUS WORK

1.4.1 Previous Investigations and Removal Action

Several investigations and a removal action have been conducted at the PRDA since its discovery in 1990. ESE conducted site investigations between 1990 and 1992. ESE's investigations included a geophysical survey, soil sampling from 10 borings, a soil gas survey, installation of 11 groundwater monitoring wells, groundwater sampling, a water level study, and aquifer (slug) tests. ESE's investigations are detailed in three documents listed in Section 5.0: ESE 1990, ESE 1991 and ESE 1993.

OHM began a removal action in Areas A-3 and A-4 in 1993, but work was halted when chemical agent identification sets (CAIS) and other materials related to chemical warfare training activities were unearthed. The Cold Regions Research and Engineering Laboratory (CRREL) performed a geophysical survey in early 1994 (CRREL 1994). The geophysical survey identified four disposal areas (later designated Areas A-1 through A-4). The survey identified significant anomalies consistent with trenches and buried waste in the four disposal areas. Areas A-3 and A-4 showed the greatest evidence of buried waste and trenching, including possible stacked canisters or cylinders.

OHM completed the removal action in Areas A-3 and A-4 in October 1994 (OHM 1995). Chemical analyses from ESE's and OHM's sampling confirmed that volatile organic compounds (VOCs) were present in the subsurface at the PRDA. The VOCs detected at the highest concentrations were chlorinated solvents, especially TCE, PCE, and 1,1,2,2-tetrachloroethane. These VOCs were detected in soils and in groundwater samples from the shallow, intermediate and deep intervals (there were no wells in the perched interval during previous sampling events). Concentrations of metals were within regional background levels and semivolatile organic compounds were not detected at the site. The only chemical warfare material (CWM) detected in soils was adamsite. Adamsite is an arsenic-based vomiting agent used in aerosol form for riot control. No CWM, CWM breakdown products or explosives were detected in groundwater samples collected by ESE and OHM except for one detection of the explosive hexahydro-1,3,5-trinitro-1,3,5-triazine (commonly known as Research Department Explosives, Royal Demolition Explosives, or RDX) in a groundwater sample from monitoring well MW-5.

Soils excavated during the removal action in Areas A-3 and A-4 were analyzed and compared to the following removal action concentrations:

Chemical	**Removal Action Concentration**
TCE	600 milligrams/ kilogram (mg/kg)
PCE	100 mg/kg
1,1,2,2-tetrachloroethane	30 mg/kg

The removal action concentrations listed above were established for the three contaminants that were detected at the most elevated concentrations during OHM's removal action. After buried debris was removed, soil sampling was performed on a grid pattern on the bottom and walls of the excavations to confirm that soils exceeding the removal action concentrations had been removed. Soils were excavated to a maximum depth of 14 feet, where water was encountered. Soils that met the removal action concentrations were mixed with borrow soil and returned to the excavations. No additional soil cover was added to Areas A-3 and A-4. Soils that exceeded the action levels were stockpiled southeast of the site on Barrs Boulevard in lined, plastic-covered piles surrounded by berms. The stockpile area is currently fenced, and remediation of the stockpiles is scheduled for spring 1997.

The CRREL performed another geophysical survey in June 1995 (CRREL 1995) to determine whether any suspicious material remained in the recently excavated areas and to define more accurately anomalous zones in areas not excavated in 1994. Results of the survey indicated that the buried material had been removed, thereby removing the primary source of subsurface contaminants.

Areas A-1 and A-2 have not been excavated or sampled. Based on the geophysical survey, these areas are expected to contain less significant quantities of buried waste, and therefore contaminated soil, than found in Areas A-3 and A-4. Information from an ex-soldier indicated that undetonated bomblets from cluster bombs may be buried in Areas A-1 and A-2 (ESE 1991). Approximately 3 feet of soil overlies the apparent disposal horizon (18 inches of soil originally overlying the disposal horizon, plus an 18-inch soil cover added in 1994).

The condition of the wetlands was largely unknown prior to the 1995 RI. Based on the geophysical survey conducted in 1994 by CRREL, the wetlands may contain small dispersed metallic objects.

1.4.2 Remedial Investigation

Procedures

Woodward-Clyde performed an RI at the PRDA in August and September of 1995. Figure 1-3 shows the locations where soil, groundwater, sediment, and surface water samples were collected during the RI. Procedures and results of the RI are presented in the Final RI Report (Woodward-Clyde 1996c). The RI included the following tasks:

- Field screening for mustard, unexploded ordnance, and chlorinated solvents
- Collection and analysis of soil samples from 43 soil borings (including 3 background)
- Collection and analysis of 34 groundwater samples from well points
- Installation of 6 groundwater monitoring wells

- Collection and analysis of groundwater samples from 17 monitoring wells (including 1 background)
- Evaluation of the presence of dense nonaqueous phase liquids (DNAPLs)
- Performance of borehole geophysical surveys in 17 monitoring wells
- Collection and analysis of 10 sediment and surface water samples (including 6 background)

Results

Detailed discussions of RI results are included in the Final RI report (Woodward-Clyde 1996c). Two contaminants, 1,1,2,2-tetrachloroethane and TCE, were found at concentrations significantly higher than any other chemical detected at the site. These two contaminants were also detected over the largest area. Section 1.4.3 discusses the extent of contamination by disposal area and by saturated interval.

Alaska maximum contaminant levels (MCLs) for groundwater were exceeded for several contaminants:

Contaminant	MCL (mg/L)	Monitoring Well	Concentration (mg/L)
Benzene	0.005	MW-14	2.9
Carbon Tetrachloride	0.005	MW-14	2.6
cis-1,2-dichloroethene	0.07	MW-4	1.6
		MW-7	0.28
		MW-14	37
trans-1,2-dichloroethene	0.1	MW-4	0.41
		MW-14	12
tetrachloroethene (PCE)	0.005	MW-4	0.31
		MW-14	11
trichloroethene (TCE)	0.005	MW-1	0.043
		MW-3	0.26
		MW-4	14
		MW-5	4.8
		MW-6	0.13
		MW-7	1.0

Contaminant	MCL (mg/L)	Monitoring Well	Concentration (mg/L)
		MW-12	0.16
		MW-13	0.0067
		MW-14	220
		MW-15	0.27
1,1,2,2-tetrachloroethane	None	MW-1	0.082
		MW-3	0.54
		MW-4	71
		MW-5	21
		MW-6	0.52
		MW-7	3.1
		MW-12	0.49
		MW-13	0.0011
		MW-14	1,900
		MW-15	0.0063

NOTES:

Only those concentrations that exceed MCLs are shown, except for 1,1,2,2-tetrachloroethane where all detections are shown.

mg/L = Milligrams per liter.

MW-10 and MW-11 were dry. MW-17 (background well) was only sampled for metals.

Several soil samples were collected from background locations and analyzed for metals. The concentrations of metals detected in soil samples collected at the site were compared with the average concentrations of metals in the background soil samples. Three metals (copper, lead and zinc) were detected in Areas A-3 and A-4 at concentrations twice the average background concentrations. Other metals detected in Areas A-3 and A-4, and all metals detected in other areas of the site, were within or near background concentrations.

Thiodiglycol, a breakdown product of mustard, was detected in one groundwater sample (0.48 mg/L in MW-14). No other samples had any CWM or CWM breakdown products detected. Minor detections of explosives were reported in the wetlands and in one wellpoint groundwater sample, but concentrations are below ARARs.

None of the constituents analyzed for in wetlands sediment and surface water exceeded ARARs.

1.4.3 Extent of Contamination

Extent of Contamination by Disposal Area

Areas A-3 and A-4

The highest concentrations of contaminants detected in soil and groundwater samples were found in Areas A-3 and A-4. Soil samples collected from the backfilled soil had concentrations of 1,1,2,2-tetrachloroethane, TCE, and PCE well below the removal action criteria established for the previous removal action; however, soil samples collected from below the backfilled soil had some of the highest concentrations of contaminants detected at the site (> 2,000 mg/kg 1,1,2,2-tetrachloroethane).

Areas A-1 and A-2

Lesser concentrations of contaminants were detected in the soils and groundwater near Areas A-1 and A-2 (soils and groundwater within A-1 and A-2 were not sampled because of the potential for unexploded ordnance). The concentrations of contaminants detected decreased from west to east across Areas A-1 and A-2. The pattern suggests that the contaminants detected near saturated intervals in Areas A-1 and A-2 migrated there from Areas A-3 and A-4. It does not appear that contaminants were released in Areas A-1 or A-2 except for potential surface spills, which may have been the source for contaminants detected in shallow soils near A-2. Since no contaminants appear to have been released in the subsurface in Areas A-1 and A-2, it is unlikely that CWM were disposed of in these areas (chlorinated solvents were poured on the CWM in Areas A-3 and A-4 for neutralization). It appears that contaminants in the groundwater migrated north-northeast from Areas A-3 and A-4, in the direction of groundwater flow.

Extent of Contamination by Saturated Interval

Contaminants were detected in each of the four saturated intervals. A well installed in Area A-3 and screened in the perched interval had the highest concentrations of 1,1,2,2-tetrachloroethane (1,900 mg/L) and TCE (220 mg/L) detected. Most of the wells are installed in the shallow and intermediate intervals. These wells had the next highest concentrations of 1,1,2,2-tetrachloroethane (71 mg/L maximum) and TCE (14 mg/L maximum). Contaminants were also detected in each of the wells screened in the deep aquifer. The groundwater sample collected from the monitoring well furthest downgradient in the deep aquifer had 0.00031 mg/L of TCE detected. The results indicate that there is interconnection between the saturated intervals which allows the contaminants to migrate vertically.

Ranges in concentrations of 1,1,2,2-tetrachloroethane and TCE detected during the RI are presented below by saturated interval:

Saturated Interval	Monitoring Wells	1,1,2,2-tetrachloroethane (mg/L)	TCE (mg/L)
Perched	MW-14	1,900	220
Shallow	MW-2, 5, 8, 12, 13, 15	0.0011 - 21	ND (0.0002) - 4.8
Intermediate	MW-3, 4	0.54 - 71	0.26 - 14
Deep	MW-1, 6, 7, 9, 16	ND (0.002) - 3.1	0.00031 - 1

NOTES:

mg/L = Milligrams per liter.

ND = Not detected at the detection limit in parentheses.

MW-17 (background well) was not sampled for VOCs. MW-10 and 11 were dry.

1.4.4 Human Health Risk Assessment

A Human Health Risk Assessment (HHRA) was performed in 1995 to evaluate whether existing concentrations of contaminants in media at the PRDA could pose a threat to human health under conservative (health-protective) exposure assumptions (Woodward-Clyde 1996d). The risk assessment is conservative because it is based on long-term residential or occupational exposures which are not likely at this site, thereby overestimating risk for site-specific exposure scenarios. The most probable future use of the site is continued use for military training.

Soil, Sediment, and Surface Water

The HHRA shows that the relatively low concentrations of contaminants in soils from 0 to 15 feet bgs (the depth of potential direct human exposure) and wetland surface water and sediments at PRDA do not pose an unacceptable risk to public health under conservative exposure assumptions of long-term residential or industrial use. It therefore follows that exposure to contaminants in soil and the wetland would not pose an unacceptable risk to current authorized personnel and/or other potential receptors such as recreational users or commercial workers, who would be expected to receive much less exposure than that assumed for residents in this assessment.

- No carcinogens were detected in surface water in the wetland. The low concentrations of VOCs, explosives, and metals in wetland surface water do not pose a threat of noncarcinogenic health effects. Trace levels of explosives in sediments in the wetland do not pose unacceptable risk of cancer or noncancer health effects.

- In Areas A-1 and A-2, risk of cancer and noncancer health effects from exposure to low concentrations of VOCs and metals in soil at depths of 0 to 15 feet bgs were negligible.

- Lifetime excess cancer risk was 1E-05 (1 in 100,000) and noncarcinogenic hazard index was less than 1 for residential exposure to soil in Areas A-3 and A-4 at depths of 0 to 15 feet bgs. The primary contributors to cancer risk were 1,1,2,2-tetrachloroethane and TCE (exposure point concentrations of 4.6 and 4.1 mg/kg, respectively) via the soil ingestion and soil-to-air inhalation route of exposure. Generally, remediation is not warranted for protection of public health if total lifetime excess cancer risk does not exceed 1E-04 and if noncarcinogenic effects are not a concern (HI < 1).

- The highest concentrations of VOCs in soil were detected in Areas A-3 and A-4 at depths greater than 15 feet bgs, below the depth of potential direct human exposure (e.g., 2,030 mg/kg 1,1,2,2-tetrachloroethane and 0.384 mg/kg TCE were detected at MW-14 at a depth of 16 to 18 feet bgs). Although these contaminants do not pose a threat to human health, they could serve as a continuing contaminant source to groundwater.

Groundwater

Use of groundwater from the shallow interval or deep aquifer at the PRDA as a drinking water source would pose an unacceptable risk of cancer and noncancer health effects. (The physical properties of the shallow saturated interval make its use as a drinking water source highly unlikely; however, to provide a more conservative measure of risk, it was evaluated in the risk assessment as a potential drinking water source.) Groundwater at the PRDA or downgradient from it is not currently used in any capacity nor is it expected to be used in the future. Groundwater fate and transport modeling indicates that contaminants at the PRDA do not pose a threat to the Eagle River in the imminent or near future.

- Primary contributors to lifetime excess cancer risk in groundwater at the PRDA were 1,1,2,2-tetrachloroethane and TCE (exposure point concentrations in the shallow interval of 16.9 and 6.3 mg/L, respectively). Concentrations of carbon tetrachloride, chloroform, cis-1,2-dichloroethene, 1,1-dichloroethene, PCE, and 1,1,2-trichloroethane also exceeded levels of concern for residential exposure to groundwater.

- The highest concentrations of contaminants in groundwater at the PRDA were detected in the perched interval (1,900 mg/L 1,1,2,2-tetrachloroethane and 220 mg/L TCE were detected in MW-14 at a depth of 22 feet bgs). Although these contaminants do not pose a threat to human health (the perched interval would not be used as a water supply), they could serve as a continuing contaminant source to the shallow interval and deep aquifer.

Based on groundwater fate and transport modeling, it would take 120 years for concentrations of TCE exceeding the drinking water MCL (0.005 mg/L) to reach the Eagle River and 170 years for concentrations of 1,1,2,2-tetrachloroethane exceeding 0.005 mg/L to reach the Eagle River (details of groundwater modeling are provided in Appendix XIII of the Final RI Report). These 0.005 mg/L concentrations of 1,1,2,2-tetrachloroethane and TCE do not exceed health-based concentrations of concern for residential drinking water or for ingestion of fish by humans (0.011 mg/L for 1,1,2,2-tetrachloroethane and 0.081 mg/L for TCE).

1.4.5 Ecological Risk Assessment

An ecological risk assessment (ERA) was performed in 1995 in conjunction with the HHRA (Woodward-Clyde 1996d). The detected organic chemicals, explosives, and metals were screened against four criteria: frequency of detection; site-specific background data; toxicity based screening; and literature-based background values. The screening was done to assess which of the detected chemicals required further evaluation to assess potential risk to ecological receptors. The results of the screening process indicated that seven VOCs in soil from 0 to 3 feet bgs (the depth of potential direct exposure for ecological receptors) and two explosives in wetland sediment were contaminants of ecological concern (COECs) that required further evaluation of risk to ecological receptors.

The northern red-backed vole and muskrat were selected as representative terrestrial site receptors for the upland and wetland habitats, respectively, based on site-specific exposure pathways and ecological considerations. The potential for adverse effects from COECs on upland and wetland plant communities and aquatic invertebrates were also evaluated. Benchmark toxicity values for the COECs were determined for each receptor. The Quotient Method (QM) was used to quantitatively evaluate potential risk from exposure to COECs in soil and sediment. The QM is based on the comparison of estimated maximum and reasonable maximum exposure (RME) dose concentrations for onsite receptors with protective benchmark toxicity values derived from the toxicological literature.

Based on the risk analysis, COEC concentrations at the PRDA result in negligible risk to small mammal populations, aquatic invertebrates, emergent wetland vegetation, and upland plant vegetation. The overall potential for valued environmental resources at this site to be adversely affected is considered negligible.

The 0.005 mg/L concentrations of 1,1,2,2-tetrachloroethane and TCE that are estimated to reach the Eagle River in 120 and 170 years, respectively, are well below levels of concern for protection of aquatic organisms. These results indicate no imminent or near future threat to the Eagle River.

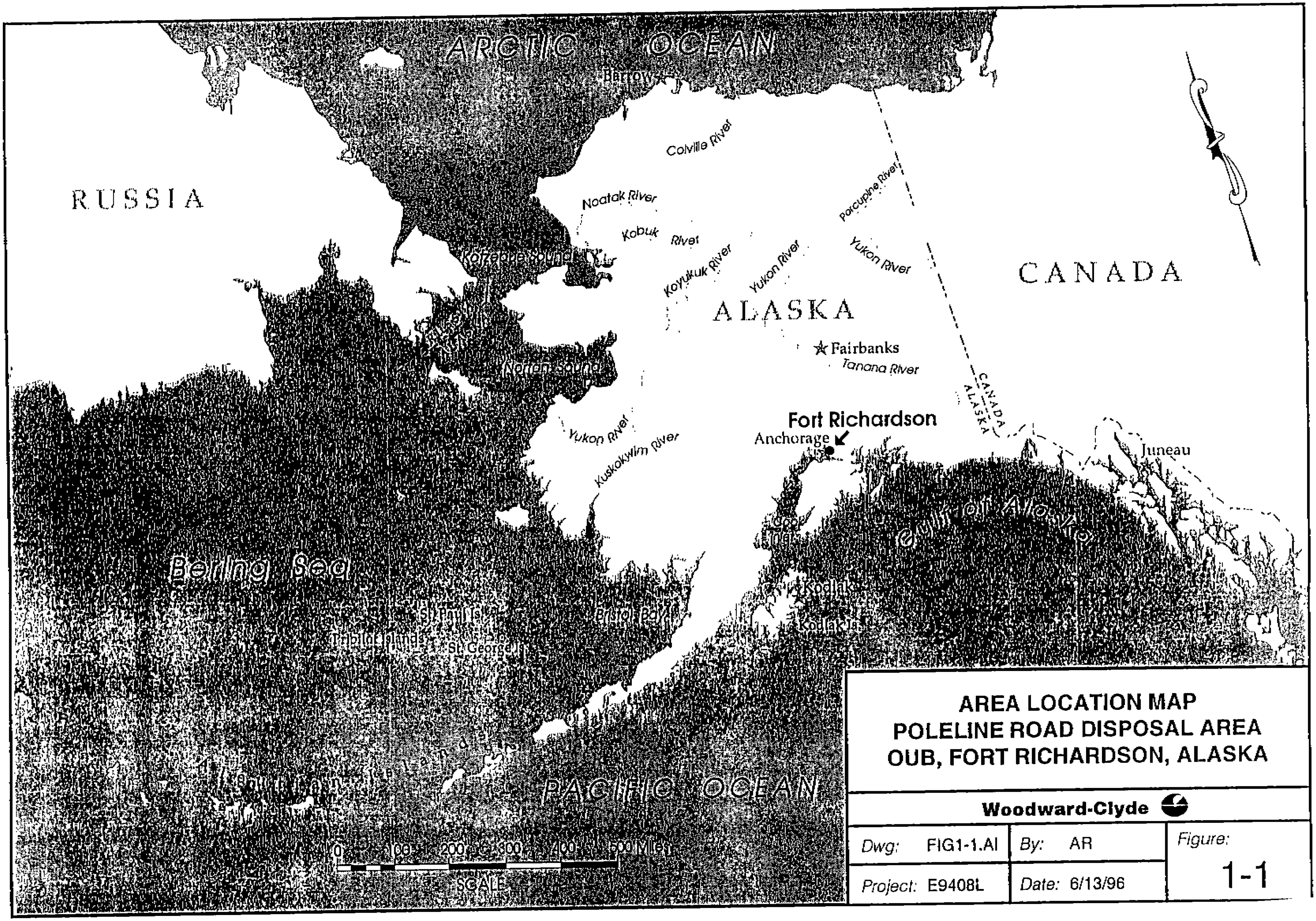
1.4.6 Treatability Study

Treatability study tests were completed at the PRDA during the fall of 1996. These tests were completed to help reduce the uncertainty involved in the alternatives proposed in this document. The treatability tests included: soil vapor extraction, air sparging, pump tests and groundwater sampling to identify natural attenuation processes.

The soil vapor extraction (SVE) test was run for 5 days. Samples of the extracted soil gas show that SVE is effective at removing the target contaminants (TCE and 1,1,2,2-tetrachloroethane) from the subsurface. The air sparge test was conducted during the last day of the SVE test. The air sparge well was located 5 feet from the SVE well. Samples of the extracted soil gas show that the concentration of TCE extracted from the SVE well increased when the air sparge blower was turned on, but there was little increase in the concentration of 1,1,2,2-tetrachloroethane observed.

Five single well pump tests were completed in wells screened in the shallow groundwater interval. The hydraulic conductivities calculated from the pump test data ranged from 0.7 to 3.4 ft/day. These values, although slightly higher, generally agree with previously estimated values.

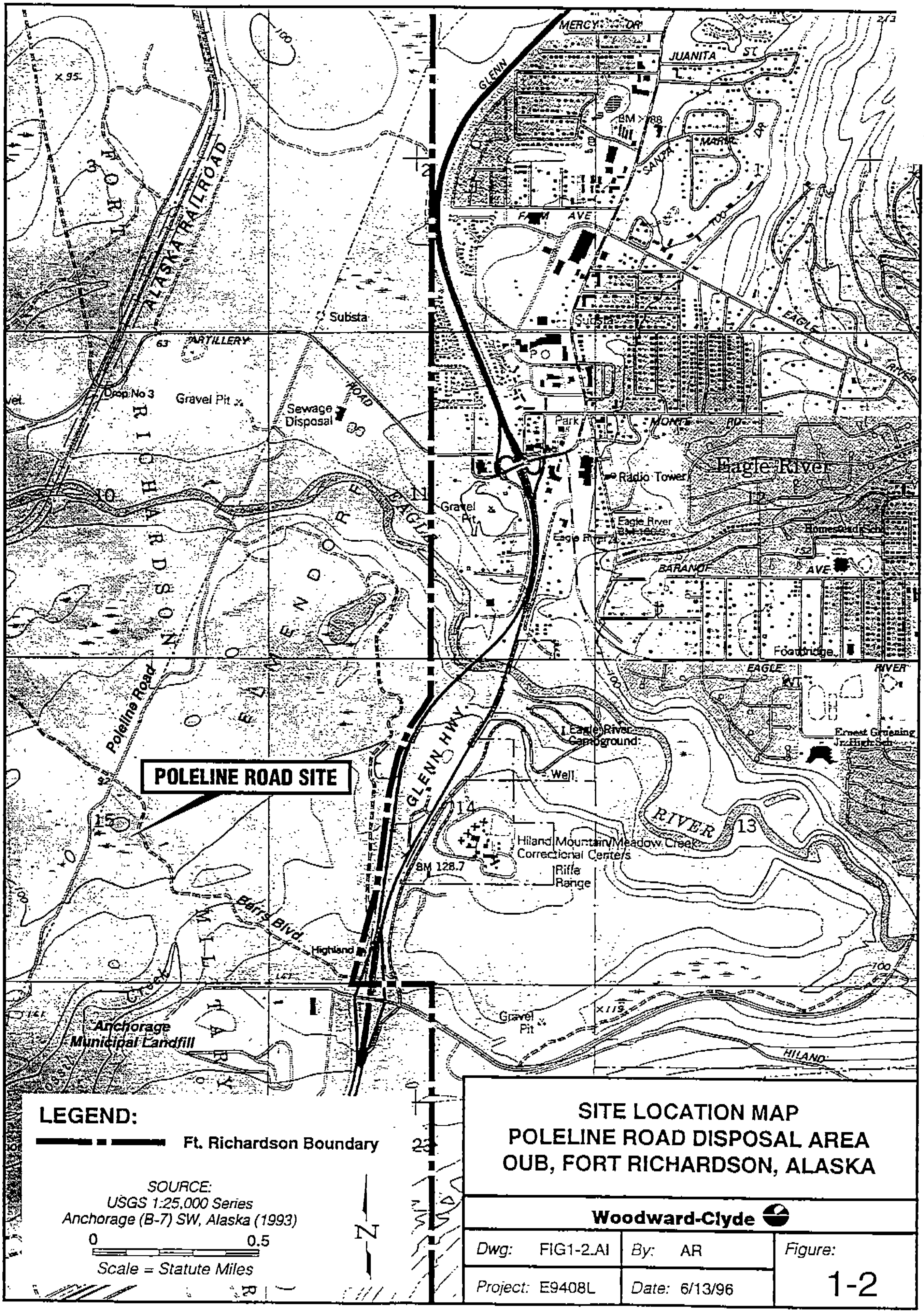
Groundwater samples were collected from seven monitoring wells and analyzed for natural attenuation parameters and volatile organic compounds. The natural attenuation parameters included nutrients needed for bioremediation (nitrate, nitrite, TOC, iron, etc.), degradation byproducts (methane, ethane, ethene, and sulfide), and bacteria counts (sulfate reducing bacteria and heterotrophic plate count). The sampling results indicated that very little if any natural attenuation of the contaminants is occurring.



AREA LOCATION MAP
POLELINE ROAD DISPOSAL AREA
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

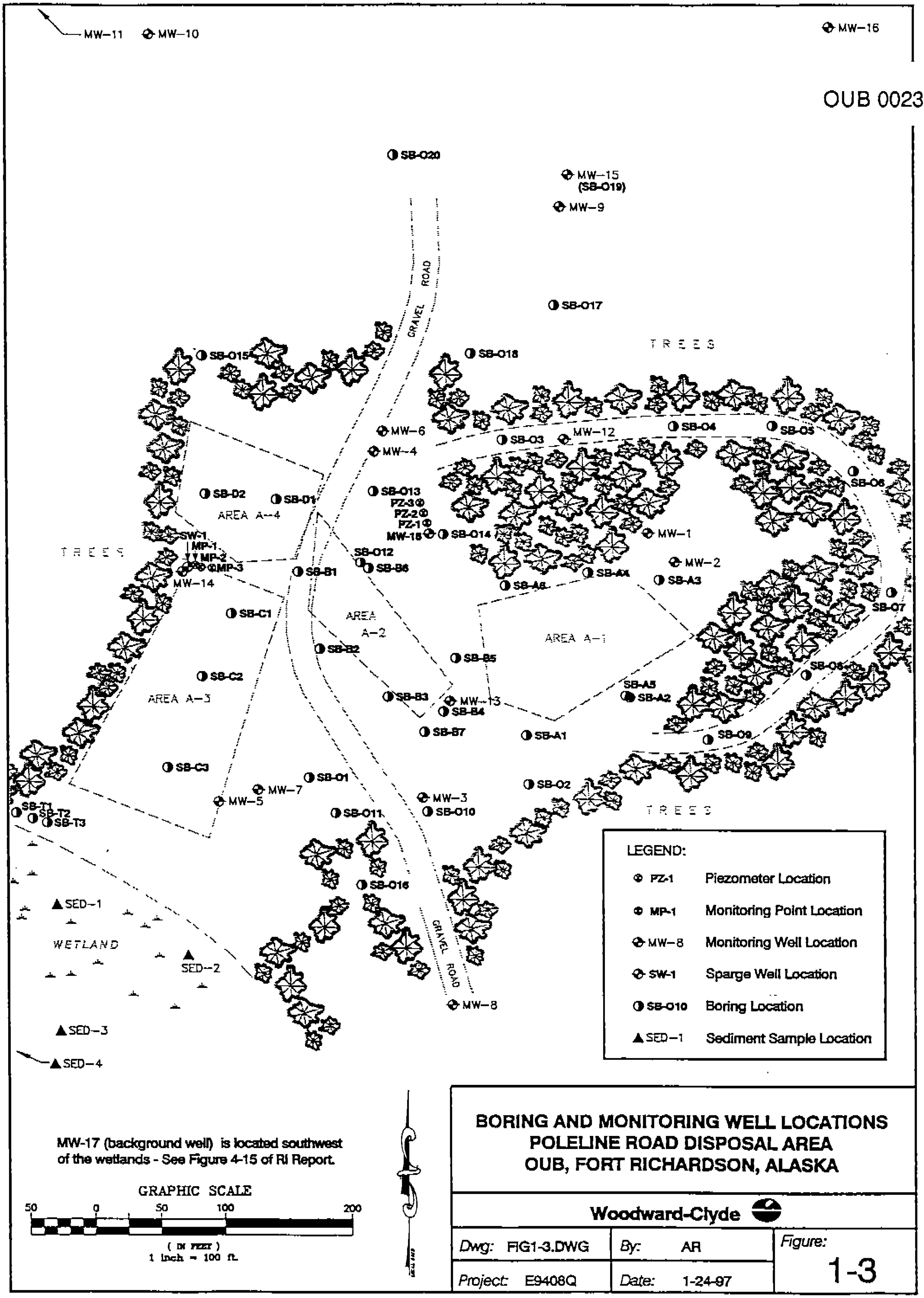
Dwg:	FIG1-1.AI	*By:* AR	*Figure:* 1-1
Project:	E9408L	*Date:* 6/13/96	



SITE LOCATION MAP
POLELINE ROAD DISPOSAL AREA
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg: FIG1-2.AI	By: AR	Figure:
Project: E9408L	Date: 6/13/96	1-2

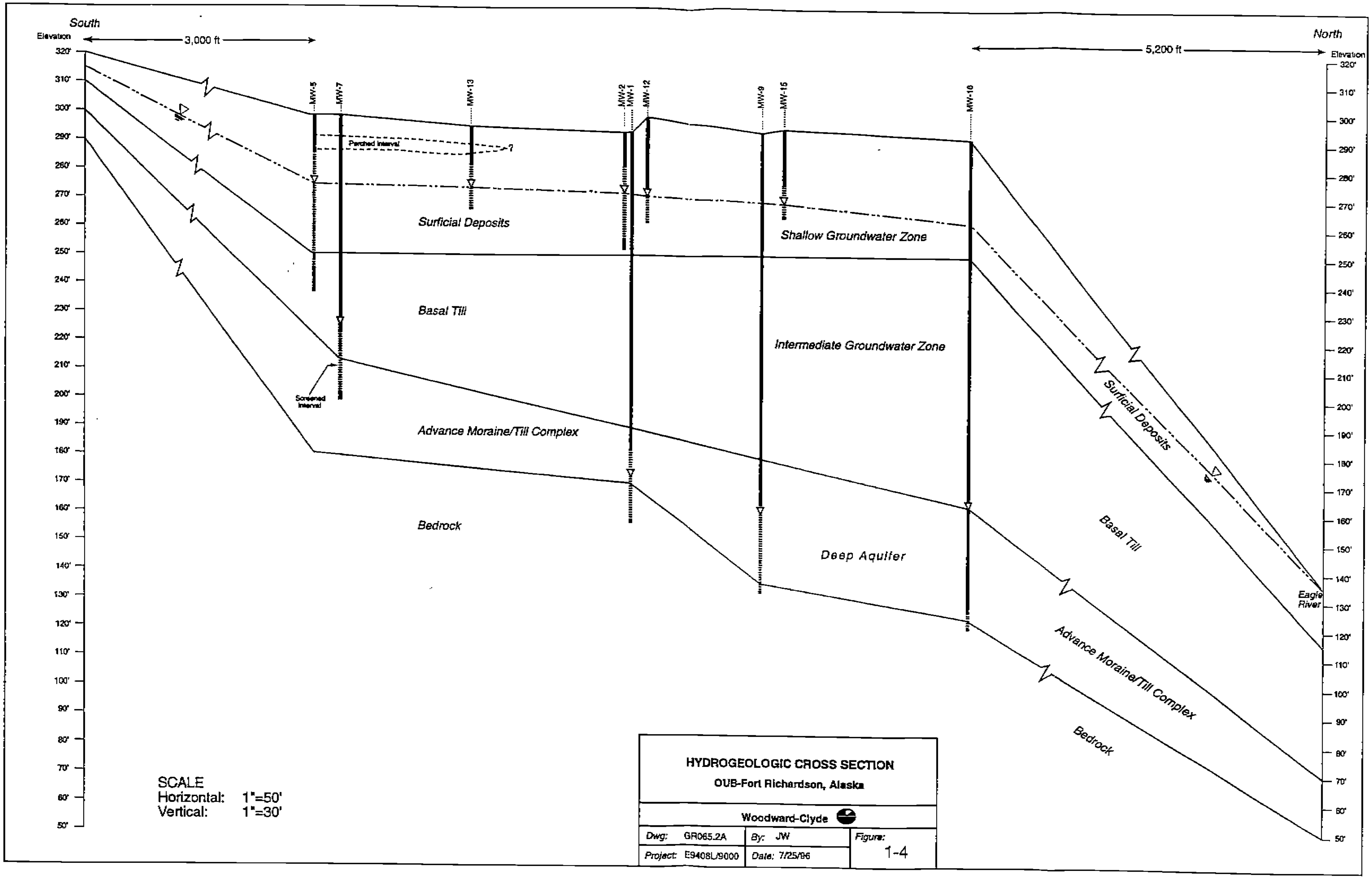


MW-17 (background well) is located southwest of the wetlands - See Figure 4-15 of RI Report.

BORING AND MONITORING WELL LOCATIONS
POLELINE ROAD DISPOSAL AREA
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg:	FIG1-3.DWG	By:	AR	Figure:
Project:	E9408Q	Date:	1-24-97	1-3



SCALE
Horizontal: 1"=50'
Vertical: 1"=30'

HYDROGEOLOGIC CROSS SECTION
OUB-Fort Richardson, Alaska

Woodward-Clyde

Dwg: GR065.2A	By: JW	Figure: 1-4
Project: E9408L/9000	Date: 7/25/96	

2.0
IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

2.1 INTRODUCTION

This section of the FS for the PRDA identifies the Remedial Action Objectives (RAOs), general response actions, technology types, and specific process options for the site. Identification of these elements was conducted following USEPA's Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA 1988).

The first step in remedial alternatives development is to develop RAOs, which are medium-specific objectives for protecting human health and the environment. RAOs are discussed in Section 2.2. The second step is to identify general response actions, technology types, and process options appropriate for the RAOs, as well as volumes and areas of media to be remediated. This step is documented in Section 2.3. Finally, the technologies and process options are screened in Section 2.4.

2.2 REMEDIAL ACTION OBJECTIVES

This section presents the development of RAOs for the site. The RAOs specify medium specific goals for protecting human health and the environment.

The media of concern for evaluation in the FS are the perched, shallow, and intermediate groundwater intervals, and "hot spot" soils, potential sources of continuing contamination to the deep aquifer. The basis for this approach is described in the following paragraphs.

Groundwater in the perched and shallow intervals was identified in the Risk Assessment (Woodward-Clyde 1996d) as the medium which represents an unacceptable risk given a residential exposure scenario. The maximum hydraulic conductivity (K) of the shallow aquifer was estimated to be 0.5 feet per day (ft/day). A mini-pump test was performed on monitoring well MW-13 on October 10, 1996. The mini-pump test consisted of pumping MW-13 for 40 minutes. The maximum sustainable pumping rate was 0.5 gallons per minute (gpm) or 720 gallons per day (gpd). The perched, shallow, and intermediate intervals may be potential drinking water sources because they could produce useable quantities (100 gallons/capita/day) of groundwater. The deep aquifer is more likely to be a potential drinking water source, because it may be able to provide higher volumes of water.

The soils located above the water table at the site are not a medium of concern. The risk assessment stated that soils 0 to 15 feet bgs do not pose an unacceptable risk to human health. In addition, these soils are not a significant source of contamination to groundwater because all of the samples, except one, had levels of TCE below the Resource Conservation and Recovery Act (RCRA) Toxicity Characteristic Leaching Procedure (TCLP) limit of 0.5 mg/kg. Therefore, these soils will not be addressed in the FS.

Soils below the water table will be treated as part of the groundwater treatment process. The groundwater extraction process option may be matched with other treatment options (e.g., soil vapor extraction) to reduce the concentration of contaminants in the soils below the water table. Soil vapor extraction would be able to treat soils below the water table once the groundwater treatment process lowered the water table.

The chemicals of concern at the site are VOCs. Two VOCs have been chosen as the indicator chemicals: 1,1,2,2-tetrachloroethane and TCE. These two VOCs were found at the highest concentrations and at the greatest frequency throughout the site. TCE was found at lower concentrations than 1,1,2,2-tetrachloroethane but was selected as an indicator chemical because it has an MCL (0.005 mg/L), whereas 1,1,2,2-tetrachloroethane does not have an MCL.

Remedial action taken at this site must comply with federal, state, and local laws and regulations. A discussion of ARARs is presented in Appendix A. In accordance with USEPA guidance, chemical-, action-, and location-specific ARARs are identified in Appendix A.

Ingestion of groundwater is the exposure pathway that will be retained for the FS.

The following RAOs were developed for the PRDA:

1. Reduce contaminant levels in the groundwater to comply with drinking water standards
2. Prevent the soil from continuing to act as a source of groundwater contamination

3. Prevent the contaminated groundwater from adversely affecting the Eagle River surface water and sediments

4. Minimize degradation of the State of Alaska's groundwater resources at the site as a result of past disposal practices.

The first RAO would be measured by monitoring the concentrations of contaminants in the shallow interval and deep aquifer, but it will be reached by removing the source of contamination to the deep aquifer. Based on these RAOs, the FS evaluation will focus on the area of concern identified on Figure 2-1 to a depth of 60 feet bgs. The depth of 60 feet was chosen because it is below the depth of the most highly contaminated groundwater, modeling showed that it is sufficient to capture contaminants, and it is the depth below which specialized and very costly equipment is necessary for trenching. The 60-foot depth was used for all applicable alternatives in order to facilitate comparisons.

2.3 IDENTIFICATION OF GENERAL RESPONSE ACTIONS, REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

Following the establishment of the RAOs, general response actions, remedial technologies, and process options that may achieve the RAOs were developed for the site. General response actions include the following: no action; institutional controls; containment; groundwater collection; ex-situ treatment of groundwater; groundwater discharge; and in situ treatment. Remedial technologies include "types" of general remedial actions (i.e., biological treatment, physicochemical treatment, and thermal treatment). Process options may include "specific types" of treatment. To meet the RAOs developed in Section 2.2, the general response actions, remedial technologies, and process options identified for the site are described in the following sections.

2.3.1 General Response Actions

Figure 2-2 identifies seven general response actions evaluated for the groundwater medium. The general response actions evaluated are:

- No Action
- Institutional Controls

- Containment
- Groundwater Collection
- Ex-Situ Treatment of Groundwater
- Groundwater Discharge
- In situ Treatment

2.3.2 Remedial Technologies

The remedial technologies identified for each general response action are shown on Figure 2-2. The No Action general response action includes no remedial technologies. Three technologies were identified for the Institutional Controls general response action: access restrictions, use restrictions, and monitoring. Two technologies were identified for the Containment general response action: capping and vertical barrier. Two technologies were identified for the Groundwater Collection general response action: extraction and subsurface drains. Three technologies were identified for the Ex-situ Groundwater Treatment general response action: physical, chemical, and biological treatment. Two technologies were identified for the Groundwater Discharge general response action: on-site discharge and off-site discharge. Four technologies were identified for the In situ Treatment general response action: physical, chemical, biological, and thermal treatment.

2.3.3 Process Options

Figure 2-2 presents specific process options selected for each remedial technology. A short description of each process is also included. The process options were selected to cover a wide range of options, from commonly used technologies to new innovative technologies. These process options were identified using USEPA guidance (USEPA 1989), the USEPA's Vendor Information System for Innovative Treatment Technologies (VISITT) software (version 4.0), and the Superfund Innovative Technology Evaluation (SITE) program (USEPA 1993).

2.4 SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

This section presents an evaluation of the remedial technologies and process options identified in the previous section. The effectiveness, implementability, and relative cost of each remedial technology type and process option will be reviewed. The cost information at this stage is based on engineering judgment. Relative capital and operation and maintenance (O&M) costs are used rather than detailed estimates. The costs are presented in low, medium, and high terms relative to other process options in the same remedial technology type. This evaluation will provide a selection of remedial technologies and process options that will be considered for further evaluation for the PRDA site. A summary of the process options that were retained or eliminated from further consideration is presented in Figure 2-3.

2.4.1 No Action

No Action is required for consideration in the FS process by the National Contingency Plan (NCP) as a baseline condition. The No Action option is retained for further evaluation. There are no costs associated with this option.

2.4.2 Institutional Controls

Institutional controls are designed to limit exposure to hazardous materials by restricting site access or land use. Three remedial technologies for institutional controls were screened: access restrictions, use restrictions, and monitoring.

Access Restrictions

Effectiveness. Access restrictions (such as fencing) can prevent exposure to surface soil or surface water that poses an unacceptable risk. Access restrictions would not be effective at the PRDA, since the risk assessment has already indicated that the only media which could pose unacceptable risks are groundwater and soil gas.

Implementability and Cost. No implementability limitations have been identified for access restrictions. The cost is relatively low.

Evaluation. Access restrictions are not retained for further evaluation, because they are not effective at reducing the potential risk to human health that groundwater and soil gas represent.

Use Restrictions

Effectiveness. Use restrictions are potentially effective methods to prevent exposure by sensitive populations (for example, children) or to prevent chronic exposure to soils. Use restrictions, such as deed or zoning restrictions, could prevent ingestion of groundwater from the site by restricting specific site uses. Restricting site uses would also reduce the potential for vapor migration from the soils into basements. For example, restrict future use of the area to non-residential use, and forbid installation of water wells in the affected area.

Implementability and Cost. No implementability limitations have been identified for use restrictions. The cost is relatively low.

Evaluation. Deed and zoning restrictions are retained for further evaluation.

Monitoring

The process options are:

- Groundwater monitoring - groundwater monitoring wells are sampled for VOCs annually.
- Intrinsic groundwater monitoring - groundwater monitoring wells are sampled for parameters that would indicate the presence and rate of natural attenuation occurring in the groundwater.

Effectiveness. Groundwater monitoring for VOCs is an effective technique for monitoring the levels of contaminants in the groundwater. Sampling groundwater for parameters related to natural attenuation of the contaminants is also an effective monitoring technique.

Implementability and Cost. No implementability issues have been identified for either groundwater monitoring for VOCs or parameters related to natural attenuation. The capital cost for groundwater monitoring of VOCs and natural attenuation parameters is low. The O&M costs for groundwater monitoring of VOCs is low, and the O&M costs for monitoring natural attenuation parameters is relatively moderate.

Evaluation. Groundwater monitoring for VOCs and natural attenuation parameters is retained for further evaluation.

2.4.3 Containment

The containment general response action includes capping and vertical barriers.

Capping

The process options are:

- Asphalt - asphalt covering over contaminated area
- Compacted clay - compacted clay covered with sand and gravel
- Synthetic liner - synthetic membrane without secondary barrier
- Composite cap—RCRA compliant composite synthetic membrane/clay impregnated fabric

Effectiveness. Capping is effective at minimizing the amount of surface water recharge to groundwater at the site. But, at the PRDA the groundwater is recharged by both precipitation and flow from the wetland. A cap by itself would not be effective at the PRDA because water from the wetland would continue to enter the site through the subsurface. A cap will only be considered when used with a vertical barrier.

Implementability and Cost. Future land use is the most significant implementability constraint for capping. The costs, both capital and O&M, for the asphalt or compacted clay options would be relatively low. The synthetic liner would have moderate capital costs and low O&M, while the composite cap would have relativity high capital costs and low O&M.

Evaluation. A synthetic cap is retained for further evaluation. The asphalt cover is not retained for further evaluation because it would be effective only with regular maintenance to repair cracks from expansion and contraction. The composite cap is not retained for further evaluation since the relative increase in cost over the synthetic cap does not justify the marginal increase in protection. The compacted clay cap is not retained because there is not a nearby source of clay.

Vertical Barriers

The process options are:

- Grout curtains - grout injected into soil sets in place to form vertical barrier
- Slurry walls - low permeability bentonite forms vertical barrier
- Sheet pile walls - steel cutoff wall is pushed into soil to form vertical barrier

Effectiveness. Vertical barriers limit the horizontal migration of groundwater moving into or out of an area. The perched water interval at the site is recharged from precipitation and from water migrating from the wetland. A vertical barrier could minimize the flow of groundwater from the wetland into the site. Precipitation at the site and water flowing from the wetland are the two sources of recharge to groundwater at the site.

A grout curtain would be effective at minimizing horizontal migration, from the wetlands into the site but that portion of the grout curtain in the active layer would be subject to freezing and cracking. This would result in the potential for groundwater flow through the curtain. The active layer is that portion of the soil that freezes and thaws each year. The active layer extends from ground surface to as deep as 8 feet. Portions of the perched aquifer may be in the active layer. The bentonite slurry wall would likely not be affected by the freeze and thaw because of the flexibility of the wall.

Implementability and Cost. No implementability issues have been identified with trenching to 60 feet bgs at the site. Filling the trench with either a bentonite slurry or grout is also technically feasible. Installing a steel sheet pile wall has implementability issues. The sheet pile wall would be difficult to install because of the dense soils, cobbles, and small boulders that characterize the site. The cost for these options is low for the slurry wall, moderate for the grout curtain, and high for the sheet pile wall.

Evaluation. A slurry wall is retained for further evaluation. The grout wall is eliminated from further consideration because the wall will likely crack in the active frost layer and would then allow shallow groundwater to flow through the wall. The sheet pile wall is eliminated from further consideration because pushing the wall through the dense soils on site would be difficult.

2.4.4 Groundwater Collection

This section presents process options to extract groundwater. The process options include:

- Groundwater extraction wells - Groundwater is extracted from the subsurface by pumping from wells installed in the saturated intervals.
- Groundwater interception trenches - Groundwater is extracted from the subsurface by pumping groundwater from trenches that intersect the saturated intervals.

Effectiveness. Groundwater pumping is a common groundwater extraction method. Groundwater modeling was conducted to estimate the maximum flow rate of groundwater that could be extracted from a well. The modeling concluded that the maximum pumping rate that a single groundwater well could yield from the shallow groundwater zone is approximately 200 gallons per day (gpd).

Groundwater extraction trenches were also modeled at the site to evaluate the effectiveness and conceptual design for this system. The total flow rate from the trench system (three, 250-feet long trenches and one, 150-foot long trench) was estimated to be 1 gallon per minute (gpm).

Implementability and Cost. No significant implementability limitations have been identified for groundwater interception trenches except for potential difficulties in disposing of the trench spoil. The implementability of groundwater extraction wells is not likely considering the large number of wells that would be necessary to capture contaminated groundwater. Each process is a commonly used and proven technology. The cost for these process options is high capital for groundwater extraction wells, and moderate capital for groundwater interception trenches. The O&M costs for either option would be low.

Evaluation. Groundwater interception trenches are retained for further evaluation. Groundwater extraction wells are eliminated from further consideration because modeling indicates that a large number of wells would be necessary to capture the contaminant plume.

Modeling was performed using MODFLOW and MT3D. The model development and results are included as Appendix B.

2.4.5 Ex-situ Groundwater Treatment

Three ex-situ groundwater treatment technologies are considered: physical, chemical and biological treatment. Each of the process options listed requires a groundwater collection option to supply the contaminated groundwater.

Ex-situ Physical Treatment

Physical treatment technologies treat contaminants by moving them from one medium to another and not by chemically changing the contaminant. The process options are:

- Air stripping - contaminants partitioned from groundwater by increasing surface area of extracted groundwater.
- Granular activated carbon (GAC) - groundwater or soil gas is pumped through a series of GAC canisters to absorb contaminants.

Effectiveness. Air stripping treats contaminated water by aerating the groundwater. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration. Air stripping is a very common technique for removing dissolved phase VOCs from groundwater.

In the GAC option, groundwater is pumped through GAC canisters until the effluent exceeds a certain level and needs to be replaced. The process is effective and easy to implement, but replacing the GAC can be costly. The exhausted GAC is typically sent off-site for thermal regeneration. GAC is not an effective treatment for vinyl chloride, but vinyl chloride has not been detected in soil or groundwater samples collected at the site.

Implementability and Cost. An advantage of air stripping is that the equipment is relatively simple and can be set up quickly. One disadvantage is that the energy costs can be high, including the need for freeze prevention in the winter. Another disadvantage is that there may be public concern about the discharge of VOCs into the atmosphere from the air stripping method if no vapor recovery is used. Discharge estimates from the air stripping system are a maximum of 1,700 pounds (0.85 tons) per year, below the 3.1 tons per year allowed by the USEPA (40 CFR 264.1032).

No implementability issues have been identified for GAC.

Capital costs are low to moderate for air stripping and moderate for GAC. The O&M costs for air stripping are low to moderate, and the O&M costs for GAC are moderate.

Evaluation. Air stripping and GAC are retained for further evaluation.

Ex-situ Chemical Treatment

Chemical technologies treat contaminants by the use of chemical processes. The process option is:

- Ultraviolet (UV) oxidation - UV oxidation degrades contaminants by subjecting the aqueous solution containing the contaminants to ultraviolet light in the presence of an oxidizer (hydrogen peroxide or ozone). UV light is the catalyst that causes the oxidation of the chemicals.

Effectiveness. UV oxidation would be used to treat the contaminated groundwater in a pump and treat system. The process produces no hazardous by-products or air emissions, if complete oxidation is achieved.

Implementability and Cost. UV oxidation systems require a considerable amount of power, which is not currently available at the site. The UV lamps require cleaning to remove mineralization that builds up during operation. The capital costs for UV oxidation systems are moderate, and the O&M costs are high.

Evaluation. UV oxidation is eliminated from further consideration due to high O&M requirements relative to other potential groundwater treatment options.

Ex-situ Biological Treatment

Biological process options treat contaminated groundwater by using microorganisms to degrade the contaminants under aerobic (oxygen rich) or anaerobic (oxygen deficient) conditions. The process options are:

- Aerobic biodegradation - microorganisms degrade contaminants under an aerobic (containing oxygen) condition.
- Anaerobic biodegradation (methanotrophic bioreactor) - microorganisms degrade contaminants while utilizing methane as a growth substrate.

Effectiveness. Aerobic biodegradation of TCE was not thought to be effective, and only within the last few years have microorganisms been identified that are effective under aerobic conditions (USEPA 1992b). A methanotrophic bioreactor would be used to treat the contaminated groundwater in a pump and treat system. A bioreactor reduced the concentration of TCE in groundwater at one site from 2.0 mg/L to 0.15 mg/L (USEPA 1993).

Implementability and Cost. Treatability study tests would need to be conducted to determine the effectiveness of an aerobic or anaerobic bioreactor on 1,1,2,2-tetrachloroethane. Additional costs would be incurred maintaining a bioreactor at an optimal temperature. The influent would have to be heated and the bioreactor would also have to be kept in a heated room. The bioreactor would have to be used with GAC or air stripping to polish the effluent. The capital and O&M costs for the bioreactor are moderate.

Evaluation. This process option is not retained for further evaluation because aerobic and anaerobic bioreactors are considered innovative technologies, and additional process options would likely be required in the treatment train to meet discharge limits.

2.4.6 Groundwater Discharge

Three process options were identified for discharging treated groundwater. The process options are:

- Pipeline to Eagle River - treated water would be discharged to the Eagle River via a pipeline.
- Groundwater recharge - treated water would be discharged to the ground at the site so that it could recharge the groundwater.
- Discharge to publicly owned treatment works (POTW) - treated water is discharged to POTW via a pipeline.

Effectiveness. All of the process options for discharging the treated water would be effective. The volume of treated groundwater from any remediation system operated at the PRDA would be low and easily handled by any of the three process options.

Implementability and Cost. It would be technically feasible to construct a pipeline to the Eagle River or a POTW, but the capital and O&M costs would be high. Installation of a groundwater recharge system at the site would be the most technically feasible of the three process options, and the capital costs would be moderate. Maintenance of a recharge system may be high.

Evaluation. The cost-benefit of constructing pipelines between the site and the Eagle River or a POTW is low, considering the amount of water (approximately 5 gallons per minute) that would be pumped through the pipe. Discharge to the Eagle River or a POTW is eliminated from further consideration due to the high cost. Discharge to a groundwater recharge system is retained for further evaluation.

2.4.7 In situ Treatment

In situ process options either degrade the contaminants in place or cause the contaminants to change phase while in situ. Several of the process options require process options from Section 2.4.4 to complete treatment of the contaminants.

In situ Physical Treatment

The process options are:

- Air sparging - air sparging volatilizes dissolved-phase contaminants by injecting air into the groundwater.

- Soil vapor extraction - soil gas is removed from the vadose zone by applying a vacuum to a well screened in unsaturated soil.

- Soil flushing - treated groundwater is discharged onto the site to flush VOCs from the soil so that the water can be recaptured by the groundwater collection system.

Effectiveness. Air sparging must be used with vacuum extraction to remove the volatilized contaminants from the vadose zone. The advantage of the system is that it is simple to implement. The disadvantage is that the on-site geology may require an excessive number of sparge points because of a small radius of influence.

Soil vapor extraction is a common and effective soil gas extraction method. Soil vapor extraction would likely be used in conjunction with other process options, since much of the contaminated soil is located below the water table. Several vacuum extraction wells would be needed to affect all the contaminated vapors.

Soil flushing is used to remove VOCs that have adhered to the soil. Once the groundwater extraction system is started, the water table is lowered and much of the contamination remains adhered to the soils above the water table. Treated water can be discharged onto the disposal area to flush the contamination from the soils.

Implementability and Cost. The minimum hydraulic conductivity for air sparging to be effective is 2.8 ft/day (Marley 1995), but the estimated hydraulic conductivity of the shallow interval is 0.5 ft/day. Generally, the costs for air sparging are moderate, but the limitations of low hydraulic conductivity make successful implementation unlikely

No significant implementability issues have been identified for soil vapor extraction or soil flushing. The costs for soil vapor extraction and soil flushing are low.

Evaluation. Air sparging did not meet screening criteria because of the low hydraulic conductivity of the soils at the PRDA. However, because of the large degree of uncertainty in flow properties in the shallow subsurface, air sparging was retained for further evaluation in the November 1996 treatability study (see Section 1.4.6). Soil vapor extraction and soil flushing are retained for further evaluation.

In situ Chemical Treatment

The process options are:

- Funnel-and-gate - Subsurface barrier has impermeable (funnel) and permeable (gate) portions. The permeable portions of the barrier are filled with a metallic catalyst (zero-valent iron). The catalyst in the wall oxides the contaminants in the groundwater, reducing them to less hazardous compounds.

- Chemically enhanced solubilization - attempts to dissolve DNAPLs into the groundwater by pumping a chemical which enhances solubilization into the aquifer. The dissolved contaminants and the solubility enhancing chemicals are then pumped out of the aquifer.

Effectiveness. The advantage of metallic enhanced abiotic degradation in a funnel-and-gate system is that it is passive (i.e., does not require human intervention for treatment). The disadvantages are that the process requires flow through the wall, and the effectiveness of the wall over time may be reduced by biological activity and precipitation of minerals in the groundwater. The substantial vertical gradient at the site (1:1) and low hydraulic gradients suggest that the flow through the funnel would be minimal. This technology would not protect the deep aquifer from migration of contaminants due to vertical flows.

The chemically enhanced solubilization process is repeated until the DNAPLs have been removed. The advantage of the system is that it provides a method to remove DNAPLs. The disadvantage of the system is that it is not proven.

Implementability and Cost. The funnel-and-gate system typically operates on the principal that there would be a hydraulic head built-up behind the wall, and the increased head behind the wall would force the flow through the permeable zone (gate). Unless the funnel-and-gate system is keyed into the bedrock, vertical gradients may be increased. Keying into bedrock is not feasible at the PRDA site because the bedrock is up to 160 feet bgs, and standard slurry wall construction techniques cannot be used. The system would have to be constructed as a hanging wall. Depending on the chemicals used for the enhanced solubilization process, there could be major implementability issues. The capital costs of the funnel-and-gate system are low to moderate, and the O&M costs are moderate. The capital and the O&M costs of the chemically enhanced solubilization are low to moderate.

Evaluation. Because the funnel-and-gate system is not likely to be effective at this site due to technical feasibility issues, it is eliminated from further consideration. Chemically enhanced solubilization is eliminated from further consideration since the technique is not proven and implementability is questionable.

In situ Biological Treatment

The process options are:

- Aerobic bioremediation - biodegradation of contaminants is increased by the addition of oxygen to stimulate aerobic microbes.
- Anaerobic - biodegradation of contaminants is increased by the addition of methane to stimulate anaerobic microbes.

Effectiveness. The effectiveness of full-scale in situ bioremediation of TCE and 1,1,2,2-tetrachloroethane is not yet proven. In situ bioremediation is still considered an innovative remediation technology for the removal of chlorinated solvents from contaminated soils and groundwater (Saaty et al. 1995).

Implementability and Cost. It is difficult to estimate the relative cost or identify implementabilty issues that may affect a full-scale in situ bioremediation system at the site, due to the technology's early stage of development. A review of papers from the Third International In situ and On-Site Bioreclamation Symposium in 1995 revealed few sites where in situ bioremediation had been attempted. Most of the papers reported the results of laboratory studies to evaluate the effectiveness of in situ bioremediation. Treatability studies would have to be conducted at the PRDA to identify any implementabilty issues. One implementability issue that has been identified is the low temperature (approximately 40°F) of groundwater at the site. This low temperature would significantly impede the rate of bioremediation. Therefore, bioremediation is expected to have limited effectiveness over a reasonable period of time. The costs for in situ biological treatment would be relatively moderate.

Evaluation. In situ aerobic and anaerobic bioremediation are eliminated from further consideration because the technology is still in the early stages of development.

In situ Thermal Treatment

The process options are:

- Electrical Resistance Heating - electrodes placed into the soil pass electricity directly through contaminated soil.
- Radio Frequency - radio frequency works by heating soils with radio waves from a probe in the ground to volatilize the contaminants.

- Steam Injection - steam is injected into the groundwater table in the same manner as air sparging to volatilize the contaminants.

Effectiveness. Radio frequency heating increases the mobility of contaminants and allows them to be removed by vacuum extraction. A disadvantage of the system is that it is not designed to heat groundwater, and it heats the soil slowly.

Steam injection is similar to air sparging except that steam is injected into the groundwater instead of ambient air. The steam acts to increase the volatilization and mobility of the contaminants. Vacuum extraction must be used with steam injection to extract the volatilized contaminants from the vadose zone. The disadvantage of the system is the high power requirements, and that the steam does not effectively heat low permeability zones.

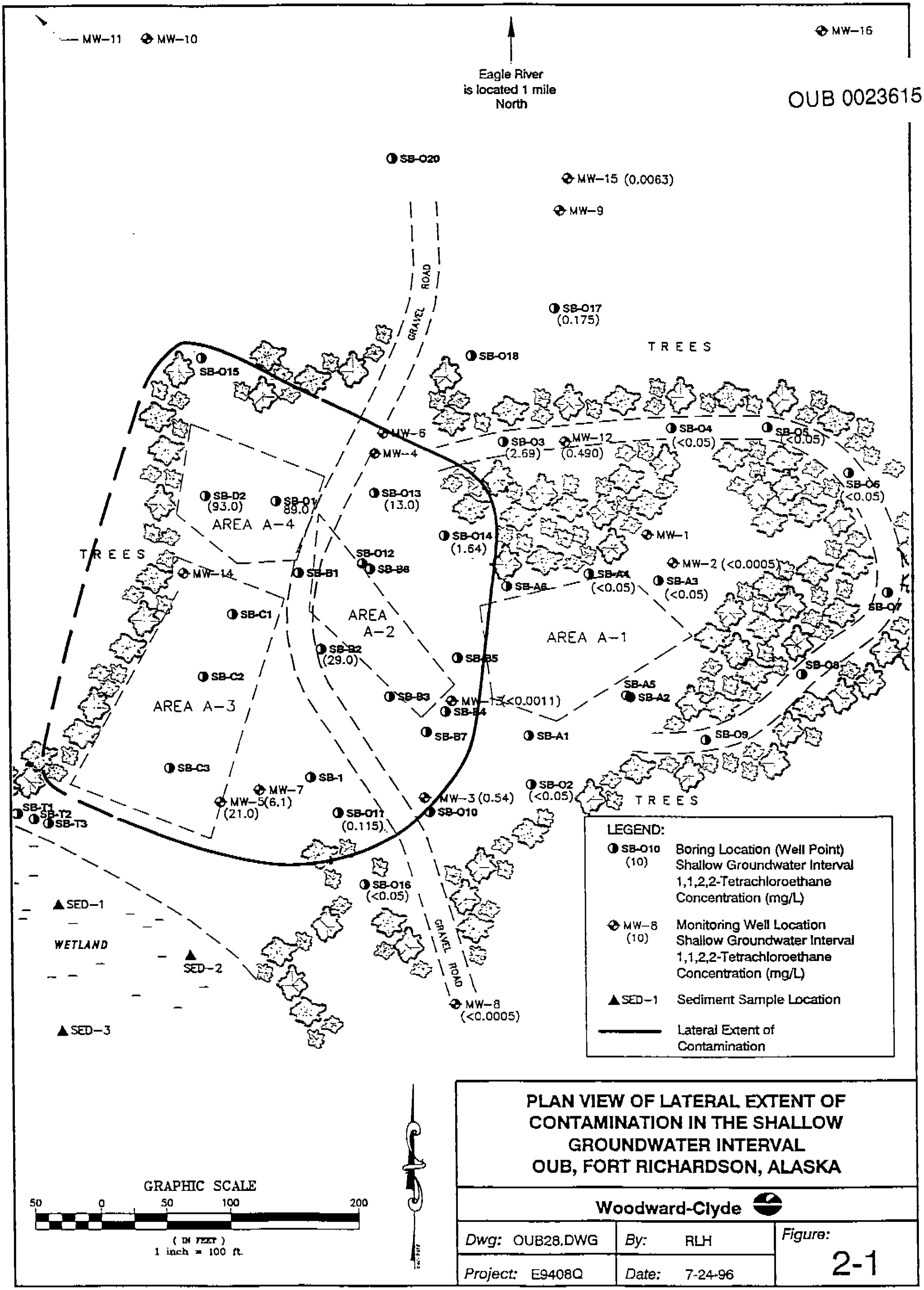
Electric resistance heating increases the mobility of contaminants and allows them to be removed by vacuum extraction. The soil can be heated to 100°C. Contaminants are either boiled off at this temperature or are more easily volatilized because of increase vapor pressure. Clean up times are measured in months rather than years for electrical heating.

Implementability and Cost. The minimum hydraulic conductivity for air sparging, and therefore steam injection, to be effective is 2.8 ft/day, but the estimated hydraulic conductivity of the shallow interval is 0.5 ft/day. Therefore, steam injection is unlikely to be effective at the PRDA.

No significant implementability considerations have been identified for radio frequency heating. The capital and O&M costs are expected to be relatively high.

No significant implementability issues have been identified for electrical resistance heating. Capital costs are expected to be moderate and operating costs are expected to be low.

Evaluation. Radio frequency heating is eliminated from further consideration because of the high costs, and because its effectiveness on groundwater is probably low. Steam injection is also not retained for further evaluation because of the expected ineffectiveness due to low hydraulic conductivities of the on-site soils and high cost. Electrical resistance heating is retained for further evaluation.



PLAN VIEW OF LATERAL EXTENT OF CONTAMINATION IN THE SHALLOW GROUNDWATER INTERVAL OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg: OUB28.DWG	*By:* RLH	*Figure:* 2-1
Project: E9408Q	*Date:* 7-24-96	

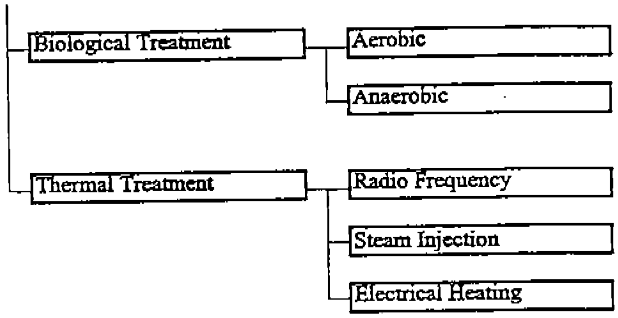
FIGURE 2-2: INITIAL IDENTIFICATION OF POTENTIAL TECHNOLOGIES AND PROCESS OPTIONS

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTIONS
No Action	None	Not Applicable	No action.
Institutional Controls	Access Restrictions	Fences	Fence around property.
	Use Restrictions	Deed Restrictions	Permanent record of residual contamination on the site and land use restrictions.
		Zoning Restrictions	Limit zoning to industrial/commercial uses
	Monitoring	Groundwater Monitoring	Sample groundwater monitoring wells for VOCs annually.
		Intrinsic Groundwater Monitoring	Sample groundwater monitoring wells for intrinsic remediation parameters annually.
Containment	Capping	Asphalt	Asphalt paving over contaminated area.
		Compacted Clay	Compacted clay covered with sand and gravel.
		Synthetic Liner	Synthetic membrane without secondary barrier.
		Composite Cap	RCRA-compliant composite synthetic membrane/clay impregnated fabric.
	Vertical Barrier	Grout Curtain	Fluid material injected into soil to set in place and form vertical barrier.
		Slurry Wall	Bentonite slurry creates low permeability wall
		Sheet Pile Wall	Steel cutoff wall pushed into the soils.
Groundwater Collection	Extraction	Extraction Wells	Groundwater is extracted from the subsurface by pumping from wells.
	Subsurface Drains	Groundwater Interception Trenches	Groundwater is extracted from the subsurface by pumping water from trenches in saturated zones.
Ex-Situ Treatment of Groundwater	Physical Treatment	Air Stripping	Solvents partitioned from groundwater by increasing surface area of extracted groundwater
		Granular Activated Carbon	Groundwater/soil gas is pumped through a series of GAC canisters to absorb solvents.
	Chemical Treatment	UV Oxidation	UV light and an oxidizer are introduced into a waste stream. Reactions catalyzed by UV.
	Biological Treatment	Aerobic	Microorganisms degrade solvents by utilizing oxygen.
		Anaerobic	Microorganisms degrade solvents while utilizing methane as a growth substrate.
Groundwater Discharge	On-Site Discharge	Pipeline to Eagle River	Discharge treated water to the Eagle River via a pipeline
		Groundwater Recharge	Discharge treated water to groundwater recharge system
	Off-site Discharge	POTW	Discharge treated water to POTW via pipeline
In Situ Treatment	Physical Treatment	Air Sparging	Air is injected into saturated soil and removes solvents through volatilization.
		Soil Vapor Extraction	Soil gas is extracted by supplying a vacuum on wells screened in the unsaturated zone.
		Soil Flushing	Discharge water on site to flush contam. from soil and into groundwater collection system
	Chemical Treatment	Funnel and Gate	Solvents are degraded by passing groundwater through an in-situ, 0-valence iron, permeable wall.
		Chemically Enhanced Solubilization	Chemically increase solubilization of contaminant and then remove via groundwater extraction.

Continued

FIGURE 2-2: INITIAL IDENTIFICATION OF POTENTIAL TECHNOLOGIES AND PROCESS OPTIONS

Continued from above



Degradation of chlorinated solvents by adding oxygen to stimulate aerobic microbes.

Degradation of chlorinated solvents by adding methane to stimulate anaerobic microbes.

Subsurface soils are heated by probe emitting radio waves, volatilizing solvents.

Steam is forced into aquifer through injection wells, volatilizing solvents.

Subsurface soils are heated by passing electric current through the soils.

O&M: Operation and maintenance
Cap: Capital
VOCs: Volatile organic compounds
POTW: Publicly owned treatment works
DNAPLs: Dense nonaqueous phase liquids
UV: Ultraviolet

FIGURE 2-3: INITIAL SCREENING OF POTENTIAL TECHNOLOGIES AND PROCESS OPTIONS

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	COST (a)
No Action	None	Not Applicable	Not applicable.	No implementation needed.	None
Institutional Controls	Access Restrictions	Fences	Surface and near surface soils do not currently pose a risk. A fence does not reduce risk.	Implementable.	Low
	Use Restrictions	Deed Restrictions	Prevents exposure to potential future residents.	Implementable.	Low
		Zoning Restrictions	Prevents exposure to potential future residents.	Implementable.	Low
	Monitoring	Groundwater Monitoring	Effective at monitoring concentration of contaminants in groundwater	Implementable	Low Cap, Low O&M
		Intrinsic Groundwater Monitoring	Effective at monitoring natural degradation of contaminants.	Implementable	Low Cap, Mod O&M
Containment	Capping	Asphalt	Effective at reducing infiltration of water	Implementable	Low Cap, Low O&M
		Compacted Clay	Effective at reducing infiltration of water	Implementable.	Low Cap, Low O&M
		Synthetic Liner	Effective at reducing infiltration of water	Implementable	Mod Cap, Low O&M
		Composite Cap	Most effective at reducing infiltration of water	Implementable	High Cap, Low O&M
	Vertical Barrier	Grout Curtain	Effective at reducing the horizontal movement of groundwater from the site.	Grout will crack from freeze and thaw, allowing groundwater flow.	Mod Cap
		Slurry Wall	Effective at reducing the horizontal movement of groundwater from the site.	Implementable	Low Cap
		Sheet Pile Wall	Effective at reducing the horizontal movement of groundwater from the site.	Soil density will make installation difficult.	High Cap
Groundwater Collection	Extraction Wells	Extraction Wells	Effective at removing groundwater from saturated intervals.	Excessive number of wells needed to capture plume.	High Cap, Low O&M
	Subsurface Drains	Groundwater Interception Trenches	Effective at removing groundwater from saturated intervals.	Implementable	Mod Cap, Low O&M
Ex-Situ Groundwater Treatment	Physical Treatment	Air Stripping	Effective at removing solvents from groundwater as part of a pump and treat system.	Implementable.	Low to Mod Cap, Low to Mod O&M
		Granular Activated Carbon	Effective at removing solvents from groundwater as part of a pump and treat system.	Implementable.	Mod Cap, Mod O&M
	Chemical Treatment	UV Oxidation	Capable of destroying solvents in groundwater as part of a pump and treat system.	Implementable.	Mod Cap, High O&M
	Biological Treatment	Aerobic	Not proven effective at degrading chlorinated VOCs	Not a proven technology.	Mod Cap, Mod O&M
		Anaerobic	Effective at destroying chlorinated VOCs	Would need additional technologies to polish effluent.	Mod Cap, Mod O&M

Continued

FIGURE 2-3: INITIAL SCREENING OF POTENTIAL TECHNOLOGIES AND PROCESS OPTIONS

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	COST (a)
Groundwater Discharge	On-Site Discharge	Pipeline to Eagle River	Effective	Would need pipeline over one mile long.	High Cap, Low O&M
		Groundwater Recharge	Effective	Implementable	Mod Cap, Low O&M
	Offsite Discharge	POTW	Effective	Difficult to implement due to distance to POTW.	High Cap, High O&M
In Situ Treatment	Physical Treatment	Air Sparging *	Effective at volatilizing solvents dissolved in groundwater into the vadose zone.	Hydraulic conductivity low, need high number of sparge points.	Mod Cap, Low O&M
		Soil Vapor Extraction	Effective at removing soil gas from the vadose zone.	Implementable.	Low Cap, Low O&M
		Soil Flushing	Effective	Implementable with Groundwater System	Mod Cap, Low O&M
	Chemical Treatment	Funnel and Gate	May be effective at degrading aqueous phase solvents. Ineffective for vertical movement of contaminants.	Wall cannot be keyed into bedrock.	Low to Mod Cap, Mod O&M
		Chemically Enhanced Solubilization	May be efffective at removing DNAPLs, if present at the site.	DNAPLs have not been identified at the site.	Low to Mod Cap, Low to Mod O&M
	Biological Treatment	Aerobic	Limited effectiveness due to low groundwater temperature (40°F)	Implementable	Mod Cap, Low to Mod O&M
		Anaerobic	Limited effectiveness due to low groundwater temperature (40°F)	Implementable	Mod Cap, Low to Mod O&M
	Thermal Treatment	Radio Frequency	May increase mobility of solvents above water table.	Implementable	High Cap, High O&M
		Steam Injection	May increase mobility of solvents above and below the water table.	Hydraulic conductivity too low	High Cap, High O&M
		Electrical Heating	Increases temperature of soil, and vapor pressure of contaminants.	Implementable	High Cap, Low O&M

Legend:

Screened Out Process Option or Technology

a: Costs are based on engineering judgment. Costs are presented as low, moderate (Mod), or high relative to other process options within the same remedial technology type.

O&M: Operation and maintenance

Cap: Capital

VOCs: Volatile organic compounds

POTW: Publicly owned treatment works

DNAPLs: Dense nonaqueous phase liquids

UV: Ultraviolet

* Air sparging did not meet screening criteria but there is enough uncertainty to warrant retaining this process option for further evaluation.

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3.0
DEVELOPMENT OF ALTERNATIVES

In this section, general response actions and the process options chosen to represent the various technology types are combined to form alternatives for the PRDA. Alternatives were developed to represent a range of potential remedial actions, including institutional controls, intrinsic remediation, onsite containment, and onsite treatment.

The alternatives include: no-action (Alternative 1); natural attenuation (Alternative 2); containment (Alternative 3); interception trench, air stripping, and soil vapor extraction (Alternative 4); air sparging and soil vapor extraction of the "hot spot" and natural attenuation (Alternative 5); and soil vapor extraction of the "hot spot." (Alternative 6). All of the alternatives include institutional controls to limit the risk posed by the site until the remedial actions have reached the RAOs.

3.1 DESCRIPTION OF ALTERNATIVES

The following sections describe the conceptual designs for these alternatives and the basis for the design approach. The conceptual designs of the alternatives presented in this section are based on the best available information at the time that this report was prepared. Information developed by further investigations conducted at the site to better define the hydrogeologic properties of the groundwater system can change the conceptual designs presented in this section. It should be noted that 30 years is used as the maximum duration for any alternative, at which time a reassessment of the selected remedial action would be conducted.

3.1.1 Alternative 1: No Action

The No Action Alternative involves no additional costs or actions at the site. This alternative is required by the NCP.

3.1.2 Alternative 2: Natural Attenuation

The Natural Attenuation Alternative includes the following:

- Institutional controls
  - Restrict groundwater use between the site and Eagle River
  - Restrict development around immediate disposal area
- Groundwater Monitoring
  - Currently existing wells (15)
  - Additional monitoring wells (2)
  - Annual groundwater sampling and analysis for VOCs (30 years)
  - Monitor geochemical analytes that will help estimate the rate of intrinsic remediation.

Groundwater samples were collected during the treatability study to help identify processes that may be reducing the concentration of contaminants in groundwater at the site. The sampling results showed that little, if any, natural attenuation of the contaminants is occurring.

Interim U.S. Army policy requires the inclusion of "Natural Attenuation" for evaluation as a remedial action alternative through the preparation of the Proposed Plan. Natural attenuation relies on biological, physical, and chemical processes that are occurring in the environment without artificial stimulus. Monitoring and documenting these processes is the major focus of this alternative. The following intrinsic remediation parameters would be monitored at the PRDA if Natural Attenuation was selected as the remedial alternative:

Nutrients/Electron Acceptors	**Substrates**	**Field Parameters**	**Metabolic End Products**	**Other**
• Nitrate-Nitrogen • Nitrite-Nitrogen	• Total Organic Carbon (TOC)	• pH	• Methane	• Sulfate-Reducing Bacteria (SRB)
• Total Kjeldahl Nitrogen (TKN)	• Biochemical Oxygen Demand	• Temperature	• Ethene	• Heterotrophic Bacteria (HET)
• Ammonia-Nitrogen (NH_3-N)		• Redox Potential (Eh)	• Ethane	• VOCs
• Total Phosphorus		• Dissolved Oxygen (DO)	• Sulfide (S^{2-})	
• Sulfate (SO_4) • Soluble Iron				

(Lee et al. 1995)

The Final Risk Assessment report for the PRDA site (Woodward-Clyde 1996d) states that there is an unacceptable risk to human health from potential inhalation of soil gas vapors in the residential use scenario. Because of this unacceptable risk, restriction on development around the immediate disposal area is included as part of the institutional controls.

Significant research is being conducted to gain a better understanding of the natural processes that tend to degrade chlorinated VOCs. Recent studies indicate that chlorinated VOCs are being naturally attenuated in both aerobic and anaerobic environments. TCE, PCE, and several of their degradation products appear to degrade under anaerobic conditions. Other degradation products, chloroethane and vinyl chloride, degrade under aerobic conditions. Even under ideal conditions, natural attenuation of chlorinated VOCs is frequently incomplete.

Figure 5-1 in the Final RI Report (Woodward-Clyde 1996c) illustrates the potential degradation pathways of the chemicals of concern at the PRDA. 1,1,2,2-tetrachloroethane is shown in the degradation pathway figure to degrade to TCE (abiotic), 1,1,1-TCA (biotic), and 1,1,2-TCA (biotic). TCE was detected at concentrations nearly as high as 1,1,2,2-tetrachloroethane. The TCE was either released at the same time as the 1,1,2,2-tetrachloroethane, or it was produced through the abiotic degradation of 1,1,2,2-tetrachloroethane. No 1,1,1-TCA was detected in groundwater samples collected at the site and small amounts of 1,1,2-TCA were detected. It is not possible to determine the rate of abiotic degradation of 1,1,2,2-tetrachloroethane, since the proportion of TCE to 1,1,2,2-tetrachloroethane in the fluids released at the site is unknown. The likelihood that biotic degradation is occurring at the site is low, since the two biotic degradation products of 1,1,2,2-tetrachloroethane were either not detected, or were detected at very low concentrations. The rates of both biotic and abiotic degradation are probably low due to the slow groundwater movement and the cooler than average soil and groundwater temperatures.

3.1.3 Alternative 3: Containment

The Containment Alternative includes the following:

- Synthetic liner with soil cover
- Bentonite slurry wall to 25 feet bgs
- Institutional controls
    - Restrict groundwater use between the site and Eagle River
    - Restrict development around immediate disposal area

- Groundwater monitoring
  - Currently existing wells (15)
  - Additional monitoring wells (2)
  - Annual groundwater sampling and analysis for VOCs (30 years)

The lateral extent of the cap and the placement of the slurry wall is shown on Figure 3-1. The cap covers the "hot spot" area only. A groundwater model was used to estimate the 25 feet bgs of the slurry wall.

The slurry wall will minimize water from the wetland from entering the site and the cap will minimize precipitation from entering the site. Once the cap and vertical barrier are in place, groundwater levels downgradient of the slurry wall will begin to lower and dewater the perched interval, leaving much of the contamination behind in the soil. The cap and vertical barrier would minimize water flow into this area, minimizing the driving force for the migration of contamination from the perched interval to the lower groundwater units.

3.1.4 Alternative 4: Interception Trench, Air Stripping and Soil Vapor Extraction

This alternative includes the following components:

- A 520-foot long, 25-foot deep vertical barrier between site and wetlands

- Soil vapor extraction system which includes 40 vertical extraction wells installed in Areas A-3 and A-4

- A series of four interception trenches (150 feet, 250 feet, 250 feet, and 250 feet long, from south to north, respectively) which extend to depth of 60 feet bgs

- Infiltration system which releases treated groundwater to an area downgradient of the treatment area

- Institutional controls
  - Restrict groundwater use between the site and Eagle River
  - Restrict development around immediate disposal area
- Groundwater monitoring
  - Currently existing wells (15)

- Additional monitoring wells (2)
- Annual groundwater sampling and analysis for VOCs (30 years)

The details discussed in this alternative are assumed so that a cost estimate can be prepared, and is not intended to reflect the final design.

Twenty soil vapor extraction wells will be installed in Areas A-3 and A-4 to 20 feet bgs and screened from 10 to 20 feet bgs. This network of wells will remediate the contaminated soil above the shallow groundwater zone. Vacuum is provided by a blower which operates at 250 standard cubic feet per minute (scfm) at 8-inch mercury vacuum. A second set of 20 wells will be installed to 40 feet bgs and screened from 20 to 40 feet bgs. The purpose of the deep wells is to remediate soil in the shallow groundwater zone which will be exposed due to drawdown of the groundwater table when the interception trenches are installed. For the deep wells, vacuum is provided by a blower which operates at 420 scfm at 8-inch mercury vacuum. The location of the soil vapor extraction wells are shown in Figure 3-2. A cross section of the area to be treated by soil vapor extraction is shown in Figure 3-3. Preliminary calculations indicate a treatment time of approximately 3 to 5 years is required for attainment of treatment objectives.

In this alternative, groundwater is collected in drainage trenches and treated through an air stripper before being discharged to a downgradient infiltration system. Figure 3-2 presents the site layout for Alternative 4. The drainage trenches are installed by excavating a trench while simultaneously pumping in a biodegradable slurry. The trench is then backfilled with permeable materials (i.e., gravel) to form the permanent drainage system. A perforated pipe is placed at the bottom of the trench and well casings (risers) are installed every 120 feet along the length of the trench for groundwater collection. When the trench is completed, the biopolymer slurry is degraded through use of a breaker solution.

As water rises in the well casings, submersible pumps (1 gpm, variable speed pumps with remote control) placed in the well casings remove the water to an equalization tank. From the equalization tank the water is pumped through a bag filter to remove suspended solids, then to an air stripper for treatment.

Areas A-3 and A-4 will be covered by a geosynthetic liner to prevent short circuiting in the extraction wells. The portion of the interception trenches installed in the zone to be treated by vapor extraction will be backfilled and compacted to obtain similar hydraulic conductivity and permeability as material currently at the site. A knockout tank will be provided for separation of air and water extracted from the wells. Water collected in the knockout tank will be pumped to the air stripping system for treatment.

A design flow of 1 gpm was used to size the air stripper system for this alternative. The 1 gpm flow rate was obtained using groundwater modeling for a case which assumed all water removed for treatment is recharged downgradient of the groundwater collection system (see Appendix B for a complete discussion of the groundwater modeling). The design groundwater contaminant concentrations and treatment goals are shown in Table 3-1. Design concentrations were calculated by dividing the 95% UCL concentrations (or maximum concentration when the maximum concentration is less than the 95% UCL concentration) in the contaminant plume at the site by a proportion number. The proportion number is the ratio of the 95% UCL concentration of 1,1,2,2-tetrachloroethane to the average concentration of 1,1,2,2-tetrachloroethane after 30 years of pumping as obtained from the groundwater model. The treatment goals are Alaska MCLs where available. For 1,1,2,2-tetrachloroethane, a treatment goal of 0.005 mg/L was assumed.

A low profile tray air stripping system will treat the groundwater. A low profile tray air stripping system was selected over a packed tower stripper for this site because: 1) tray strippers can operate more effectively at low liquid flow rates than can packed towers; 2) for equivalent removal efficiencies, a packed tower stripper is often larger than a tray air stripper resulting in higher insulation costs and/or the packed tower being too large to fit into a typical treatment building; and 3) if a packed tower is not housed in a treatment building or not properly insulated, thermal expansion and contraction of the tower due to large temperature changes typical of Alaska may crush the packing.

A low profile tray air stripping system with a water heater and an air heater will be used for groundwater treatment. The water and air heaters are provided to maintain the water and air temperatures required for effective contaminant removal in the air stripper. An effluent recirculation line is included to maintain a certain flow rate in the air stripper. A process flow diagram for the air stripper system is presented in Figure 3-4.

Vapors from the air stripper will be discharged to the atmosphere without treatment. For this alternative, the maximum estimated mass of organic compounds that would be released from the air stripper to the atmosphere is 170 pounds per year. The estimated average mass of organic compounds that would be released over 30 years of operation is approximately 70 pounds per year.

Water treated by the air stripper is discharged to an infiltration system located downgradient of the groundwater extraction trenches. The infiltration system includes a 200-foot long 4-inch diameter PVC pipe with 0.5-inch diameter holes drilled into the pipe on either side at a space of 1 foot. A bedding of sand and gravel will be placed around the pipe to improve infiltration and to act as a filter. The infiltration system will be placed below the freeze line (8 feet bgs). The large pipe, low flow rate, and large number of holes will allow the water to infiltrate into the soil over a sufficiently large area that mounding of the water into the freeze zone should not occur.

3.1.5 Alternative 5: Air Sparging and Soil Vapor Extraction of the "Hot Spot" and Natural Attenuation

This alternative includes the following components:

- An air sparging system consisting of 80 vertical sparging wells installed in Areas A-3 and A-4
- A 520-foot long, 25-foot deep vertical barrier between site and wetlands
- Soil vapor extraction system which includes 20 vertical extraction wells installed in Areas A-3 and A-4
- Institutional controls
    - Restrict groundwater use between the site and Eagle River
    - Restrict development around immediate disposal area
- Groundwater Monitoring
    - Currently existing wells (15)
    - Additional monitoring wells (2)
    - Annual groundwater sampling and analysis for intrinsic remediation parameters and VOCs (30 years)

The details discussed in this alternative are assumed so that a cost estimate can be prepared, and is not intended to reflect the final design.

The purpose of the air sparging system is to inject clean air into the shallow groundwater interval to induce transfer of VOCs in the groundwater within this zone to the soil pore spaces in the unsaturated zone above the shallow groundwater table. Eighty air sparging wells will be installed in Areas A-3 and A-4 to 42 feet bgs and screened from 37 to 42 feet bgs. The high number of air sparging wells is necessary to compensate for the low hydraulic conductivity. Four compressors each operating at 200 scfm and 20 psi will be used to provide air for sparging. A system of soil vapor extraction wells (described in the next paragraph) will capture the VOCs stripped from the shallow groundwater zone.

Twenty soil vapor extraction wells will be installed in Areas A-3 and A-4 to 20 feet bgs and screened from 10 to 20 feet bgs. Figure 3-3 shows the soil vapor extraction system, and the location of the air sparging wells and vapor extraction wells is shown in Figure 3-5. Areas A-3 and A-4 will be covered by a geosynthetic liner to prevent short circuiting in the extraction wells. Vacuum is provided by a blower which operates at 250 scfm at 8-inch mercury vacuum. A knockout tank will be provided for separation of air and water extracted from the wells. It is expected the volume of water extracted from the extraction wells will be minimal. This water will be analyzed for VOCs for determination of the disposal option.

The air sparging system and soil vapor extraction system will operate continuously initially. It is expected that after five years, a cycling method of operation where the systems are turned on and off with a specific frequency can be more effective. The primary benefit of cycling is the agitation and mixing provided to the groundwater as air channels form and collapse during each sparging cycle can enhance mass transport of VOCs through the bulk water phase (Ahlfeld et al 1994).

As the estimated hydraulic conductivity of the shallow interval (0.5 ft/day) is smaller than the minimum hydraulic conductivity suggested for effective air sparging (2.8 ft/day) (Marley 1995), the length of time estimated for treatment used in the cost estimate (i.e., 30 years) is the maximum period suggested by EPA Guidance (EPA 1988). Groundwater monitoring will also be performed for 30 years (see Section 3.1.2 for the list of analytes).

3.1.6 Alternative 6: Soil Vapor Extraction of the "Hot Spot"

This alternative includes the following components:

- Soil vapor extraction system which includes 20 vertical extraction wells installed in the "hot spot"
- Air stripping system for groundwater extracted from the SVE wells

- Institutional controls
  - Restrict groundwater use between the site and Eagle River
  - Restrict development around immediate disposal area
- Groundwater Monitoring
  - Currently existing wells (15)
  - Additional monitoring wells (2)
  - Annual groundwater sampling and analysis for VOCs (30 years)

The details discussed in this alternative are assumed so that a cost estimate can be prepared, and is not intended to reflect the final design.

Ten soil vapor extraction wells will be installed in the "hot spot" area around MW-14 to 40 feet bgs and screened from 10 to 40 feet bgs. The "hot spot" area will be covered by a geosynthetic liner to prevent short circuiting in the extraction wells. Vacuum is provided by two blowers operating at 1500 scfm at 12-inch mercury vacuum and a third blower operating at 800 scfm at 12-inch mercury vacuum. The two larger blowers will be connected to four SVE wells each and the smaller blower will be connected to two SVE wells. Knockout tanks will be used for separation of air and water extracted from the wells. Each blower will have a separate knockout tank. A considerable amount of water is expected to be extracted from the SVE wells. An air stripping system will be used to treat the extracted groundwater.

DNAPLs were found in a 2-inch monitoring well located near MW-14. The 2-inch well was installed in the shallow groundwater interval. Since the SVE wells may also have DNAPLs, a bubble tube will be installed in each SVE well. The bubble tube will extend to the bottom of the well, where air will exit the tube and create bubbles in the DNAPL. The bubbles will help to volatilize the DNAPLs and will increase the amount of liquid vapors in the extracted soil gas.

The soil vapor extraction system will operate continuously initially. It is expected that after five years, a cycling method of operation where the systems are turned on and off with a specific frequency can be more effective. Groundwater monitoring will also be performed for 30 years.

The total estimated program cost, including contingency and USACE SIOH and excluding escalation costs, for Alternative 6 is $4,000,000.

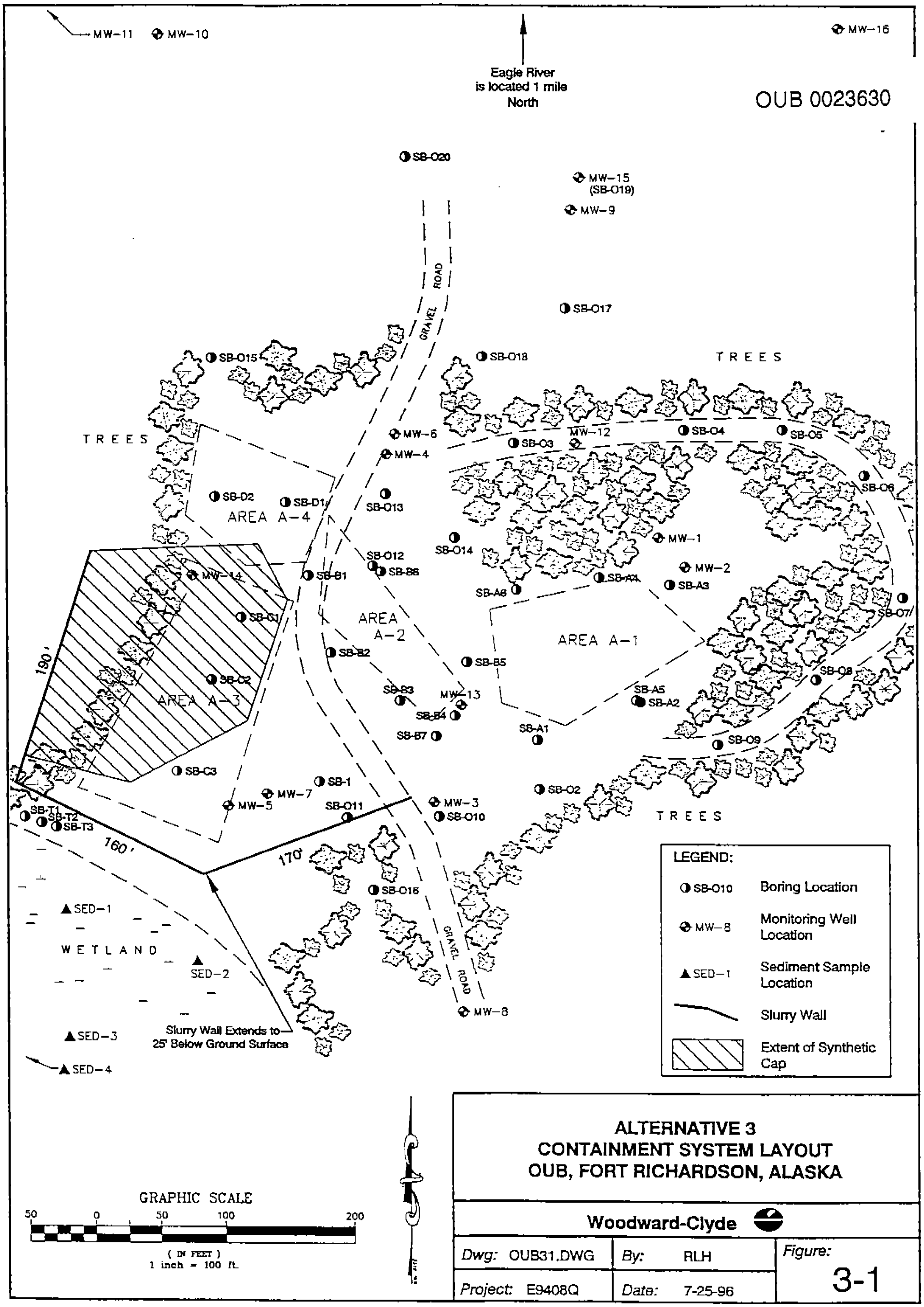
TABLE 3-1
DESIGN CONCENTRATIONS OF CONTAMINANTS IN GROUNDWATER PRDA, FORT RICHARDSON, ALASKA

Chemical	Concentration (mg/L) Alternative 4	Design Treatment Goals[1] (mg/L)
benzene	0.005	0.005
carbon tetrachloride	0.025	0.005
chlorobenzene	0.00016	--
chloroform	0.018	0.1
1,4-dichlorobenzene	0.00021	--
1,2-dichloroethane	0.0006	--
1,1-dichloroethene	0.003	0.007
cis-1,2-dichloroethene	0.33	0.07
trans-1,2-dichloroethene	0.11	0.1
hexachloroethane	0.002	--
1,1,2,2-tetrachloroethane	11.4	0.005
tetrachloroethene	0.076	0.005
toluene	0.0002	1
1,1,2-trichloroethane	0.048	0.005
trichloroethene	4.4	0.005

NOTES:

(1) Alaska MCLs are used as design treatment goals where available.
1,1,2,2-tetrachloroethane has no MCL: a treatment goal of 0.005 mg/L is assumed.

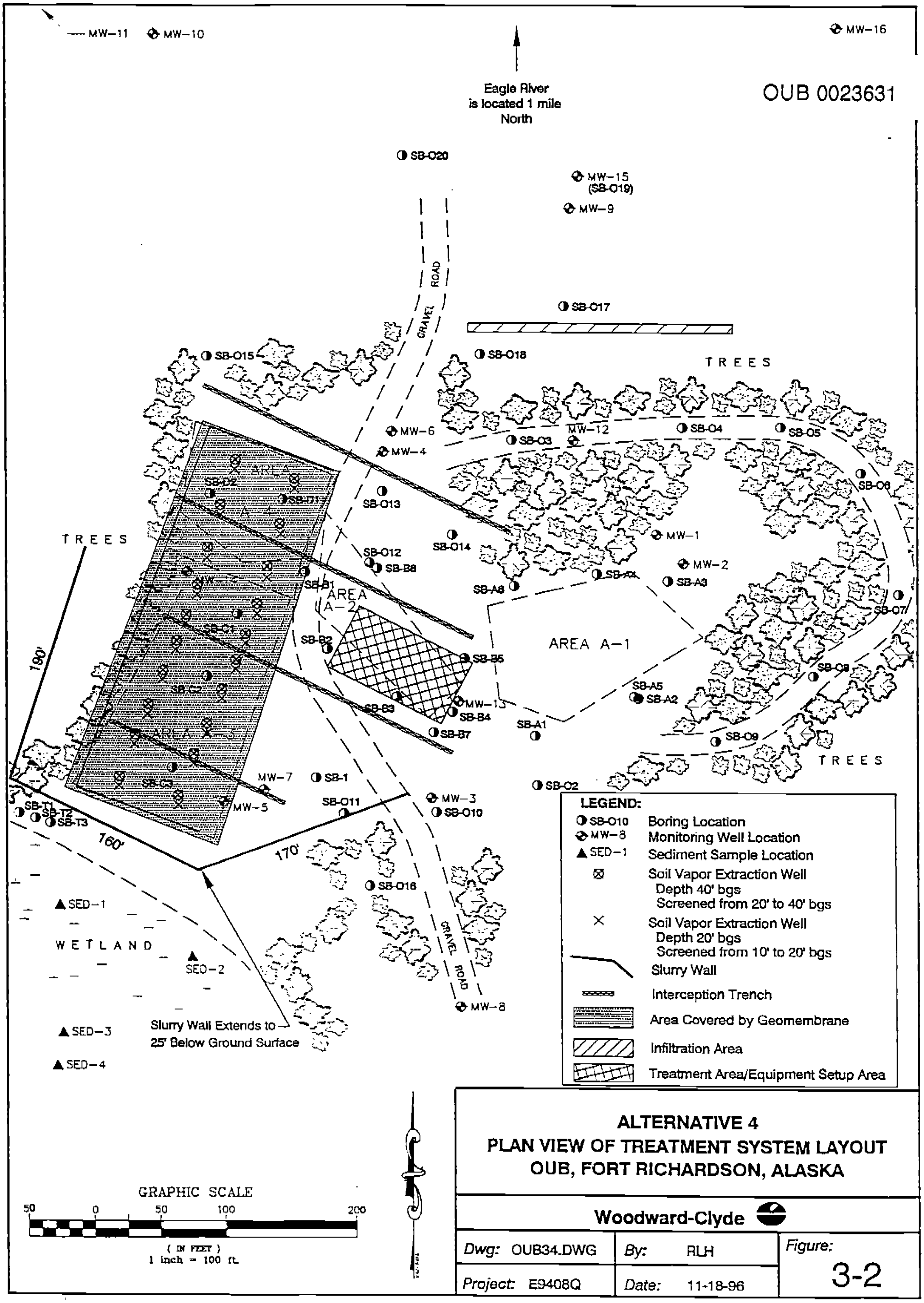
--: No treatment goal.



ALTERNATIVE 3
CONTAINMENT SYSTEM LAYOUT
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

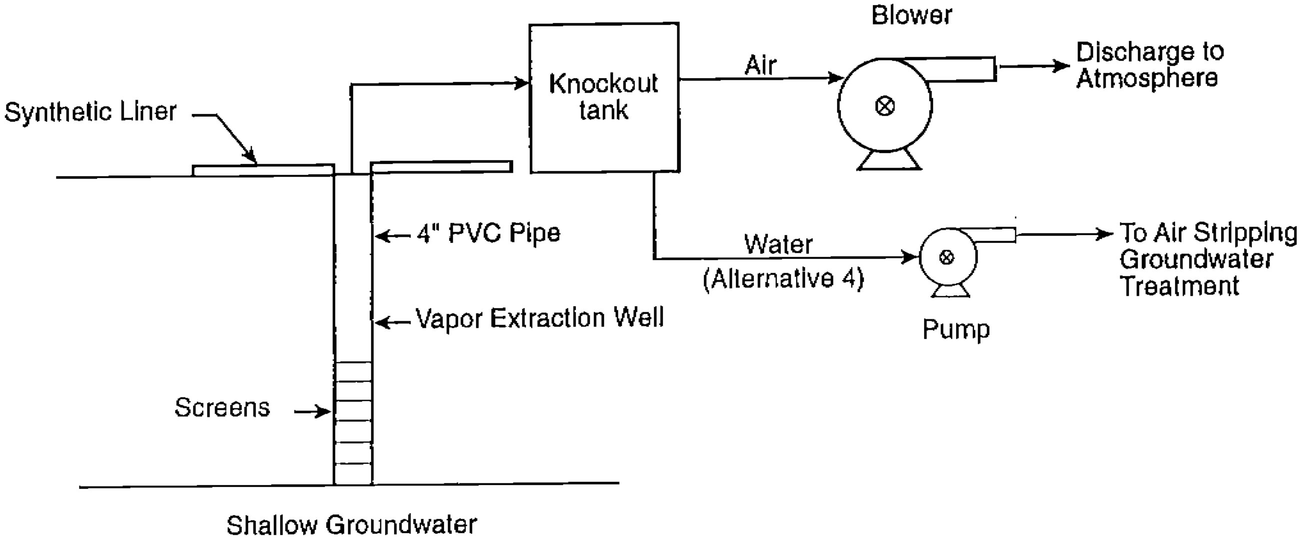
Dwg: OUB31.DWG	*By:* RLH	*Figure:* 3-1
Project: E9408Q	*Date:* 7-25-96	



ALTERNATIVE 4
PLAN VIEW OF TREATMENT SYSTEM LAYOUT
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg:	OUB34.DWG	*By:*	RLH	*Figure:* 3-2
Project:	E9408Q	*Date:*	11-18-96	



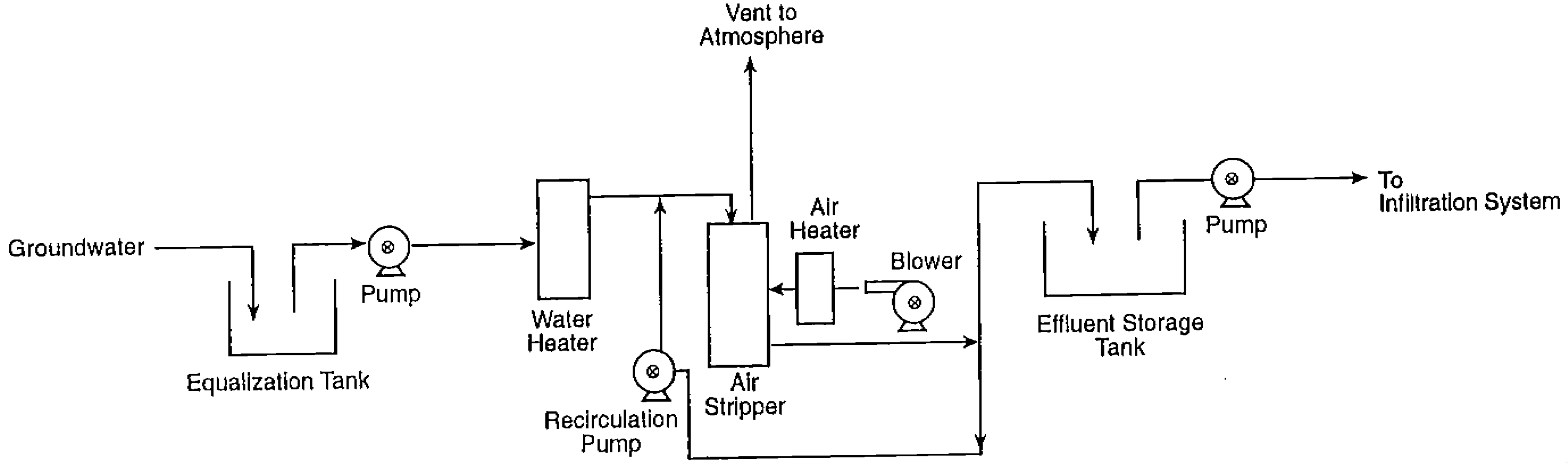
ALTERNATIVES 4, 5 & 6
SOIL VAPOR EXTRACTION SYSTEM

OUB Fort Richardson, Alaska

Woodward-Clyde

Dwg: GR065.1	By: JW	Figure: 3-3
Project: E9408Q/4000	Date: 7/26/96	

GR065.1/Ft.Rich/01

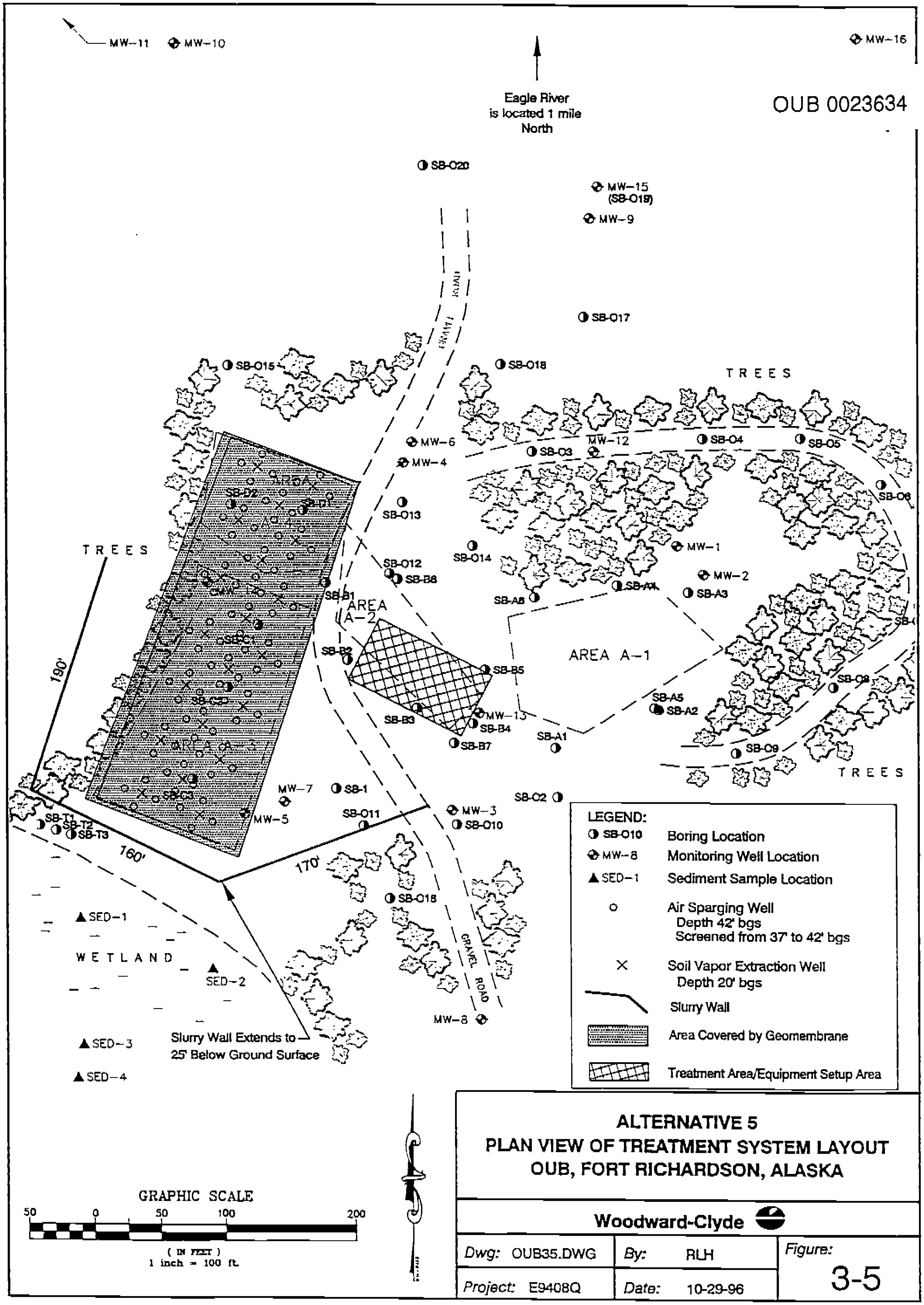


ALTERNATIVES 4 & 6 - PROCESS FLOW DIAGRAM FOR AIR STRIPPING

OUB Fort Richardson, Alaska

Woodward-Clyde

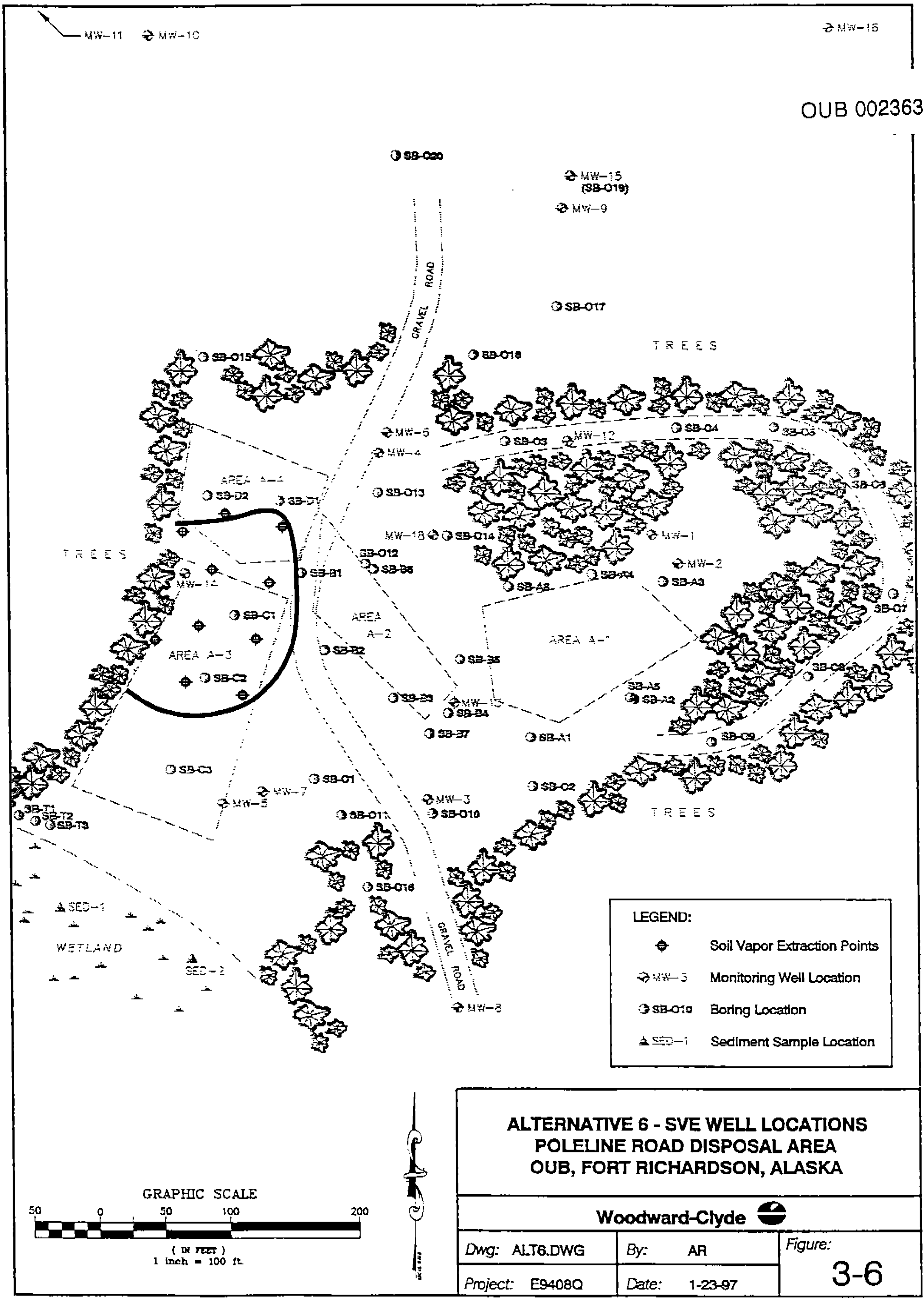
Dwg: GR065.2b	By: JW	Figure: 3-4
Project: E9408Q/4000	Date: 7/26/96	



ALTERNATIVE 5
PLAN VIEW OF TREATMENT SYSTEM LAYOUT
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg: OUB35.DWG	*By:*	RLH	*Figure:*	3-5
Project: E9408Q	*Date:*	10-29-96		



ALTERNATIVE 6 - SVE WELL LOCATIONS
POLELINE ROAD DISPOSAL AREA
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg: ALT6.DWG	*By:* AR	*Figure:* 3-6
Project: E9408Q	*Date:* 1-23-97	

4.0
DETAILED ANALYSIS OF ALTERNATIVES

This section provides the results of the evaluation for the alternatives developed for the PRDA site in Section 3.0. First, the individual analysis of alternatives is presented using the seven evaluation criteria described in Section 4.1. A comparative analysis of alternatives is then presented using the same evaluation criteria.

4.1 INDIVIDUAL ANALYSIS OF ALTERNATIVES

This section presents an analysis of each of the alternatives by comparing them to seven specific criteria:

- Overall protection to human health and the environment
- Attainment of cleanup standards and compliance with applicable state and federal laws, and local requirements
- Short-term effectiveness
- Long-term effectiveness
- Reduction of toxicity, mobility, and volume through treatment
- Implementability
- Cost

These factors are described below.

<u>Overall protection to human health and the environment</u>. This assessment focuses on whether a specific alternative achieves adequate protection of human health and the environment, and describes how site risks are eliminated, reduced, or controlled through treatment or institutional controls.

<u>Attainment of cleanup standards and compliance with applicable state and federal laws, and local requirements.</u> This addresses the federal, state, and/or local requirements which are applicable or relevant and appropriate for a specific alternative and how the alternative meets these requirements.

Short-term effectiveness. Short-term effectiveness considers the protection of public health, worker health and the environment during the construction and implementation of a remedy until remedial response action objectives are met.

Long-term effectiveness. Long-term effectiveness considers the effectiveness of each alternative in maintaining protection of human health and the environment after response action objectives have been met. The magnitude of remaining risk from untreated soil or treatment residuals, if any, and the adequacy and reliability of controls for providing protection from residuals, are considered in this assessment.

Reduction of toxicity, mobility, and volume through treatment. This criterion considers the type and quantity of residuals that will remain following treatment, and the degree to which the treatment reduces the hazards posed by the site. Where possible, numerical comparisons before and after remediation are presented.

Implementability. The technical and administrative feasibility of each alternative is evaluated in this criterion. Technical feasibility includes the ability to construct the system used, the ability to operate and maintain the equipment, and the ability to monitor the effectiveness of operations. Administrative feasibility refers to the ability to obtain necessary permits and approvals from applicable regulatory agencies and the likelihood of favorable community response.

Cost . The capital costs associated with the development and construction, and the annual O&M costs of each alternative are evaluated in this step. The cost estimates are prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The actual costs of remediation depend on many variables, including groundwater extraction flow rate, concentration and total mass of contaminants treated, groundwater effluent concentrations, cleanup levels, health and safety regulations, labor and equipment costs, and the final project scope. As a result, the final project costs will vary from the estimates presented herein. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper evaluation and adequate funding. Costs are expected to be within the range of accuracy typical of FS-level cost estimates (-30 to +50 percent).

4.1.1 Alternative 1 - No Action

Analysis of the No Action Alternative is required by the NCP. This alternative involves no further action at the site, and is sometimes referred to as the "walk-away" alternative.

4.1.1.1 Assessment

Overall Protection. The No Action Alternative does not reduce the risk currently posed by the site. The current use of the site does not have any complete exposure pathways, and therefore the alternative is currently protective of human health and the environment; however, it does not protect groundwater as an environmental resource of the state. This alternative does not provide protection to future use scenarios that may include construction at the site or the potential for groundwater use.

Compliance with ARARs The No Action Alternative does not comply with MCLs, since there would be no reduction in the concentration of contaminants in the groundwater at the site.

Short-Term Effectiveness. There are no short term risks posed by the site or implementation of Alternative 1. Since the site does not currently pose an unacceptable risk as outlined by EPA (a cumulative carcinogenic risk exceeding 1E-6, or a hazard quotient exceeding one), Alternative 1 is protective of the community and the environment. No adverse environmental impacts related to the site are anticipated in the near future.

Long-Term Effectiveness. The No Action Alternative does not reduce the long-term risks associated with the site.

Reduction of Toxicity, Mobility, or Volume. The No Action Alternative will not reduce the toxicity, mobility, or volume of contaminated groundwater.

Implementability. No technical or administrative implementability issues have been identified for the No Action Alternative.

Cost. The estimated cost for Alternative 1 is $0.

4.1.2 Alternative 2 - Natural Attenuation

The Natural Attenuation Alternative includes the following:

- Institutional controls
  - Restrict groundwater use between the site and Eagle River
  - Restrict development around immediate disposal area
- Groundwater Monitoring
  - Currently existing wells (15)
  - Additional monitoring wells (2)
  - Annual groundwater sampling and analysis for VOCs (30 years)
  - Monitor geochemical analytes (nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total organic carbon, pH, redox potential, and dissolved oxygen among other analyses) to estimate the rate of intrinsic remediation

Natural attenuation relies on biological, physical, and chemical processes that are occurring in the environment without artificial stimulus. Monitoring and documenting these processes is the major focus of this alternative.

The Final Risk Assessment for the PRDA site states that there is an unacceptable risk to human health from inhalation of soil gas vapors in basements in the residential use scenario. Because of this unacceptable risk, restriction on development around the immediate disposal area is included as part of the institutional controls.

4.1.2.1 Assessment

Overall Protection. The Natural Attenuation Alternative does not reduce the risk currently posed by the site. Implementation of institutional controls to prevent use of the groundwater and restricting construction at the site minimizes potential future residents from being exposed to contaminated groundwater or soil vapors in basements until natural attenuation reduces the concentration of VOCs to levels below acceptable concentrations (e.g., MCLs for groundwater). This alternative would reduce the risk posed by ingesting groundwater from the deep aquifer, or reduce the risk of exposure to soil gas vapors that might migrate into a building. Groundwater sampling for instrinsic remediation parameters was performed in November 1996. Analytical results indicated that natural attenuation is not occurring at a measurable rate. This alternative does not protect groundwater as an environmental resource of the state.

Compliance with ARARs. The Natural Attenuation Alternative does not comply with MCLs, since there would be no significant reduction in the concentration of contaminants in groundwater at the site.

Short-Term Effectiveness. There are no short term risks posed by the site or the implementation of Alternative 2. Since the site does not currently pose an unacceptable risk as outlined by EPA (a cumulative carcinogenic risk exceeding 1E-6, or a hazard quotient exceeding one), Alternative 2 is protective of the community and the environment. No adverse environmental impacts related to the site are anticipated in the near future. There are no estimates concerning the amount of time necessary for Natural Attenuation to meet the RAOs. Based on the degradation products that were detected in the groundwater samples collected at the site, Natural Attenuation does not appear to be occurring at a high rate and the contaminants in the groundwater are expected to persist without appreciable degradation.

Long-Term Effectiveness. The institutional controls in the Natural Attenuation Alternative would be protective of future residents by preventing them from ingesting groundwater and preventing construction at the site. Groundwater modeling results presented in the RI indicate that groundwater with contaminant concentrations at 0.005 mg/L will arrive at the Eagle River in roughly 100 years. The risk that the site will likely pose at the end of 30 years will be nearly the same as it is currently, if the Natural Attenuation Alternative is implemented.

Reduction of Toxicity, Mobility, or Volume. The toxicity and mobility of contaminated groundwater would not be reduced significantly by natural attenuation. The volume of contaminated groundwater is likely to increase.

Implementability. No technical or administrative implementability issues have been identified for the Natural Attenuation alternative.

Cost. Total project costs, excluding escalation factors, for Alternative 2 is approximately $1.3 million. The capital costs for this alternative are $80,000, the O&M costs for 30 years are $872,100, and the 30% contingency and USACE SIOH (Site Investigation and Over Head) is $385,000. A summary of the costs for Alternative 2 is presented in Table 4-1.

4.1.3 Alternative 3 - Containment

The Containment Alternative includes the following:

- Synthetic liner with soil cover, over "hot spot" area
- Soil-bentonite slurry wall to 25 feet bgs
- Institutional controls
  - Restrict groundwater use between the site and Eagle River
  - Restrict development around immediate disposal area
- Groundwater monitoring
  - Currently existing wells (15)
  - Additional monitoring wells (2)
  - Annual groundwater sampling and analysis for VOCs (30 years)

The slurry wall would minimize water from the wetland from entering the site and the cap would minimize precipitation from entering the site. The cap and vertical barrier would minimize water flow into Areas A-3 and A-4, minimizing the driving force for the migration of contamination from the perched interval to the lower groundwater units.

4.1.3.1 Assessment

Overall Protection. A cap and vertical barrier at the site would minimize the amount of contamination moving from the shallow interval to the deep aquifer. Containment alone may not meet the RAOs. Institutional controls would be needed to prevent ingestion of groundwater outside the PRDA until concentrations of contaminants in the deep aquifer lower to MCLs.

Compliance with ARARs. The Containment Alternative may not comply with MCLs for the deep aquifer. There would be no reduction in the concentration of contaminants in the perched and shallow intervals. Over time there would be a slow reduction in the concentration of contaminants in the deep aquifer and they may eventually comply with MCLs.

Short-Term Effectiveness. Workers installing the slurry wall could be exposed to contaminated soil and groundwater. Worker exposure would be minimized by the use of appropriate health and safety personal protective equipment. The site is a sufficient distance from populated areas so that the community would have adequate protection during the installation of the slurry wall. It is unlikely that the concentration of contamination will be reduced in 30 years to the point that the RAOs are met in the deep aquifer through containment.

Long-Term Effectiveness. The residual risk posed by the site would be reduced by this alternative because the risk posed by the deep aquifer would be reduced. Institutional controls would be needed for the deep aquifer between the site and Eagle River until the concentrations of contaminants reach MCLs. Since the source of contamination to the deep aquifer would remain, long-term groundwater monitoring would have to be maintained.

The cap would minimize infiltration of precipitation in the contaminated area of the PRDA site. The slurry wall would minimize groundwater recharge into the vadose zone and perched interval. This Containment Alternative would reduce the driving force for movement of contaminants to the lower groundwater units.

Reduction of Toxicity, Mobility, or Volume. There would be a reduction in the mobility of the contaminants that are contained in the soil within the cap area. Groundwater outside the containment area would lower in toxicity over time because the source would be contained and diffusion of the plume would lower the concentration of contaminants.

Implementability. No technical implementability issues have been identified for installation of a slurry wall to 25 feet bgs at the site. The slurry wall may impact the wetlands by raising surface water levels. There are several data gaps that would need to be filled before the Containment Alternative can be implemented. These data gaps include:

- Hydraulic properties of the groundwater system (e.g., flow direction, and vertical and horizontal hydraulic conductivity)
- Extent of contamination to the west of the PRDA

This information is needed to provide the most efficient position and extent of the slurry wall.

Cost. The total estimated program cost, including contingencies and USACE SIOH and excluding escalation costs, for Alternative 3 is $2.5 million. This cost includes the design and installation of the slurry wall and the synthetic cover, and O&M costs for 30 years. The estimated total capital costs are $879,000, the total estimated O&M costs are $907,000, and the 30% contingency and USACE SIOH is $721,000. A summary of the costs for Alternative 3 is presented in Table 4-2.

4.1.4 Alternative 4 - Interception Trench, Air Stripping, and Soil Vapor Extraction

The interception trench with air stripping and soil vapor extraction alternative includes the following:

- Soil Vapor Extraction (SVE) system to treat unsaturated soil and soil in perched groundwater interval in Area A-3 and A-4
- Interception trench as described in Alternative 4
- Groundwater extracted from the interception trench will be treated by air stripping and discharged to a downgradient infiltration system
- 25-foot deep vertical barrier between site and wetlands
- Institutional Controls
    - Restrict groundwater use between the site and Eagle River
    - Restrict development around immediate disposal area
- Groundwater monitoring
    - Currently existing wells (15)
    - Additional monitoring wells (2)
    - Annual groundwater sampling and analysis for VOCs (30 years)

4.1.4.1 Assessment

Overall Protection. This alternative would reduce the risk posed by the site by reducing the concentration of contamination in the perched and shallow groundwater, minimizing the amount of contaminants migrating to the deep aquifer. An additional risk may be associated with the emission of vapors from the soil vapor extraction and air stripping systems.

Compliance with ARARs. This alternative would not reduce the level of contamination in the upper groundwater units at the PRDA to MCLs. The groundwater modeling results of this system indicates that the extracted groundwater concentration for 1,1,2,2,-tetrachloroethane would be reduced from an initial concentration of 29.0 mg/L to 1.0 mg/L after 30 years of treatment (see Appendix B). Modeling results also indicate that while the system is operating, the shallow interval would be prevented from recharging the deep aquifer, providing optimization of the groundwater interception trench collection system.

Discharging the treated groundwater back onto the site would require a permit from ADEC.

The estimated mass of VOCs released from the air stripper to the atmosphere is 170 pounds per year (or 0.085 tons per year). This is two orders of magnitude less than required under 40 CFR 264.1032. Since emissions from the air stripper would potentially move off-site, air permitting may be required.

Short-Term Effectiveness. There is a potential for exposure to site workers while installing the interception trench system. Exposure of site workers to contaminants would be minimized by using appropriate health and safety personal protective equipment and procedures. The site is a sufficient distance from populated areas that the community would have adequate protection. The short-term risks are manageable.

Groundwater monitoring would be required to monitor the effectiveness of the system during treatment. This information would be used to evaluate when treatment objectives are attained, and treatment could be stopped. Based on the results of the groundwater modeling conducted (see Appendix B), a minimum of 30 years of operation would be required.

Long-Term Effectiveness. The residual risk posed by the site would be reduced by this alternative because the risk posed by the deep aquifer would be reduced. Institutional controls would be implemented to prevent ingestion of groundwater until the alternative reduces the concentration of contaminants to meet the RAOs.

Reduction of Toxicity, Mobility, or Volume. The mobility of the contaminants would be reduced by trapping them in the air stripper. The volume of contaminated groundwater would be reduced. The toxicity of the contaminants would not be reduced.

Implementability. No administrative implementability issues have been identified. Modeling indicates that the interception trenches would be able to dewater the site and prevent recharge of the deep aquifer. Air stripping is a standard technology used for treating VOCs. Further characterization of the hydrogeology of the shallow and intermediate groundwater intervals would be required for implementation of this alternative, including, but not limited to, low flow, long duration pump tests. The vertical barrier may impact the wetlands by raising surface water levels.

Cost. The total estimated program cost including contingency and USACE SIOH and excluding escalation costs, for Alternative 4 is $7.5 million. This includes the costs for design and installation of a groundwater extraction and treatment system, and O&M costs for 30 years. The estimated total capital costs are $2.0 million, the total estimated O&M costs are $3.1 million, and the 35% contingency and USACE SIOH is $2.4 million. A summary of the costs for Alternative 4 is presented in Table 4-3.

4.1.5 Alternative 5 - Air Sparging and Soil Vapor Extraction of the "Hot Spot and Natural Attenuation

This alternative includes the following components:

- An air sparging system consisting of 80 vertical sparging wells screened in the shallow interval from approximately 37 to 42 feet bgs
- A 520-foot long, 25-foot deep vertical barrier between site and wetlands
- Soil vapor extraction system which includes 20 vertical extraction wells installed in Areas A-3 and A-4
- Institutional controls
  - Restrict groundwater use between the site and Eagle River
  - Restrict development around immediate disposal area

- Groundwater Monitoring
    - Currently existing wells (15)
    - Additional monitoring wells (2)
    - Annual groundwater sampling and analysis for intrinsic remediation parameters and VOCs (30 years)

In this alternative, air is blown into the shallow saturated interval through air sparging wells. Contaminants in groundwater move into the air bubbles and are carried up to the unsaturated zone. The vapors are then treated by a soil vapor extraction system. A vertical barrier between the wetlands and the disposal area lowers the water table to facilitate soil vapor extraction.

4.1.5.1 Assessment

Overall Protection. This alternative would reduce the risk posed by the site by reducing the concentration of contamination in the perched and shallow groundwater, minimizing the amount of contaminants migrating to the deep aquifer. There may be a risk associated with the emission of vapors from the soil vapor extraction system.

Compliance with ARARs. This alternative would probably not reduce the level of contamination in the upper groundwater unit to MCLs. Although the technology of air sparging has the potential to greatly decrease concentrations of volatile contaminants, the nature of the subsurface at the PRDA is a major limiting factor (see Implementability below). This alternative will not prevent water from migrating downward but will protect the State's groundwater resource by decreasing the concentrations of contaminants.

Short-Term Effectiveness. There is a potential for exposure to site workers while installing the air sparging and soil vapor extraction wells. Exposure of site workers to contaminants would be minimized by using appropriate health and safety personal protective equipment and procedures. The site is a sufficient distance from populated areas that the community would have adequate protection. The short-term risks are manageable.

Long-Term Effectiveness. The residual risk posed by the site would be reduced by this alternative because the risk posed by the deep aquifer would be reduced. Institutional controls would be implemented to prevent ingestion of groundwater until the alternative reduces the concentrations of contaminants to meet the RAOs.

Reduction of Toxicity, Mobility, or Volume. Toxicity of the contaminants would not be reduced; they would be transferred from the groundwater to the atmosphere. Mobility of the contaminants would be reduced because the vertical barrier would prevent groundwater recharge from the wetlands into the perched and shallow intervals. The volume of contaminated groundwater would be reduced.

Implementability. No implementability issues have been identified for the *installation* of the air sparging and soil vapor extraction systems. However, the *effectiveness* of the system is uncertain. The soils are dense and relatively impermeable, so the radius of influence around each sparging well is small (thus the high number of required sparge wells). The possibility that air will be able to penetrate the majority of the contaminated saturated interval is remote. In order for an air sparging system to be effective, groundwater must flow horizontally past the sparge wells so that new pulses of water are always coming into contact with the injected air. Groundwater at the PRDA moves mostly in a vertical direction; therefore, the volume of groundwater moving horizontally past the sparge wells would be insignificant. The treatability study performed in November 1996 confirmed a low radius of influence for air sparging.

Emissions from the soil vapor extraction system may require a permit. The vertical barrier may impact the wetlands by raising surface water levels.

Cost. The total estimated program cost, including contingency and USACE SIOH and excluding escalation costs, for Alternative 5 is $5,500,000. This includes the cost for design and installation of the air sparging system, soil vapor extraction system, and vertical barrier. The cost also includes O&M costs for 30 years. The estimated total capital costs are $1,600,000, the total estimated O&M costs are $2,200,000, and the 35% contingency and USACE SIOH is $1,700,000. A summary of the costs for Alternative 5 is presented in Table 4-4.

4.1.6 Alternative 6 - Soil Vapor Extraction of the "Hot Spot"

This alternative includes the following components:

- Soil vapor extraction system which includes 10 vertical extraction wells installed in the hot spot.
- Air stripping system for groundwater extracted from the SVE wells
- Institutional control
    - Restrict groundwater use between the site and Eagle River
    - Restrict development around immediate disposal area
- Groundwater Monitoring
    - Existing wells (15)
    - Additional monitoring wells (2)
    - Annual groundwater sampling and analysis VOCs (30 years)

4.1.6.1 Assessment

Overall Protection. This alternative would reduce the risk posed by the site by reducing the concentration of contamination in the vadose zone. There may be a risk associated with the emission of vapors from the soil vapor extraction system.

Compliance with ARARs. This alternative would probably not reduce the level of contamination in the upper groundwater unit to MCLs. This alternative will not prevent water from migrating downward but will protect the State's groundwater resource by decreasing the concentrations of contaminants.

Short-Term Effectiveness. There is a potential for exposure to site workers while installing the soil vapor extraction wells. Exposure of site workers to contaminants would be minimized by using appropriate health and safety personal protective equipment and procedures. The site is a sufficient distance from populated areas that the community would have adequate protection. The short-term risks are manageable.

Long-Term Effectiveness. The residual risk posed by the site would be reduced by this alternative because the risk posed by the deep aquifer would be reduced. Institutional controls would be implemented to prevent ingestion of groundwater until the alternative reduces the concentrations of contaminants to meet the RAOs.

Reduction of Toxicity, Mobility, or Volume. Toxicity of the contaminants would not be reduced; they would be transferred from the vadose zone to the atmosphere. This alternative would not reduce the mobility or volume of contaminants.

Implementability. No implementability issues have been identified for the installation of the soil vapor extraction system. A treatability study performed in November 1996 indicated that SVE is effective at removing contaminants from the subsurface. Emissions from the soil vapor extraction system may require a permit.

Cost. The estimated total program cost, including contingency and USACE SIOH and excluding escalation costs, for Alternative 6 is $4,000,000. This includes the cost for design and installation for the SVE system, and vertical barrier. The cost also includes O&M costs for 30 years. The estimated total capital costs are $801,841, the total estimated O&M costs are 1,975,400, and the 35% contingency and USACE SIOH is $1,270,000. A summary of the costs for Alternative 6 is presented in Table 4-5.

4.2 COMPARATIVE ANALYSIS

In this section of the FS, the alternatives developed in Chapter 3 and evaluated with respect to specific criteria in Section 4.1 are compared to one another to allow for selection of the remedial action at the PRDA.

4.2.1 Overall Protection of Human Health and the Environment

The site does not pose an unacceptable risk to human health or the environment under current and most probable future use scenarios. Therefore, all of the alternatives are equally protective. Under the unlikely future residential scenario, Alternatives 4, 5, and 6 would be most protective because they actively remediate contaminated media. Alternative 3 will minimize contaminants migrating to the deep aquifer but will not otherwise protect the groundwater resource. Alternatives 1 and 2 would not prevent or minimize contaminants migrating to the deep aquifer and would not protect the groundwater resource. Each of the alternatives, except Alternative 1, prevents ingestion of groundwater from the deep aquifer with contaminants exceeding MCLs by implementing institutional controls to prevent ingestion of the groundwater. Alternatives 4, 5, and 6 include remedial actions to reduce the concentration of contaminants entering the deep aquifer.

The alternative that is most protective of human health and the environment is the one which most quickly lowers the concentration of contaminants in the shallow and perched groundwater to concentrations that are protective of the deep aquifer. Once the RAOs are achieved by cleaning the site, the institutional controls can be removed. Alternatives 4, 5, and 6 protect human health and environment by intercepting and/or treating groundwater migrating to the deep aquifer.

4.2.2 Compliance with ARARs

Alternatives that include groundwater extraction (Alternatives 4 and 6) and active in situ groundwater treatment (Alternative 5) are expected to be protective of the deep aquifer by reducing contaminants during operation of the treatment system. The final concentration in groundwater of the upper groundwater units for treatment to be considered complete is uncertain (i.e., concentrations that would be protective of the deep aquifer after the treatment system is turned off). Alternatives 1 through 3 would likely not be protective of the on-site part of the deep aquifer.

No off-site contamination has been detected to date. Based on the results of groundwater modeling performed during the RI, regulatory limits of contaminants are not expected to be exceeded at the Eagle River within 100 years. Therefore, all the Alternatives (except No Action) would be in compliance with ARARs at the Eagle River within 100 years. The RI groundwater modeling is presented in Appendix XIII of the RI report.

4.2.3 Short-Term Effectiveness

None of the alternatives represent an unacceptable risk to the community, workers or the environment during implementation. The biggest difference between the alternatives is the time until the RAOs are achieved. All of the alternatives, except the No Action Alternative, meet the first RAO by implementing institutional controls.

After 30 years of treatment, the estimated concentration of 1,1,2,2-tetrachloroethane in the extracted groundwater is 1.0 mg/L for Alternative 4. It is uncertain whether this concentration is sufficient to turn off the groundwater extraction system and still be protective of the deep aquifer.

4.2.4 Long-Term Effectiveness

Institutional controls would have to remain in effect permanently or until the selected remedial alternative permanently lowers the concentrations of contaminants in the deep aquifer to below MCLs. Alternatives 4, 5, and 6 have the highest long-term effectiveness because these alternatives have the highest potential to permanently remove the greatest mass of contaminants from the site. Alternatives 4, 5, and 6 remove contaminants from the shallow groundwater, but also use soil vapor extraction to remove contaminants from the soil in Areas A-3 and A-4. However, the effectiveness of air sparging (Alternative 5) is questionable because of the low hydraulic conductivities at the site.

Alternative 3 would reduce the rate of migration of contaminants from the shallow groundwater units that are migrating to the deep aquifer. Alternatives 1 and 2 provide the least long-term effectiveness, since none include action to remediate the site.

4.2.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 1 and 2 do not reduce the toxicity, mobility, or volume of the contaminated soil. Alternative 3 provides for containment (reduction of mobility) of the contaminated materials. However, because contaminants that are presently in the shallow and intermediate intervals would continue to migrate and disperse once the Containment Alternative is implemented, the size of the groundwater plume would likely increase (the volume of contaminants will not increase, but the size of the plume will increase due to dispersion). Alternatives 4, 5, and 6 reduce the volume and mobility of contaminants through treatment, but do not reduce toxicity.

4.2.6 Implementability

All of the alternatives can be implemented using commercially available services. The technical implementability issues affecting the alternatives relate to uncertainty concerning the western boundary of the plume, the horizontal and vertical hydraulic conductivity of the soil, and the variability of the soils. Alternative 1 is least impacted by this uncertainty. The remaining alternatives are listed in order of least to most impacted by the uncertainty: Alternative 2, Alternative 3, Alternative 6, Alternative 4, and Alternative 5.

4.2.7 Cost

Table 4-6 presents a summary of the total estimated costs for each of the alternatives. Alternative 4, groundwater interception trenches with air stripping and SVE, has the highest estimated program costs ($7,500,000). The remaining alternatives listed from highest to lowest cost are: Alternative 5 ($5,500,000), Alternative 6 ($4,000,000), Alternative 3 ($2,500,000), Alternative 2 ($1,300,000), and Alternative 1 ($0).

TABLE 4- 1
ESTIMATED COSTS - ALTERNATIVE 2
NATURAL ATTENUATION

ITEM	UNIT COST	UNIT	QUANTITY	COST
I. CAPITAL COSTS				
Additional Monitoring Well Installation	$40,000	well	2	$80,000
TOTAL CAPITAL REQUIREMENTS				**$80,000**
II. ANNUAL O&M COSTS				
Groundwater Monitoring				
Sampling Labor	$60	hr	40	$2,400
Sampling Analysis-VOCs (17 wells + 10% dupl)	$180	sample	19	$3,420
Sampling Analysis(1) (9 wells + 10% dupl)	$360	sample	10	$3,600
Sampling Analysis(2) (9 wells + 10% dupl)	$145	sample	10	$1,450
Supervision	$100	hr	40	$4,000
Data Evaluation and Reporting	$85	hr	160	$13,600
Supplies and Materials	$600	ls	1	$600
TOTAL ANNUAL O&M COSTS				**$29,070**
TOTAL O&M COSTS (for 30 years)				**$872,100**
TOTAL CAPITAL AND O&M COSTS				**$952,100**
CONTINGENCY (30% of Total Capital and O&M Costs)				$285,630
SUBTOTAL (Total Capital and O&M Costs and Contingency)				**$1,237,730**
USACE SIOH (8% Total Capital and O&M Costs and Contingency)				$99,018
TOTAL ESTIMATED PROGRAM COSTS (3)				**$1,300,000**

NOTES:

(1) Analysis for parameters which can indicate biodegradation of chlorinated solvents (e.g., NO_3-nitrogen, NH_3-nitrogen, total Kjeldahl nitrogen, total phosphorus, SO_4, soluble iron, methane, ethane, ethene)

(2) Bacteria enumeration

(3) Escalation costs are not included

TABLE 4-2
ESTIMATED COSTS - ALTERNATIVE 3
CONTAINMENT

ITEM	UNIT COST	UNIT	QUANTITY	COST
I. CAPITAL COSTS				
CAPITAL DIRECT COSTS				
A. Preparation Work/Mob & Demob				
Mobilization & Demobilization	$120,000	LS	1	$120,000
Additional Monitoring Well Installation	$40,000	well	2	$80,000
Site Preparation (Clearing & Grubbing)	$1,785	acre	3.0	$5,355
B. Soil/Bentonite Slurry Wall				
Excavate Trench	$2.67	sf	13,000	$34,710
Backfill Trench - Placement of Slurry	$3.20	sf	13,000	$41,600
C. Multi-Layer Cap				
Synthetic Cap Material	$2.70	sy	8,400	$22,680
Cap Placement	$1.35	sy	8,400	$11,340
Sand and Gravel Placement	$16	cy	5,600	$89,600
Grading	$1.00	sy	8,400	$8,400
Drainage	$5,000	LS	1	$5,000
TOTAL DIRECT COSTS (TDC)				$418,685
CAPITAL INDIRECT COSTS				
A. Contractor's Overhead and Profit (50% TDC)				$209,343
B. Engineering Design (25% TDC)				$104,671
C. Design Studies (30% TDC)				$125,606
D. Health and Safety (5% TDC)				$20,934
TOTAL INDIRECT COSTS				$460,554
TOTAL CAPITAL COSTS **(Total Direct Costs + Total Indirect Costs)**				$879,239
II. ANNUAL O&M COSTS				
A. Cap Maintenance				
Maintenance (8 hr/month @ 12 months)	$100	hr	96	$9,600
B. Groundwater Monitoring				
Sampling Labor	$60	hr	40	$2,400
Sampling Analysis (17 Monitoring wells + 10% dupl)	$180	sample	19	$3,420
Supervision	$100	hr	40	$4,000
Data Evaluation and Reporting	$85	hr	120	$10,200
Supplies and Materials	$600	ls	1	$600
TOTAL ANNUAL O&M COSTS				$30,220
TOTAL O&M COSTS **(for 30 years)**				$906,600
TOTAL CAPITAL AND O&M COSTS				$1,785,839
CONTINGENCY (30% of Total Capital and O&M Costs)				$535,752
SUBTOTAL **(Total Capital and O&M Costs and Contingency)**				$2,321,590
USACE SIOH (8% Total Capital and O&M Costs and Contingency)				$185,727
TOTAL ESTIMATED PROGRAM COSTS (1)				$2,500,000

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(1) Escalation costs are not included

TABLE 4-3
ESTIMATED COSTS - ALTERNATIVE 4
INTERCEPTION TRENCH, AIR STRIPPING, AND SOIL VAPOR EXTRACTION

ITEM	UNIT COST	UNIT	QUANTITY	COST
I. CAPITAL COSTS				
CAPITAL DIRECT COSTS				
A. Preparation Work/Mob & Demob				
Mobilization & Demobilization	$130,000	LS	1	$130,000
Additional Monitoring Well Installation	$40,000	well	2	$80,000
Barrier Wall Excavation (between wetlands & disposal areas)	$2.67	sf	13,000	$34,710
Barrier Wall Installation (between wetlands & disposal areas)	$3.20	sf	13,000	$41,600
Site Preparation (Clearing & Grubbing)	$1,785	acre	3.1	$5,534
B. Soil Vapor Extraction				
Extraction Well Installation (HDPE, 20' length)	$1,500	well	20	$30,000
Extraction Well Installation (HDPE, 40' length)	$3,000	well	20	$60,000
Blower/Motor Systems (incl. knockout tank & instrumentation)	$26,742	LS	1	$26,742
Piping (HDPE)	$13.65	lf	1,400	$19,110
Insulation for Piping and Equipment	$4,685	LS	1	$4,685
Pump (from knockout tanks to air stripper)	$500	pump	2	$1,000
HDPE Liner	$4.05	sy	4,270	$17,294
Vapor Extraction System Installation	$11,713	LS	1	$11,713
Electrical	$4,685	LS	1	$4,685
C. Groundwater Extraction and Treatment				
Biopolymer Trench Excavation	$3.25	sf	54,000	$175,500
Collection Trench Installation (w/ piping)	$3.88	sf	54,000	$209,520
Pump (from collection trenches to equalization tank)	$2,600	pump	7	$18,200
Equalization Tank	$12,200	tank	1	$12,200
Piping (HDPE)	$2.70	lf	1,400	$3,780
Water Heating Units	$2,524	each	1	$2,524
Air Heating Units	$8,506	each	1	$8,506
Air Stripping Unit (incl. blower)	$18,683	unit	1	$18,683
Treatment Building	$95	sf	200	$19,000
Pump	$500	pump	2	$1,000
Insulation for Piping and Equipment	$4,166	LS	1	$4,166
Storage Tank	$12,200	tank	1	$12,200
Infiltration System (incl. piping, fittings, filters, emitters)	$14,370	LS	1	$14,370
Infiltration Piping Preparation (punch holes in pipes, install fittings, etc.)	$3,593	LS	1	$3,593
Infiltration Piping Bedding	$21	cy	40	$840
Infiltration Piping Installation	$20	lf	500	$10,000
GW Collection & Air Stripping System Installation	$19,273	LS	1	$19,273
Electrical	$5,269	LS	1	$5,269
TOTAL DIRECT COSTS (TDC)				**$1,005,697**
CAPITAL INDIRECT COSTS				
A. Contractor's Overhead and Profit (50% TDC)				$502,848
B. Engineering Design (25% TDC)				$251,424
C. Design Studies (25% TDC)				$251,424
D. Health and Safety (3% TDC)				$30,171
TOTAL INDIRECT COSTS				**$1,035,868**
TOTAL CAPITAL COSTS (Total Direct Costs + Total Indirect Costs)				**$2,041,564**
II. ANNUAL O&M COSTS				
A. Soil Vapor Extraction Unit O&M (5 years)				
Operations Labor (8 hr/wk @ 52 wks)	$60	hr	416	$24,960
Supervision Labor (4 hr/wk @ 52 wks)	$100	hr	208	$20,800
Electrical Power	$16,000	LS	1	$16,000
Maintenance (8 hr/month @ 12 months)	$100	hr	96	$9,600
B. Air Stripping Unit O&M (30 years)				
Operations Labor (8 hr/wk @ 52 wks)	$60	hr	416	$24,960
Supervision Labor (4 hr/wk @ 52 wks)	$100	hr	208	$20,800
Electrical Power	$14,000	LS	1	$14,000
Treatment Performance (1 water sample/month @ 12 months)	$180	sample	12	$2,160
Maintenance (8 hr/month @ 12 months)	$100	hr	96	$9,600

TABLE 4- 3
ESTIMATED COSTS - ALTERNATIVE 4
INTERCEPTION TRENCH, AIR STRIPPING, AND SOIL VAPOR EXTRACTION

ITEM	UNIT COST	UNIT	QUANTITY	COST
C. Groundwater Monitoring (30 years)				
Sampling Labor (40 hr/year)	$60	hr	40	$2,400
Sampling Analysis (17 Monitoring wells + 10% dupl)	$180	sample	19	$3,420
Supervision	$100	hr	40	$4,000
Data Evaluation and Reporting	$85	hr	120	$10,200
Supplies and Materials	$600	ls	1	$600
TOTAL O&M COSTS (30 years)				**$3,121,000**
TOTAL CAPITAL AND O&M COSTS				**$5,162,564**
CONTINGENCY (35% of Total Capital and O&M Costs)				$1,806,898
SUBTOTAL (Total Capital and O&M Costs and Contingency)				**$6,969,462**
USACE SIOH (8% Total Capital and O&M Costs and Contingency)				$557,557
TOTAL ESTIMATED PROGRAM COSTS (1)				**$7,500,000**

NOTES:

(1) Escalation costs are not included

TABLE 4-4
ESTIMATED COSTS - ALTERNATIVE 5
AIR SPARGING AND SOIL VAPOR EXTRACTION OF "HOT SPOT" AND NATURAL ATTENUATION

ITEM	UNIT COST	UNIT	QUANTITY	COST
I. CAPITAL COSTS				
CAPITAL DIRECT COSTS				
A. **Preparation Work/Mob & Demob**				
Mobilization & Demobilization	$130,000	LS	1	$130,000
Additional Monitoring Well Installation	$40,000	well	2	$80,000
Barrier Wall Excavation (between wetlands & disposal areas)	$2.67	sf	13,000	$34,710
Barrier Wall Installation (between wetlands & disposal areas)	$3.20	sf	13,000	$41,600
Site Preparation (Clearing & Grubbing)	$1,785	acre	1.4	$2,499
B. **Soil Vapor Extraction**				
Extraction Well Installation (HDPE, 20' length)	$1,500	well	20	$30,000
Blower/Motor System (incl. knockout tank & instrumentation)	$13,400	LS	1	$13,400
Piping (4" HDPE)	$13.65	lf	880	$12,012
Insulation for Piping and Equipment	$2,591	LS	1	$2,591
Pump (from knockout tanks to discharge)	$500	pump	1	$500
HDPE Liner	$4.05	sy	4,270	$17,294
Vapor Extraction System Installation	$6,478	LS	1	$6,478
Electrical	$2,591	LS	1	$2,591
C. **Air Sparging**				
Sparging Well Installation (PVC, 42' length)	$2,650	well	80	$212,000
Compressor/Motor Systems (incl. instrumentation)	$60,000	LS	1	$60,000
Piping (2" PVC)	$9.20	lf	1,920	$17,664
Insulation for Piping and Equipment	$12,360	LS	1	$12,360
Air Sparging System Installation	$45,933	LS	1	$45,933
Electrical	$22,966	LS	1	$22,966
Treatment Building	$95	sf	200	$19,000
TOTAL DIRECT COSTS (TDC)				**$763,598**
CAPITAL INDIRECT COSTS				
A. Contractor's Overhead and Profit (50% TDC)				$381,799
B. Engineering Design (25% TDC)				$190,899
C. Design Studies (25% TDC)				$190,899
D. Health and Safety (3% TDC)				$22,908
TOTAL INDIRECT COSTS				**$786,506**
TOTAL CAPITAL COSTS **(Total Direct Costs + Total Indirect Costs)**				**$1,550,103**
II. ANNUAL O&M COSTS				
A. **Treatment System O&M (years 1 to 5)**				
Operations Labor (8 hr/wk @ 52 wks)	$60	hr	416	$24,960
Supervision Labor (8 hr/wk @ 52 wks)	$100	hr	416	$41,600
Electrical Power (SVE)	$5,500	LS	1	$5,500
Electrical Power (Air Sparging)	$20,900	LS	1	$20,900
Electrical Power (Treatment Building heating, lighting, etc.)	$1,200	LS	1	$1,200
Maintenance (8 hr/month @ 12 months)	$100	hr	96	$9,600
B. **Treatment System O&M (years 6 to 30)**				
Operations Labor (8 hr/month @ 12 months)	$60	hr	96	$5,760
Supervision Labor (8 hr/month @ 12 months)	$100	hr	96	$9,600
Electrical Power (SVE)	$1,400	LS	1	$1,400
Electrical Power (Air Sparging)	$5,250	LS	1	$5,250
Electrical Power (Treatment Building heating, lighting, etc.)	$1,200	LS	1	$1,200
Maintenance (8 hr/month @ 12 months)	$100	hr	96	$9,600
C. **Groundwater Monitoring (30 years)**				
Sampling Labor (40 hr/year)	$60	hr	40	$2,400
Sampling Analysis - VOCs (17 wells + 10% dupl)	$180	sample	19	$3,420
Sampling Analysis (2) (9 wells + 10% dupl)	$360	sample	10	$3,600
Sampling Analysis (3) (9 wells + 10% dupl)	$145	sample	10	$1,450
Supervision	$100	hr	40	$4,000
Data Evaluation and Reporting	$85	hr	160	$13,600
Supplies and Materials	$600	ls	1	$600

TABLE 4-4
ESTIMATED COSTS - ALTERNATIVE 5
AIR SPARGING AND SOIL VAPOR EXTRACTION OF "HOT SPOT" AND NATURAL ATTENUATION

ITEM	UNIT COST	UNIT	QUANTITY	COST
TOTAL O&M COSTS (30 years)				**$2,211,150**
TOTAL CAPITAL AND O&M COSTS				**$3,761,253**
CONTINGENCY (35% of Total Capital and O&M Costs)				$1,316,439
SUBTOTAL (Total Capital and O&M Costs and Contingency)				**$5,077,692**
USACE SIOH (8% Total Capital and O&M Costs and Contingency)				$406,215
TOTAL ESTIMATED PROGRAM COSTS (1)				**$5,500,000**

NOTES:

(1) Escalation costs are not included

(2) Analysis for parameters which can indicate biodegradation of chlorinated solvents (e.g., NO_3-nitrogen, NO_2-nitrogen, NH_3-nitrogen, total Kjeldahl nitrogen, total phosphorus, SO4, soluble iron, methane, ethane, ethene, sulfide, TOC, BOD)

(3) Bacteria enumeration

TABLE 4-5
ESTIMATED COSTS - ALTERNATIVE 6
SOIL VAPOR EXTRACTION OF "HOT SPOT"

ITEM	UNIT COST	UNIT	QUANTITY	COST
I. CAPITAL COSTS				
CAPITAL DIRECT COSTS				
A. Preparation Work/Mob & Demob				
Mobilization & Demobilization	$130,000	LS	1	$130,000
Additional Monitoring Well Installation	$40,000	well	2	$80,000
Site Preparation (Clearing & Grubbing)	$1,785	acre	1.4	$2,499
B. Soil Vapor Extraction				
Extraction Well Installation (HDPE, 40' length)	$3,000	well	10	$30,000
Blower/Motor System (incl. knockout tank & instrumentation)	$26,500	LS	1	$26,500
Piping (4" HDPE)	$13.65	lf	500	$6,825
Insulation for Piping and Equipment	$3,483	LS	1	$3,483
Pump (from knockout tanks to discharge)	$500	pump	3	$1,500
HDPE Liner	$4.05	sy	2,100	$8,505
Vapor Extraction System Installation	$8,706	LS	1	$8,706
Electrical	$3,483	LS	1	$3,483
C. Groundwater Treatment				
Equalization Tank	$12,200	tank	1	$12,200
Piping (HDPE)	$2.70	lf	1,400	$3,780
Water Heating Units	$2,524	each	1	$2,524
Air Heating Units	$8,506	each	1	$8,506
Air Stripping Unit (incl. blower)	$18,683	unit	1	$18,683
Treatment Building	$95	sf	200	$19,000
Infiltration System (incl. piping, fittings, filters, emitters)	$14,370	LS	1	$14,370
Infiltration Piping Preparation (punch holes in pipes, install fittings,	$3,593	LS	1	$3,593
Infiltration Piping Bedding	$21	cy	40	$840
Infiltration Piping Installation	$20	lf	500	$10,000
TOTAL DIRECT COSTS (TDC)				**$394,996**
CAPITAL INDIRECT COSTS				
A. Contractor's Overhead and Profit (50% TDC)				$197,498
B. Engineering Design (25% TDC)				$98,749
C. Design Studies (25% TDC)				$98,749
D. Health and Safety (3% TDC)				$11,850
TOTAL INDIRECT COSTS				**$406,846**
TOTAL CAPITAL COSTS (Total Direct Costs + Total Indirect Costs)				**$801,841**
II. ANNUAL O&M COSTS				
A. Treatment System O&M (years 1 to 5)				
Operations Labor (8 hr/wk @ 52 wks)	$60	hr	416	$24,960
Supervision Labor (8 hr/wk @ 52 wks)	$100	hr	416	$41,600
Electrical Power (SVE)	$5,500	LS	1	$5,500
Electrical Power (Treatment Building heating, lighting, etc.)	$1,200	LS	1	$1,200
Maintenance (8 hr/month @ 12 months)	$100	hr	96	$9,600
B. Treatment System O&M (years 6 to 30)				
Operations Labor (8 hr/month @ 12 months)	$60	hr	96	$5,760
Supervision Labor (8 hr/month @ 12 months)	$100	hr	96	$9,600
Electrical Power (SVE)	$1,400	LS	1	$1,400
Electrical Power (Treatment Building heating, lighting, etc.)	$1,200	LS	1	$1,200
Maintenance (8 hr/month @ 12 months)	$100	hr	96	$9,600
C. Groundwater Monitoring (30 years)				
Sampling Labor (40 hr/year)	$60	hr	40	$2,400
Sampling Analysis - VOCs (17 wells + 10% dupl)	$180	sample	19	$3,420
Sampling Analysis (2) (9 wells + 10% dupl)	$360	sample	10	$3,600
Sampling Analysis (3) (9 wells + 10% dupl)	$145	sample	10	$1,450
Supervision	$100	hr	40	$4,000
Data Evaluation and Reporting	$85	hr	160	$13,600
Supplies and Materials	$600	ls	1	$600

TABLE 4-5
ESTIMATED COSTS - ALTERNATIVE 6
SOIL VAPOR EXTRACTION OF "HOT SPOT"

ITEM	UNIT COST	UNIT	QUANTITY	COST
TOTAL O&M COSTS (30 years)				**$1,975,400**
TOTAL CAPITAL AND O&M COSTS				**$2,777,241**
CONTINGENCY (35% of Total Capital and O&M Costs)				$972,034
SUBTOTAL (Total Capital and O&M Costs and Contingency)				**$3,749,276**
USACE SIOH (8% Total Capital and O&M Costs and Contingency)				$299,942
TOTAL ESTIMATED PROGRAM COSTS (1)				**$4,000,000**

NOTES:

(1) Escalation costs are not included

(2) Analysis for parameters which can indicate biodegradation of chlorinated solvents (e.g., NO_3-nitrogen, NO_2-nitrogen, NH_3-nitrogen, total Kjeldahl nitrogen, total phosphorus, SO4, soluble iron, methane, ethane, ethene, sulfide, TOC, BOD)

(3) Bacteria enumeration

TABLE 4-6
SUMMARY OF ESTIMATED COSTS

Alternatives	Total Capital Costs	Total O&M	30% Contingency and USACE SIOH	Estimated Program Costs Plus Contingency
Alternative 1	$0	$0	$0	$0
Alternative 2	$80,000	$872,100	$384,700	$1,300,000
Alternative 3	$879,000	$906,600	$721,000	$2,500,000
Alternative 4	$2,042,000	$3,121,000	$2,312,000	$7,500,000
Alternative 5	$1,600,000	$2,200,000	$1,700,000	$5,500,000
Alternative 6	$802,000	$1,975,000	$127,200	$4,000,000

5.0
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APPENDIX A

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

APPENDIX A
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

A.1 DISCUSSION OF ARARs

Cleanup standards for remedial action must attain a general standard of cleanup that assures protection of human health and the environment, is cost-effective, and uses permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, the Superfund Authorization and Recovery Act (SARA) requires that any hazardous substance or pollutant remaining on site meet the level or standard of control established by standards, requirements, criteria or limitations that have been established under federal environmental law, or any more stringent standards, requirements, criteria, or limitations promulgated in accordance with a state environmental statute.

A requirement may be either applicable or relevant and appropriate to remedial activities at a site, but not necessarily both. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a site.

If a regulation is not applicable, it may still be relevant and appropriate. The basic considerations are whether the requirement (1) regulates or addresses problems or situations sufficiently similar to those encountered at the site (i.e., relevance), and (2) is appropriate to the circumstances of the release or threatened release, such that its use is well suited to the particular site. Determining whether a requirement is relevant and appropriate is site-specific and must be based on best professional judgment. This judgment is based on a number of factors, including the characteristics of the site and of the release, as compared to the statutory or regulatory requirement.

In some situations, a promulgated regulation does not address a particular issue. In the case when there is not a promulgated regulation, a state or federal advisory, proposed rules, criteria, or guidance documents may be "to be considered" (TBC) to establish remediation cleanup levels or procedures. TBCs are not enforceable and their use may not be economically feasible.

Applicable or Relevant and Appropriate Requirements (ARARs) are provided in this section for three specific areas including: (1) chemical-specific ARARs, (2) location-specific ARARs, and (3) action-specific ARARs. Generally, potential chemical-specific ARARs and location-specific ARARs are identified during the site characterization phase of a project and the potential action-specific ARARs are identified during the development of remedial alternatives in the FS. However, at the request of the USEPA, action-specific ARARs for a variety of remediation technologies were initially included in the Management Plan. A more detailed list of action-specific ARARs has been prepared as remedial action alternatives were refined in the FS, and is included here.

A.1.1 Chemical-Specific ARARs

Chemical-specific requirements are based on health or risk-based concentration limitations in environmental media (i.e., water, air, soil) for specific hazardous chemicals. These requirements may be used to set cleanup levels for the chemicals of concern in the designated media, or to set a safe level of discharge where discharge occurs as part of the remedial activity.

Sources for potential target cleanup levels include selected standards, criteria, and guidelines that are typically considered as ARARs for remedial actions conducted under CERCLA. In addition, USEPA Region III risk-based concentrations, developed as guidance for determining groundwater and soil action levels, are presented and should be regarded as TBCs.

A.1.1.1 Maximum Contaminant Levels for Drinking Water

For groundwater, MCLs established under the Safe Drinking Water Act (SDWA) and codified in 40 Code of Federal Regulations (CFR) 141 are often accepted by regulatory agencies as cleanup levels for groundwater remedial activities, especially if the groundwater is or could be a drinking water source. The state MCLs (18 Alaska Administrative Code [AAC] 80) for chemicals and metals found at the site are the same as the federal MCLs, and are listed on Table A-1.

MCLs are applicable where the water will be provided directly to 25 or more people or will be supplied to 15 or more service connections. Since the PRDA at Fort Richardson is a remote site, the Alaska Department of Environmental Conservation's (ADEC) *Interim Guidance for Surface and Groundwater Cleanup Levels* (ADEC 1990) allows for the adoption of alternative cleanup levels (ACLs) if an approved risk assessment is performed and achieving MCLs is technically unfeasible. The decision to allow development of ACLs must be made by the ADEC.

A.1.1.2 RCRA TCLP for Groundwater

The RCRA toxicity characteristic leaching procedure (TCLP) (40 CFR 261.24) is commonly used to determine whether a solid material, if disposed of on the land, will leach chemical contaminants into the groundwater and therefore make the solid material a hazardous waste. Concentrations of contaminants in groundwater may be compared to TCLP values where other regulatory levels do not exist. TCLP limits are ARARs for the PRDA because detected concentrations of PCE, TCE, and carbon tetrachloride exceed TCLP limits in groundwater, indicating the potential for groundwater, once pumped for treatment, to be classified as a RCRA characteristic waste. TCLP values for chemicals detected at Fort Richardson OUB are shown on Table A-1.

A.1.1.3 Risk-Based Concentrations for Groundwater

Risk-based concentrations (RBCs) established by USEPA Region III (October 1995) may be used as TBC for groundwater where no other ARARs exist. The RBCs are meant to serve as benchmarks for evaluating site data and developing preliminary remediation goals. Since the RBCs are not site-specific and based on very conservative exposure assumptions that do not reflect site conditions, the RBCs are used as a screening level evaluation. As an additional conservative measure, residential RBCs are used for groundwater. RBCs for residential use of groundwater are shown on Table A-1.

A.1.1.4 Water Quality Criteria

The *Interim Guidance for Surface and Groundwater Cleanup Levels* (ADEC 1990) states that, for contaminants that have not been assigned a final or proposed MCL, cleanup levels should be based on ambient water quality criteria (AWQC). AWQC are non-enforceable guidelines developed under the Clean Water Act Section 304, and used by the state to establish water quality standards for specific bodies of water or stream segments. The ADEC Water Quality Standards (18 AAC 70) are a combination of the Alaska drinking water standards (18 AAC 80), federal drinking water standards (40 CFR 141), and 96-hour lethal concentrations (LC50) for the most sensitive species in the area (including a safety factor of 0.01). Table A-2 reproduces the potentially applicable parts of the criteria for toxic substances and petroleum hydrocarbons as stated in 18 AAC 70 (April 1995).

A.1.1.5 RBCs and TCLP for Soils

RBCs established for soil by the USEPA Region III (October 1996) are shown on Table A-3. The RBCs are intended to be used as screening levels only, and are based on conservative residential exposure scenarios. Table A-3 also reproduces the RCRA TCLP concentrations. TCLP is commonly used to determine whether a solid material, if disposed of on the land, will leach chemical contaminants into the groundwater and therefore make the solid material a hazardous waste.

A.1.1.6 Ambient Air Quality Standards

Federal ambient air quality standards are implemented by each state through the State Implementation Plan (SIP) (codified in 18 AAC 50), which established air quality control regions and attainment and non-attainment areas. The Anchorage metropolitan area is a moderate non-attainment area for particulate matter (PM-10) and carbon monoxide; therefore, PM-10 and carbon monoxide emissions from activity related to the investigation or remediation of the PRDA both must be less than 100 tons per year or a Clean Air Act Title V Operating Permit is required. This activity includes the use of gasoline or diesel powered vehicles such as construction equipment. In addition, the state sets an annual average and 24-hour and 3-hour maximums for priority pollutants that may not be exceeded in the ambient air. The priority pollutants include: particulate matter, sulfur dioxide, carbon monoxide, ozone, nitrogen oxides, and lead. Title III of the Clean Air Act, which regulates hazardous air pollutants, may also apply.

Additional sections of the Alaska Air Quality Regulations that regulate specific processes may also be applicable to specific remedial actions and are listed in the action-specific ARARs (Section A.1.3).

A.1.2 Location-Specific ARARs

Location-specific ARARs are restrictions placed on the types of activities that may occur in particular locations. The location of a site may be an important characteristic in determining its impact on human health and the environment. These ARARs may restrict or preclude certain remedial actions. Examples of location-specific ARARs include federal and state requirements for preservation of historic landmarks, wetlands protection, and siting of a hazardous waste management facility. Table A-4 summarizes the location-specific ARARs discussed below.

A.1.2.1 Executive Order 11990 Protection of Wetlands

The PRDA is located near a wetland so standards that apply to the protection of wetlands are potentially applicable. Executive Order 11990 as implemented by 40 CFR 6 and Appendix A on Protection of Wetlands are applicable. The regulations require federal agencies to avoid, as much as possible, the destruction or loss of wetlands and avoid new construction in wetlands. If alternatives are not practicable, an environmental assessment or environmental impact statement must be conducted to avoid long and short-term adverse impacts associated with the modification or destruction of wetlands.

A.1.2.2 Clean Water Act Section 404

Disposal of contaminated soil, waste material or dredged material into surface water, including wetlands, are activities that may be considered dredge-and-fill operations. They must be evaluated for alternatives pursuant to Section 404 of the Clean Water Act as codified in 40 CFR 230.10 and 33 CFR 320 to 330. These regulations are implemented by the USEPA and the USACE and prohibit the discharge of dredge or fill material into the waters of the United States or wetlands without a permit. Although permits are not required for CERCLA on-site actions, the substantive requirements of Section 404 and the implementing regulations are potential ARARs for remedial actions that could impact wetlands.

A.1.2.3 Migratory Bird Treaty Act

The Migratory Bird Treaty Act (16 United States Code [USC] 703) protects the migratory residence and range of all migratory birds including species not on the Endangered Species List. There are many migratory birds that reside in the area surrounding the PRDA. Coordination with the U.S. Fish and Wildlife Service may be required to prevent damage to the habitat of migratory birds, if the species or their habitat are impacted by remedial activities.

A.1.2.4 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (16 USC 661 et seq.) is considered applicable if remedial activities impact fish or wildlife habitat in the vicinity of or downstream from the PRDA. Such impacts could include sediment loading in streams or destruction of animal burrows or food sources. Coordination with the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game may be necessary to discuss mitigation measures to prevent loss or damage to these resources.

A.1.3 Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous waste. These requirements are triggered by the particular activities that are selected to accomplish a remedy. Since there are usually several alternative actions for any remedial site, different requirements may be identified to implement a specific alternative. These action-specific requirements do not in themselves determine the remedial alternative: rather, they indicate how a selected alternative can be achieved.

Table A-5 lists general federal and state action-specific ARARs. This table presents the regulations that may serve as action-specific ARARs for on-site activities generally encountered in hazardous waste site remediation (e.g., generation, storage, on-site disposal, etc.). Additional requirements address general closure standards, and the need to manage contaminated wastes and wastes generated during site activities.

A.1.3.1 Resource Conservation and Recoverv Act

RCRA Standards for Hazardous Waste Generators

RCRA Subtitle C regulates the generation, transportation, treatment, storage and disposal of hazardous waste. The general management system for hazardous waste is discussed in 40 CFR 260, and hazardous waste is defined in 40 CFR 261. It is the waste generator's responsibility to determine if their waste is RCRA-hazardous either due to a characteristic or because it is specifically listed as a hazardous waste. The generator standards in 40 CFR 262 establish the duties of the generator to obtain a USEPA identification number, manifesting for waste sent off-site, pre-transport requirements, short-term storage requirements, and record keeping and reporting requirements. The substantive requirements in 40 CFR 262 are applicable for potential treatment residuals, such as exhausted GAC.

Standards for Hazardous Waste Treatment, Storage or Disposal

Specific waste management requirements governing the treatment, storage, and disposal of RCRA hazardous waste are codified in 40 CFR 264 and 265 (interim status). These requirements are normally associated with facilities that have received a RCRA operating permit; however, since CERCLA waives the administrative requirements of regulations, the substantive requirements of these regulations are applicable to on-site remedial actions that treat, store or dispose RCRA hazardous waste. Only those hazardous waste management options that may potentially be included in the remedial activity are identified and briefly described below:

- Management of waste in containers (40 CFR 264 Subpart I) regulates long-term storage of waste in portable containers such as drums or portable liquid storage vessels. Subpart I may be applicable if contaminated soil is stored in drums prior to treatment or disposal.

- Management of waste in tank systems (40 CFR 264 Subpart J) regulates long-term storage of liquid waste in permanent tanks or tank systems. Subpart J may be applicable or relevant and appropriate if contaminated groundwater is stored in tanks prior to treatment or disposal.

- Management of waste in waste piles (40 CFR 264 Subpart L) regulates storage of contaminated soil without using containers. Subpart L may be applicable if contaminated soil is stockpiled in waste piles prior to treatment or disposal or as a means of ex-situ bioremediation.

General Groundwater Monitoring Requirements

40 CFR 264.97 Subpart F regulates groundwater monitoring systems. This would be relevant and appropriate for the groundwater monitoring programs included in the alternatives.

RCRA Air Emission Standards for Process Vents and Equipment Leaks

40 CFR 264 Subpart AA contains action-specific organic air emission standards for process vents from distillation, fractionation, thin-film evaporation, solvent extraction, or air or steam stripping equipment that is in hazardous waste service and processes hazardous waste that contains 10 ppm by weight (ppmw) organic constituents. This Subpart may be applicable to air or steam stripping associated with groundwater extraction and treatment systems, or vacuum extraction.

40 CFR 264 Subpart BB requires fugitive emission monitoring of equipment that is in hazardous waste service and contacts waste with organic concentrations of at least 10 percent by weight. Although it is unlikely that any waste would have such high organic concentrations, this regulation may be applicable if air stripping or incineration operations tend to concentrate VOCs in any part of their process.

Land Disposal Restrictions

An issue that is pertinent to the application of the land disposal restrictions is discussed in the NCP. The NCP discusses when a CERCLA action constitutes "land disposal", which is defined as placement into land disposal units under section 3004(K) of RCRA. This definition is critical because several significant requirements are triggered when placement occurs onto a land disposal unit. One requirement that is triggered when placement occurs is the land disposal restrictions (LDR) documented in 40 CFR 268. LDR requires that RCRA-hazardous waste be treated in accordance with best demonstrated available technology (BDAT) or be treated to a specific numerical standard prior to placement in a land-based unit such as a landfill.

Standards for Containment

Containment will be required if Alternative 3 is selected. The containment cover will be required to meet minimum functional guidelines. 40 CFR 264.310(a) lists guidelines for landfill covers which may be applicable to a containment cap for the PRDA. Such guidelines include: minimize long-term migration of liquids; function with minimal maintenance; promote drainage and minimize erosion or abrasion of the cover; accommodate settling and subsistence; and have a permeability less than or equal to the permeability of natural subsoils present.

A.1.3.2 Alaska Air Quality Control Regulations

Although remedial actions that involve air emissions would not require a permit at this site (projected emissions would fall well below concentrations that require a permit), the substantive requirements of ADEC's Air Quality Control Program (18 AAC 50) would have to be met. The following provisions from the Air Quality Control Program are action-specific ARARs for remedial actions that involve air emissions from a stationary source such as air stripping:

- Source Testing: 18 AAC 50.500
- Ambient Analysis Methods: 18 AAC 50.510 and
- Emission and Ambient Monitoring: 18 AAC 50.520

The only VOC regulated under 18 AAC 50.510 is vinyl chloride with an allowable 24-hour average emission of 15 micrograms per cubic meter (ug/m^3).

A.1.3.3 Alaska Solid Waste Management Regulations

The substantive provisions of Alaska's Solid Waste Management regulations (18 AAC 60) may be applicable to the management of wastes that do not meet the definition of RCRA hazardous waste but contain contaminants that exceed other non-RCRA cleanup levels. These regulations are more specific than federal regulations. The following sections are potential ARARs for remedial actions that involve storage, treatment, or disposal of non-RCRA waste that exceed cleanup levels:

- Accumulation and Storage: 18 AAC 60.010,
- Disposal of Polluted Soil: 18 AAC 60.025
- Permit Requirements: 18 AAC 60.200(a)(3)

A.1.3.4 Alaska Hazardous Waste Regulations

Alaska is not authorized to oversee the federal RCRA regulations, and their regulations codified in 18 AAC 62 primarily incorporate federal RCRA regulations by reference. Therefore, Alaska hazardous waste regulations are not specifically cited in this document.

A.1.3.5 Siting of Hazardous Waste Management Facilities

18 AAC 63.040 presents the substantive provisions of the regulations regarding siting of hazardous waste management facilities. If any on-site hazardous waste management facilities, as defined by this regulation, are part of a remedial action, the substantive portion of these regulations are applicable.

A.1.3.6 Alaska Water Quality Standards

18 AAC 70 sets water quality standards which specify the degree of degradation that may not be exceeded in a water body as a result of human actions. The regulation defines different water classes (industrial, drinking, etc.) and the water quality criteria which apply to each class.

A.1.3.7 Alaska Waste Water Disposal Regulations

Chapter 72 of 18 AAC covers domestic and nondomestic waste water systems. 18 AAC 72.600 requires a person who operates a nondomestic disposal system to first have written department approval of engineering plans. Article 9 of the regulation describes the procedures for applying for a general waste water disposal permit. Chapter 72 may be applicable for discharge of treated groundwater.

A.1.3.8 Alaska Oil and Hazardous Substances Pollution Control Requirements

18 AAC 75 describes requirements for reporting cleanup and disposal of any discharge of an oil or hazardous substance. Determination of the adequacy of the cleanup rests with the ADEC, unless the USEPA orders the cleanup operation to cease. Article 5 of the regulation describes the civil penalties which can be levied as a result of a discharge.

TABLE A-1
ALASKA MCLs AND RESIDENTIAL RBCs FOR TAP WATER
OUB, FORT RICHARDSON, ALASKA

	Alaska MCLs (1) (mg/L)	RCRA TCLP (2) (mg/L)	Residential Tap Water RBCs (3) (mg/L)
Organic Compounds:			
benzene	0.005	0.5	0.00036
carbon tetrachloride	0.005	0.5	0.00016
chloroform	0.1	6	0.00015
chlorobenzene	-	100	0.039
1,1-dichloroethene	0.007	0.7	0.000044
cis-1,2-dichloroethene	0.07	-	0.061
trans-1,2-dichloroethene	0.1	-	0.12
1,3-dinitrobenzene	-	-	0.0037
2,4-dinitrotoluene	-	0.13	0.073
1,1,2,2-tetrachloroethane	-	-	0.000052
tetrachloroethene	0.005	0.7	0.0011
toluene	1	-	0.75
1,1,2-trichloroethane	0.005	-	0.00019
trichloroethene	0.005	0.5	0.0016
Metals:			
Antimony	0.006	-	0.015
Arsenic	0.05	5	0.000045, 0.011*
Beryllium	0.004	-	0.000016
Cadmium	0.005	1	0.018
Chromium	0.1	5	0.18 (4)
Copper	1 (5)	-	1.5
Lead	0.05 (6)	5	-
Mercury	0.002	0.2	0.011
Nickel	0.1	-	0.73
Selenium	0.05	1	0.18
Silver	0.1 (5)	5	0.18
Thallium	0.002	-	-
Zinc	5 (5)	-	11

NOTES:

(1) Alaska Department of Environmental Conservation, 18 AAC 80. In all cases, state MCLs are equivalent to federal MCLs.

(2) EPA 40 CFR 261

(3) EPA Region III, October 20 1995. RBCs are based on residential tap water ingestion.

(4) RBC for chromium VI = 0.18 mg/L
RBC for chromium III = 37 mg/L

(5) Secondary MCL

(6) ADEC Interim Guidance for Surface and Groundwater Cleanup Levels, September, 26, 1990.

* 0.000045 carcinogenic, 0.011 noncarcinogenic

\- = Not established.

TABLE A-2
WATER QUALITY CRITERIA (18 AAC 70)
APRIL 1995

1. FRESH WATER USES	TOXIC AND OTHER DELETERIOUS ORGANIC AND INORGANIC SUBSTANCES	PETROLEUM HYDROCARBONS, OILS, AND GREASE
(A) Water Supply (i) drinking, culinary, and food processing	Substances may not exceed Alaska Drinking Water Standards (18 AAC 80) or where those standards do not exist, EPA Quality Criteria for Water (See Note 1)	May not cause a visible sheen upon the surface of the water. May not exceed concentrations that individually or in combination impart odor or taste as determined by organoleptic tests.
(A) Water Supply (ii) agriculture, including irrigation and stock watering	Same as (1) (A) (i) where contact with a product destined for human consumption is present. Same as (1) (C) or Federal Water Pollution Control Administration, Water Quality Criteria (WQC/FWPCA) as applicable to substances for stockwaters: concentrations for irrigation waters may not exceed WQC/FWPCA or WQC 1972 (See Notes 2 and 3)	May not cause a visible sheen upon the surface of the water.
(A) Water Supply (iii) aquaculture	Same as 1(c)	Total aqueous hydrocarbons (TAqH) in the water column may not exceed 15 ug/l (See Note 4). Total aromatic hydrocarbons (TAH) in the water column may not exceed 10 ug/l (See Note 4). There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life. Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.
(A) Water Supply (iv) industrial	Substances that pose hazards to worker contact may not be present.	May not make the water unfit or unsafe for the use.
(B) Water Recreation (i) contact recreation	Same as (1) (A) (i).	May not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shorelines. Surface waters must be virtually free from floating oils.
(B) Water Recreation (ii) secondary recreation	Substances that pose hazards to incidental human contact may not be present.	May not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shorelines. Surface waters must be virtually free from floating oils.

TABLE A-2 (CONTINUED)

1. FRESHWATER USES	TOXIC AND OTHER DELETERIOUS ORGANIC AND INORGANIC SUBSTANCES	PETROLEUM HYDROCARBONS, OILS, AND GREASE
(C) Growth and Propagation of Fish. Shellfish, other Aquatic Life and Wildlife	Individual substances may not exceed criteria in EPA, Quality Criteria for Water (See Note 1) or, if those criteria do not exist, may not exceed the Primary Maximum Contaminant levels of the Alaska Drinking Water Standards (18 AAC 80). If those criteria are absent, or if the department finds that the criteria are not appropriate for sensitive resident Alaskan species, the department will, in its discretion, establish in regulation chronic and acute criteria to protect sensitive and biologically important life stages of resident Alaskan species, using methods approved by EPA or alternate methods approved by the department. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that singly or in combination, cause, or reasonably can be expected to cause, toxic effects on aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests (See Note 1).	Same as 1(A)(iii)

NOTES:

1. The term "EPA Quality Criteria for Water" includes Quality Criteria for Water, July 1976, U.S. Environmental rotection Agency, Washington, D.C. 20460, U.S. Government Printing Office: 1977 0-222-904, The Ambient Water Quality Criteria for the 64 toxic pollutants listed in the Federal Register, Vol. 45, No. 231, pg. 79318, November 1980, the Ambient Water Quality Criteria Document for 2, 3, 7, 8-tetrachlorodibenzopdioxin (TCDD) listed in the Federal Register, Vol. 49, No. 32, pg. 5831, February 1984, and the final ambient water quality criteria documents listed in the Federal Register, Vol. 50, No. 145, pg. 30784, July 1985. These documents may be seen at the central office of the department or may be purchased through the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

2. The Report of the Committee on Water Quality Criteria, Federal Water Pollution Control Administration, Washington, D.C., April 1, 1968, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. See Note 5.

3. Water Quality Criteria 1972, Environmental Studies Board of the National Academy of Sciences and the National Academy of Engineering, Washington, D.C., 1972, USEPA-R3-73-033, March 1973, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20204 (Stock No. 5501-00520). See Note 5.

4. Total aromatic hydrocarbons (TAH) and total aqueous hydrocarbons (TAqH) must be determined using the following sampling procedures: (see 18 AAC 70 for the continuation of this note).

5. The cited document is on file in the lieutenant governor's office and may be seen at any department office.

TABLE A-3
RESIDENTIAL SOIL RBCs
OUB, FORT RICHARDSON, ALASKA

Compounds	RCRA TCLP (1) (mg/L)	Residential Soil RBCs (2) (mg/kg)
Organic Compounds:		
benzene	0.5	22
bromoform	-	81
carbon tetrachloride	0.5	4.9
chloroform	6	100
1,1-dichloroethene	0.7	1.1
cis-1,2-dichloroethene	-	780
trans-1,2-dichloroethene	-	1600
ethylbenzene	-	7800
m-nitrotoluene	-	780
1,1,1,2-tetrachloroethane	-	25
1,1,2,2-tetrachloroethane	-	3.2
tetrachloroethene	0.7	12
toluene	-	16000
1,1,2-trichloroethane	-	11
trichloroethene	0.5	58
1,3,5-trinitrobenzene	-	3.9
2,4,6-trinitrotoluene	-	21
xylenes	-	160000
Metals:		
antimony	-	31
arsenic	5	0.43, 23 (4)
beryllium	-	0.15
cadmium	1	39
chromium	5	390 (3)
copper	-	3100
lead	5	-
mercury	0.2	23
nickel	-	1600
selenium	1	390
silver	5	390
thallium	-	-
zinc	-	23000

NOTES:

(1) TCLP data from 40 CFR 261.24.

(2) RBC data from EPA, Region III, October 20, 1995.

(3) RBC for Chromium VI = 390 mg/kg
RBC for Chromium III = 78000 mg/kg

(4) 0.43 carcinogenic, 23 noncarcinogenic

- = Not established.

TABLE A-4

SUMMARY OF POTENTIAL LOCATION-SPECIFIC ARARs
OUB, FORT RICHARDSON, ALASKA

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
FEDERAL			
Protection of Wetlands	40 CFR 6 and Appendix A	Requires federal agencies to avoid, as much as possible, destruction of, loss of, and new construction in wetlands.	Applicable if remedial actions impact the wetlands south of the treatment area.
Section 404 of Clean Water Act	40 CFR 230.10 and 33 CFR 320 to 330.	Regulates dredge and fill operations in waters of the United States including wetlands.	Applicable of soil or waste material is placed in the wetlands.
Migratory Bird Treaty Act	16 USC 703	Protects the migratory residence and range of all migratory birds.	Applicable if remedial activities damage migratory bird habitat.
Fish and Wildlife Coordination act	16 USC 661 et seq.	Protects fish and wildlife habitat.	Applicable if remedial activities damage fish or wildlife habitat.

CFR = Code of Federal Regulations
USC = United States Code

TABLE A-5

SUMMARY OF POTENTIAL ACTION-SPECIFIC ARARs
OUB, FORT RICHARDSON, ALASKA

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
FEDERAL			
Hazardous Waste Management System	40 CFR 260	Provide definitions, general standards, and information applicable to parts 260 through 265 and 268.	General information to be used with listed parts.
Identification and Listing of Hazardous Waste	40 CFR 261	Establishes criteria for use in determining if a waste is hazardous	Applicable to disposal requirements.
Standards Applicable to Generators of Hazardous Waste	40 CFR 262	Establishes temporary storage, transportation, and recordkeeping and reporting requirements for generators of hazardous waste.	Applicable if soil is contaminated and determined to be RCRA hazardous by characteristic.
<u>Standards for Hazardous Waste Treatment, Storage, and Disposal</u>	40 CFR 264 & 265	Regulates on-site storage, treatment, or disposal of hazardous waste and closure of hazardous waste units.	No permit required, but substantive requirements for on-site storage or disposal of hazardous waste and closure and post-closure care.
Storage in Containers	Subpart I	Regulates long-term storage of waste in portable containers.	Relevant and appropriate if hazardous waste is stored in portable man-made containers.
Storage in Tanks	Subpart J	Regulates long-term storage of liquid waste in permanent tanks.	Relevant and appropriate if hazardous waste is stored in tanks
Storage in Waste Piles	Subpart L	Regulates storage of contaminated soil in stockpiles.	Relevant and appropriate if hazardous waste is stored in waste piles
Emission Standards for Process Vents	Subpart AA	Regulates process emissions from specified hazardous waste treatment units.	Relevant and appropriate if air or steam stripping is used to treat process vents from hazardous waste treatment units.
Equipment Leak Standards	Subpart BB	Regulates fugitive emissions from hazardous waste treatment units	Relevant and appropriate if air stripping is used to treat hazardous waste.

TABLE A-5

SUMMARY OF POTENTIAL ACTION-SPECIFIC ARARs
OUB, FORT RICHARDSON, ALASKA (continued)

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Land Disposal Restrictions	40 CFR 268	Sets treatment standards for hazardous waste that must be met prior to disposal on the land.	Relevant and appropriate if hazardous waste is disposed of in a landfill. Applicable if RCRA hazardous characteristic waste is disposed of off-site.
DOT Requirements	49 CFR 107-180	Regulates transportation of hazardous materials	Applicable to off-site transport of hazardous waste.
STATE			
Alaska Air Quality Control Regulations	18 AAC 50	Regulates emission from incinerators and sets numerical limits on pollutants in the ambient air. Also requires source testing of motor vehicles including diesel-powered equipment.	Ambient air quality standards are applicable to all remedial actions. Incinerator standards are applicable to on-site incineration of wastes.
Alaska Solid Waste Management Regulations	18 AAC 60	Regulates storage, treatment and disposal of non hazardous waste.	Applicable if non-hazardous waste is generated as a result of remedial actions.
Accumulation and storage	18 AAC 60.015	Regulates the collection and storage of solid waste.	Applicable if non-hazardous waste is stored on site.
General Requirements for a Solid Waste Disposal Facility	18 AAC 60.035	Regulates surface water runoff, erosion, leachate, public nuisance, and access by persons and wildlife.	Applicable if any waste storage, treatment or disposal occurs on-site.
Siting of Hazardous Waste Management Facilities	18 AAC 63.040	Regulates siting of hazardous waste disposal facilities	Applicable if hazardous waste management facilities are built on-site.
Alaska Water Quality Standards	18 AAC 70	Regulates the quality of surface	Applicable to human actions which

TABLE A-5

SUMMARY OF POTENTIAL ACTION-SPECIFIC ARARs
OUB, FORT RICHARDSON, ALASKA (continued)

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
		waters	cause degradation of a water body.
Alaska Wastewater Disposal Regulations	18 AAC 72	Regulates disposal of wastewater	Applicable to disposal of investigation-derived purge or decontamination water.
Requirements for ADEC approval of wastewater systems	18 AAC 72.600	Regulates engineering plans for wastewater treatment works and disposal systems	Applicable if a wastewater system is constructed and operated on site.
Alaska Oil and Hazardous Substances Pollution Control	18 AAC 75	Regulates discharge, prevention, and cleanup of hazardous substances	Applicable if hazardous substances are discharged on site.

AAC = Alaska Administrative Code
ADEC = Alaska Department of Environmental Conservation
CFR = Code of Federal Regulations
USC = United States Code

APPENDIX B

GROUNDWATER MODELING RESULTS

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1.0
INTRODUCTION

1.1 SITE BACKGROUND

The Poleline Road Disposal Area (PRDA) is located on the Fort Richardson Army post. The PRDA is located approximately 1 mile south of the Eagle River and 0.6 miles north of the Anchorage Regional Landfill as shown in Figure 1-1.

The PRDA is a low-lying, relatively flat area which is bordered by a wooded, 80-foot high hill to the northwest, a wooded hill to the south and southeast and a wetland to the south and southwest. The main disposal area is approximately 1.5 acres in size and consists of four individual disposal areas (A-1, A-2, A-3 and A-4) as shown in Figure 1-2.

Site history including disposal activities and site cleanup activities are discussed in the Remedial Investigation (RI) Report. A brief overview of information relevant to the fate and transport modeling are summarized in this section. The PRDA was active from approximately 1950 to 1972. Various materials were disposed of at the PRDA including solvents. Two solvents, 1,1,2,2-tetrachloroethane and TCE, were found at the highest concentrations and over the widest area at the site. It is not clear whether both solvents were released at the site or just 1,1,2,2-tetrachloroethane since it can degrade to TCE.

In 1994 soils from areas A-3 and A-4 were excavated to a maximum depth of 14 feet below ground surface (bgs), where perched groundwater was encountered. Soils that met the removal action levels (TCE 600 mg/kg; PCE 100 mg/kg; 1,1,2,2-tetrachloroethane 30 mg/kg) were mixed with borrow soil and returned to the excavations. No additional soil cover was added to Areas A-3 and A-4. Soils that exceeded the actions levels were stockpiled southeast of the site on Barrs Boulevard in lined, plastic-covered piles surrounded by berms. Areas A-1 and A-2 have not been excavated.

1.2 GROUNDWATER MODELING OBJECTIVES

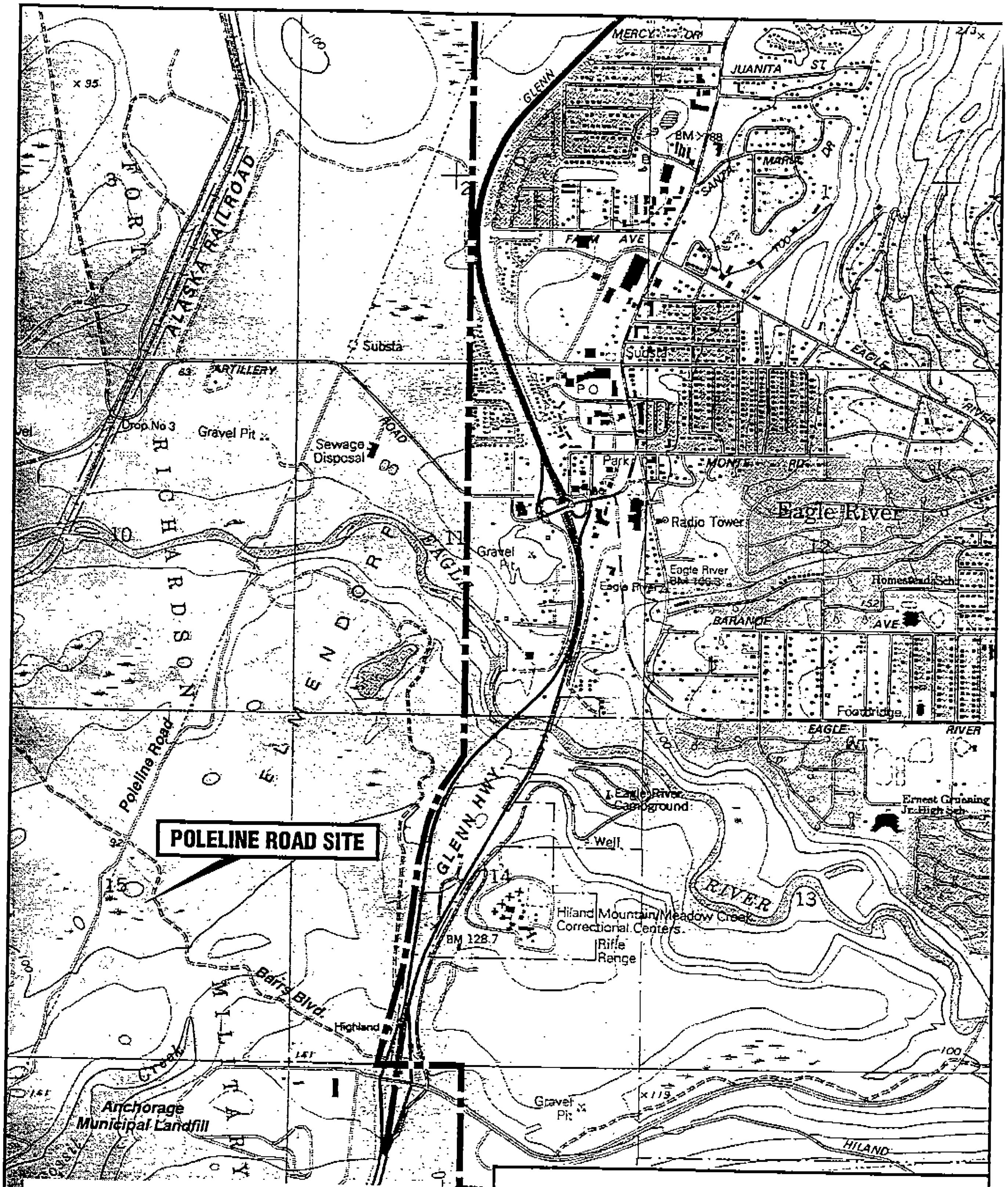
Chemical compounds have leached from the PRDA into the adjacent groundwater. In this report, the fate and transport of PRDA-derived compounds in groundwater is evaluated by modeling the processes that affect migration. The purpose of modeling groundwater flow and contaminant transport is to evaluate the effectiveness of the various groundwater treatment alternatives. Groundwater modeling is used to estimate groundwater extraction rates and 1,1,2,2-tetrachloroethane concentrations in the extracted groundwater.

This model is based on the conceptual model developed for the RI and documented in the RI Report Appendix XIII. The reader is referred to Appendix XIII for a complete discussion. From this conceptual model, a numerical model was developed and used to estimate groundwater flow and contaminant transport.

The groundwater modeling study area extends approximately 1,500 feet in the north/south and east/west directions. Disposal Areas A-3 and A-4 are located in the middle of the study area. The numerical model developed for the RI could not be used because the model cell size in the vicinity of the disposal areas (100 feet by 100 feet) was too large to meet the objectives of this analysis.

1.3 REPORT ORGANIZATION

The PRDA groundwater fate and transport modeling report is organized in seven sections. Section 2.0 summarizes the site characteristics that provide a framework for the development of the fate and transport model. The modeling approach is described in Section 3.0. A description of the groundwater flow and contaminant transport models and their data requirements are presented in Sections 4.0 and 5.0, respectively. Section 6.0 presents the model results. Limitations of the work described herein are presented in Section 7.0 and references are listed in Section 8.0. Supporting documentation for the modeling is included as Attachment B1.



LEGEND:

▬ ▬ ▬ Ft. Richardson Boundary

SOURCE:
USGS 1:25,000 Series
Anchorage (B-7) SW, Alaska (1993)

0 0.5

Scale = Statute Miles

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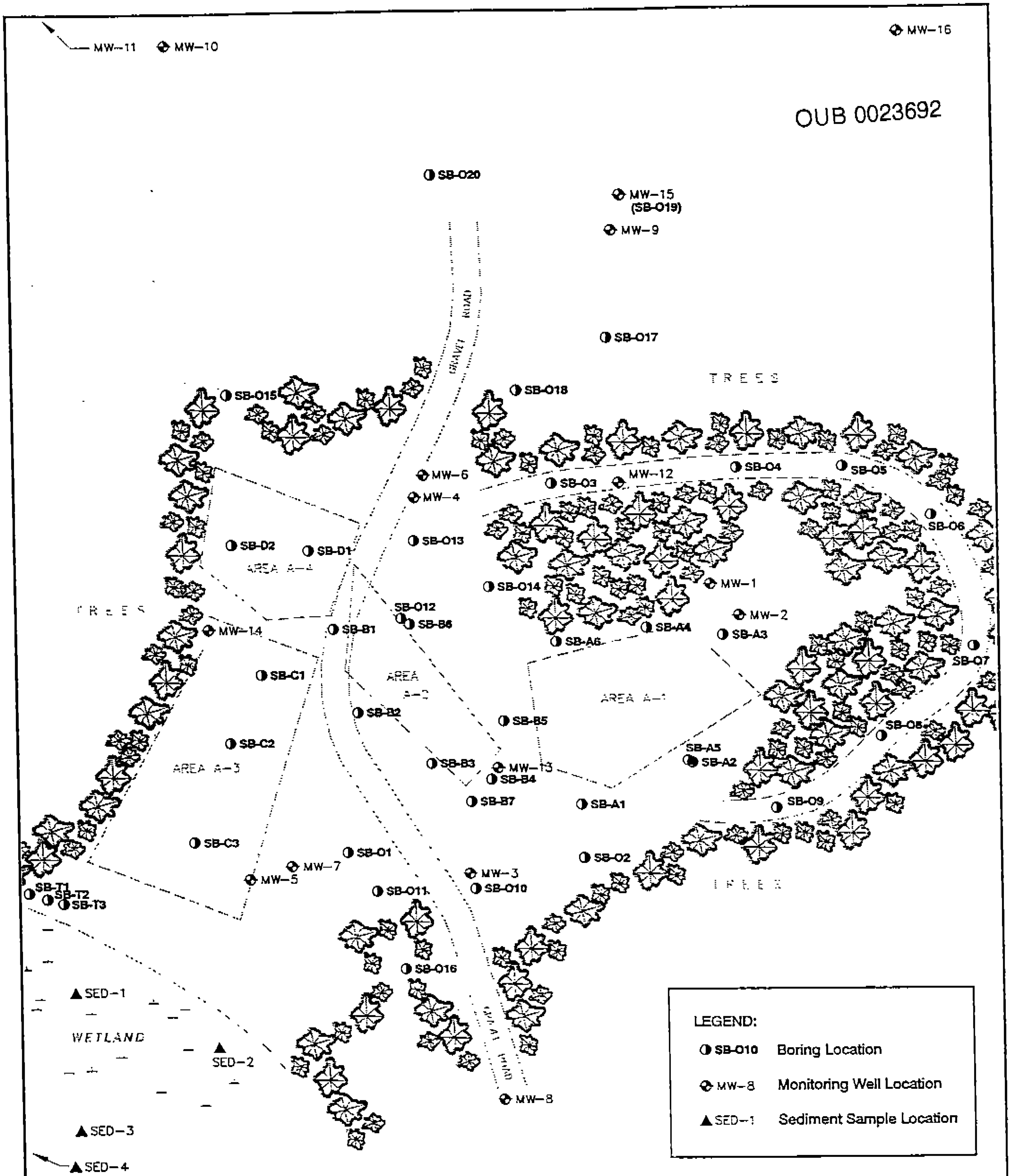
SITE LOCATION MAP
POLELINE ROAD DISPOSAL AREA
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg: FIG1-1.AI	*By:* AR	*Figure:* 1-1
Project: E9408Q	*Date:* 6/13/96	



MW-17 is shown on Figure 4-15.

BORING AND MONITORING WELL LOCATIONS
POLELINE ROAD DISPOSAL AREA
OUB, FORT RICHARDSON, ALASKA

Woodward-Clyde

Dwg: FIG1-2.DWG	*By:* AR	*Figure:* 1-2
Project: E9408Q	*Date:* 11-15-96	

2.0
SITE CHARACTERISTICS

This section summarizes the site characteristics, geology, and hydrogeology presented in the RI. This information is used to develop the conceptual model presented in RI Appendix XIII. The conceptual model provides the framework for development of the numerical groundwater flow and transport models that were used to assess groundwater contaminant transport.

This section presents a conceptual interpretation of the geologic, hydrogeologic, and contaminant source, based on soil borings, previous investigations, topographic information, water levels and field investigations. It is recognized that the actual geologic and hydrogeologic conditions in the study area are more complicated than characterized by this conceptual interpretation due to the geologic and structural complexity of the area. However, it is believed that the conceptual interpretation presented herein is a reasonable characterization of the flow system in the vicinity of the PRDA site, and is useful as a framework for development of the numerical models presented in Sections 4.0 and 5.0. The conceptual interpretation presented herein of the chemical source loadings to groundwater at PRDA has been simplified and is limited by the available information on past disposal practices.

2.1 GEOLOGIC FRAMEWORK

Surficial deposits in the region are composed of fluvially reworked glacial sediments and glacial tills. These deposits consist of unstratified to poorly stratified clays, silts, sands, gravels and boulders (ESE 1991).

A basal till lies below the surficial deposits. The basal till is lithologically similar to the surficial deposits; however, the basal till materials are more compact and may have lower hydraulic conductivities.

An advance moraine/till complex underlies the basal till. The advance moraine/till complex is lithologically similarly to the surficial deposits and the basal till. The vertical extent of this unit is difficult to define based on the lithologic similarly to the basal till.

Bedrock underlies the advance moraine/till complex. It is composed of a hard black fissile claystone with fine sandy siltstone interbeds (ESE 1991). Bedrock was encountered beneath the

PRDA at a minimum elevation of 123 feet mean sea level (fmsl) at well MW-16 to a maximum elevation of 172 fmsl at well MW-6.

These straigraphic units are shown in a north-south cross-section (FS Figure 1-4). The vertical extent of these unit was modified from the conceptual model developed in the RI regional model and shown in RI Appendix XIII Figure 2-1. This modification resulted from difficulty reproducing the groundwater elevations and hydraulic gradients (vertical) estimated in the RI regional model.

2.2 HYDROGEOLOGIC FRAMEWORK

2.2.1 Conceptual Groundwater Zones

For the purpose of characterizing the groundwater flow regime in the vicinity of the site, four general groundwater elevation zones are assumed: perched, shallow, intermediate, and deep. The separation of the groundwater system into vertical zones is not intended to imply the zones are hydraulically separate. On the contrary, it is believed that the shallow, intermediate, and deep zones are connected. This assumption is supported by the presence of VOCs in the deep groundwater zone at the PRDA site. The three zones do differ, however, in the way that they are influenced by recharge and by their average hydraulic properties. A conceptual hydrogeologic cross-section of these units is shown in FS Figure 1-4.

2.2.1.1 Perched Groundwater

Perched groundwater was encountered in the vicinity of the disposal areas, but was not encountered away from the disposal areas. The water elevations of the perched water range from 280.6 fmsl (at SB-08 on eastern edge of area A-1) to 293.7 fmsl (at SB-C2 located in area A-3). It is likely that excavation and trenching of the disposal areas resulted in reducing the degree of consolidation and compaction of the material. As a result these areas have an increased permeability and the adjacent wetland may be discharging into the PRDA. Perched groundwater recharges the shallow groundwater zone. The perched groundwater zone is not included in the groundwater model, because it is not laterally continuous beyond the disposal areas.

2.2.1.2 Shallow Groundwater Zone

Shallow groundwater was encountered in the surficial glacial sediments and glacial tills. The monitoring wells screened in the shallow groundwater zone and their groundwater elevations are presented in Table 2-1. A minimum average groundwater elevation of 270.9 fmsl (MW-15) was measured northeast of the PRDA site and a maximum average groundwater elevation 284.5 fmsl (MW-17) to the southwest of the PRDA site.

Groundwater contours of this shallow groundwater are shown in Figure 2-1. The horizontal hydraulic gradient in this zone is characterized by well pairs MW-8/MW-2, MW-5/MW-15, MW-17/MW-15. The horizontal hydraulic gradient ranges from a minimum of 0.006 feet per feet (ft/ft) (MW-8/MW-2) to a maximum of 0.010 ft/ft (MW-5/MW-2 and MW-5/MW-12).

Shallow groundwater in the surficial deposits is modeled as an unconfined aquifer and is defined in the model as Layer 1.

2.2.1.3 Intermediate Groundwater Zone

Monitoring wells MW-4, MW-7, MW-10 and MW-11 are screened in the basal till. The average groundwater elevations in MW-4 and MW-7 are 239.1 fmsl and 226.5 fmsl, respectively. Groundwater was not encountered in MW-10 or MW-11.

The vertical component of flow is expected to be downward from the shallow zone to the deep zone. This interpretation is supported by downward vertical gradients and the presence of VOCs in the deep groundwater zone. The vertical hydraulic gradient across the intermediate zone is high. The observed vertical hydraulic gradient across the basal till is characterized by the well pairs MW-1/MW-2 and MW-15/MW-9. The vertical hydraulic gradient ranges from a minimum of 0.92 ft/ft (MW-15/MW-9) to a maximum of 0.99 ft/ft (MW-2/MW-1).

Groundwater in the basal till unit is modeled as a semi-confined aquifer and is defined in the model as Layers 2 and 3. Layer 2 represents groundwater in the basal till from the transition between the surficial deposits and the basal till to a minimum elevation of 240 fmsl. Layer 3 represents groundwater in the basal till from a maximum elevation of 240 fmsl to the transition between the basal till and the advance moraine/till complex.

2.2.1.4 Deep Groundwater Zone

A deep groundwater zone was encountered in the advance moraine/till complex. The monitoring wells screened in the deep groundwater zone and their groundwater elevations are presented in Table 2-1. A minimum average groundwater elevation of 160.1 fmsl (MW-9 and MW-16) was measured northeast of the PRDA site and a maximum average groundwater elevation of 177.4 fmsl (MW-6) was measured at the PRDA site.

Groundwater contours of this deep groundwater are shown in Figure 2-2. The horizontal hydraulic gradient in this zone is characterized by well pairs MW-6/MW-9, MW-6/MW-16, and MW-1/MW-16. The average horizontal hydraulic gradient ranges from a minimum of 0.026 ft/ft (MW-1/MW-16) to a maximum of 0.079 ft/ft (MW-6/MW-9).

Deep groundwater in the advance moraine/till complex is modeled as a semi-confined aquifer and is defined in the model as Layer 4.

The bedrock underlying the advance moraine/till complex is modeled as an impermeable unit that groundwater does not penetrate. This conceptual model is based on the following information and assumptions. None of the groundwater monitoring wells are screened exclusively in the bedrock unit and as a result the groundwater potentiometric head in the bedrock is unknown. It is likely that the hydraulic conductivity of the advance moraine/till complex is higher than the hydraulic conductivity of the bedrock, and groundwater flow in the advance moraine/till complex would be a preferential pathway relative to groundwater flow in the bedrock unit.

2.2.2 Aquifer Properties

Grain size analysis was performed on four soil samples at or above the shallow groundwater (Alaska Testlab 1995). Hazen's method (Freeze and Cherry 1979) was used to estimate the hydraulic conductivities of the four samples based on results of the grain-size analysis (Appendix VII). A hydraulic conductivity of 0.3 ft/day was estimated for two of the samples. Hydraulic conductivities of 0.03 ft/day and 284 ft/day were estimated for the remaining two samples.

The total porosity was estimated by Alaska Testlab (1995) for four soil samples collected at or above the water table. The calculated values are based on a dry density of 120 lbs/cubic foot and a specific gravity of 2.65. The total porosity ranged from 0.21 to 0.27 with a geometric mean of 0.25.

2.3 CHEMICAL FATE AND TRANSPORT FRAMEWORK

Source loading is defined by the source concentration (mg/L) and the source flux per unit area (in/yr). The source loading used in the calibrated RI regional groundwater model was assumed.

Perched groundwater is located in disposal areas A-1, A-2, and A-3. VOC concentrations in perched groundwater at disposal areas A-1 and A-2 are low (RI Section 4.0). Based on the lack of VOCs detected in the perched and shallow groundwater (RI Section 4.0) in the vicinity of areas A-1 and A-2, it is assumed that areas A-1 and A-2 are not sources of VOCs. Higher concentrations of VOCs were detected in perched and shallow groundwater below areas A-3 and A-4 (e.g., 1,1,2,2-tetrachloroethane concentrations of 1,900 mg/L and 93 mg/L at MW-14 [perched groundwater at area A-3] and SB-D2 [shallow groundwater at area A-4], respectively). Areas A-3 and A-4 are assumed to be source locations.

The concentrations in the perched water were used as an initial basis for estimating source concentrations. During calibration of the RI groundwater model, the upper bound of the source concentration was limited by the solubility. The solubility of 1,1,2,2-tetrachloroethane is approximately 2,900 mg/L (Montgomery and Welcom 1991). Source concentrations of 212 mg/L to 381 mg/L were assumed in the calibrated RI regional model and this model.

Releases of solvents since disposal operations commenced in 1950 resulted in high concentrations of VOCs in the subsurface soils. Past disposal of solvents apparently saturated the soils and drained to the groundwater. Residual pore water, the water remaining in the soil after the soil is drained, is assumed to contain high concentrations of VOCs. Existing groundwater contamination below the sources may be attributed to infiltration displacing or mixing with the residual pore water. Since information specifying the source flux is not available, the historical source flux (1971 to 1995) is assumed to equal the recharge rate.

Several VOCs have been detected in groundwater. Fate and transport modeling was performed on 1,1,2,2-tetrachloroethane. This compound was selected, because it has the highest observed groundwater concentrations and it is the contaminant that adsorbs most strongly. Because it adsorbs more strongly, it migrates in groundwater more slowly. Estimated concentrations in the extracted groundwater for the various treatment alternatives will be conservative, because of the mobility of 1,1,2,2-tetrachloroethane.

TABLE 2-1
MONITORING WELL INFORMATION AND OBSERVED GROUNDWATER AND BEDROCK ELEVATIONS
OUB, FORT RICHARDSON, ALASKA

Monitoring Well	Ground Surface (fmsl)	Top of Casing (fmsl)	Bedrock (fbgs)	Bedrock (fmsl)	Screen (fmsl)		Screen Length (ft)	Screen Midpoint (fmsl)	Observed Groundwater Elevation (fmsl)				
					Bottom	Top			10/1/95	11/1/95	12/4/95	1/3/96	2/1/96
Shallow Wells													
MW-2	293.78	293.96			256	282	26	268.8	274.6	274.1	273.4	272.7	272.3
MW-3	298.35	300.16			252	285	33	268.8	275.1	274.0	272.8	271.6	270.8
MW-5	298.70	299.32			246	286	40	265.7	278.2	277.4	276.6	275.3	275.2
MW-8	301.80	302.86			243	283	40	262.8	277.2	276.7	276.0	275.2	274.6
MW-12	298.96	300.70			263	273	10	268.0	274.4	273.7	273.0	272.2	271.8
MW-13	295.04	296.96			267	277	10	272.0	276.6	275.9	275.2	274.5	273.9
MW-14	304.14	305.85			285	295	10	290.1	291.6	290.9	289.9	289.0	288.4
MW-15	294.67	296.58			265	275	10	269.7	272.9	271.9	270.8	269.8	269.3
MW-17	303.45	305.48			281	291	10	286.4	286.0	285.4	284.5	283.7	283.1
Intermediate Wells													
MW-4	296.80	297.50			238	248	10	242.8	240.5	237.8	dry	dry	
MW-7	298.77	299.75			203	223	20	212.8	226.6	226.7	226.4	226.3	226.4
MW-10	303.09	303.98			244	264	20	254.1	dry	dry	dry	dry	Dry
MW-11	309.40	310.55			220	250	30	235.4	dry	dry	dry	dry	Dry
Deep Wells													
MW-1	293.19	295.13	123	170	155	181	26	168.2	173.4	173.3	173.3	173.2	173.3
MW-6	296.73	297.49	125	172	118	178	60	147.7	177.6	177.4	177.2	177.4	177.5
MW-9	294.00	295.97	159	135	134	164	30	149.0	160.2	dry	160.2	160.1	159.9
MW-16	291.80	295.17	169	123	122	127	5	124.3	162.2	162.4	162.2	162.1	162.1

HYDRAULIC GRADIENTS

Horizontal	Distance between Wells (ft)	Observed Hydraulic Gradients (ft/ft)				
Shallow wells						
MW8/MW2	390	0.0067	0.0066	0.0067	0.0064	0.0059
MW5/MW15	560	0.0095	0.0099	0.0104	0.0098	0.0105
MW5/MW12	390	0.0097	0.0095	0.0092	0.0079	0.0087
MW17/MW15	1,480	0.0089	0.0091	0.0093	0.0094	0.0093
Deep wells						
MW6/MW9	220	0.0791		0.0773	0.0786	0.0799
MW6/MW16	460	0.0335	0.0326	0.0326	0.0333	0.0335
MW1/MW16	420	0.0267	0.0259	0.0264	0.0264	0.0266
Vertical						
MW5/MW7	53	0.97	0.96	0.95	0.93	0.92
MW4/MW6	95	0.66	0.64			
MW2/MW1	101	1.01	1.00	1.00	0.99	0.98
MW15/MW9	121	0.93		0.92	0.91	0.91

fmsl: feet mean sea level
fbgs: feet below ground surface

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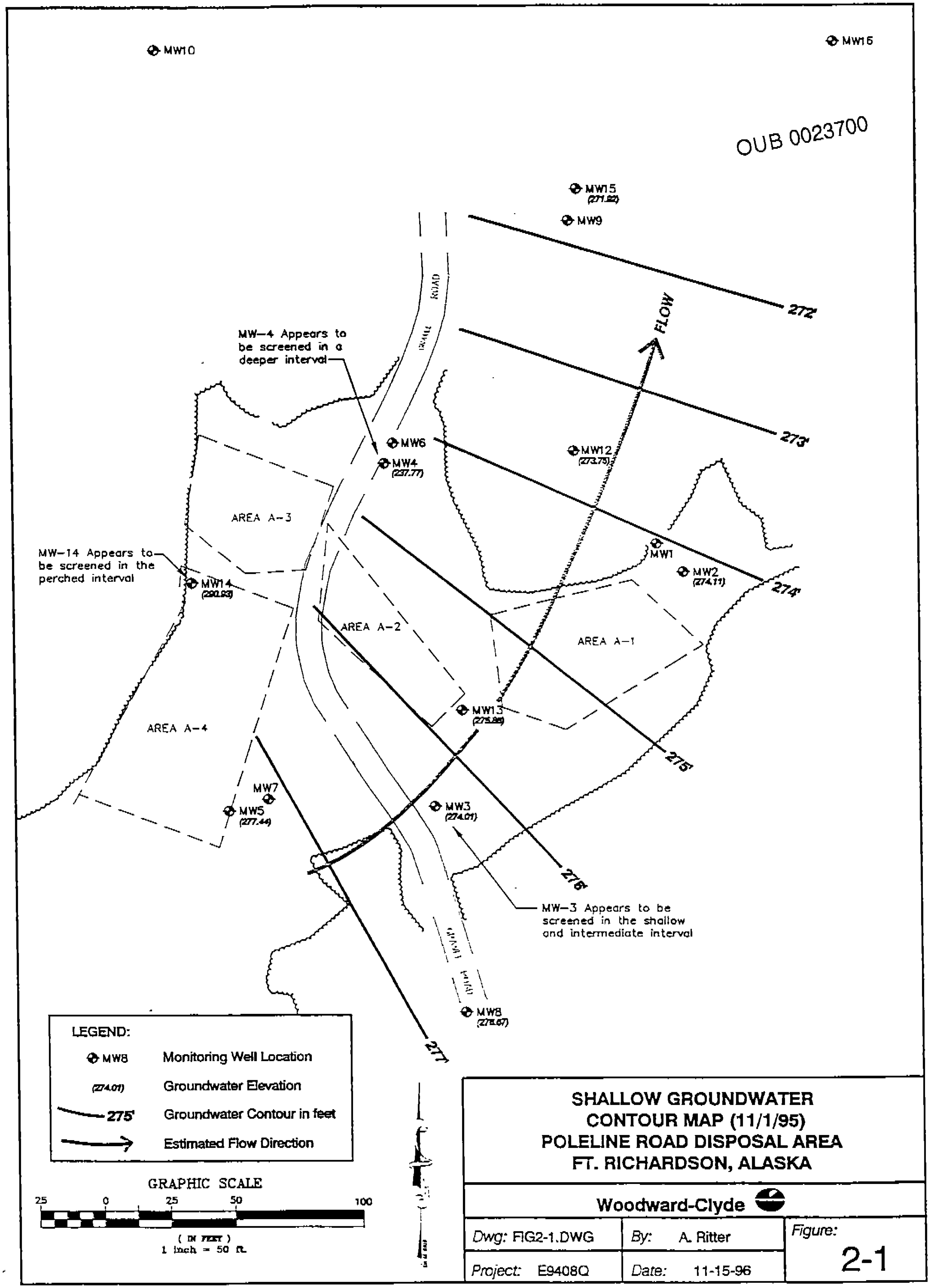
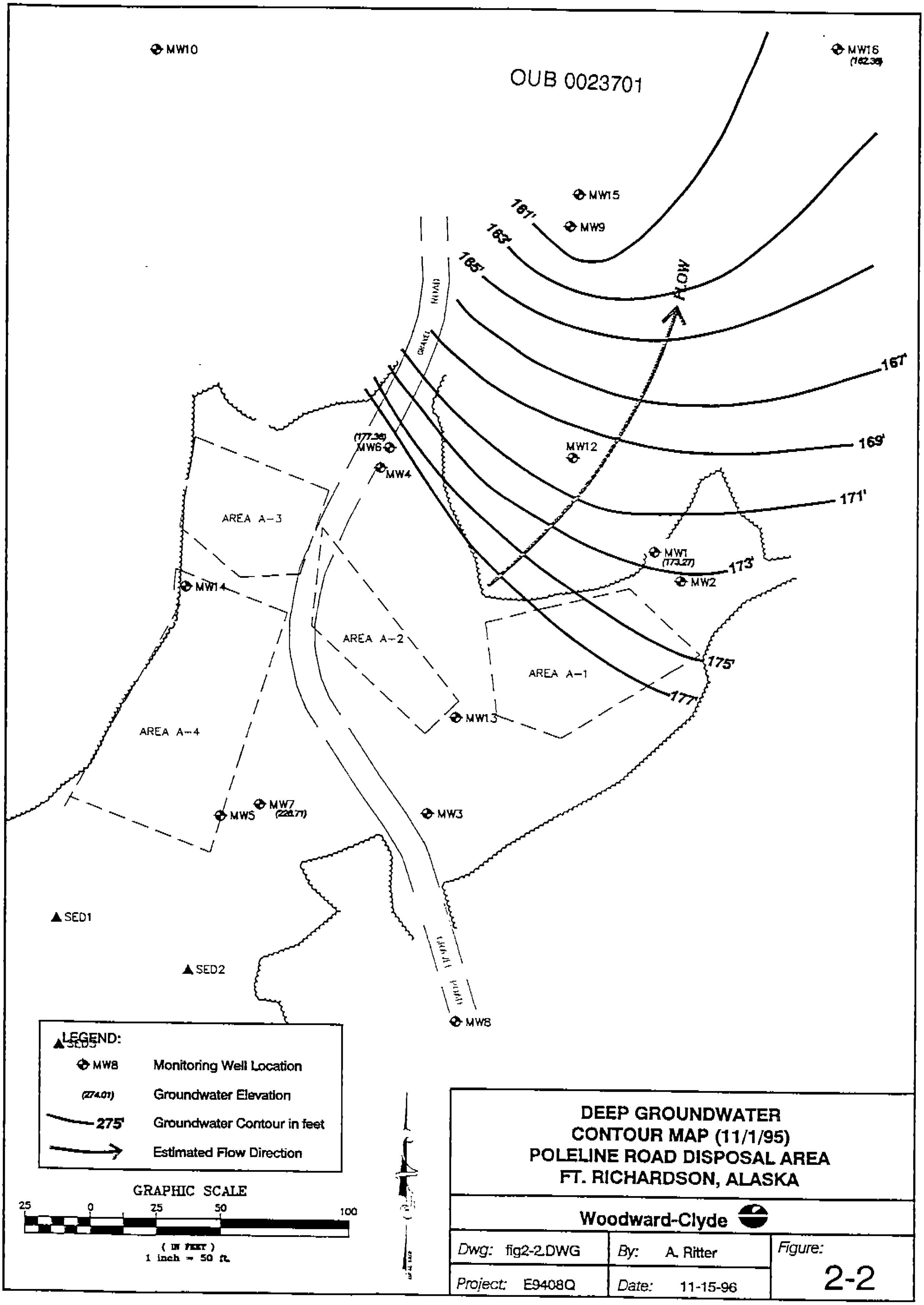


SHALLOW GROUNDWATER CONTOUR MAP (11/1/95)
POLELINE ROAD DISPOSAL AREA
FT. RICHARDSON, ALASKA

Woodward-Clyde

Dwg: FIG2-1.DWG	*By:* A. Ritter	*Figure:* 2-1
Project: E9408Q	*Date:* 11-15-96	



DEEP GROUNDWATER CONTOUR MAP (11/1/95) POLELINE ROAD DISPOSAL AREA FT. RICHARDSON, ALASKA

Woodward-Clyde

Dwg: fig2-2.DWG	*By:* A. Ritter	*Figure:* 2-2
Project: E9408Q	*Date:* 11-15-96	

3.0
MODELING APPROACH

3.1 CONCEPTUAL MODEL

The physical scenario being considered is a disposal area that released chemical compounds into the groundwater. The conceptual model was developed in RI Appendix XIII from the hydrogeology (RI Section 1.0) and the extent of contamination (RI Section 4.0) at the site and simplifying assumptions about disposal operations.

Based on data consisting of water levels, precipitation and aquifer properties, and reasonable assumptions concerning the local and regional flow system in the area, a conceptual groundwater flow model was developed to serve as a framework for numerical flow model presented in Section 4.0. This conceptual model considers steady-state horizontal and vertical flow in the shallow, intermediate, and deep zones of the groundwater flow system.

Based on data consisting of soil and groundwater concentrations and reasonable assumptions about source loadings, a conceptual groundwater fate and transport model was developed to serve as a framework for a numerical model presented in Section 5.0. This conceptual model considers chemical migration in the shallow, intermediate, and deep zones of the groundwater flow system. PRDA-derived VOCs are transported through the groundwater by the processes of advection and dispersion. Linear equilibrium adsorption of organic compounds to soil organic matter is included in the model.

3.2 NUMERICAL MODEL

The U.S. Geological Survey (USGS) three-dimensional finite difference groundwater flow model (MODFLOW) (McDonald and Harbaugh 1989) was selected for use. This model code was selected because it is applicable for simulating site flow conditions on a large scale and because it is a thoroughly documented and widely accepted modeling code.

A three-dimensional finite difference model, MT3D (Papadopulos 1992) was selected to simulate the fate and transport of dissolved organic compounds in groundwater. MT3D incorporates the flow field estimated by MODFLOW and simulates advection, dispersion, retardation and biodegradation in groundwater.

4.0
GROUNDWATER FLOW MODEL DEVELOPMENT

4.1 EXTENT OF MODEL DOMAIN AND SPATIAL DISCRETIZATION

The extent of the model domain is approximately 1,500 feet in the north/south direction and east/west direction. Vertically, the model domain extends from the water table to the bedrock surface.

The model domain was discretized using a rectangular block grid consisting of four layers with 64 columns and 55 rows in each layer. The vertical discretization allowed simulation of vertical groundwater gradients and heterogeneity in the vertical direction. The four layers correspond to the vertical extent of the shallow (Layer 1), intermediate (Layers 2 and 3) and deep (Layer 4) groundwater zones. Horizontally, each layer of the model grid was divided into 3,520 cells, with cell lengths varying between 10 feet in the vicinity of the Areas A-3 and A-4 to 100 feet near the model boundary.

4.2 MODEL DESCRIPTION AND DATA REQUIREMENTS

Groundwater flow modeling requires boundary conditions, aquifer parameters and recharge/discharge characteristics. The data requirements are listed below and are discussed in this section.

- Boundary conditions
- Hydraulic conductivity
- Areal recharge
- Leakance

4.2.1 Boundary Conditions

Development of the numerical model requires that the hydraulic conditions at the model domain boundaries be specified. The model boundary conditions represent the hydrologic interaction between the area modeled and the outside area. In the application of MODFLOW, boundary conditions are specified by assigning certain cell types to the cells at the model boundaries. In addition, the model automatically specifies the outside edge of the model grid to be a no-flux (i.e.., no-flow) boundary. The cell types used for this steady-state model are prescribed-head cells (constant head) and inactive (no-flow) cells.

All four boundaries in Layers 1 and 4 are specified as a constant head boundaries. The assumed groundwater elevation at the boundary is approximately equal to the groundwater elevation estimated by the calibrated RI regional model. All four boundaries in Layers 2 and 3 are specified as no flow boundary conditions, because vertical flow between Layers 1 and 4 is assummed to be the principle flow direction in Layers 2 and 3.

4.2.2 Hydraulic Conductivity

The hydraulic conductivity values assumed in the calibrated RI regional model were used. Hydraulic conductivity values of 0.5 ft/day and 0.3 ft/day were assumed in the shallow (Layer 1) and deep (Layer 4) groundwater zones, respectively. A hydraulic conductivity value of 0.05 was assumed in the intermediate groundwater zone (Layers 2 and 3).

4.2.3 Areal Recharge

The recharge rate (3 in/yr) assumed in the calibrated RI regional model was used.

4.2.4 Leakance

The leakance between the shallow and deep groundwater zones is defined as the vertical hydraulic conductivity of the low permeability basal till unit divided by its thickness. Initially, the leakance (0.00001/day) used in the calibrated RI regional model was assumed in this model. However, the leakance value was increased (0.00003/day). This increase was required to simulate vertical migration of 1,1,2,2-tetrachloroethane to the deep groundwater zone.

4.3 MODEL CALIBRATION

The calibrated regional model developed from the RI was used as a basis for this PRDA site model. The input parameters assumed in the regional model (RI Appendix XIII Table 5-1) were used. This model was not calibrated. The groundwater elevations estimated by this model approximate the groundwater elevations estimated by the calibrated RI regional model. The results of this model indicate that groundwater in all four layers flows north across the site.

The groundwater elevation in Layer 1 in this flow model range from 275 fmsl to 278.5 fmsl in the vicinity of Areas A-3 and A-4 as compared to the estimated heads (RI Appendix XIII Figure 4-7) in the calibrated RI regional model of 276 fmsl to 278 fmsl. The groundwater elevation in Layer 4 in this flow model range from 176.5 fmsl to 193 fmsl in the vicinity of Areas A-3 and A-4 as compared to the estimated heads (RI Appendix XIII Figure 4-8) in the calibrated RI regional model of 184 fmsl to 210 fmsl.

The basal till is a low permeability layer between the shallow and deep groundwater zones. The downward vertical hydraulic gradients likely dominate the flow direction within the basal till. MODFLOW is a quasi-three dimensional model which averages the hydraulic head within each layer. The combine thickness of Layers 2 and 3 is approximately 50 feet. The minimum observed vertical hydraulic gradient across the basal till is approximately 0.91 ft/ft. Therefore, by design the numerical model cannot estimate the observed hydraulic heads at monitoring wells MW-4 and MW-7.

5.0
GROUNDWATER TRANSPORT MODEL DEVELOPMENT

5.1 COUPLING OF FLOW AND TRANSPORT MODEL

MT3D assumes the same mathematical representation of the flow field in the study area as was used in MODFLOW. MT3D incorporates the flow field simulated by MODFLOW and therefore incorporates the model domain and the hydrologic boundary conditions assumed in MODFLOW.

5.2 MODEL DESCRIPTION AND DATA REQUIREMENTS

MT3D requires aquifer parameters, initial conditions, chemical and source characteristics. These data requirements are listed below and are discussed in this section.

- Porosity
- Initial concentrations
- Dispersivity
- Chemical reactions
- Source concentrations and flux rate

5.2.1 Porosity

The effective porosity (0.15) assumed in the calibrated RI regional model was used.

5.2.2 Dispersion

Dispersion in porous media refers to the spreading of contaminants over a greater region that would be predicted solely from variations in the groundwater velocity. Current research indicates that dispersion is scale dependent. The greater the distance between the source and the point of interest, the greater the dispersion.

Dispersion is calculated from the groundwater velocity and the dispersivity. Longitudinal, transverse and vertical dispersivities are model inputs. Since longitudinal dispersivity is scale dependent and the length of the model cells varies from 10 to 100 feet. The longitudinal dispersivity was assumed to equal 10% of the minimum cell length for each cell (1 feet to 10 feet) throughout the model domain. The transverse and vertical dispersivities are assumed to equal 0.2 and 0.1 of the longitudinal dispersivity, respectively.

5.2.3 Initial Conditions

Contaminant transport simulation requires initial conditions. The initial condition is equal to the chemical concentration in the model domain at the start of the simulation. In this simulation, the initial concentration is assumed to be equal to zero. In other words, the chemical concentration throughout the saturated zone is equal to zero when the PRDA commences operation.

5.2.4 Chemistry

The chemical reaction included in the transport model is equilibrium-controlled linear adsorption.

5.2.4.1 Adsorption

Adsorption refers to the mass transfer process between the contaminants dissolved in groundwater (solution phase) and the contaminants adsorbed on the porous medium (solid phase). Retardation of contaminants due to adsorption is described by the retardation factor. The retardation factor is defined as the ratio of the groundwater flow velocity to the velocity of the contaminant. Adsorption is assumed to be defined by a linear equilibrium isotherm which assumes that the relationship between the concentration of the compound in the adsorbed and dissolved phases is linear. The model also assumes that the adsorbed phase is in local equilibrium with the dissolved phase.

The retardation is estimated from aquifer properties and chemical specific properties. The aquifer properties consist of bulk density, effective porosity and fraction organic carbon. A bulk density of 120 lbs/ft^3 foot was assumed. An effective porosity of 0.15 was assumed as presented in Section 5.2.1. Fraction organic carbon was estimated from laboratory tests performed on four soil samples collected at or above the water table. The fraction organic carbon ranged from 0.19 percent to 0.66 percent with a geometric mean of 0.39 percent. The fraction organic carbon content of 0.39 assumed in the calibrated RI regional model was used.

The normalized organic carbon distribution coefficients (K_{oc}) for 1,1,2,2-tetrachloroethane assumed in the calibrated RI regional model (117.5 millileter per gram [mL/g];Knox et. al 1993) was assumed.

5.2.5 Source Areas and Concentration

The source concentration, flux (recharge rate at source) and timing (when VOCs began recharging groundwater) assumed in the calibrated RI regional model were assumed. The source concentration entering the groundwater is assumed to be constant from 1971 to 1995. The source flux is assumed to equal the recharge rate used in the flow model.

5.3 MODEL CALIBRATION

The calibrated regional model developed for the RI was used as a basis for this PRDA site model. The input parameters assumed in the regional model (RI Appendix XIII Table 5-1) were used. This model was not calibrated. The 1,1,2,2-tetrachloroethane concentrations estimated by model approximate the concentrations estimated by the calibrated RI regional model and the observed concentrations in 1995.

The transport model assumes that 1,1,2,2-tetrachloroethane enters the groundwater in the year 1971 and the source concentration remains constant until 1995. The 1995 estimated 1,1,2,2-tetrachloroethane concentrations assume that the source has been contaminating the groundwater for 25 years (1971 to 1995). A 1,1,2,2-tetrachloroethane source concentration equal to the solubility limit of 2,900 mg/L was initially assumed during calibration of the RI regional model . The groundwater concentrations estimated by the RI regional model based on this assumption were significantly higher than the observed 1,1,2,2-tetrachloroethane groundwater concentrations. The calibrated RI regional model and this model assume source concentrations ranging from 212 mg/L to 381 mg/L, as shown in RI Appendix XIII Table 5-1.

The estimated concentration contours in Layers 1 and 2 reasonably estimate the areal extent of the plume estimated by the RI regional model and are comparable to the available data. The estimated concentrations in Layers 3 and 4 underestimate the 1,1,2,2-tetrachloroethane concentrations estimated by the RI regional model and the available data.

6.0
GROUNDWATER FLOW AND TRANSPORT MODELING RESULTS

The groundwater fate and transport model was used to evaluate the movement of PRDA-derived compounds in the shallow, intermediate, and deep groundwater zones. The purpose of modeling groundwater flow and contaminant transport is to evaluate the effectiveness of the various groundwater treatment alternatives. Groundwater modeling is used to estimate groundwater extraction rates and the 1,1,2,2-tetrachloroethane concentration in the extracted groundwater.

6.1 Interception Trenches With Soil Vapor Extraction

The interception trench system, shown in Figure 3-2 of the FS, was modeled and the extraction/flow rate and 1,1,2,2-tetrachloroethane concentration of the extracted groundwater were estimated. It was assumed that the interception trench system was installed in 1996 and was operated for 30 years. During the first four years of operation, the soil vapor extraction system was concurrently operated. It is assumed that at the end of four years the soil vapor extraction system removed all of the contaminant in the soils located above the interception trench system installed in the intermediate groundwater zone.

The 1996 1,1,2,2-tetrachloroethane concentrations in groundwater were estimated using the calibrated RI regional groundwater fate and transport model assumptions as discussed in Sections 3.0, 4.0, and 5.0 of this appendix. Specifically, the source concentration is constant for 4 years (1996 through 1999) until the soil vapor extraction system has removed all of the soil contamination. In the years 2000 through 2015, it is assumed that no additional 1,1,2,2-tetrachloroethane enters the groundwater.

The interception trenches were simulated as drains in the MODFLOW computer simulation. Four trenches were placed in Areas A-3 and A-4. Three of the four trenches are assumed to be 250 feet in length. This length was estimated based on the width of the lateral extent of contamination in groundwater, as shown in Figure 2-1 of the FS. The fourth and most southerly drain is 150 feet in length, because the lateral extent of the observed groundwater contamination is smaller in this area. The drains were placed in Layer 1 at an elevation of 264 fmsl to 269 fmsl and in Layer 2 at an elevation of 237 fmsl to 240 fmsl. The ground surface is at an elevation of approximately 300 fmsl in the vicinity of the interception trench system. A drain conductance of 1,000 ft/day was assumed in Layers 1 and 2. Five interception trenches were initially assumed for this analysis. This configuration resulted in dewatering the intermediate groundwater zone in the vicinity of the trenches. Because the results of the groundwater flow and contaminant transport computer simulations are invalid under dewatering conditions, four interception trenches were assumed and modeled.

The minimum elevation of the trench system (238 to 241 fmsl) was selected based on observed 1,1,2,2-tetrachloroethane concentrations. Two monitoring wells (MW-4 and MW-7) are screened in the intermediate groundwater zone. Monitoring well MW-4 is screened at an elevation of 238 to 248 fmsl as shown in Figure 1-4 of the FS. Monitoring well MW-7 is screened deeper than well MW-4 and is screened at an elevation of 203 to 223 fmsl. The observed 1,1,2,2-tetrachloroethane concentration in wells MW-4 and MW-7 are 71.0 mg/L and 3.1 mg/L, respectively. Based on these data, high concentrations have been observed at an elevation of approximately 240 fmsl. The interception trench system will extract contaminated groundwater above an elevation of 240 fmsl.

The total flow rate for the trench system in Layers 1 and 2 estimated by the model is approximately equal to 1 gpm. This extraction rate results in a lateral capture zone in both Layers 1 and 2 that includes the extent of contamination shown in Figure 2-1 of the FS. This extraction rate results in lowering the groundwater elevations in Layer 1 from approximately 274.4 to 278.2 fmsl in the vicinity of Areas A-3 and A-4 to approximately 264.0 fmsl to 269.0 fmsl (which is approximately equal to the assumed elevation of the bottom of the Surficial Deposits (266 fmsl as shown in Figure 1-4 in the FS). This extraction rate results in lowering the groundwater elevations in Layer 2 from approximately 247 fmsl to 248.9 fmsl in the vicinity of Areas A-3 and A-4 to approximately 237 fmsl to 240 fmsl.

The 1,1,2,2-tetrachloroethane concentrations were estimated for the 30 years time period (1996 to 2015). The initial concentration extracted from the drain in 1996 was 29.0 mg/L and the final concentration extracted from the drain in 2015 was 1.0 mg/L. The average drain concentration was 11.4 mg/L.

The model results indicate that this system would be effective in removing groundwater contamination in the shallow and intermediate groundwater zone above an elevation of 240 fmsl. The locations of the four trenches was not optimized such that the migration of 1,1,2,2-tetrachloroethane to the deep aquifer was eliminated. However, the model results indicate that with further optimization of the system layout, this alternative could effectively protect the deep aquifer from the migration of 1,1,2,2-tetrachloroethane contamination, when the interception system is operating.

As discussed in Section 2.3 of this appendix, the contaminant 1,1,2,2-tetrachloroethane was modeled, because it has the highest concentrations and is the contaminant that adsorbs most strongly. Because it adsorbs strongly, it moves in the groundwater more slowly than the other contaminants. Based on this information, it is likely that the other contaminants would migrate through the groundwater to the interception trenches at a faster rate.

6.2 Interception Trenches with Soil Flushing

The interception trench and soil flushing system, shown in Figure 3-7 of the FS, was modeled. The interception trench configuration assumed in the model is presented in Section 6.1.

It is assumed that the groundwater extracted from the interception trench system was infiltrated through the soils in Areas A-3 and A-4. The groundwater extraction rate/infiltration rate, and the 1,1,2,2-tetrachloroethane concentration of the extracted groundwater were estimated. It was assumed that the interception trench system was installed in 1996 and was operated for 30 years.

Site specific data that estimate the effectiveness of soil flushing are not available. Based on bench-scale soil flushing treatability testing conducted by Woodward-Clyde for a confidential client, the concentration in the leachate decreased by 94 percent, if four pore volumes are flushed through the soil. For this site, it is assumed that five pore volumes are flushed through the soil and remove all soil contamination. Although the effectiveness of five volumes is uncertain for this site, it is the best estimate that can be made with the available data.

The soil volume to be flushed is based on an area approximately equal to Areas A-3 and A-4 (29,000 square feet) and a depth of 15 feet. The depth is based on the distance between the bottom of the previous excavation in Areas A-3 and A-4 (290 fmsl) and the elevation of the shallow groundwater (275 fmsl). A pore volume is estimated from this soil volume and a total porosity of 0.25.

Assuming a flushing rate of 5 gpm and a natural recharge rate of 3 inches/years (refer to Section 4.2.3 of this appendix), one pore volume is flushed in 120 days. It is assumed that at the end of 600 days of operation (five pore volumes), the soil flushing removed all of the soil contamination above the shallow groundwater. It is assumed that the extracted and treated groundwater is infiltrated into the soils in Areas A-3 and A-4 for 30 years, and that soil vapor extraction and soil flushing will remediate unsaturated soils.

The 1996 1,1,2,2-tetrachloroethane concentrations in groundwater were estimated using the calibrated RI groundwater fate and transport model assumptions as discussed in Sections 3.0, 4.0 and 5.0 of this appendix. The source concentration decreases during the first 600 days of operation. After the first 600 days of operation, it is assumed that no additional 1,1,2,2-tetrachloroethane enters the groundwater.

The total flow rate for the trench system in Layers 1 and 2 estimated by the model is approximately equal to 5 gpm. This extraction rate results in a lateral capture zone in both Layer 1 and 2 that includes the extent of contamination shown in Figure 2-1 of the FS. This extraction rate results in lowering the groundwater elevations in Layer to approximately 264 fmsl to 269 fmsl in the vicinity of Areas A-3 and A-4. This extraction rate results in lowering the groundwater elevations in Layer 2 to approximately 237 fmsl to 240 fmsl in the vicinity of Areas A-3 and A-4.

The 1,1,2,2-tetrachloroethane concentrations were estimated for the 30 years time period (1996 to 2015). The initial concentration extracted from the drain in 1996 was 29.0 mg/L and the final concentration extracted from the drain in 2015 was 0.1 mg/L. The average drain concentration was 5.8 mg/L.

The model results indicate that this system will be effective in removing groundwater contamination in the shallow and intermediate groundwater zone above an elevation of 240 fmsl. The locations of the four trenches was not optimized such that the migration of 1,1,2,2-tetrachloroethane to the deep aquifer was eliminated. However, the model results indicate that with further optimization of the system layout, this alternative could effectively protect the deep aquifer from the migration of 1,1,2,2-tetrachloroethane contamination, when the interception system is operating.

6.3 Funnel-and-Gate System

The funnel-and-gate system, shown in Figure 3-3 of the FS, was modeled. The rationale for the length, depth and configuration of the system is presented in Section 6.1. It is assumed that the funnel and gate system is installed in 1996 and was operated for 30 years.

The slurry wall portion of the system is modeled as no-flow cells in Layer 1 (shallow groundwater zone) and Layer 2 (intermediate groundwater zone to a minimum elevation of 240 fmsl). The gate is assumed to be 20 feet in length. It is assumed that the hydraulic conductivity of the surrounding native material will control the hydraulic gradient and groundwater flow velocity through the gate. The hydraulic conductivity of the native material is assumed for the gate material. It is assumed that the groundwater model cells that represent the gate have zero concentrations throughout the operation of the funnel-and-gate system. Specially, groundwater passing through the gate has a 1,1,2,2-tetrachloroethane concentration of zero.

The groundwater elevations in Layer 1 and Layer 2 did not change significantly in the vicinity of the funnel and gate system. The groundwater elevations in Layer 1 at the gate in the most northerly reaction wall decreased from approximately 274.4 fmsl to 273.9 fmsl. The groundwater elevations in Layer 1 at the gate in the most southerly reaction wall increased from approximately 278.2 fmsl to 278.5 fmsl. The groundwater elevations in Layer 2 at the gate in the most northerly reaction wall decreased from approximately 247.0 fmsl to 246.0 fmsl. The groundwater elevations in Layer 2 at the gate in the most southerly reaction wall decreased from approximately 248.9 fmsl to 248.6 fmsl

The effectiveness of this system was compared to the interception trenches with soil vapor extraction and interception trenches with soil flushing. Like the interception trenches, the funnel-and-gate system contains the plume in Layer 1 and Layer 2 and the plume does not migrate laterally beyond the most northerly funnel-and-gate wall. However, the vertical migration of contamination below a depth of 240 feet is approximately 4 times higher than either of the interception trench systems. Therefore the reaction wall is not as effective at protecting the deep aquifer as the interception trench systems.

6.4 Pumping Well

The maximum pumping rate a single groundwater well can yield from the shallow groundwater zone was estimated with the groundwater flow model to be approximately 200 gpd. This was estimated by placing a well in layer 1 and applying various flow rates until the cell was dewatered. At greater then 200 gallons per day, the model cell was dewatered.

7.0
UNCERTAINTIES AND LIMITATIONS

When a complex chemical and physical system is simplified and modeled there is uncertainty in the results. Although uncertainty is present in this analysis, the intent was to estimate conservative and reasonable results. The uncertainties resulting from the simplifying assumptions used in this analysis are discussed in this section.

The complex geology in the study area is one of the largest sources of uncertainty at this site. This uncertainty affects the estimated groundwater velocities, flow direction and plume concentrations.

A reliable estimate of source strength over the last 45 years (1950 to 1995) requires data at several locations and at several points in time. Because these data are unavailable, source strength was estimated based on 1,1,2,2-tetrachloroethane concentrations in the groundwater. It is not possible to know with what degree of precision the model source strength reflects actual contamination loadings.

The conclusions and recommendations presented in this report are based on professional opinion and available data concerning subsurface geologic and hydrogeologic conditions; groundwater quality; and past disposal operations. In some cases, available data and analyses of those data were provided by others. Conclusions in this report are also partially based on results of numerical modeling. It should be recognized that variations from the conditions assumed for this investigation may occur and, if additional data are collected, the conclusions and recommendations drawn herein may be revised. It is recommended that this potential variability from assumed conditions be considered when making decisions regarding this project.

Woodward-Clyde warrants that our services are performed with the usual thoroughness and competence of the engineering and hydrogeologic professions. No other warranty or representation, either expressed or implied, is included or intended.

8.0
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Personal Communications:

Letter to Sally Rothwell, Woodward-Clyde. September 5, 1995. Weston, Howard K., P.E., Technical Director, Alaska Testlab, Inc.

Munter, James A., Senior Hydrogeologist, Bristol Environmental, with Tracy Evans, Woodward-Clyde. Telephone conversation. February 1996.

ATTACHMENT B1

SUPPORTING DOCUMENTATION FOR FS GROUNDWATER MODEL

The source is not quite in the correct place it was okay for RI, but not okay for FS. So move the source [Jeff L says he agrees that it should be moved]

move source from col 8 row 16 [value = 10 8]
to col 9 row 16 " "

OUB FS MODELING

July 5, 1994

The RI model cannot be used for the FS because the cell size (100'x100') is too big to evaluate the lateral effectiveness of the drain. In addition Layer 2 is 40-80 ft thick & the average heads will not be representative.

set up a new simplified model

cell size = 10 x 10

domain =

				RI model
x	144000 to 146500	Δ=2500		j = 5 to 18
y	132500 to 135000	Δ = 2500		i = 5 to

This will extend to boundary 1000 ft (100 cells) from the area of interest

RI model

			Thickness
Layer 1 Bot	= ~ 250 ft		25'
Layer 2 Bot	= ~ 180 to 210	= Δ 40	40-70'
Layer 3 Bot	150 to 180	= Δ 30	30'

The RI model had 3 layers, 26 rows & 23 col. 1794 cells

FS model for tech memo #2 Layer 90x60 = 5400

2500 ÷ 10 = 250 cells

250 x 250 x 5 = 312,500 cells (too many)

2500 ÷ 20 = 125

125 x 125 x 5 = 78125 cells

125 x 125 x 4 = 62500 cells

50,000 to 100,000 ← Bass gms is very slow
according to cm3

keep Constant head BC 5 cells away from drain

If model domain boundary is only 500 ft away from trench
→25 cells

1500 ÷ 20 = 75 cells

75x75x4 = 22500 cells

Revised Domain (500 ft away from area of interest)

R1 domain

x 144500 to 146000 j = 6 + 17

y 133000 to 137500 i = 21 to 8

Use variable grid
10 ft cells in area of interest, because
slurrywalls are usually < 10 ft
grade from 10 → 20 → 40 → 60 → 100
this is easy

result 55 rows
64 cols = 14,080 cells
4 Layers

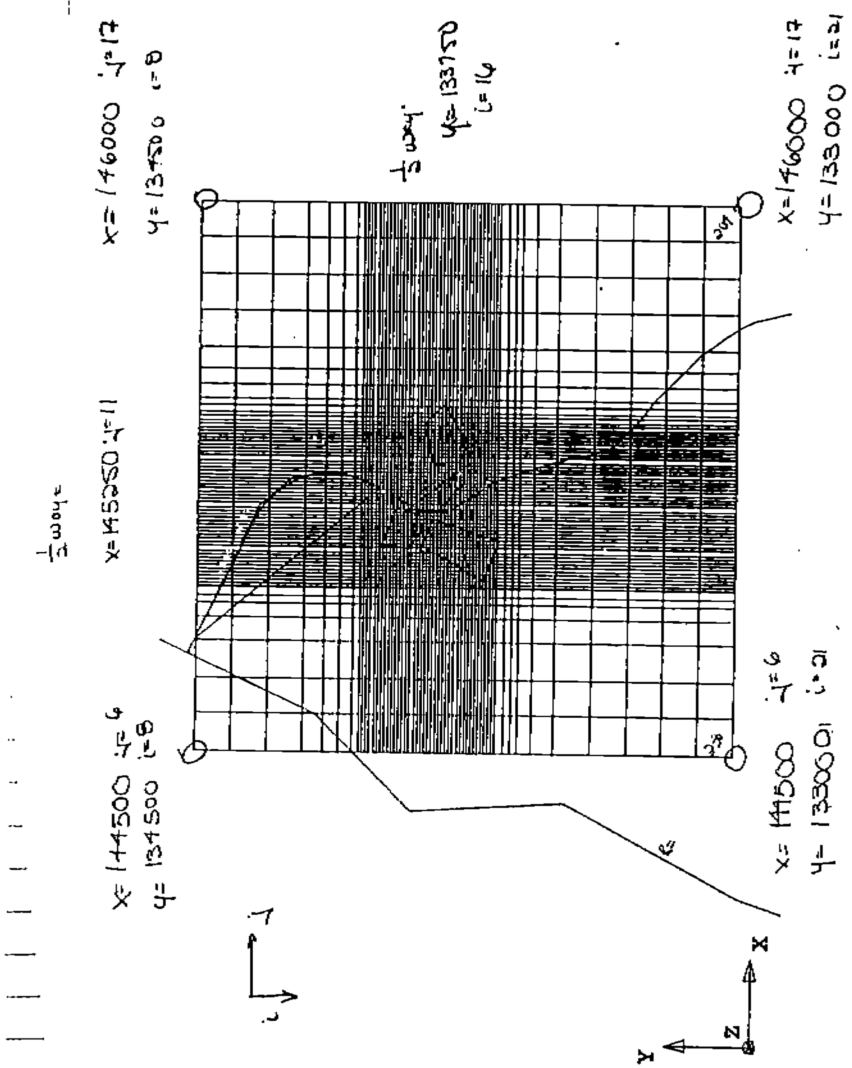
Parameter values will have to be transferred from R1 to F5 inc for

	Layer			
	1	2	3	4
old Layer #	1.	2	2	3
K	0.5	0.05	0.05	0.3
Leak	1×10^{5} = 0.00001	1×10^{-5}	1×10^{-5}	0
Bot. Elev	255 250	220	195	~~165~~ – ~~(16)~~ 15
Heads	263 - 284			165 - 296
thickness	~~25~~ 22	~~30~~ 35	25	30
[illegible]	277-255			[illegible] = 27

Heads IBOUND = -1 Constant Head
=0 no flow
= +1 Variable head

recharge

Grid : fs.3Dg



Recharge
from RI

j = 6
i = 8
R = 6.8×10⁻⁴

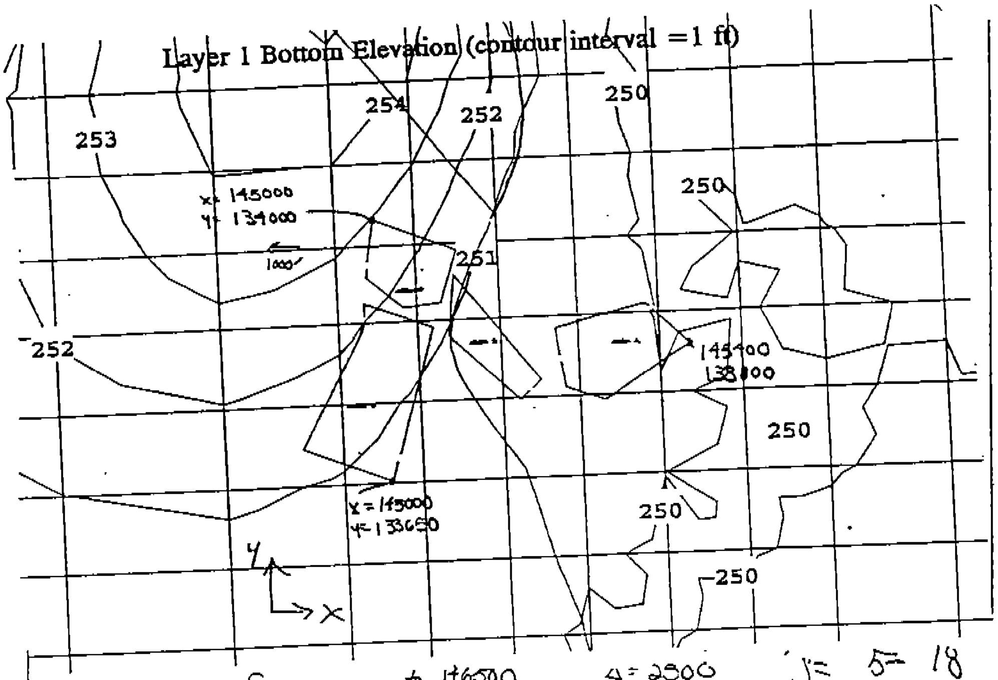
j = 17
i = 8
R = 6.8×10⁻⁴

j = 6
i = 21
R = 6.8×10⁻⁴

j = 17
i = 21
R = 6.8×10⁻⁴
= 0.00068

From RI

Layer 1 Bottom Elevation (contour interval =1 ft)

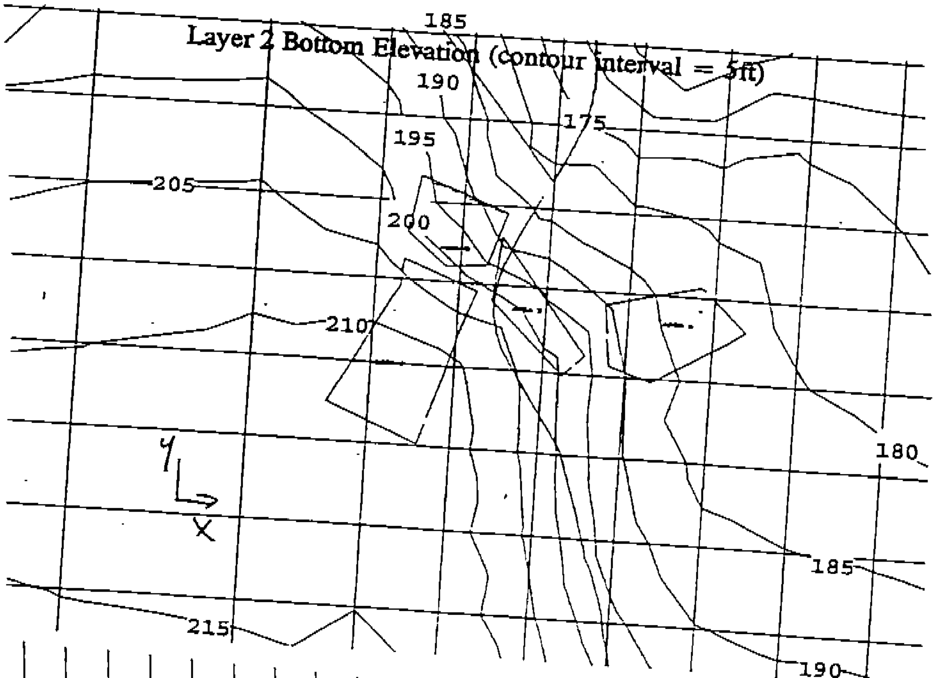


x from 144000 to 146500 Δ=2500 J= 5- 18

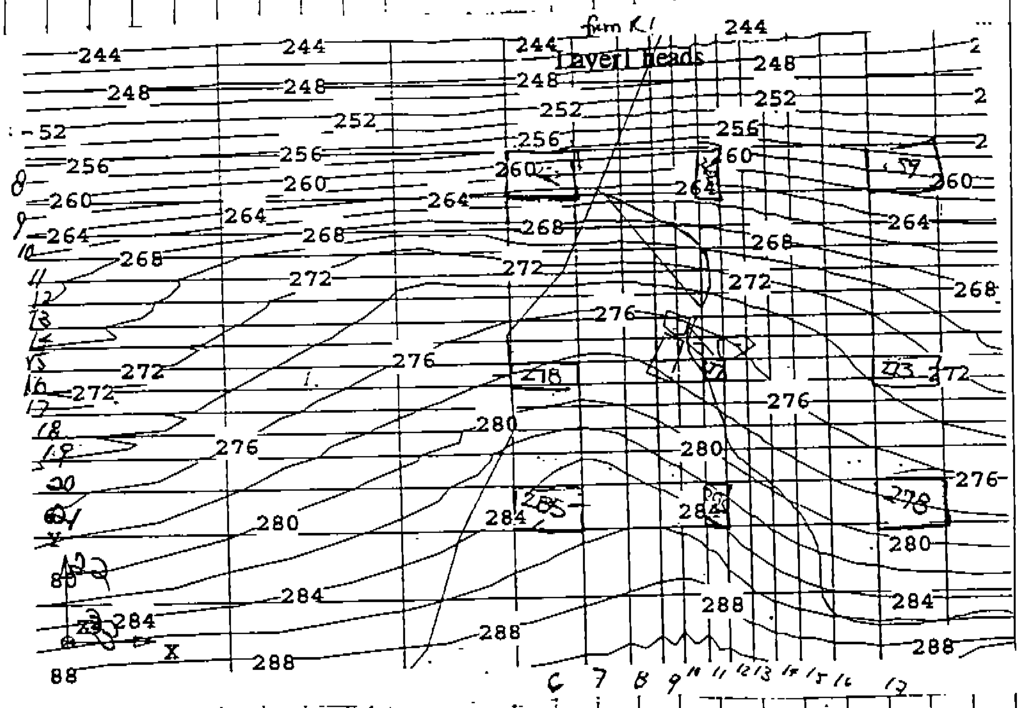
y from 132500 to 135000 Δ=2500 I = 5- 23

From R1

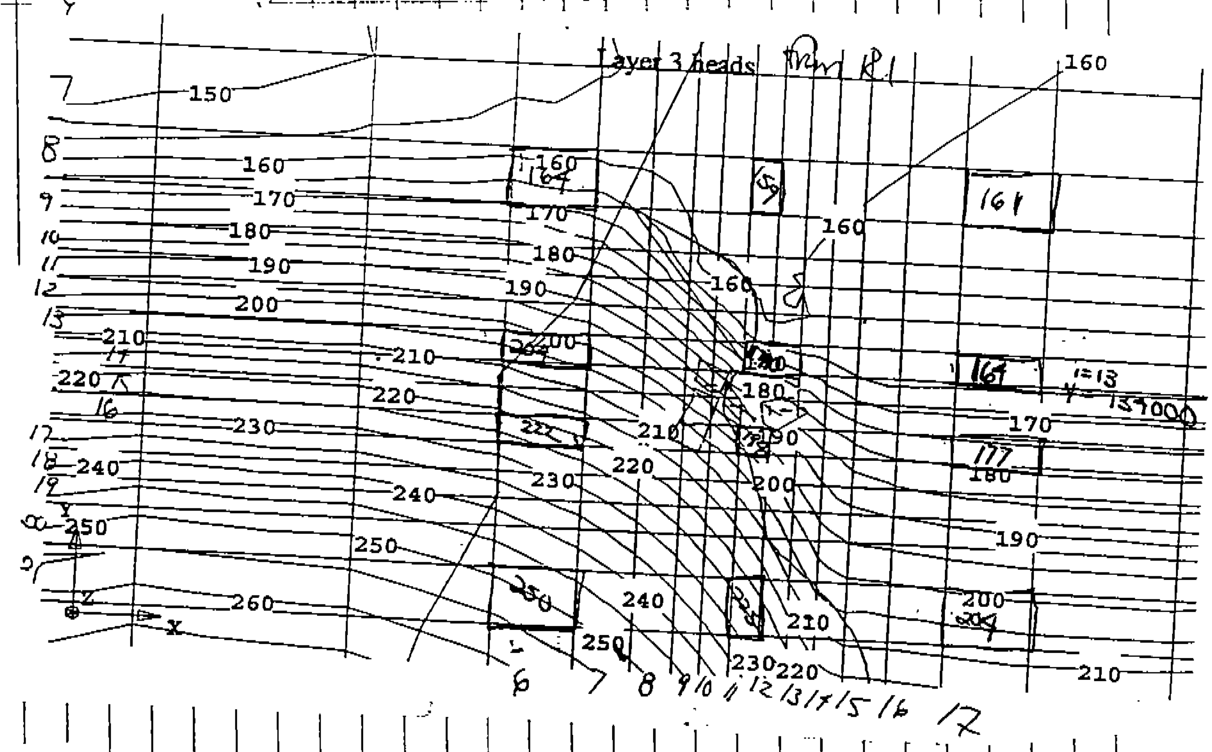
Layer 2 Bottom Elevation (contour interval = 5ft)



8


Layer1 heads
from R1
244
248
252
256
260
264
268
272
276
280
284
288
X
Y
6 7 8 9 10 11 12 13 14 15 16 17

9


Layer 3 heads
from R1
150
160
170
180
190
200
210
220
230
240
250
260
X
Y
Z
6 7 8 9 10 11 12 13 14 15 16 17
I=13
Y=137000

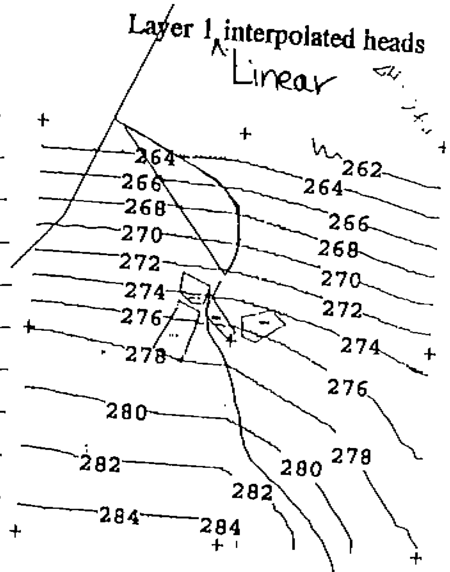
file c:\prdafs\lay1HD.PTS

```
SCAT2D
DELEV    0.0
XYD  9 corners 1 lay1hd
  144500  134500       262
  145250  134500       262
  146000  134500       259
  144500  133750       278
  145250  133750       277
  146000  133750       273
  144500  133000       285
  145250  133000       285
  146000  133000       278
```

c:\...lay4hd.pts

```
SCAT2D
DELEV 300.0
XYD 12 corners 1 lay4hed
  144500  134500       164
  145250  134500       159
  146000  134500       161
  144500  134000       204
  145250  134000       170
  146000  134000       164
  144500  133750       222
  145250  133750       197
  146000  133750       177
  144500  133000       250
  145250  133000       225
  146000  133000       204
```

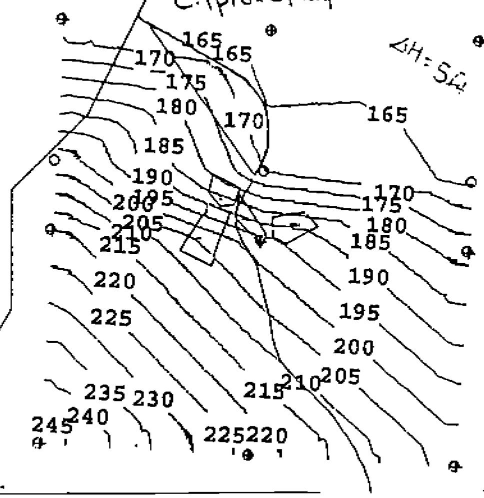
Layer 1 interpolated heads
Linear



from scatter pt file
c:\prdafs\lay1HD.PTS

Layer 3 linear interpolated heads
from scatter pt file
c:\prdafs\lay4HD.PTS

ΔH=54

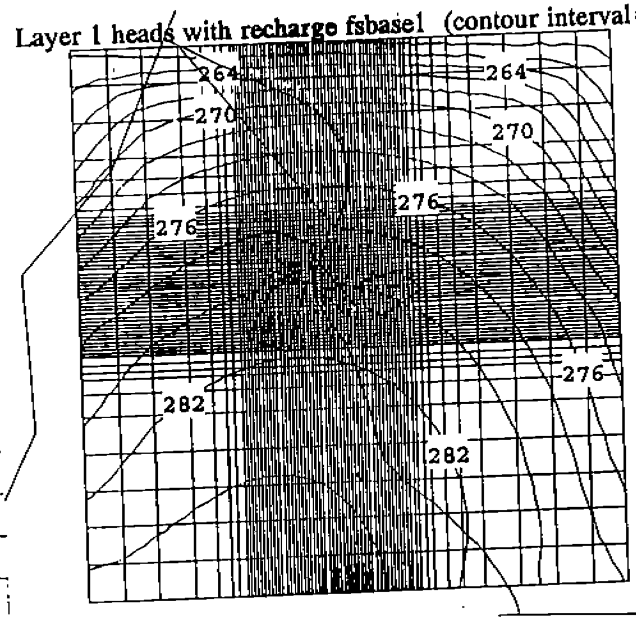


imported head file from fsbase
and saved as starting heads
for fsbase1

mass balance
total CH in = 701.75
" " bah " " = 1149.2
total in = 1850.9

14unit 1
overlooked
the ~~[illegible]~~ solution

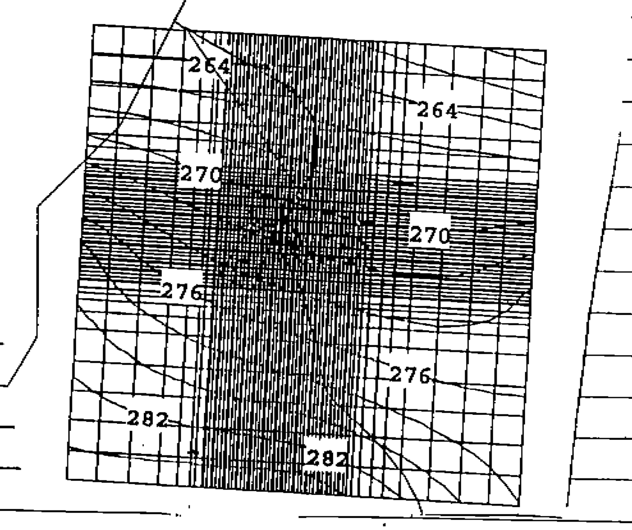
Layer 1 heads with recharge fsbase1 (contour interval=2ft)



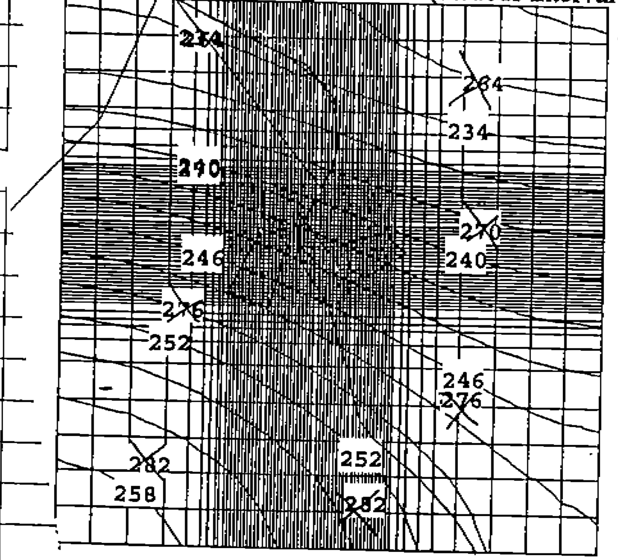
12

fsbase 2 no recharge

layer 1 heads no recharge fsbase2 (contour interval=2 ft)

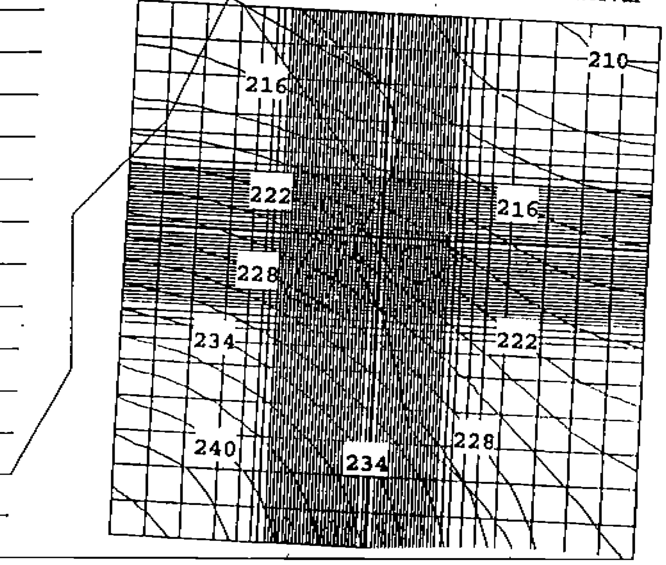


layer 2 heads no recharge fsbase2 (contour interval=2 ft)

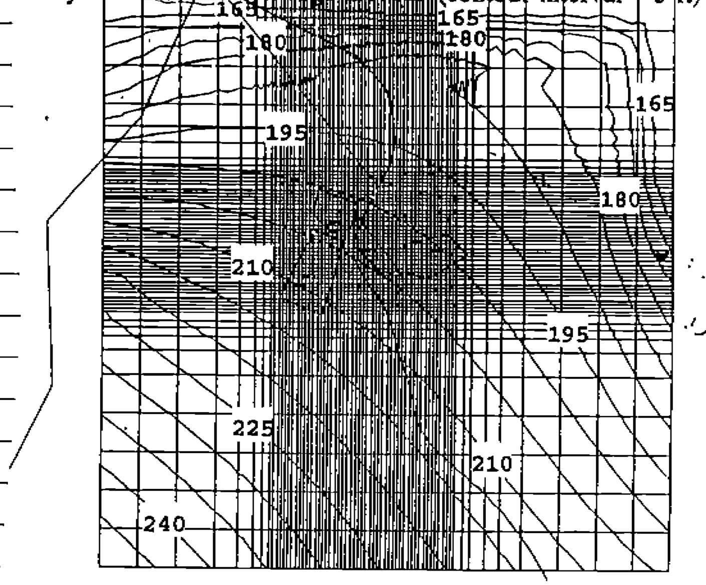


13

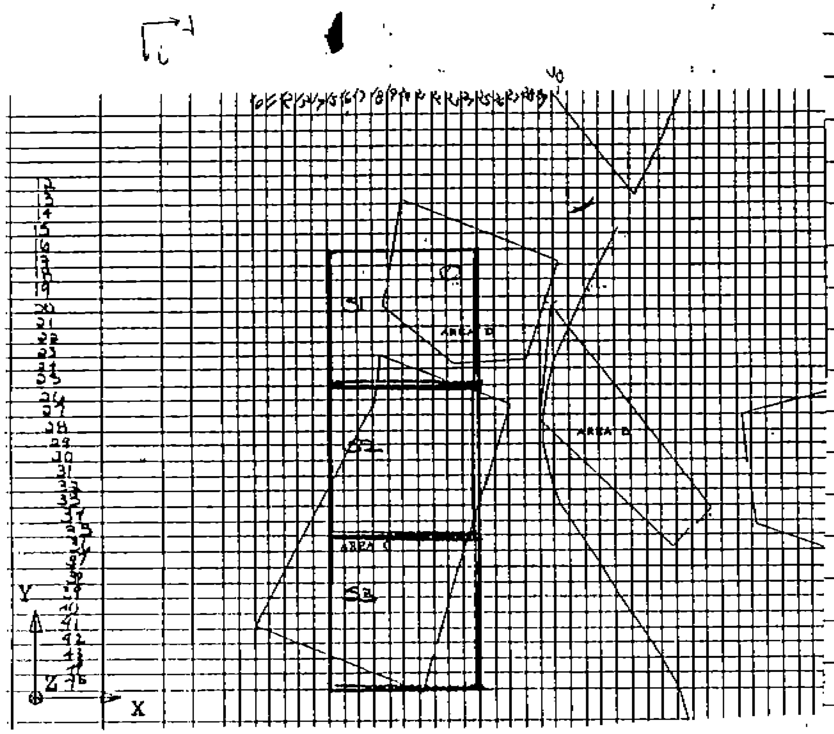
Layer 3 heads no recharge fsbase2 (contour interval= 2 ft)



Layer 4 heads no recharge fsbase2 (contour interval= 5 ft)



14



$S1 = 6 gm/ft^3 = 211,800 \mu g/L$

$S2 = 6 gm/ft^3 = 211,800 \mu g/L$

$S3 = 10.8 gm/ft^3 = 38 1240 \mu g/L$

recharge rate = 3"/yr = 6.8×10^{-4} ft/day

0.00068

$\frac{3''}{4'} \times \frac{ft}{12''} \times \frac{yr}{365 day} = 6.8\times10^{-7}$

CH IN = .1 E+0

Poch " " = .18 E4

Htin = .102E8

% discrep invs lmt = 0

fsbase 3 has recharge and source

fstran3 " "

Simulation = 9123 days = 25 yrs

✓ effective porosity = 0.15

✓ Dispersivity

Longitudinal = 10% of min cell length

Transverse = 20% of long

Vertical = 10% "

cell size (ft)	Dis (ft)
10	1
20	2
40	4
60	6
100	10

-X- Retardation = 1.6x10^{-3}

(decay constant)

Bulk density = 54545 gm/ft^3

= 120 lb/ft^3

✓ HTOP = 286

✓ THICKNESS L1 286-255 = 31

L2 255-220 = 25

L3 220-195 = 25

L4 195-160 = 35

Back track 79 4pm

I just got off the phone w/ Jeff Leighton

Because I need to evaluate soil flushing, I cannot ignore recharge

Recharge @ 3"/yr (like RI model) changes the head distribution alot

So what should I do.

Since I believe 3"/yr is reasonable I think I should modify the B.C. to allow for the

So decrease heads at ~~s~~ south of side by 2 ft

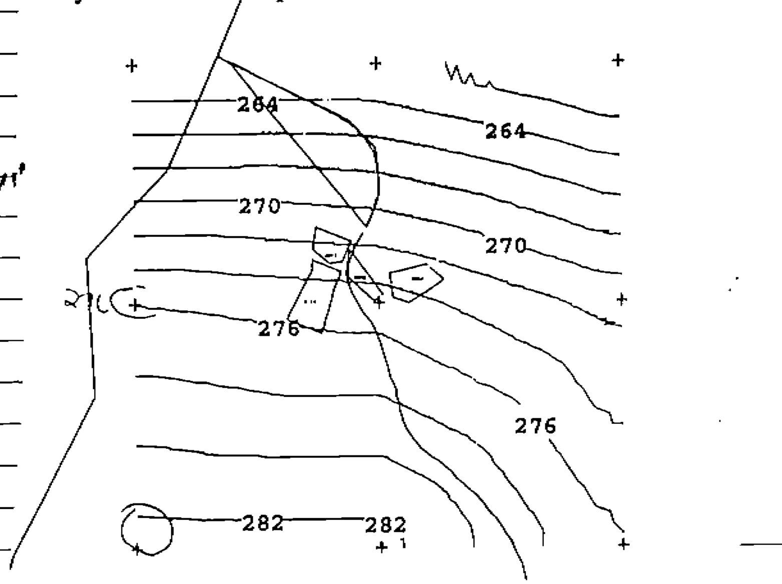
$$\frac{3''}{yr} \times \frac{yr}{365} \times \frac{ft}{12''} = 0.00068 = 6.8\times10^{-4}$$

File c:\prnafs\lay1HD.FTS → lay1HDA.FTS

SCAT2D
DELEV 0.0
XYD 9 corners 1 lay1hd
144500 134500 262
145250 134500 262
146000 134500 259
144500 133750 ~~278~~ 276 → 278
145250 133750 ~~277~~ 275
146000 133750 ~~271~~ 271 ~~272~~ ~~278~~
144500 133000 ~~285~~ 283 ~~278~~ → 280 282
145250 133000 ~~285~~ 283 278 279 → 278
146000 133000 ~~278~~ 276 278

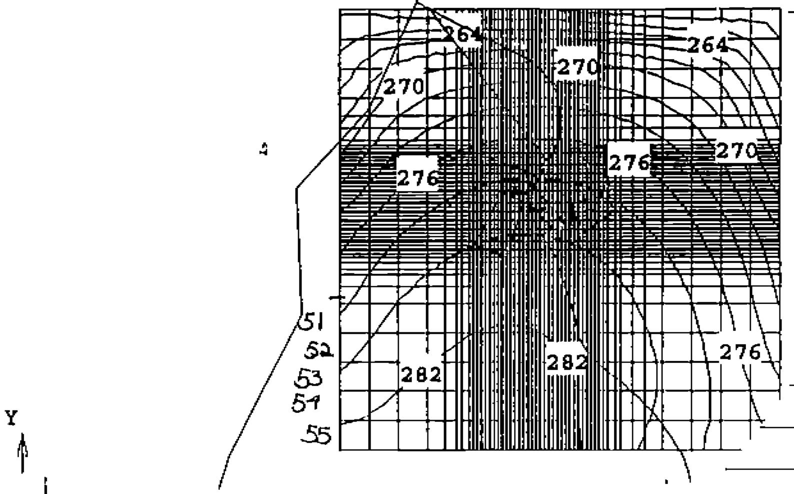
make the modflow file fsbase4.sup

Layer 1 Linear Interp Head (too acct for recharge contour=2ft)



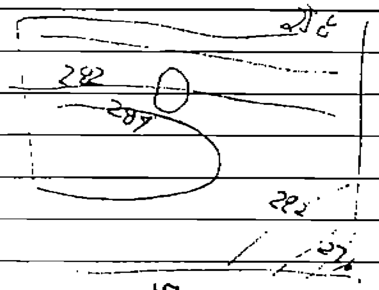
resulting shape looks weird so ~~remove~~.

Layer 1 heads



So remove CH on E & W & make it a no flow IBOUND=0 (fsbase5)

This didn't look right either & heads to high (282) at site



Reduce recharge in rows 51 → 55 from 3" to 1.5"

go back to fsbase4

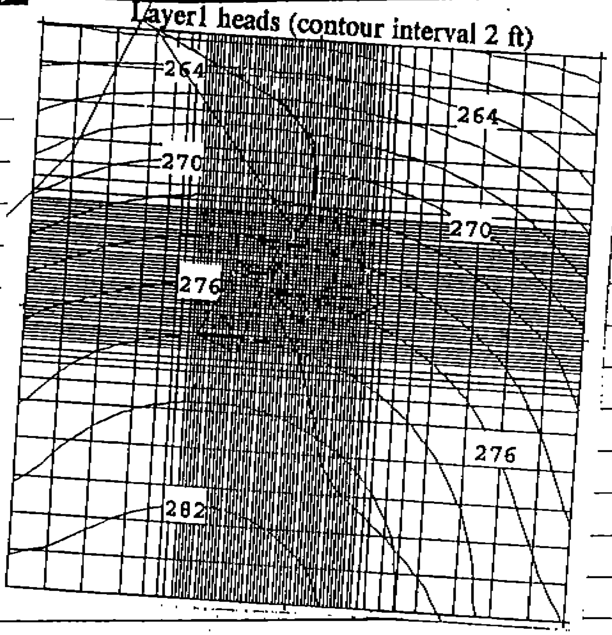
result heads look about the same at site &
gradients to south of site are too low.

↑ B
T=KB
↑ T
↑ Q

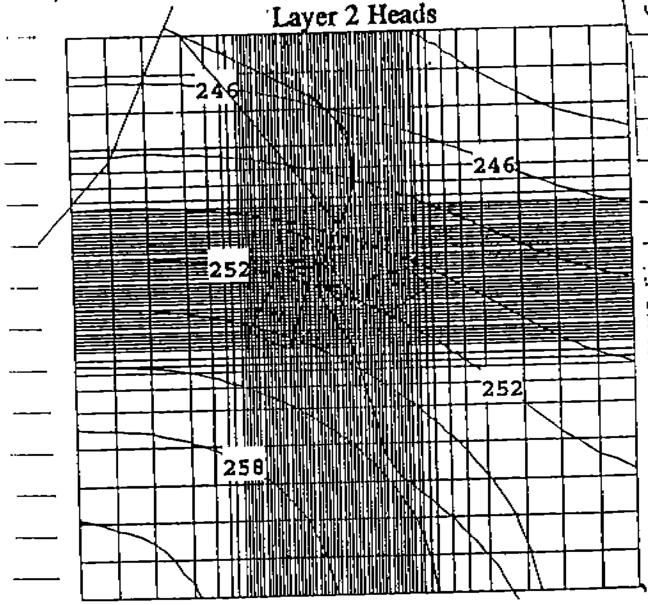
What if I slope the bottom of layer 1 so that the saturated thickness is a constant of 25 ft.
change recharge to be uniform

Save as fsbase5

Layer1 heads (contour interval 2 ft)



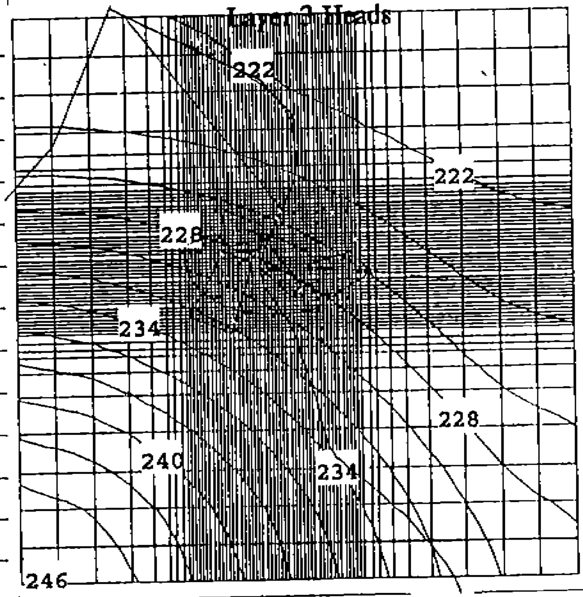
Layer 2 Heads



Thickness 15-37'

heads
much
higher
than
[illegible]

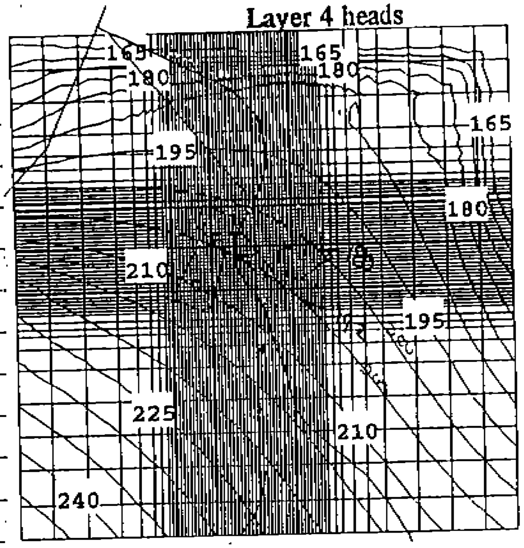
Layer 3 Heads



Thickness 2?

run

Layer 4 heads



Thickness 3?

heads
as
run
7

9

fix MT3D (fstrans3
Hthick layer1 = 25'
Hthick layer2 = lay1Bot - 220
↑
interpolated

new Modflow file
fbasic5 hff

X(J) axis = 1499 ft
y(I) " = 1500 ft
Length = 122 ft

error
retardation factor was 6.82 in layer 1
2
3
4

Fixed.

ppb = 35300 gm/ft³

for some reason there are high concentrations in the NE corner up to 110,000
rows
i = 3 j = 61
if you look at the data they are negative # -10 -2, -

Log (fstrans3) will get rid of neg & 0?

It didn't?

try Grid Contours instead of layer contours

now just 5 ppb contour in row 3 col 6?
the value is 3.7
if I up it to 10 it is still there
" " 20 ppb it goes away

For layer & grid contours. I am getting 2 contours for each
Its printing for top & bottom of layer and they don't match
It does this for grid contours. Not a good app

layer 1
5, 500, 5000, 20,000, 50,000, 105,000
layer 2
5, 500, 5000, 20,000, 50,000

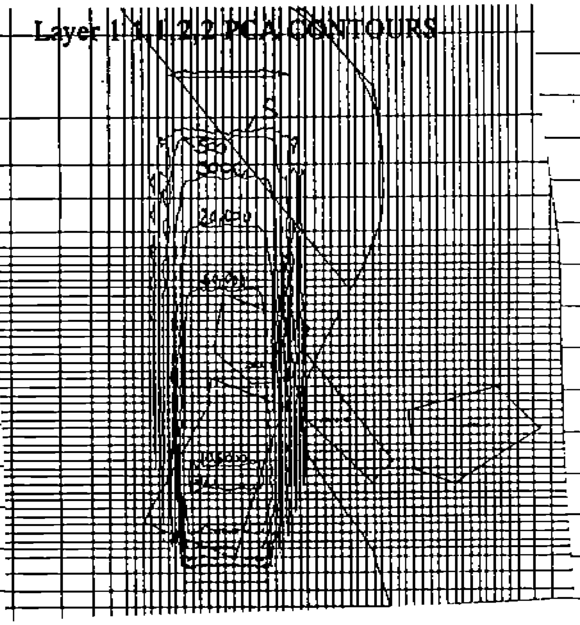
why am I getting positive contours? Get rid -999 values in layer 1 row col 62, 63, 67

col	62	63	67
starting heads	260.86	260.46	260.06

final " " not dry 25' saturated thickness ∴

So where are the -999 values coming from??

Layer 1 1,1,2,2 PCA CONTOURS



Layer 2 very few cells in Area C
are > 10,000 ppb.
many cells in Areas C & D > 5000 ppb.
more " " > 1000

Layer 3 none > 1000
Layer 4 none > 1000
none >

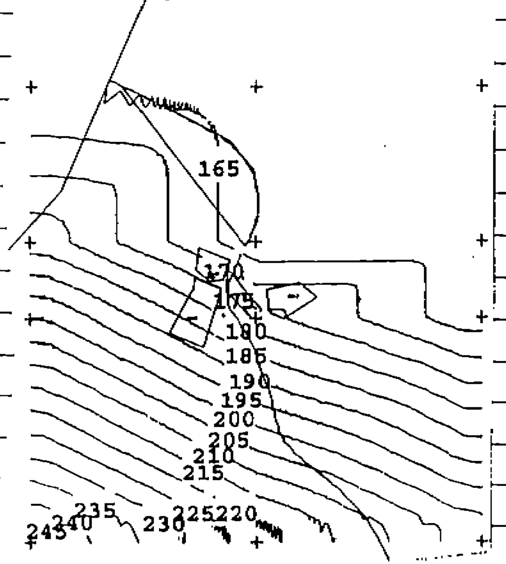
no contamination because heads
in the lower layer are 20 ft
too high

SCAT2D ·cd...lay4hd.pts subtract 20 ft
DELEV 300.0
XYD 12 corners 1 lay4hed

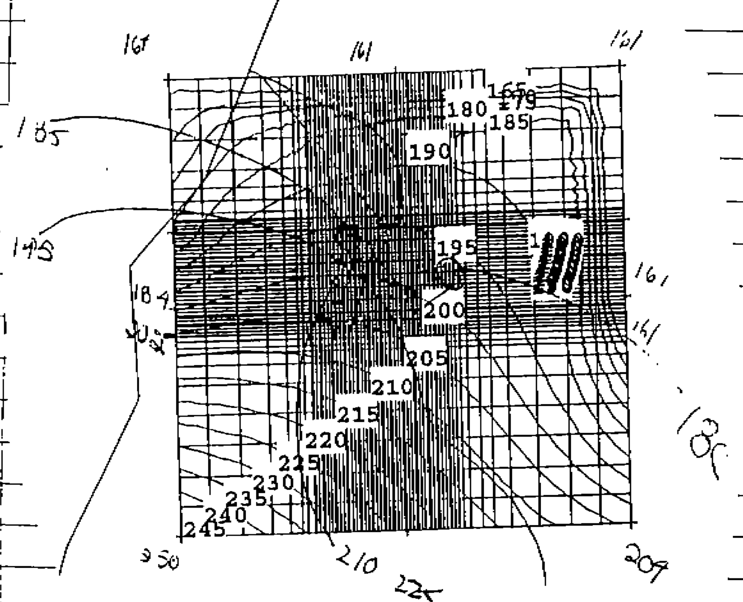
144500	134500		~~164~~	144 — constant head cell went back to original 160 is bottom
145250	134500	160 —	~~159~~	139
146000	134500		~~161~~	141
144500	134000		~~204~~	187
145250	134000		~~170~~	~~150~~ 161
146000	134000		~~164~~	~~144~~ 161
144500	133750		~~222~~	202
145250	133750		~~197~~	177
146000	133750		~~177~~	~~157~~ 161
144500•	133000		250	
145250	133000		225	
146000	133000		204	

save as fsbase 6

layer 3 linear starting heads



layer 3 linear heads



Gradient in layer 1 is twice to big across areas 3 + 4 so decrease head at SW corner

save as fsbase 7

save as LAY1HOB.PTJ.

Mass Balance CH IN = 0.65084 E7

Recharge in = 0.1048688

total in 0.16995E8

60% in from recharge?

% discrepancy = 0.00%

Heads in L1 Look funny

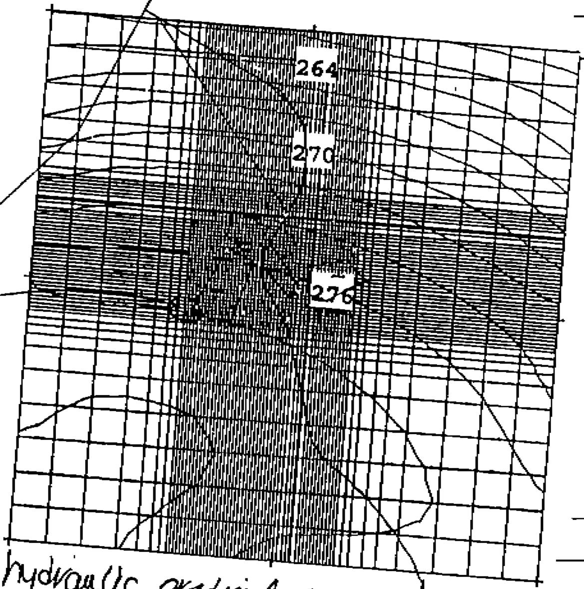
too low at site model says 276 in middle of area C should be 277.5

Revise LAY1HBE [illegible]

still to low

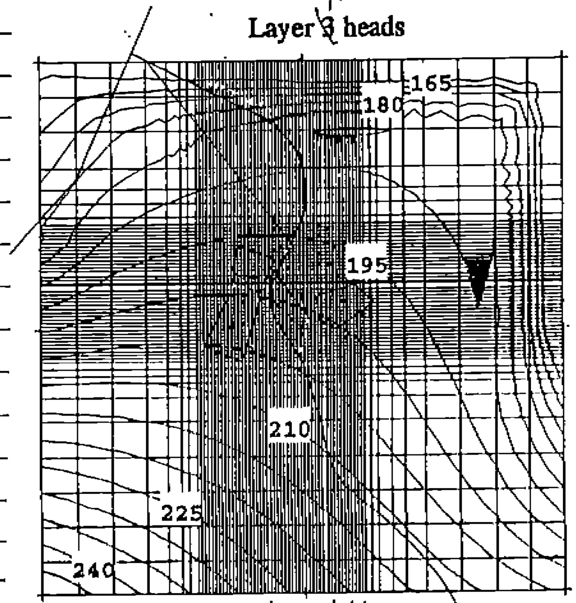
Revise " "blue

Layer 1 heads



hydraulic gradient across strike still too high

Layer ~~3~~ 4 heads



heads are about the same

So lower head in layer 4

Lay4HDB.PTS

SCAT2D
DELEV 300.0
XYD 12 corners 1 lay4hed

144500	134500	~~164~~157
145250	134500	161/51
146000	134500	161/51
144500	134000	184 169
145250	134000	~~161~~151
146000	134000	~~161~~151
144500	133750	202
145250	133750	~~177~~ 161
146000	133750	~~161~~ 151 90
144500	133000	250
145250	133000	225
146000	133000	204

change bottom = starting head - ~~10~~' 5

Because it will mound up a lot

no bottom of L4 is [illegible]

-15

50695

Bottom elev

L1 257 – 235

L2 220

L3 195

L4 237 – 141 150

~~hand fix rows~~
~~53,54,55 all cols~~
~~set = to row 52~~
~~will make L3 20' thick~~
~~x-198 = -14~~
~~col lizrow 30 10/1~~

Too much work

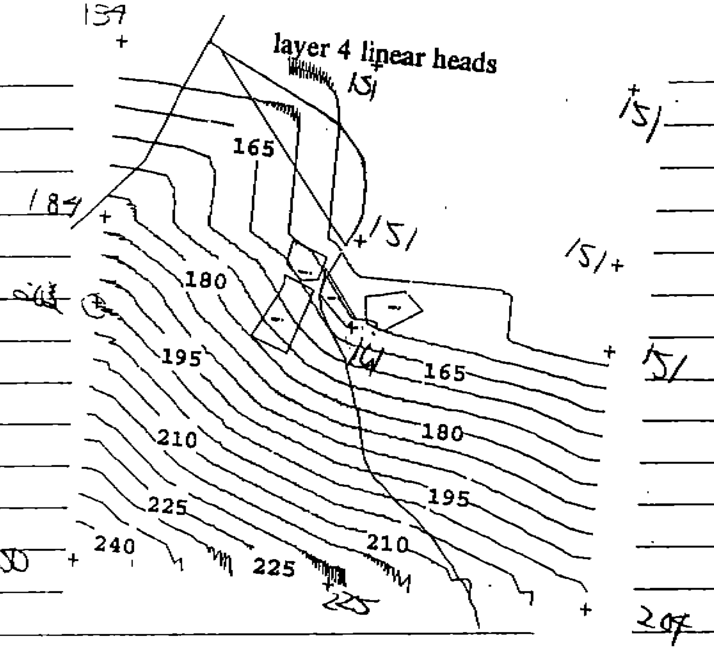
Change

Doesnt matter what thickness is upgradient of site

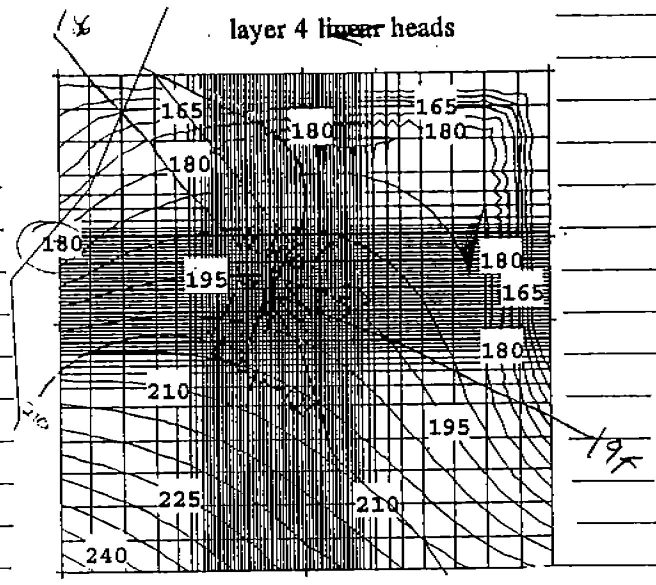
SAVEAS fsbase8

result

layer 1 about the same


layer 4 linear heads

layer 4 is better


layer 4 ~~linear~~ heads

update thickness of bottom layer
in
fortrans}

195-50= 45 lay4 bot

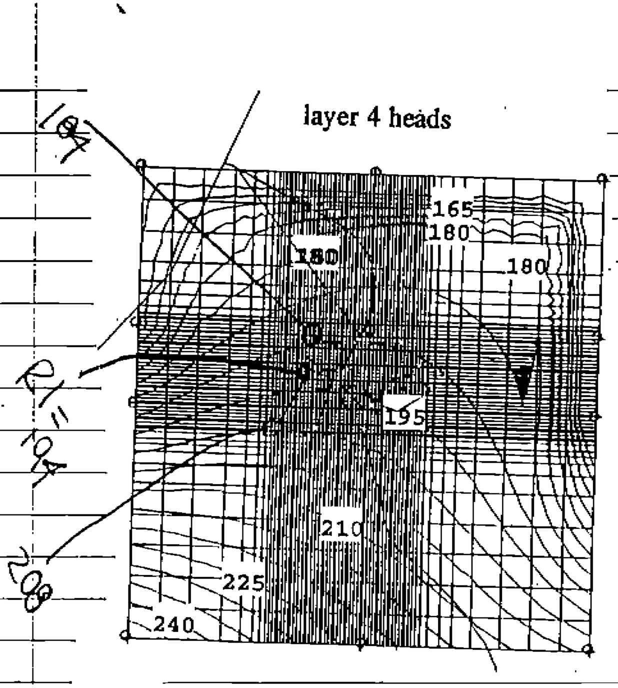
~~to~~ MT3D results
max C = 1,151,300 ?

same C in L4

70,000	L1	row 18
? 11,890	L2	col 23
100	L3	
5	L4	

conc to low so decrease
heads in L4 by 15 more ft
save as lay4HDC.FTS
in green

These results did not
use the updated flow file
but I updated the flow
file before I could [illegible]


layer 4 heads

[illegible]
row 18 col 23

L1	7.098x10^4	=70980
L2	1.023x10^3	1023
L3	9	
L4	.1	

max conc = 115328.7

why aren't conc getting down to layer 4?

1. not enough $\overset{\text{vertical}}{\wedge}$ hydraulic gradient

2. Intermediate is too thick
as compare to RI

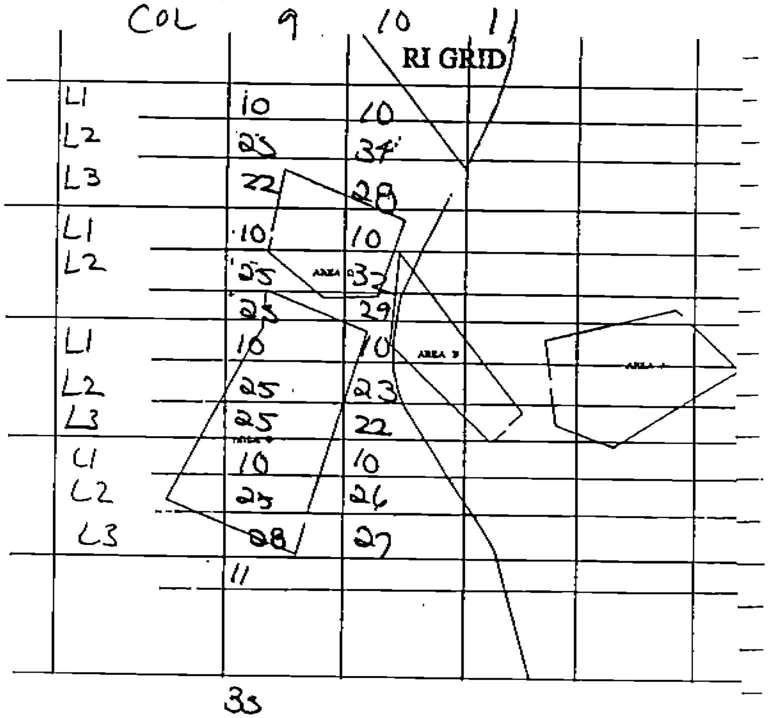
ck...

at Area ~~2~~ 4 SW corner / bottom
RI (col 8 row 16 FS (col 10, row 41)

L1	10	L1	25	235-257
L2	31	L2	30.8	720
L3	3[illegible]	L5	25	195
L5			55.5	
L3	34	L4	45	150
	75		125.8	

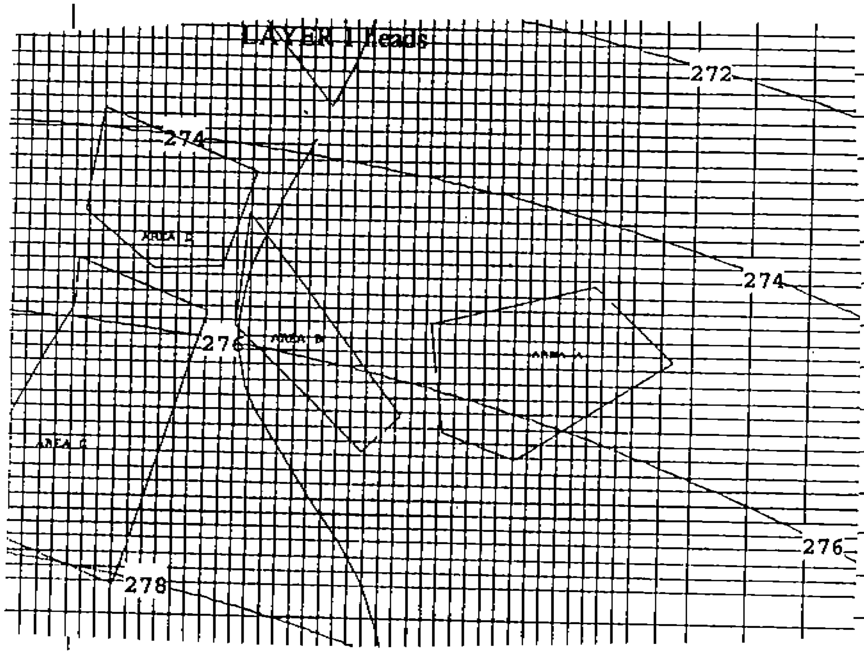
So have to fix thicknesses

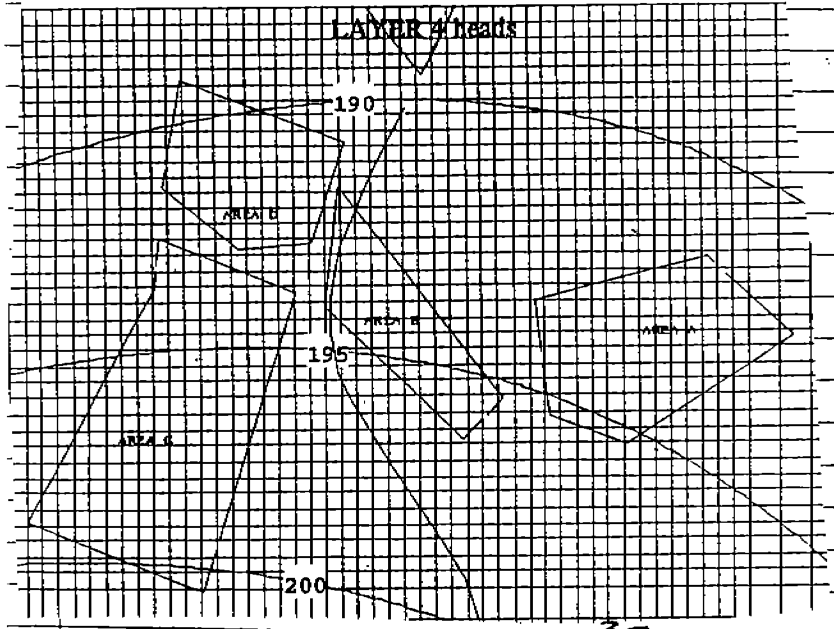
not



COL	9	10	11
L1	10	10	
L2	25	34	
L3	22	28	
L1	10	10	
L2	25	32	
	25	29	
L1	10	10	
L2	25	23	
L3	25	22	
L1	10	10	
L2	25	26	
L3	28	27	
	11		

35

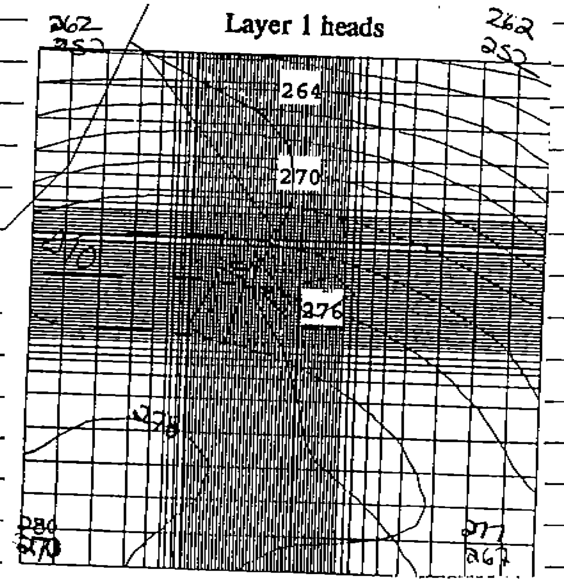

LAYER 1 Heads


LAYER 4 heads

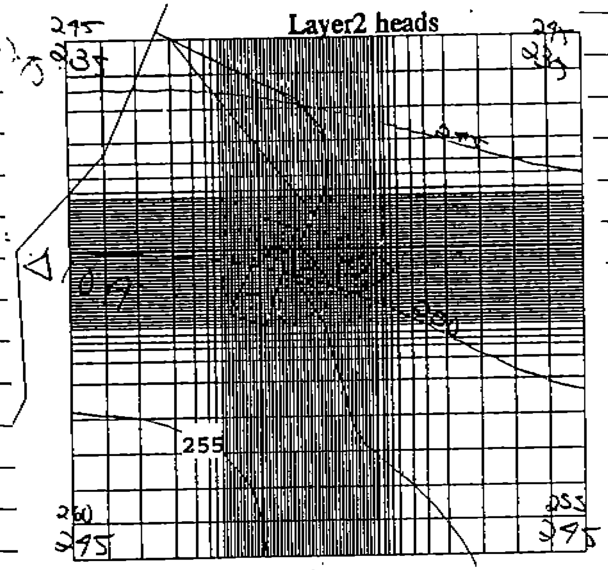
		NW		NE		SW		Se	
sat thickness		Head	Bot Elev	Head	Bot Elev	Head	Bot Elev	Head	Bot Elev
0	L1	262	252	262	252	280	270	277	267
-			22		22		28		27
15	L2	245	230	245	230	260	245	255	240
			25		25		30		25
15	L3	220	205	220	205	240	225	230	215
			79		77		10		35
25	L4	151	126	151	126	240	215	205	180
	Δ	112		112		40		72	
			252 -151 100	252 -151 101		270 -240 30		267 -205 62	

Heads from ft base 8 before I changed bttm elev

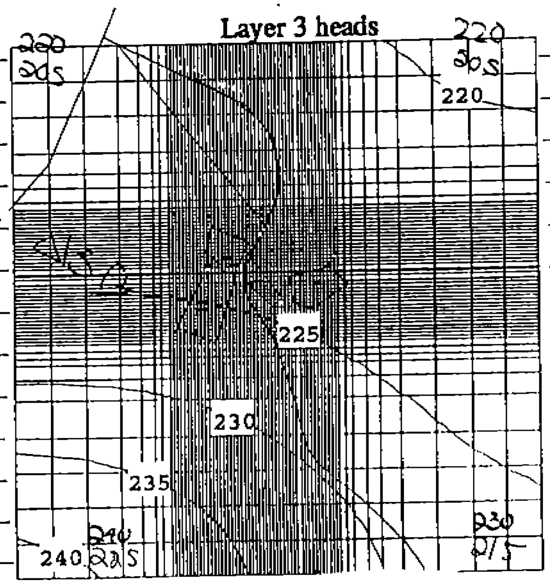
Layer 1 heads



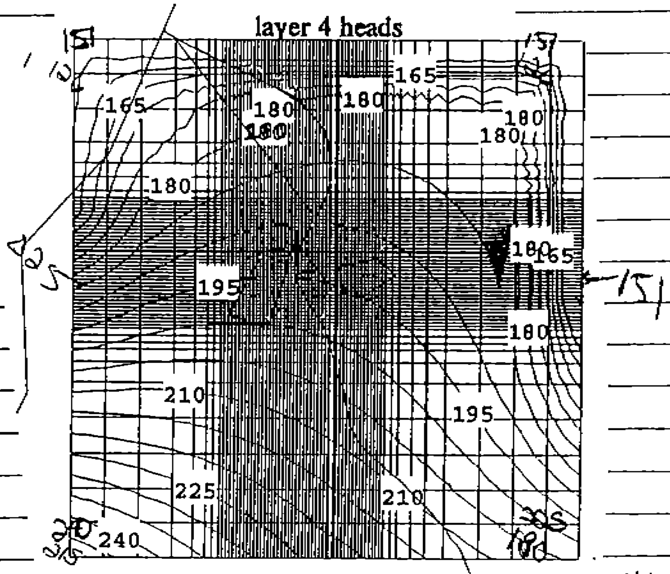
Layer2 heads



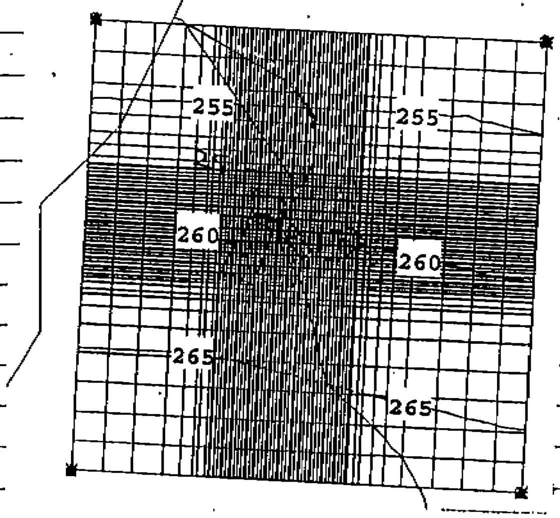
Layer 3 heads



layer 4 heads

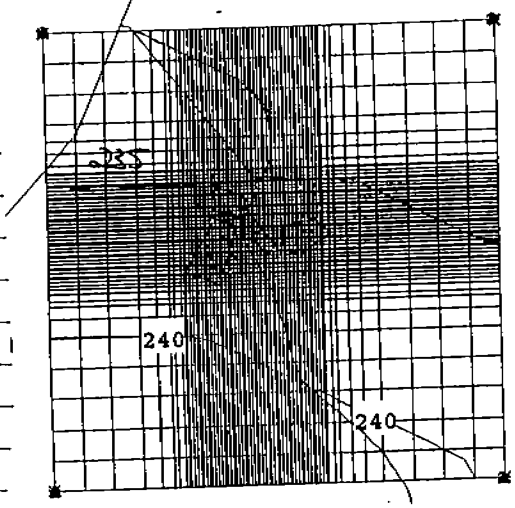


Layer 1 bot



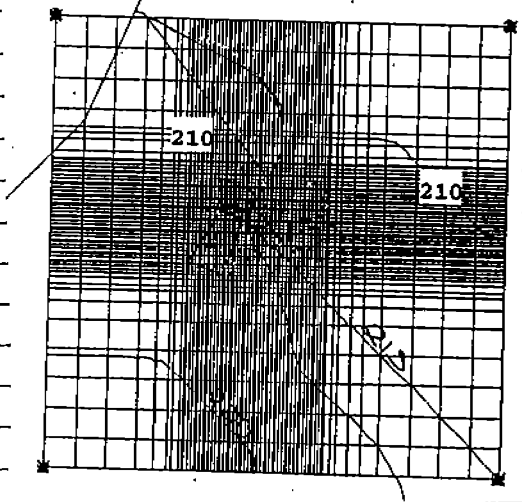
L1bot. pts
ay

Layer 2 bot



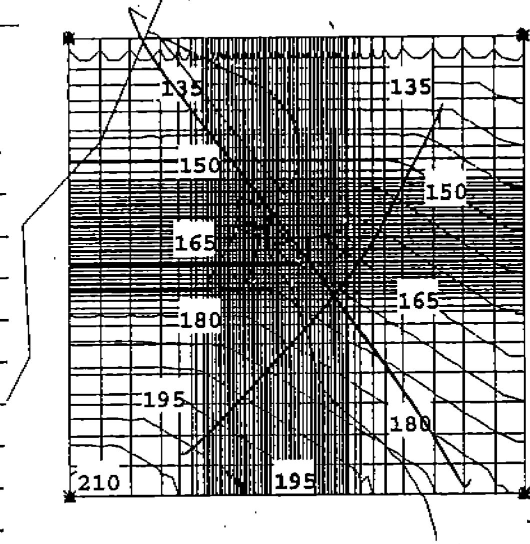
L2bot. pts
ay

Layer 3 bot



L3bot pts
ay

Layer ~~1~~ 4 bot



L4Bot. pts
ay

→ this change

d4
run it as fsbase9
layer 4 went dry
aborted because L4 row 30 col 64 went dry

Bot elev = 151.8
head = 151.6
soln drop Bot elev at SE boundary 5ft
from 180 to 17.5
Layer 4 still went dry
add pt x= 146000 (j=12)) midway
y= 133750 (i=16)) N/S
L4 Bot = 151
save as Lay4B2.pts
Ran..

heads in L1 much higher
2 5ft higher at site

compare thickness at site
at Area 4 SW corner

FINAL

fsbase1

P1(col 8 row 16)	F3(col 10 row 41)	.FS
L1 10	L1 281 head - 261.54 bot = 20	-262
L2 31	L2 261 - 238 = 23	46 262-237
	L3 238 - 215 = 23	237-215
L3 34	L4 215 - 159 = 56	165
tot 75	tot	

Still too Big
Soln → set Bot elev at site add pt
col 10 row 41 =
x 145000
y 133700
assume old heads because they are what we want

LAyer	Head	desired thickness	resulting pt
1	278	10	268
2	251	15	236 ← these
3	226	15	211 ← are close to exist.
4	199	34	163

check cu

save as Lay1B3.pts
Lay4B3.pts

some 0 heads in L4
col 38-41
row 19-22) Bot elev = 154
-155

CK law

add pt x 145200
y 133900 Bot elev = 152 in (q4r3).p

Lay4B2.pts

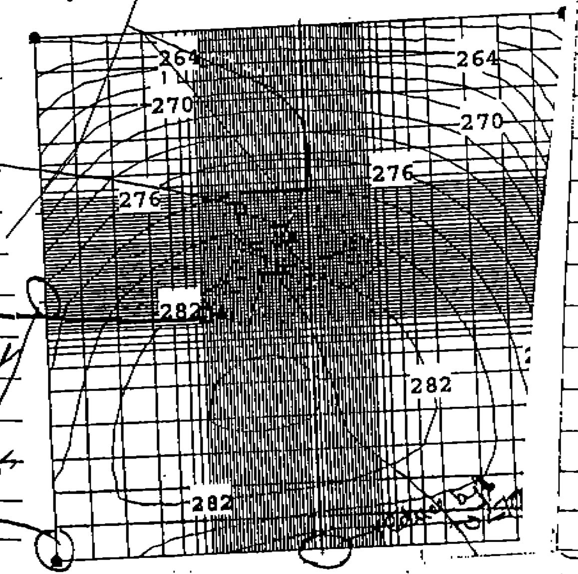
```
SCAT2D
DELEV    0.0
XYD  5 corners 1 14bot
   144500  134500       126
   146000  134500       126
   146000  133750       126
   144500  133000       215
   146000  133000       170
```

SCAT2D Lay4B3.pts

```
DELEV    0.0
XYD  7 corners 1 14bot
   144500  134500       126
   146000  134500       126
   146000  133750       126
   144500  133000       215
   146000  133000       170
   145000  133700       165
   145200  133900       ~~152~~
                        140
```

save as f3base10.

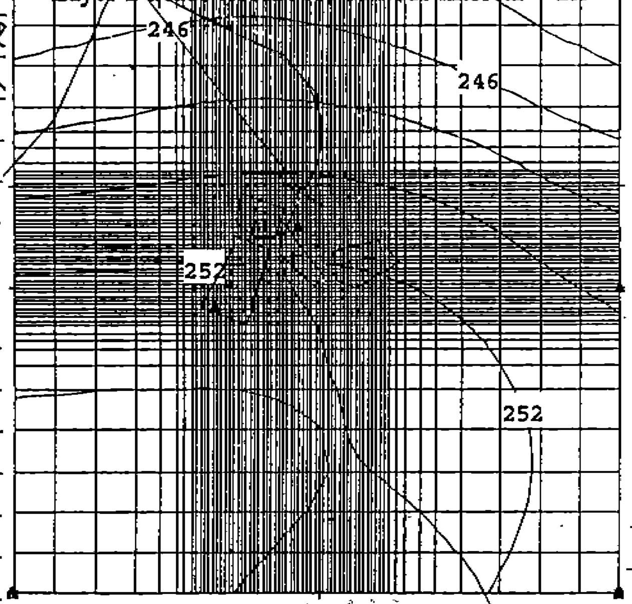
Layer 1 heads (fsbase10) contour interval =2ft



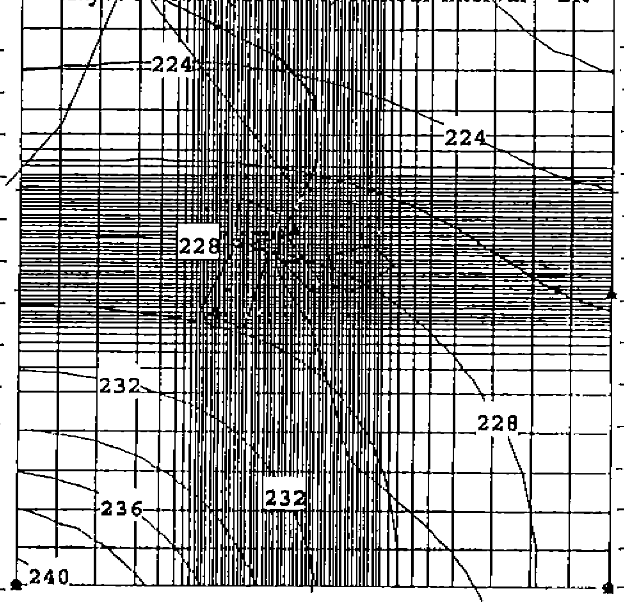
14430
13578
3
...uce by 6 ft
from 282 to 277

reduce by 2 ft to 277

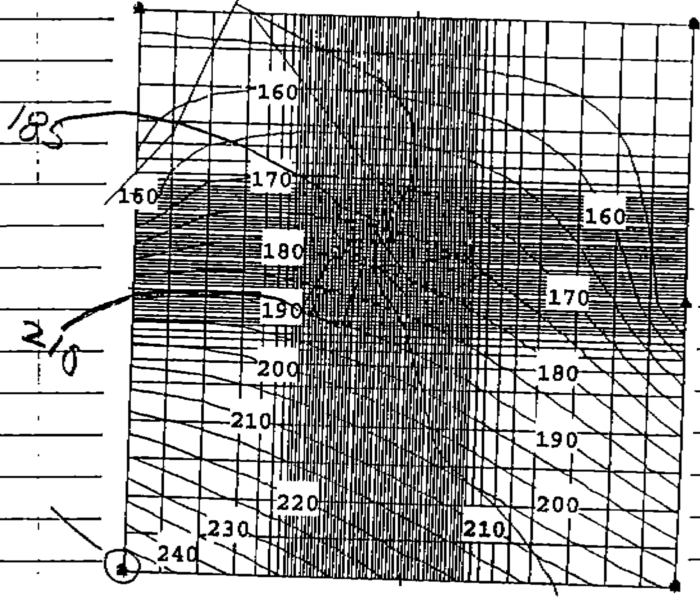
Layer 2 heads (fsbase10) contour interval =2ft



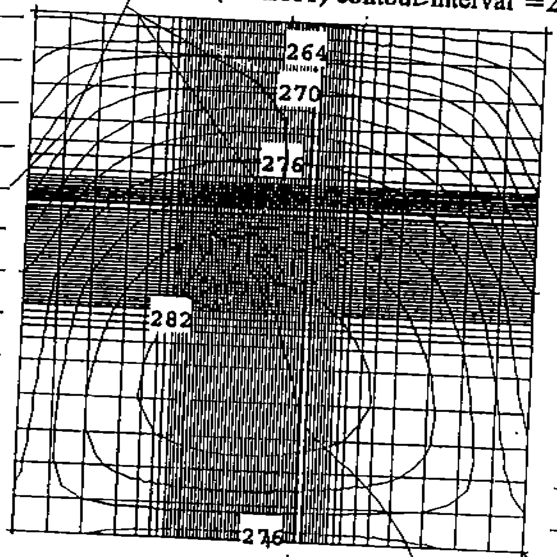
Layer 3 heads (fsbase10) contour interval =2ft



Layer 4 heads (fsbase10) contour interval =5ft



layer 1/heads (fsbase11) contour interval =2ft



reduce from 277 to 272

② reduce from to 277 274

3 reduce from 272 to 270

② Reduce head by 5ft from 277 to 272

reduce from 272 to 268

②

① Reduce recharge by 25%
from 6.8×10^{-4} to 5.1×10^{-4}
result better, but still get a mound

③ change sides to no flow.
Didn't work well

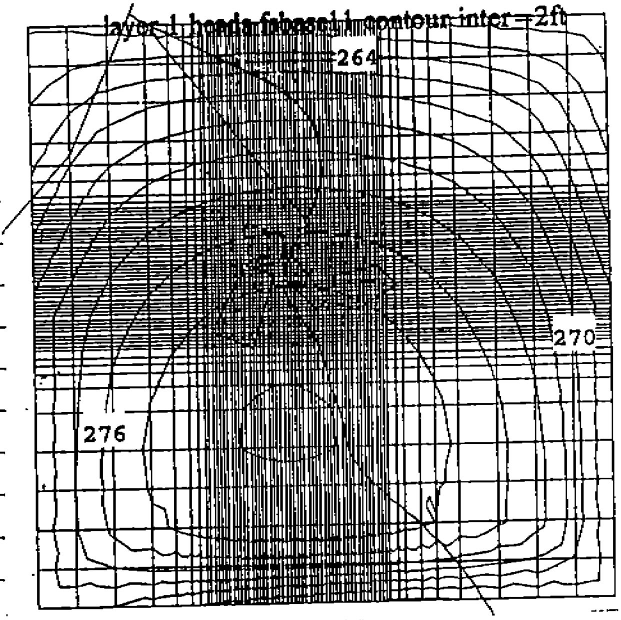
```
SCAT2D
DELEV    0.0
XYD  9 corners 1 lay1hd
  144500  134500        262
  145250  134500        262
  146000  134500        259
  144500  133750   273  ~~275~~
  145250  133750   271  275
  146000  133750   268  273
  144500  133000   270  ~~277~~
  145250  133000   270  274
  146000  133000   268  ~~272~~
```

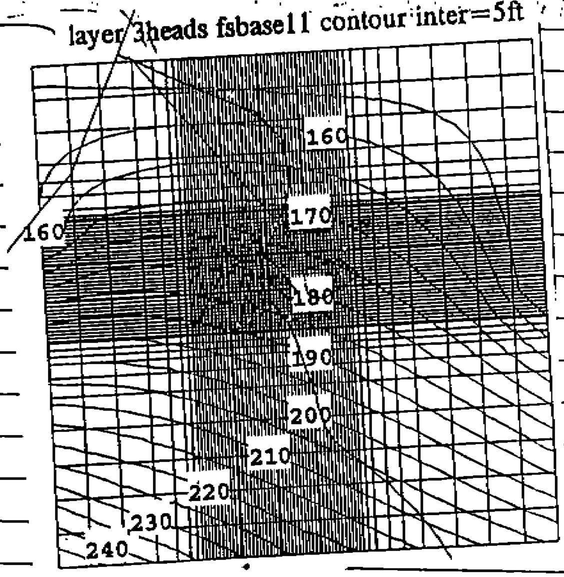
change recharge back to 100%
and leave it no more time

no heads in layer 1 off too
much. Change back to 75%

ran MT3D
Change max # particles
from 75000 to 125,000
adv MXPART

Concentrations for RI in Lower Aquifer (L
were > 500. Conc for this run in
Lower Aquifer (L4) were only as high
as 100





hy ayer 3?

RI Layer 3 max C =

row 16 col 8 - 1151

80 - 60 = 20

change recharge back to 100% &

Increase leakance by factor of 2

from 1x10⁻⁵ to 2x10⁻⁵ = 0.00002

no improvement to concentrations in layer 4

increase to 5x10⁻⁵

result 1 zero head L2 row 55 col 64

far SE corner

so change that cell L to 2x10⁻⁵ (8%

concentrations in L4 as high as 1,0C

lots at 750 in areas 3 & 4 & down

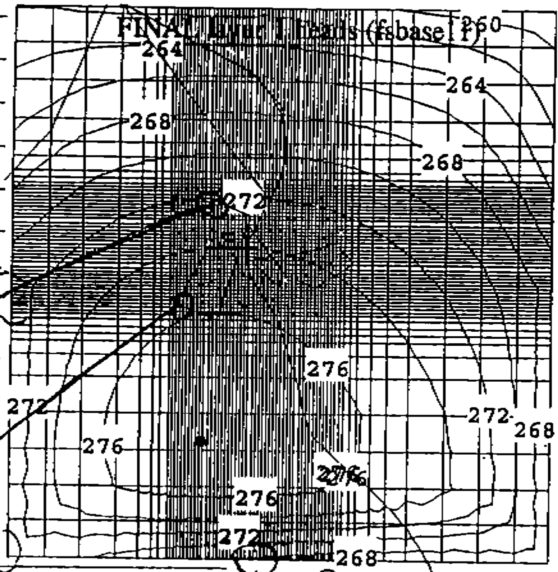
~~gradient of~~ 4 It is moving faster

in L4 but that doesn't matte

~~[illegible]~~

conc in layer 1 as high as 311,369

(way too high!)


FINAL layer 1 heads (fsbase11)

heads way too low

increase by 2

276

in 72 to 274

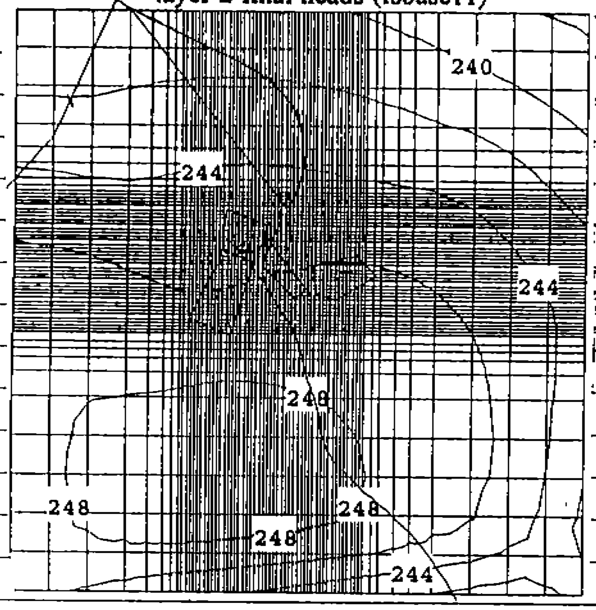
278

increase by 4

from 272 to 276

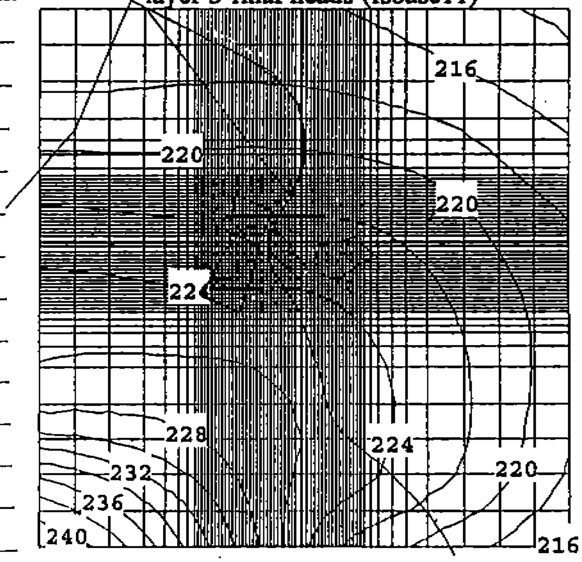
increase from 270 to 274

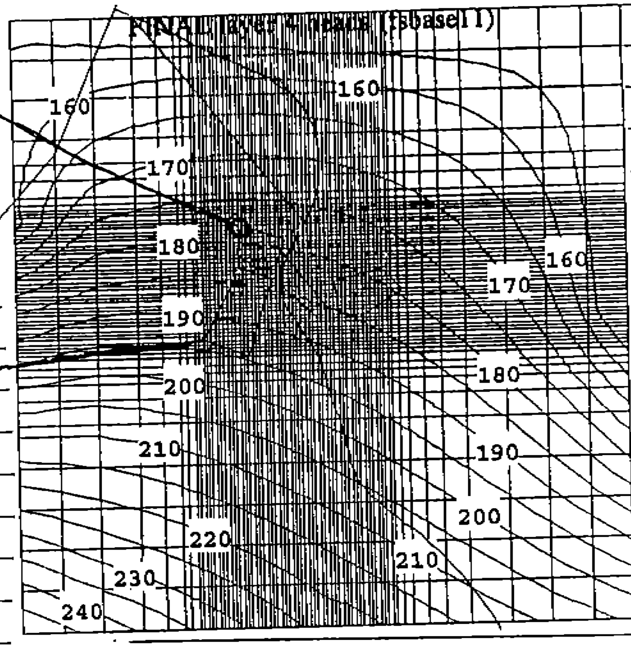
layer 2 final heads (fsbase11)



54

layer 3 final heads (fsbase11)




FINAL layer 4 heads (fsbase11)

15

heads too

210

55

~~Decrease leak to $3x10^5$~~

Increase starting heads in L1

maxconc still 300,000 & something in L1

heads are a little better

decrease leak to $3x10^{-5}$

forgot to fix MT3D thickness I think

LAY1B3.pts
LAY2bot.pts
lay3bot.pts
lay4B4.pts

save as fstrans4.~~pts~~

~~w~~FSTRANS3.RCT & FSTRANS4.RCT have the wrong retardation factor

Stick w/ fstrans4 but fix ~~too~~ rct file
still will not run. ⇒ runs very slow
max particles exceeded.

FINAL FSTRANS4

Fstrans3 runs fine w/ same heads so I will assume that I didn't calc thickness correctly & will redo them & ~~put them~~ store them in FSTRANS4

L1 leave
L2 22-29 mean 27
L3 20-24 mean 23
L4 [13-83 ft mean 63 ft

FSTRANS4 runs now

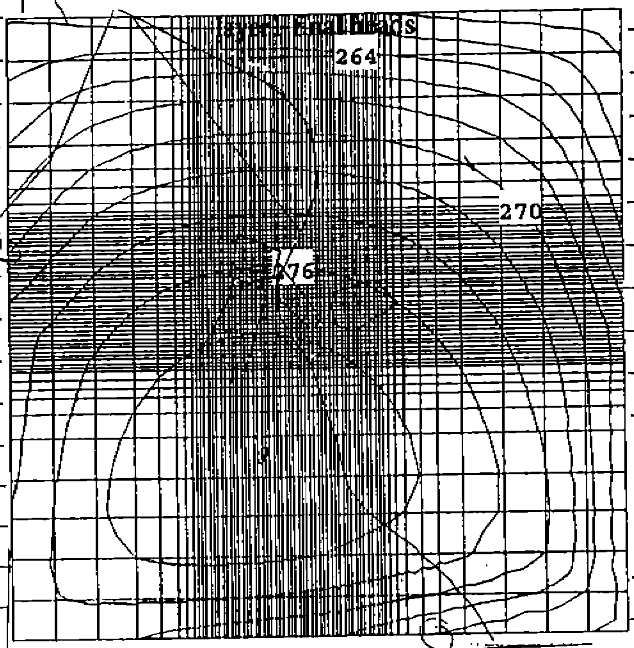
L1 >50,000 in Areas 3 & 4 good match w/ RI
100,000 in Area 3

L2 concentrations of 10,000 in Areas 3 & 4
conc of 25,000 / 21,000 Area 3

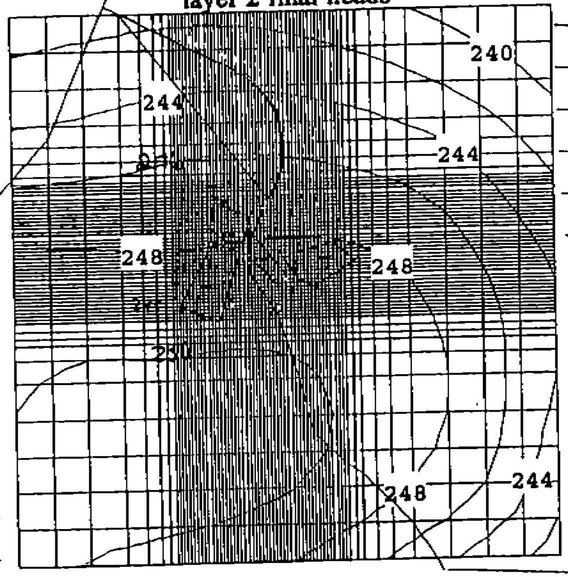
L3 ≤10

L4

23

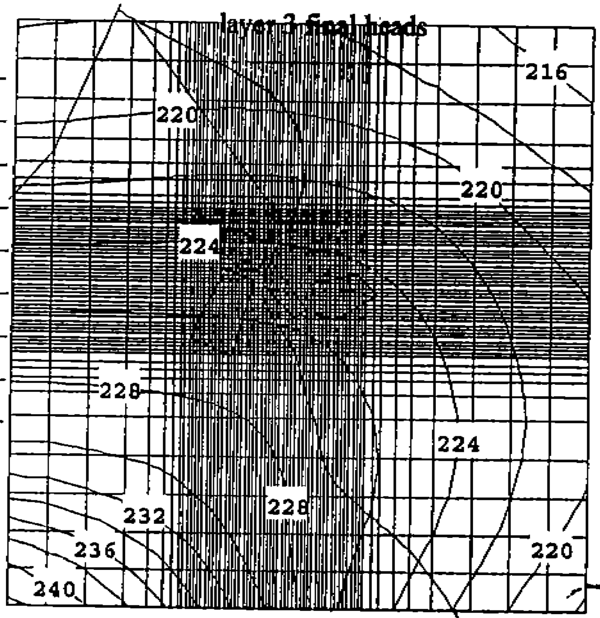


layer 2 final heads

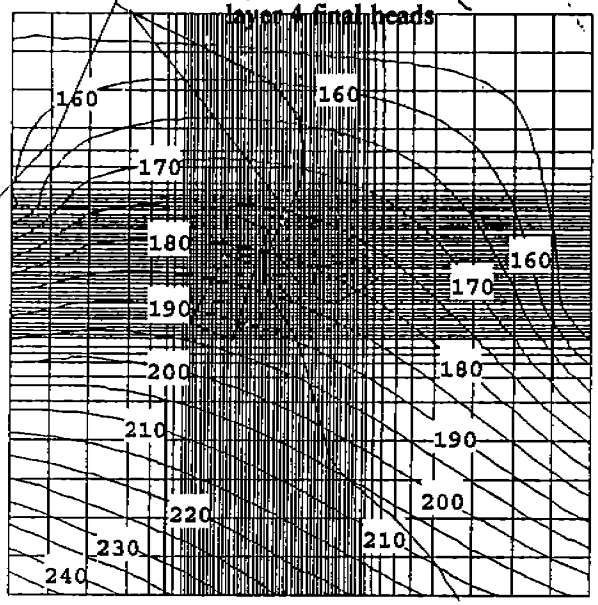


ory
ked
ins
- drain
47-249

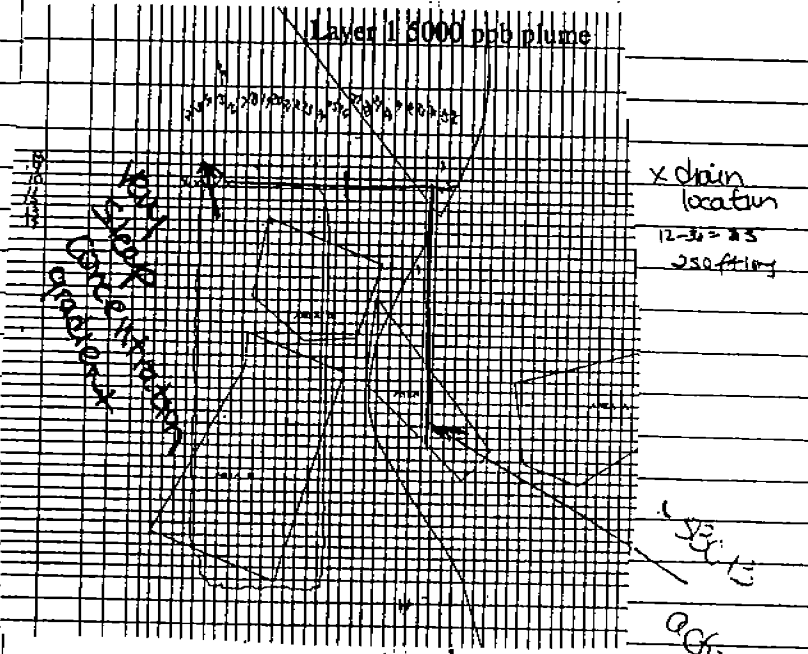
layer 3 final heads

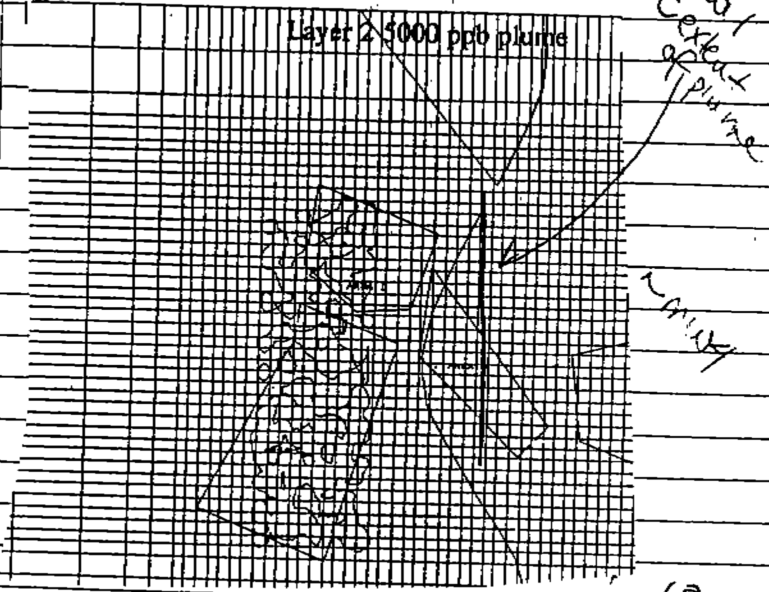


layer 4 final heads



15 to 8 //
% discrep:





Install drain in layer 2 at bottm
Bottom of layer 2 = 234

gravel k = 5-100 cm/sec

$\frac{5 cm}{sec} \times \frac{3600 sec}{hr} \times \frac{24 hr}{day} \times \frac{in}{254 cm} \times \frac{ft}{12 in} = 14173 \frac{ft}{day}$

If Leakance = $\frac{b}{k}$

$3 \times 10^{-5} = \frac{b}{k}$

$k = 20 / 3 \times 10^{-5} = 666,666$?

Hmm if Leakance is constant for each layer am I really simulating dif ks.

Save as fspuml

getting zero heads at draincells so change elevation from 234 to 235

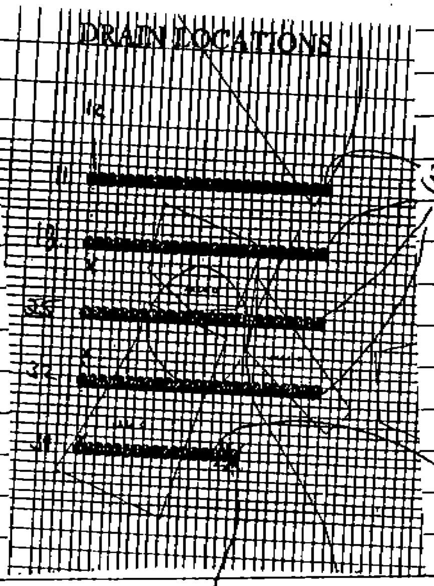
result no zero heads

radius of influence is very small approx 10' on each side

add — drains:

change bottm elev to 240
because at S end bottm of L2 = 238

Bot ele



Layer 1	L2
241	234
263	235
264	236
264	~~237~~
~~267~~	237

36

24

)1
)2
)3
)4
)5

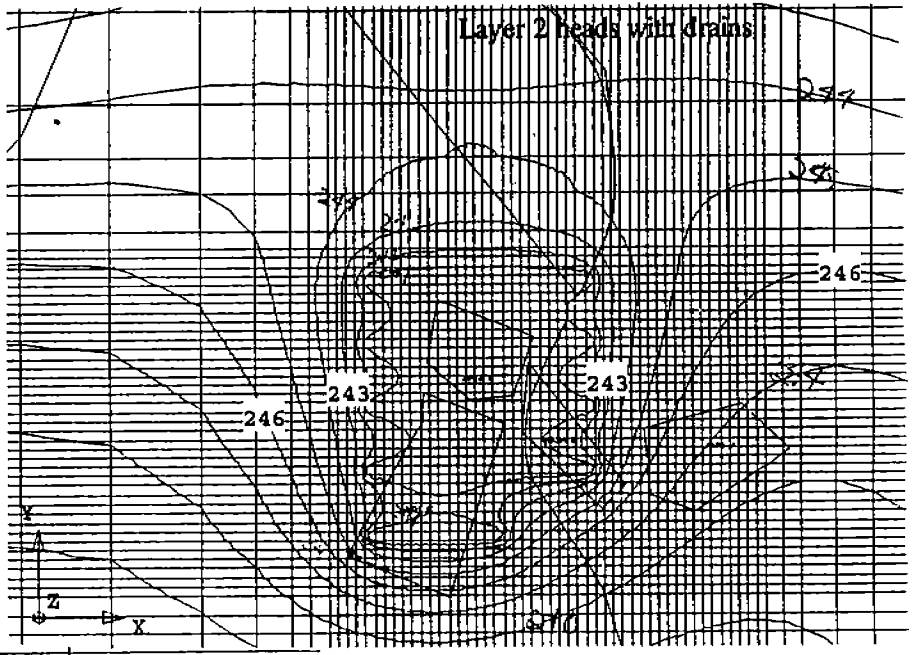
dry cel 27828 c(131)

removed no reed

no dupcells

[illegible]

no changes in heads in layer1



Drain ① = 45.85 $\frac{ft^3}{day}$

$45.85 \frac{\cancel{ft^3}}{\cancel{day}} \times \frac{\cancel{day}}{24 \cancel{hr}} \times \frac{\cancel{hr}}{60 min} \times \frac{7.48 gal}{\cancel{ft^3}} = 0.24 \frac{gal}{min}$

= 350 gal/day

put drains in Layer 1 q/o

save as fspum2.

Bot elev of layer 1 at row 11 = 261.8
267.5

assume drain at 263

drycells [almost all of layer 1
so assume drain at 264

still zero head

assume drain at 265

add +2 to bot elev for Drain elev

still have zero head
in layer 2

Increase Drain 2 elevation
from 240 to 242

decrease Drain 1 elev from 240 to 237

still zeros

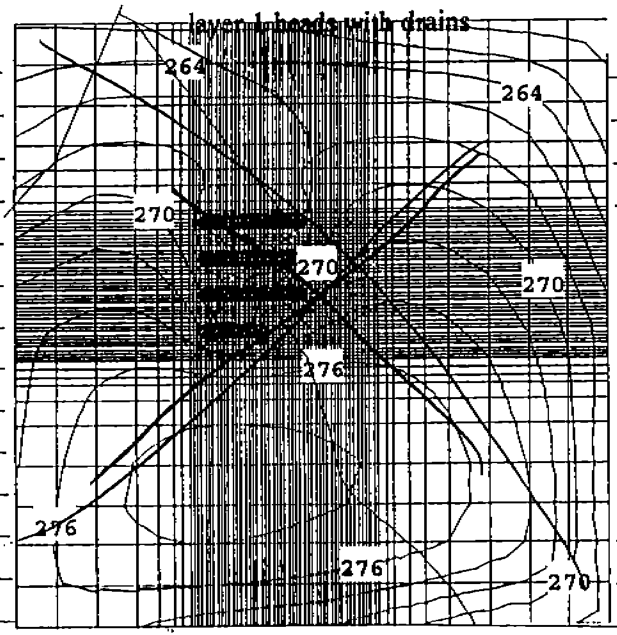
Decrease from 8 drains to 7 drains

save as fspum3

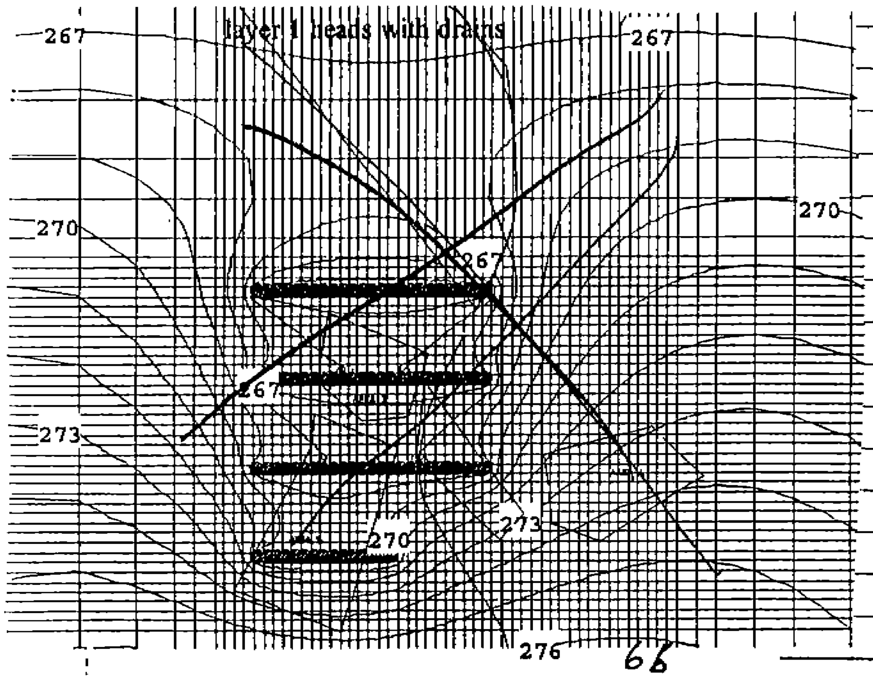
Row	L1	Elev	L2	
	BOT	DRAIN	BOT	DRAIN
11	261.9	264	234.9	237
20	263.7	266	235.8	238
29	265.5	268	236.7	239
30	267.3	269	237.6	240

drycells in L2 at
rows 17-32
so row 20 & 29 raise Drain elev to 240

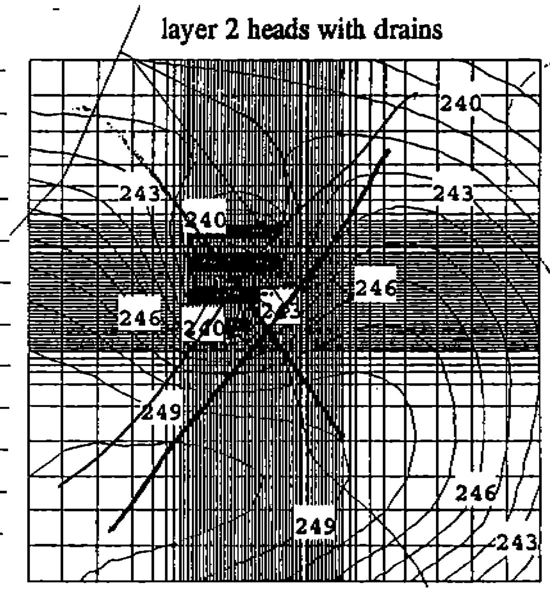
heads okay no dry cells



layer 1 heads with drains

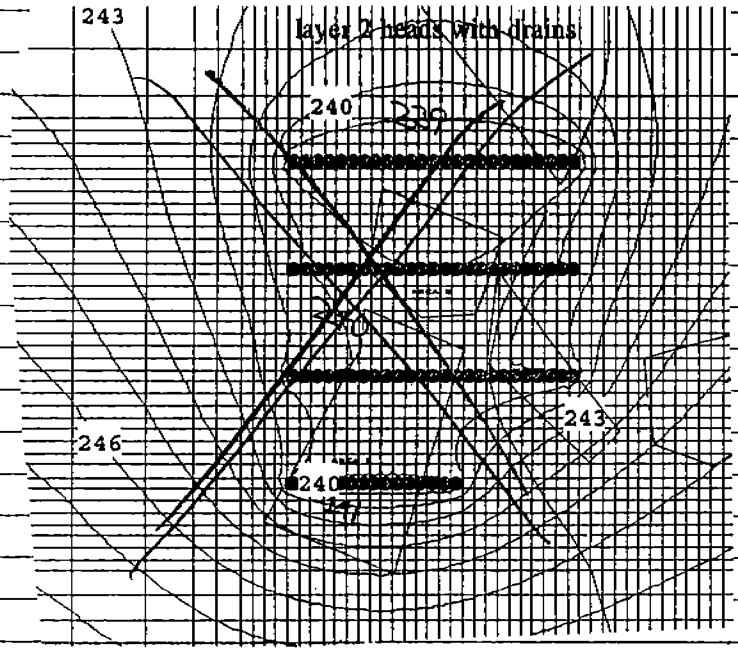


layer 1 heads with drains



layer 2 heads with drains

Unstab



layer 2 heads with drains

this soln didn't converg

drains = 1303 ft³/day

read in starting heads
save as fspum4

still failed to converge
drains 2771 8.0

munt13
sip soln
max it = 200
it par = 5
acc par = 0.5
head change crit = 0.01
printout In = 0
seed = 0.990

save as fspum5

still will not converge heads look
like same

Change acc parameter from .5 to .4
change seed from 99 to .999
converged after [illegible] 198 iterations

Drains out 768.38 ft³/day

4 gpm

5700 gal/day

16% off in soln rerun
reran w/new heads
converged by 29% off
drains 938.8 ft³/day

rerun
change accel par from .4 to .3

53 interation
51.1% off
Drains 1763.2

Change acc par from .3 to .5
didn't converge

default SIP values
~~a~~ max iter = 50
#of iter par = 5
acc par = 1
head change criteria for conv = 0.001

TM ⟶
acc par = 1
seed calc by program
head change = 0.001

didn't conv
soln 200% off
doesnt tell you what seed is

---

rerun w/ seed = .99
didnt converge.
% off = ~~180~~ 176%

---

rerun w/ seed = 0.99
acc = 0.5
didn't conv 89% off

rerun w/
Δhead = 0.005
didnt conv
89% off

change acc par to .3
didnt conv
70% off

retry
acc = 1
seed calc by prog.
$\boxed{\text{head chang = 0.01}}$
didnt conv
193% off

rerun w/ acc = 1; seed = 0.990; head ch = 0.01
didnt conv

rerun w/ acc = 0.5 seed = 0.99
didnt conv
89% off

---

change acc par from .5 to .7
converged at 290 iterations
23% off
drain = 856.4 ft³/day
change ΔH from 0.01 to 0.005
& use new head
didnt converge?
change to 0.008 conv in 4 iteration
Drains = 575.69
soln is ~~e~~ 8.77% off

conv w/ CMZ

If Ctl value are ~~rea~~ reasonble

3" too high
or .5ft to low

T lower
recharge

flushing will be slow
Thunderstorm
3" → 5-15ft
D 1.0" into gw →
C .5ft/day

decrease 0.01
.001

look head
mass balance > 1%
reduce head criteria
to run more balance

1%
results as initial head

Bigger the seed the

smaller
smooth converge process

Change
Small seed faster conv

~~to~~ use new heads ~~at~~ and change
ΔH to 0.005
didn't conv soln 83.9% off

change ΔH to 0.006
didn't conv

chang ΔH to 0.007
didn't conv 83.9% off

chan ΔH to 0.0075 beyond
resolution of gms

All instability in layer 2 at 2,11
& 2,29
2,38

Bring drain elev up 1 ft

Row	old drain elev	new drain el
11	237	238
20	240	241
29	240	241
38	240	241

ΔH = 0.007
It converged in 469 iteration

14% off
drain = 691.61

go back to old drain elev

decrease acc from to 0.3

except 211 / ~~leave at 238~~ /
~~most of the problem is the~~
change to 240

conv in 126 iteration

37% off

go back to orginal drain elev
ΔH = 0.0087
& change acceleration to 0.35
~~didn't converge~~
~~off by 29%~~
conv in 11 iteration
3% off
drains = 455.45

change ΔH to 0.006
didn't run so rerun with old starting head

still didn't converge 100% off

change acc par to 0.3
~~% change =~~ Only 0.7% off

Drain = 378.89

Its worse so go back

changed back to acc = 0.35
converged but
28% off

rerun w/
$\Delta H = 0.007$
now 3.9% off

I'm not sure how I got
% off = 0.7%

$\Delta H = 0.006$
acc par = 0.35
% off = 3.4%
Drain 325.91 ft^3/day

rerun
with new head
5% off

change acc from 0.30 to 0.2
4% off

chang acc to .1
4.7% off

acc = 0.35
$\Delta H = 0.006$
off by 18.9%

rerun ~~of~~ after importing head
off by 24.9%

not sure how time units
were changed to minutes ??

as far back as ftbase11.sup ??

converged
% of = 16.7

drain = 701.99 ft^3/day

change ΔH to 0.005 16% off
converged

import heads
change to 0.004 = ΔH
didn't converge
read heads in again
didn't converge
change $\Delta H = 0.005$
converged 15%
Change ΔH to 0.004
didn't converge
since heads .1 off

~~change~~
change seed to ~~.900~~ 0.999
ΔH to 0.0045
converged 15% off

read in fsbase11 heads
ΔH = 0.006
acc = 0.35

didnt converge
read in heads

21% off

Change ΔH = 0.005
Converged in 1 iteration
15% off

Change ΔH = 0.004
didnt converge
read in heads
didnt converge

Change acc to 0.3
Converged in 80 iterations
37% off
Drain = 1008
read in heads
converged in 4 iterations 13% off.

Change ΔH to 0.003
converged
% change is 11.43%
read in heads
change ΔH to 0.002
converged in 198 iteration
11.5% off

Change ΔH to 0.001
& input heads
didnt conv
read heads in again and
didnt converge
Change ΔH to 0.0015
didnt converge
change acc from 0.3 to 0.25
didnt conver
31.7% off

The soln is unstable at drain
increase K drain to 50cm/sec
= 141730 ft/day
save as fspump6

didnt conver 57% off

Change back to
Use fspump5
run to 300 iterations; didnt converge
17% off

ran with package
for 300 iteration
didn't converge 150% off

try decreasing K in drain to
sand
k = 5x10⁻² cm/sec 0.05
=
0.05 cm/sec × 3600 sec/hr × 24 hr/day × in/2.54 cm × ft/12 in = 141.73

use SIP
acc = 0.35
ΔH = 0.006
seed = 0.99

same as fs~~[illegible]~~ pum 6
converged in 6 iteration
discrep = 0.34%

drain Q = 202.78

Heads layer 2 at drains / A3/A
heads from 249 - 252 higher
than base case?

fspum 6.

Increase k drain to .5 cm/sec
k = 1417 ft/day
drain Q = 235.1 ft³/day = 1.3gpm
= 1800ga/day
converged
1.95 % off

L1 & L2 looks good

Increase k drain to
k = 5000 ft/day
% off = 7.3%

go back to k = 1417 ft/day

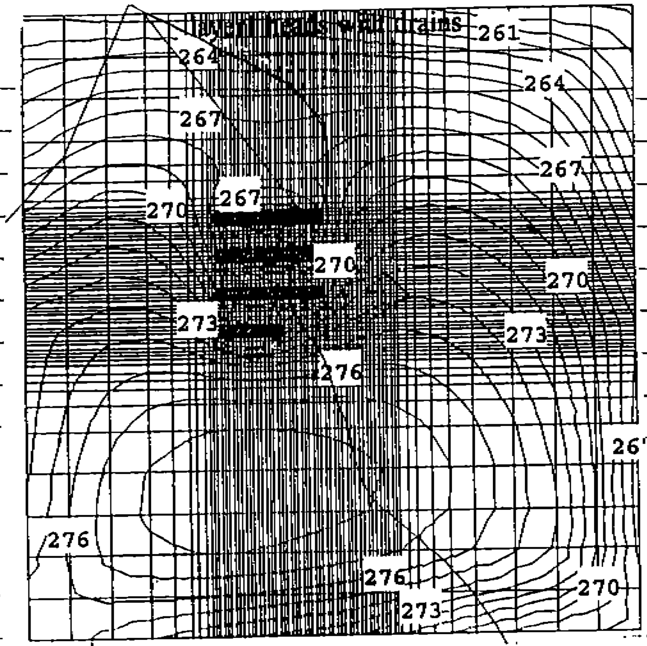
+ read in heads & rerun
1.52% off

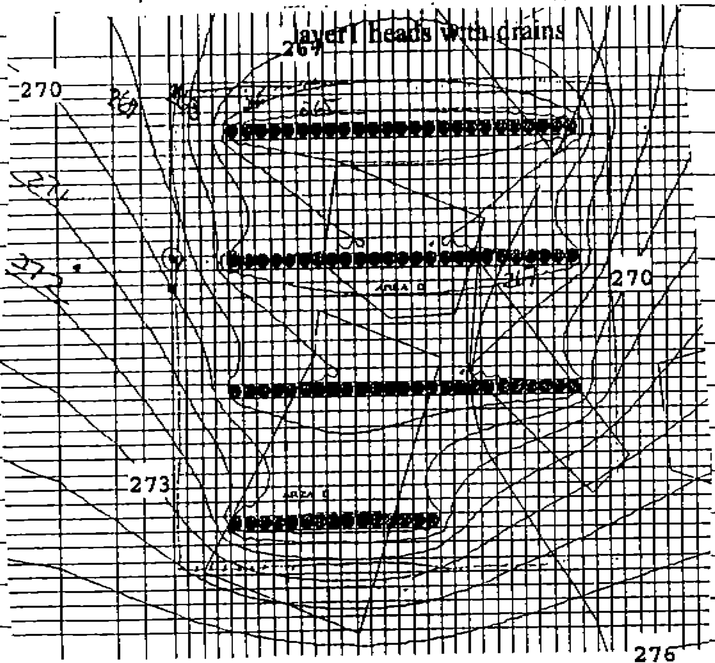
---

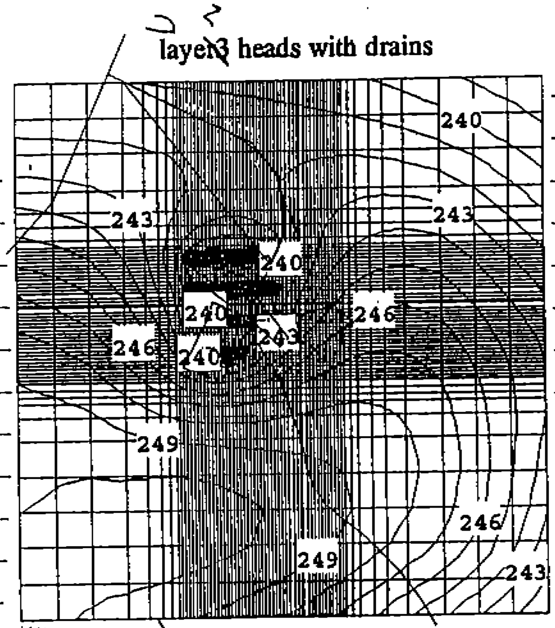
reduce k to 1000 ft/day
% off by 0.75%
~~Q = 181 ft³/day~~

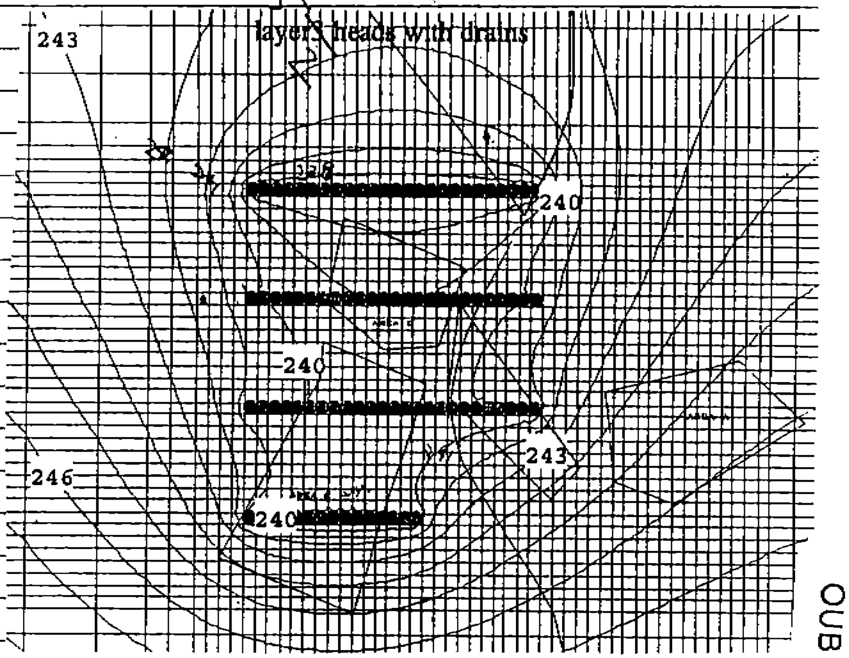
— Heads look good

Final = fsPUM6


layer1 heads with drains


layer1 heads with drains


layer3 heads with drains


layer3 heads with drains

rerun fstrans 4
using heads from fsbase11
that have been rerun w/ correct time
will be used as starting conc.

```
                 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1
IN STRESS PERIOD  1
                 ------------------------------------------------

0          CUMULATIVE VOLUMES     L**3                    RATES FOR THIS TIME
STEP     L**3/T
           ------------                      ------------

             IN:                                  IN:
             ---                                  ---
              STORAGE =    .00000                             STORAGE =    .00000
           CONSTANT HEAD =    .74420E+07                        CONSTANT HEAD
=   815.56
             RECHARGE =    .10486E+08                          RECHARGE =
1149.2
0             TOTAL IN =    .17928E+08                        TOTAL IN =
1964.8
0            OUT:                                  OUT:
             ----                                  ----
              STORAGE =    .00000                             STORAGE =    .00000
           CONSTANT HEAD =    .17929E+08                        CONSTANT HEAD
=   1964.8
             RECHARGE =    .00000                            RECHARGE =
.00000
0           TOTAL OUT =    .17929E+08                        TOTAL OUT =
1964.8
0            IN - OUT =    -676.00                        IN - OUT =   -.73975E-
01
0         PERCENT DISCREPANCY =              .00              PERCENT
DISCREPANCY =             .00


0


    TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  1
               SECONDS      MINUTES      HOURS      DAYS       YEARS
               -----------------------------------------------
   TIME STEP LENGTH     .788400E+09  .131400E+08  219000.    9125.00    24.9829
  STRESS PERIOD TIME    .788400E+09  .131400E+08  219000.    9125.00    24.9829
 TOTAL SIMULATION TIME     .788400E+09  .131400E+08  219000.    9125.00
24.9829
1

                 CUMMULATIVE MASS BUDGETS AT END OF TRANSPORT STEP   26, TIME
       STEP    1, STRESS PERIOD    1
                 -------------------------------------------------

                                     IN              OUT
                                   ------          ------
               CONSTANT CONCENTRATION:   .0000000               .0000000
                    CONSTANT HEAD:   .0000000             2342.826
                       RECHARGE:   1374290.             .0000000
               DECAY OR BIODEGRADATION:   .0000000               .0000000
                MASS STORAGE (SOLUTE):   11009.94             -214316.8
               MASS STORAGE (ADSORBED):   64057.29              -1246925.
               ------------------------------------------------
                        [TOTAL]:   1449357.      gm      -1458899.     gm

                             NET (IN - OUT):   -9541.625
                          DISCREPANCY (PERCENT):   -.6561750

 ---
| M T |
| 3 D | End of Model Output
 ---
```

Soil Vapor Extraction

File = soilqt1.sup
use fspumle heads
use fstrans4 conc as starting Conc

stress period 1 = 4 years = 1460
no cleanup

1	stress period 2 =	6 months =	360 day	1820
	3	6	360	2180
2	4		360	2540
	5		360	2900
3	6		360	3260
	7			
	8			
	9			
	10			
	11			

6 stress periods

ssm
934
~~1000 1.0~~ (10911.4) 0

~~total~~ = 3260 days
= 9 yrs

copy soilqt2.ssm soilqt2.org

didn't fix sorption
~~ret~~ delete a lot of the print stuff

conc in drain consistantly ~312471.9 gm
per stress period

rerun by changing stress period 2 to
from 180 days to 6 years = 219
soln ran for
6.5% off

→ fixed add drains in ssm
file
fixed to print out at specified
intervals

Final is
soilqt3

							rerun
Transport Step	10	1	1	1	1		
Time Step	1	10	10	10	10		
Stress Period	1	2	3	4	5	6	
time	1460	1820	2180	2540	2900	3260	
	4yrs	5yrs	6yrs	7yrs	8 yrs	9yrs	4months
Recharge (gm)	219886.2	219886.2	219886.2	219886.2	219886.2	219886.2	18072
Drain gm	-145694.3	-183390.8	-210954.2	-252387.5	-283880.11	-313011.6	-11212.81
Δdrain (gm)		37696.2	35613.7	33433.3	31417.6	29206	

$$\frac{29206\text{ gm}}{1\text{ yrs} \times 181\frac{ft^3}{day} \times 365\frac{day}{yr}} = \frac{0.442\text{ gm}}{ft^3}$$

$$.227\frac{gm}{ft^3} \times 35,300\frac{\mu g/L}{gm/ft^3} = 15605\text{ppb} \quad 6\text{ yrs}$$

max C in layer 4 = 3ppb in 6 yrs

L 2 small to 20,000 ppb

Q drain

(from fspum6.out)

88

$$\frac{18072\text{ gm}}{4\text{months} \times \frac{yr}{12\text{months}} \times 181\frac{ft^3}{day} \times 365\frac{day}{yr}} = 0.821\text{ gm}/ft^3$$

= 28,969 ppb

89

Keep it to 6 stress periods

Run again

			time past	
stress periods	4yrs	1460	4yrs	1460
	6yrs	2190	10yrs	3650
	5	1825	15yrs	5475
	5	1825	20	7300
	5	1825	25	9125
	5	1825	30	10950

byu
MT3D
- output
circumstances
- evidance of bug
corrected
down toward off.

~~rerun at~~
~~4/6 8 10/12 15 yrs to make sure~~
~~it is protective of gw.~~

stress period	time	yrs	recharge	drain	sdrain
1	1460	4	219886.2	-145644.3	
2	3650	10	"	" -343586.5	197,942.
3	5475	15	"	" -448080.5	104494.
4	7300	20	"	" -509193.6	61,113.
5	9125	25	"	-516373.5	37179.9
6	10950	30	"	-572732.9	26359

$$\frac{26359}{5\,yrs \times 181\frac{ft^3}{day} \times 365\frac{day}{yr}} = 0.079\ gm/ft^3$$

$= 2,816$ ppb   30yrs

stress period		time [illegible]		
1	4yrs	4	1460	
2	16yrs	20	5840	7300
3		30	3686	10950
4		40	3650	14600
5		50	3650	18280
6		60	3650	21900

stress period	time post	recharge	drain	Δdrain
1	4	219886	-145644	
2	20	" "	-510227.4	508947
3	30		-573351.9	63124.5
4	40		-610662.9	37311
5	50	" "	-635329.0	24667
6	60		-652807.3	17478

$$\frac{17478 \text{ gm}}{10\text{yrs} \times 181 \frac{ft^3}{yr} \times 365} = 0.026 \text{ gm}/ft^3$$

$= 933$ ppb 60 yrs

Run for TCE & 1,1,2 TCA

TABLE 6-1

TCE AND 1,1,2 TCA SOURCE CONCENTRATIONS AND RETARDATION FACTORS

OUB, FORT RICHARDSON, ALASKA

		TCE		1,1,2 TCA
Source Concentration (μg/L)	gm/ft³			
Source 1	3	105,900	3	105,900
Source 2	3	105,900	0.05	635
Source 3	2.4	84,720	0	0
Volumetric Recharge Rate (cf/day)				
Source 1		6.6		6.6
Source 2		6.9		6.9
Source 3		9.9		9.9
K_{oc} (ml/gm) [1]		64.5		56.2
Log Koc	=	1.81	≈	1.75
Kd		8.9×10^{-6}		7.7×10^{-4}
Retardation Factor (-)		4.2		3.8

I. TCE (listce)

files need a ~~tca~~ fstrans4.* equivalent.

only need to change .rct & sources

for source 6 → 3 rem

$\boxed{10.8 \to 2.4}$

in ssm file

copy fstrans4.* listce.*

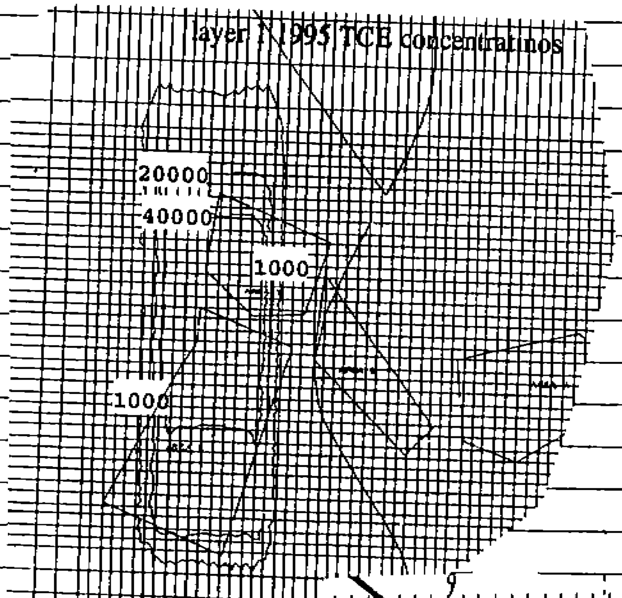
simulate the starting concentration

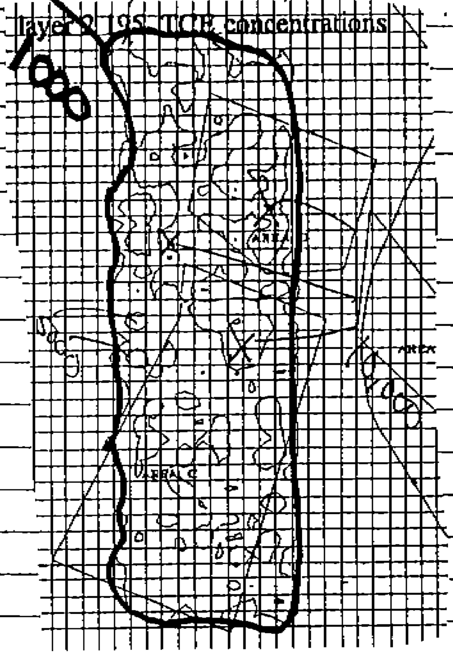
Soln >.0 listce.c

1,1,2TCA

tca.lis

soln is 6.76% off

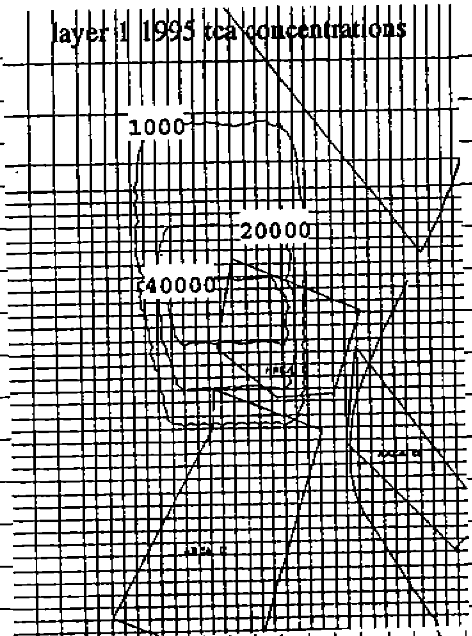


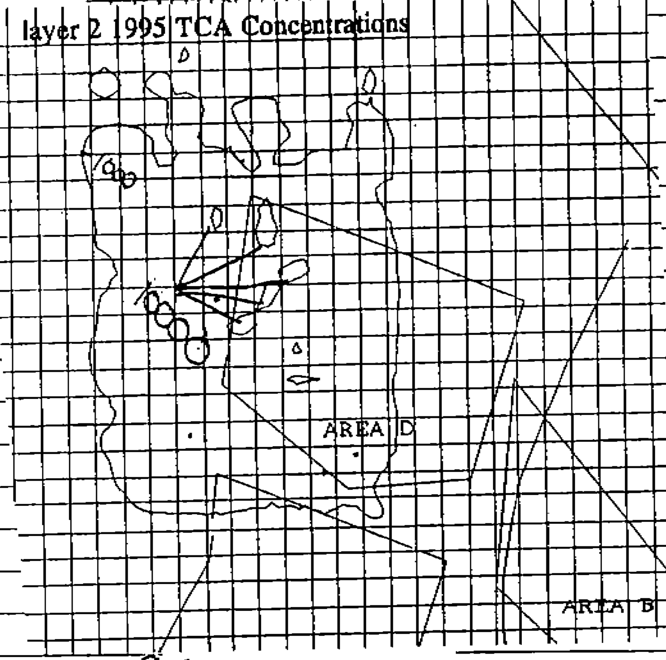


t liste
ech ✓
etard ✓
off! = 2.7%
ass'n = 501637

ct tca us
rech Conc ✓
retardation ✓

%off = 6.7%
mass'n = 12093 gm





1,1,2,2 PCA soil vapor extraction

TCE

copy (soilgt3) → FUTTCE

merge soilgt3.ssm
histce.ssm
& hand edit

read in histce conc to starting conc @
& get rid of -999 cells

✓ edit Futtce.rct

run for 6 stress periods

yrs past	4yrs	6	10	15	20	30yrs
days past	1460	2190	3650	5475	7300	10950
th of design	1460	730	1460	1825	1825	3650

12

4147

3764 engineer 7

4042
3769
42,520

3764

17 x 2

41568.00

tcafut.ssm → tcatemp.ssm
.bth

e.hrs
10 hrs/mo
2 days
12

13cc

TCA is ready
print out refa data tin
recharge etc initially to make sure it is correct
except read in histor conc

TCE futresults :

stress period	time past	recharge	drain	Δdrain
1	4	80261	68594	68594
2	6	80261	97964.	29370
3	10	"	137316	39352
4	15	"	164018	26702
5	20	"	180319	16301
6	30	"	199922	19603

soln is 556% off

4yrs

$$\frac{68594\,gm}{(4yrs)(181\,\frac{ft^3}{day})(365\,\frac{day}{yr})} = 0.259\ gm/ft^3$$

$$= 9,163\ ppb$$

6yrs

$$\frac{29320}{(2yrs)(181)(365)} = 0.222\ gm/ft^3$$

$$= 7846\ ppb$$

30 yrs

$$\frac{19603}{(10yrs)(181)(365)} = 0.029\ gm/ft^3$$

$$= 1047\ ppb$$

Tcafuf

TCA

stress period	time past	recharge	drain	Δdrain
1	4	27316	22541	22541
2	6	"	30568	18027
3	10	"	40762	10194
4	15	"	48938	8175
5	20	"	53122	4185
6	30	"	57649	4527

seln is % off

4yrs

$$\frac{22541}{(4yrs)(181\,\frac{ft^3}{day})(365\,day/yr)} = 0.08\ gm/ft^3$$

$$= 3011.\ ppb$$

6yrs

$$\frac{8027}{(2yrs)(181\,ft^3/day)(365\,day/yr)} = 0.06\ gm/ft^3$$

$$= 2144\ ppb$$

30 yrs.

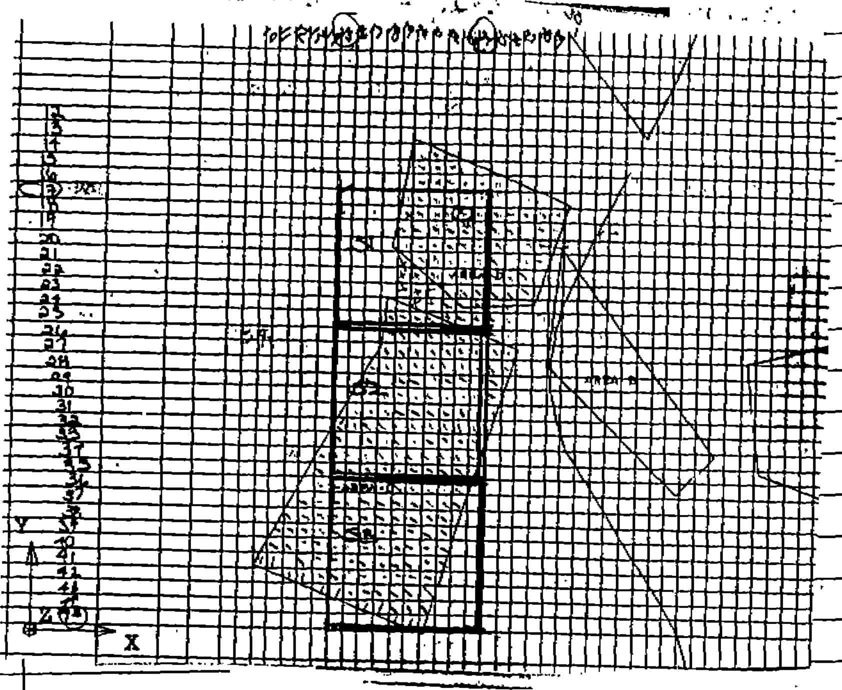
$$\frac{4527}{(10yrs)(181)(365)} = 0.0079\ gm$$

$$= 241\ ppb$$

Soil Flushing

assume 2gpm

$\frac{2 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{24 \text{ hr}}{\text{day}} = \frac{385 \text{ ft}^3}{\text{day}}$



Source area = 29 cells × 10 cells = 290×100 = 29,000 sf

272 squares = Area C3 (×100 sf/cell)

= 27,200 ft + = 29,500

23 cells between = 2300 ft

29000 sq ft as an area to flush is reasonable.

$\frac{385 \text{ ft}^3/\text{day}}{29000 \text{ sf}} = 0.0133 \text{ ft/day}$

$0.0133 \frac{\text{ft}}{\text{day}} \times \frac{365 \text{ day}}{\text{yr}} \times \frac{12''}{\text{ft}} = 58''/\text{yr}$

too much water reduce Q to 1gpm

1gpm = 192 ft³/day

$\frac{192 \text{ ft}^3/\text{day}}{29000 \text{ sf}} = 0.0066 \text{ ft/day}$

$= 29''/\text{yr}$

There is no way I can get that much water thru the system so.

1) find out how much recharge I can get thru system so that heads are 5 ft bgs = ~292-5=28

292 is lowest groundsurface elev recorded at site

use fsbase11

save as fsbase20

increase recharge from 3"/yr (6.8x10⁻⁷)

to

$6.8\times10^{-7} + 0.0066 = 0.00728$
(natural recharge) (flushing water)

rows 17-45
col 15-24

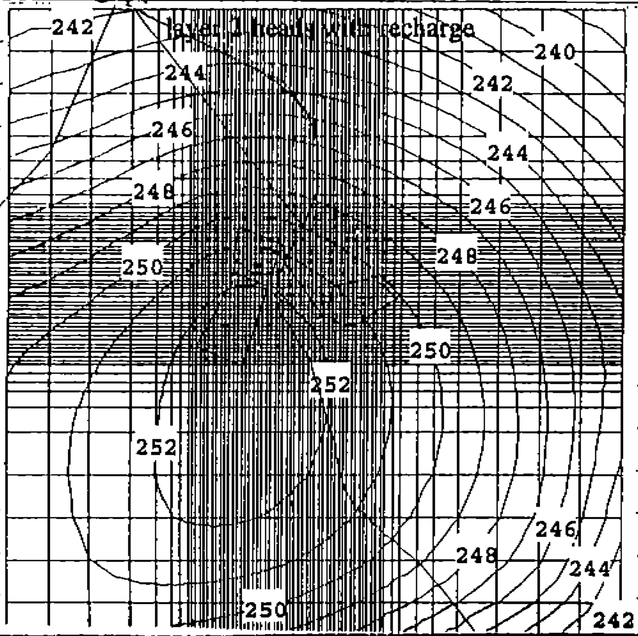
s/n converged percent off = 0

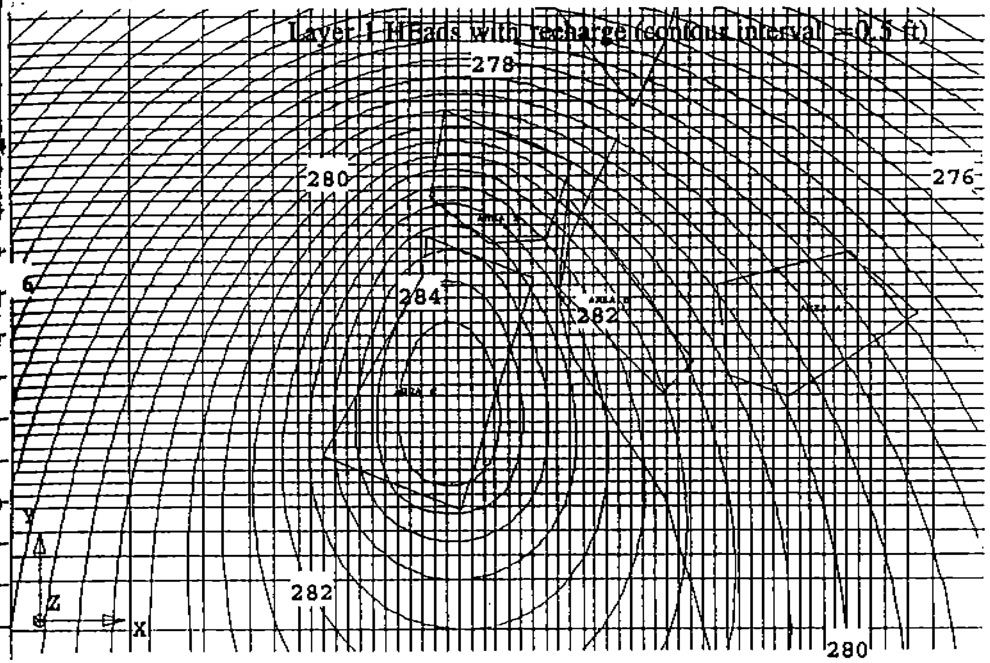
max head = 284.9 which is ≈ 292-285 = 7' bgs

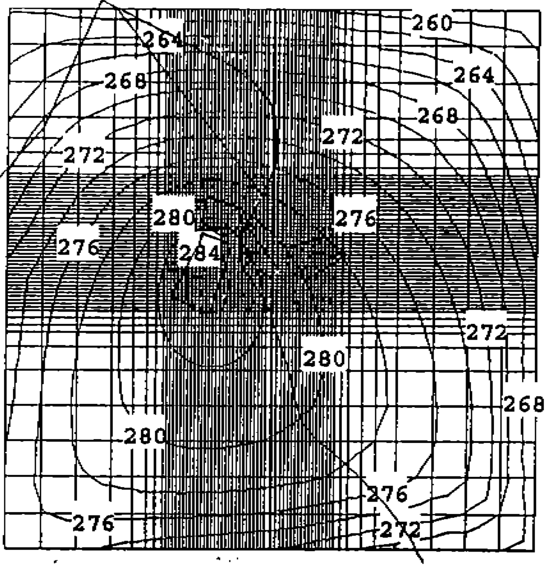
old head max at site (~~base~~ fsbas11)

= ~278.2

Δ = 284.9-278.2 = 6.7 ft


Layer 2 heads with recharge


Layer 1 HEads with recharge (contour interval = 0.5 ft)


Layer 1 HEads with recharge

Go back to
soil9+3 (drain w/ no soil flushing)
~~So~~
Is it protective of gw in layer 4?

yrs	length of stress period	length of time p[illegible]
4	1460	1460
6	736	2190
8	736	2920
10	736	3650
12	730	4380
⑮	1095	5475

drain out = -447471.6 gm
recharge in = 217886.2

% off = 7.5%
dif between this run & previous run a[illegible] yrs
for drain mass (gm) = 6089 gm
So this run is okay.

after 4 yrs of drain on w/ continuing source max C in layer 4 = ~3.7 ppb
L4 0 cells > 10 ppb ; ~20 cells > 1 ppb
layer 3 max ~ 875 ppb
only ~ 19 cells w/ C > 100

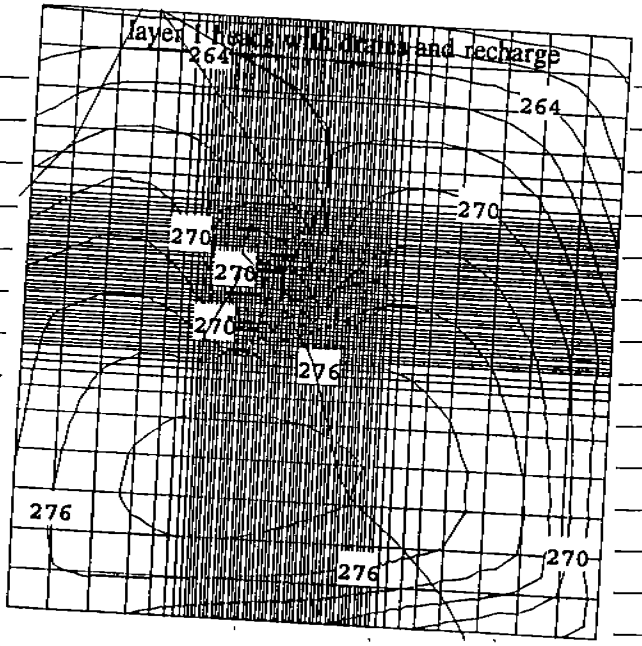
Non soil flushing Case
go back to fspum6 (flow)
and add recharge of 1 gpm + natural rec
save as fspum20
Q in drain = 379 ft³/day

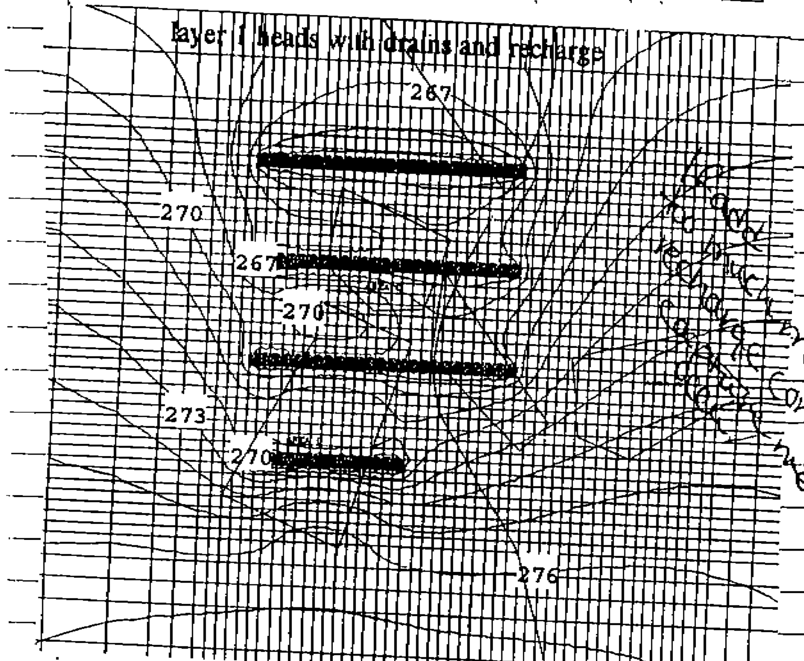
$$\frac{379\ ft^3}{day} \times \frac{day}{24 hrs \times 60 \frac{min}{hr}} \times \frac{748\ gal}{ft^3} = 1.9\ gpm$$

Soln is off by 0.32%

Heads in layers 1 & 2 →

for soil flushing case revise flow
→ so that flush 2 gpm
through soil →
see file fspum21


layer 1 heads with drains and recharge


layer 1 heads with drains and recharge

Heads
too much more
recharge complete
coverage
drain not

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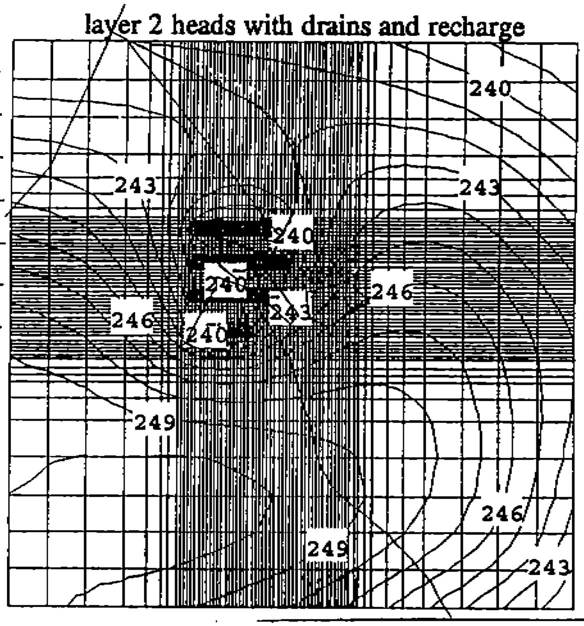
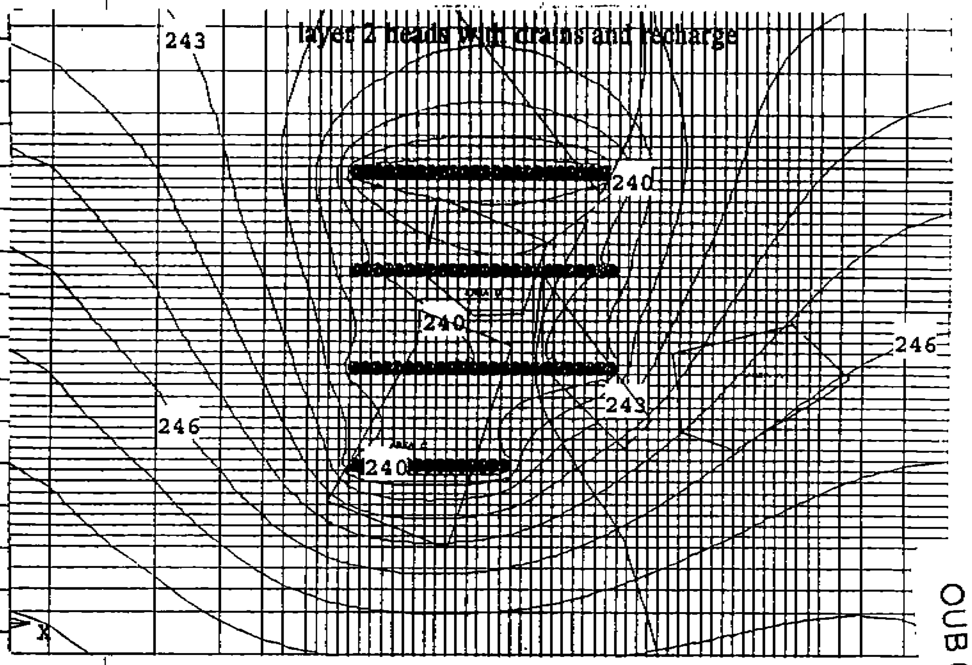

layer 2 heads with drains and recharge


layer 2 heads with drains and recharge

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Calculate 1 pore volume

= Volume of soil * ~~effective~~ porosity
total (*)

Assume thickness of soil = 290' - 275'
= 15'

Area = 29,000 sf
Vol = 29,000 (15') =
= 435,000 cf

Total porosity = 0.25 (see PT modeling appendix)

Pore Volume = 0.25 (435000)
= 108,750 cf

How long does it take to flush 1 pore volume

$\frac{108750 \text{ cf}}{29000 \text{ sf}} = 3.75 \text{ ft}$

How long does it take to flush 3.75 ft at a rate of ~~0.00728 ft/day~~ 0.0313 ft/day =

$\frac{3.75 \text{ ft}}{\text{~~0.00728~~ ft/day}}$ = ~~515~~ days = ~~1.4~~ yrs = ~~17~~ months
0.0313 = 120 days = 0.33 yrs

4 pore volumes = ~~5.6 yrs.~~
= 1.3 yrs

(*) St Helens used effective porosity; I used total porosity at Umatilla. Use total porosity here because it is more conservative.

St Helens chevron for nitrate (no adsorption) found that 96% was removed from soil in 4 pore volumes

PV	Original Pore Water Conc removed (%)		Δ remo
1	32	% left - 68	32%
2	68	.32	36%
3	90	10	22%
4	94	6	4%
5	100	0	6%

Source Concentrations used in Simulation

original 1,1,2,2 PCA conc used in FSTRANS 1

Source #	Conc (gm/ft³)
1	6
2	6
3	10.8

~~PV #5~~	~~Source Conc.~~	~~PV #1~~	~~PV #2~~	~~PV #3~~	~~PV #4~~
~~6(0.06) =~~	~~6~~	~~6(1-.32) = 4.08~~	~~6(1-0.62) = 1.9~~	~~6(1-0.9) = 0.6~~	~~6(1-0.94) = 0.4~~
~~10(0.06)~~	~~10.8~~	~~10(1-0.32) = 6.8~~	~~10(1-0.88) = 3.2~~	~~10(1-0.9) = 1~~	~~10(1-0.94) = 0.6~~

~~32%~~ ~~36%~~ ~~22%~~ ~~4%~~ ~~6%~~

I think I did it wrong

Source Concentration	PV #1	PV #2	PV #3	PV #4	PV #5
6	6(.32) = 1.92	6(.36) = 2.12	6(.22) = 1.32	6(0.04) = 0.24	6(0.06) = 0.36
10	10(.32) = 3.2	10(.36) 3.6	10(.22) 2.2	10(0.04) .4	10(0.06) = 0.6

modify Soilgt3

- ~~3~~ make it flush 1 pore volume file name = flush)

fix recharge rates [use fspum~~20~~ : file

✓ starting conc

✓ - rct (correct disp)

✓ - s8m (rch & drains)

- btn (stress periods)

fspum2

head

final

	stress period	length of sp	time lapsed	days
	1	120	4 months	120
	2	120	8 months	240
	3	120	12 months	360
	4	120	16 months	480
5yrs	5	1345	" " "	1825
10yrs	6	1825		3650

<0.0w ug/L

↓

rerun flow

recharge 2gpm (from drains thru (fspum2))

natural rech = $\frac{0.0066\ ft}{day} \times 29000\ ft^2 \times \frac{7.48\ gal}{ft^3} \times \frac{day}{24 \times 60\ min} = 0.99\ gpM$

$\frac{379\ ft^3/day}{29000\ sf} = 0.0131\ ft/day$

total recharge = 0.0131 + 0.0066 = 0.0197 ft/day

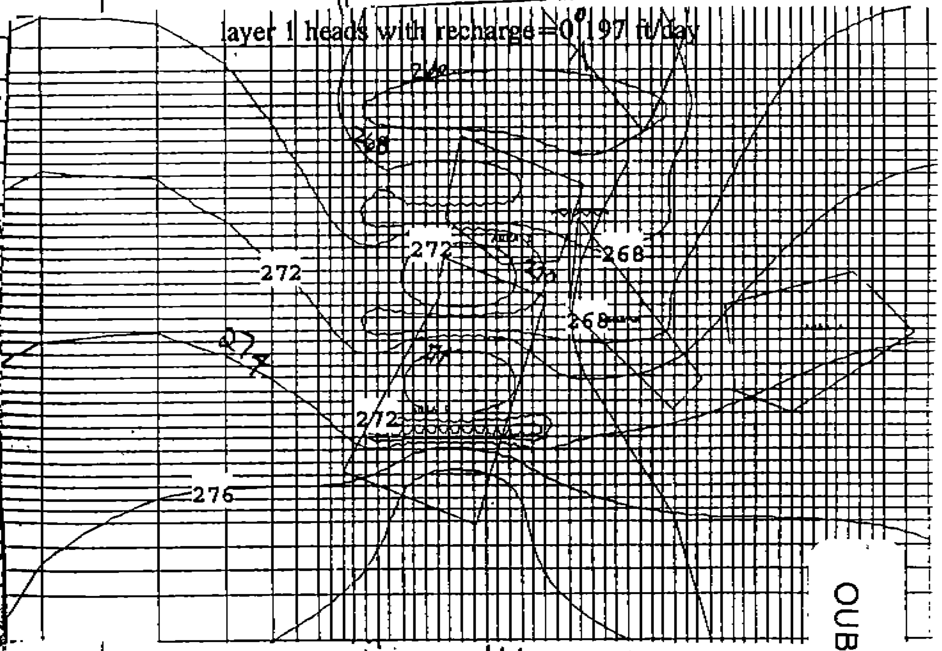
row 17-45

col 15-24

soln is off only 0.93%

Q drains 713.44

= 3.7 gpm



layer 1 heads with recharge =0.0197 ft/day

$\frac{713\ ft^3/day}{29000\ ff}$ = 0.0247 ft/day

Recharge total = 0.0247 + 0.0066 = 0.0313 ≈ 11 ft/YR

Soln is 1.19% off

Drain out = 1026.2 ft³/day ≈ 0.7"/day

$= \frac{1026.2\ ft^3}{day} \times \frac{day}{24 \times 60\ min} \times \frac{7.48\ gal}{ft^3}$

= 5.33 gpm

max head =

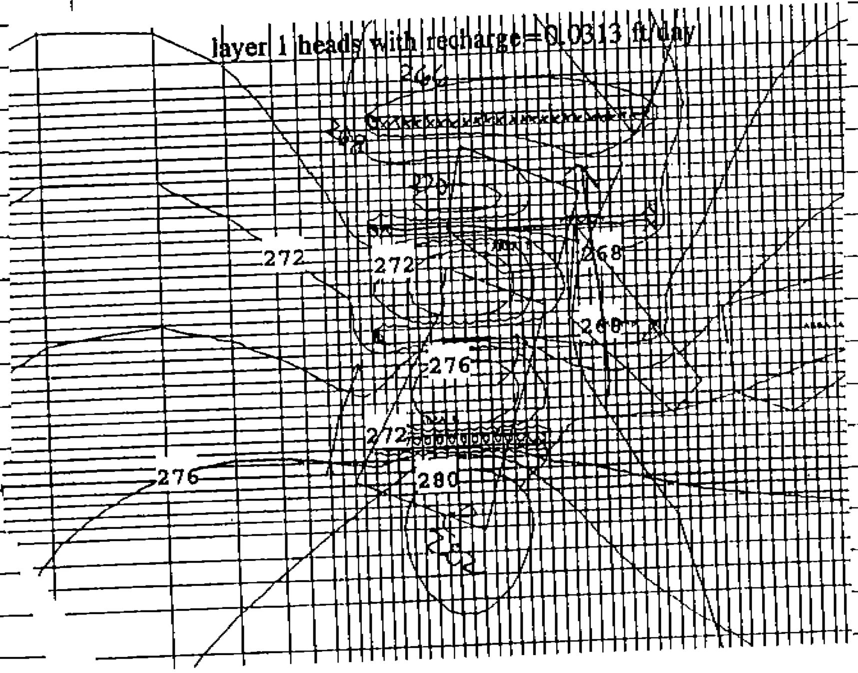
~ 5 gpm

Recharge In		Drain out
natural	from drain	from model w/ this recharge in
1	1 = 2	2
1	2 = 3	3.7 37/3 = 1.23
1	3.7 = 4.7	5.33 = 1.13

$q = \frac{ki}{n}$ $\frac{0.5(1)}{0.15}$

q = .5 ft/day   max Q thru soil?

=



assume that capture will not occur if we increase recharge any more

~~Plus 1~~ (1,1,22 PCA) results

Soln 4% off

Run 1

That % off	stresspenid	time	recharge (gm)	drain (gm)	△ drain (gm)
.8	1	4 months	545317	189911	
.4	2	8 months	800512	452,537	
.3	3	12 months	880704	662,121	209584
.9	4	16 months	931673	824,741	162620
.04	5	5 yrs	1502930	1816623	991882
.32	6	10 yrs	2,278,056	2,637,085	820462

1-4yr

$$\frac{662121\,gm}{1yr\left(1026\frac{ft^3}{day}\right)\left(\frac{365\,day}{yr}\right)} = 1.76\ gm/ft^3 = 62,413\ ppb$$

-5

$$\frac{1816623}{5yr\left(1026\frac{ft^3}{day}\right)\left(\frac{365\,day}{yr}\right)} = 0.97\ gm/ft^3 = 34,247$$

10

$$\frac{820462}{(5yr)\left(1026\frac{ft^3}{day}\right)\left(\frac{365\,day}{yr}\right)} = 0.44\ gm/ft^3$$

$$= 15,468\ ppb$$

Run 2

0-4 yrs

stress period	time (yrs)	time (days)	stress period length (days)	recharge (gm)	drain (gm)	△drain (gm)	% that soln is off
1	4	1460	1460	6,634,700	4,593,718		-0.0
2	7	2555	10951	8,963,350	7,470,379		1.3
3	15	5475	2920	.109147 E+8	0.1038628 E+8		0.
4	20	7300	1825	0.1168987 E+8	0.1132865 E+8	942370	
5	25	9125	1825	0.12465 E+8	0.121021 E+8		2.
6	31	10950	1825	0.1324013 E+8	0.1286363 E+8	753420	

soln 2% off

15-20

$$\frac{942370\ gm}{5yrs\left(1026\frac{ft^3}{yr}\right)(365\ d/yr)} = 0.51\ gm/ft^3 = 17,765$$

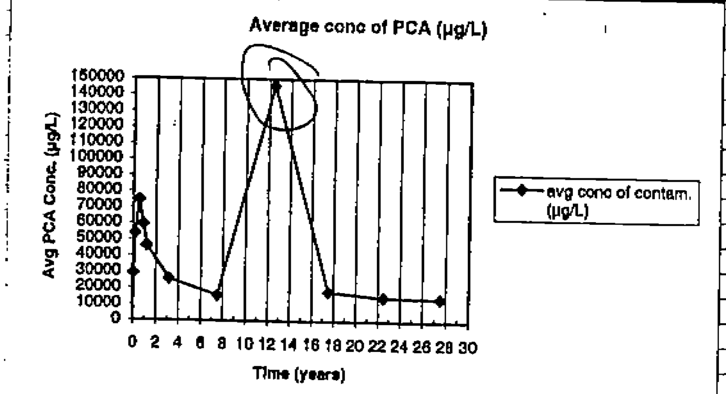
25 to 30yrs

$$\frac{753420}{5yrs\left(1026\frac{ft^3}{yr}\right)(365\ d/yr)} = 0.40\ gm/ft^3 = 14,204$$

Protective of gw the max conc = 1.4 ppb
in 1 cell
in L4

Is it protecting gw - yes

r	Total mass of contam. removed (g)	delta time (yr)	delta contam. mass (g)	volume of water removed at rate of 1026 cf/yr (cf)	delta water volume (cf)	avg conc of contam. (g/cf)	Time (year)	avg conc of contam. (µg/L)
0	0			0			0	29000
3	189,911	0.333	189911	124830	124830	1.521357	0.166667	53719
7	452,537	0.333	262626	249660	124830	2.103869	0.5	74288
1	662,121	0.333	209584	374490	124830	1.678955	0.833333	59284
3	824,741	0.333	162620	499320	124830	1.302732	1.166667	45999
5	1,816,623	3.667	991882	1872450	1373130	0.722351	3.166667	25506
0	2,637,085	5	820462	3744900	1872450	0.438176	7.5	15472
5	10,368,280	5	7731195	5617350	1872450	4.128919	12.5	145792
0	11,328,650	5	960370	7489800	1872450	0.512895	17.5	18110
5	12,110,210	5	781560	9362250	1872450	0.4174	22.5	14738
0	12,863,630	6	753420	11234700	1872450	0.402371	27.5	14208



I reran Run 1 & Run 2 due to the discrepancy Both runs were the same I think the discrepancy is due to the % the soln is off rerun for

	recharge(gm)	drain(gm)	% off
4yrs	6,639,700	4,59.2718	0.27
10yrs	0.1129200E+8	9776762	1.5
15yrs	0.1251162E+8	0.1175739E+8	2.05%
20yrs	0.138675E+8	0.1277062E+8	2.2
25yrs.	0.1406188E+8	0.135758 E+8	2.2
30yrs	0.1483701E+8	0.1433611 E+8	2.1

too conservative to run w/ 4% of source remaining for 30yrs assume the last 4% is removed in Pure Volume S

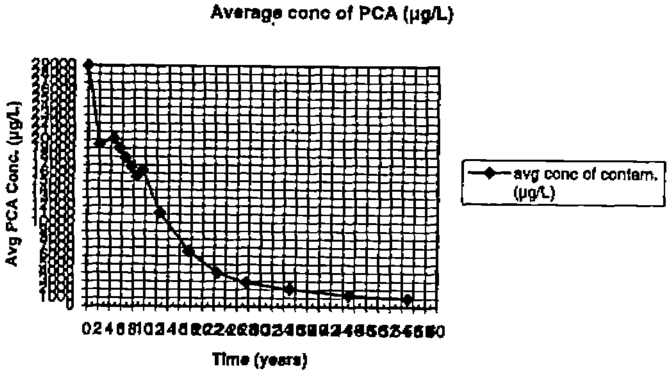
I also ~~was~~ had the wrong conc in recharge fix & rerun

Run of Flush2.f

			length of SP	recharge (gm)	drain gm	% soln is off
		120	120	256,620.3	189,911.2	1.59
		240	120	512,467	387,559	1.19
		360	120	718,894	579,508	1.7
		480	120	750,971	737,081	2.4
2y.		600	120	799,087	864,933	3.1
5	0	1825	1225	799,087	1,392,760	6.9
10	1	3650	1825	799,087	1,547,476	6.3
15	2	5475	1825	799,087	1,582,963	6.1
20	3	7300	1825	799,087	1,597,756	5.9
25	4	9125	1825	11	1,606,367	5.7
30	5	10950	1825	11	1,612,924	5.4

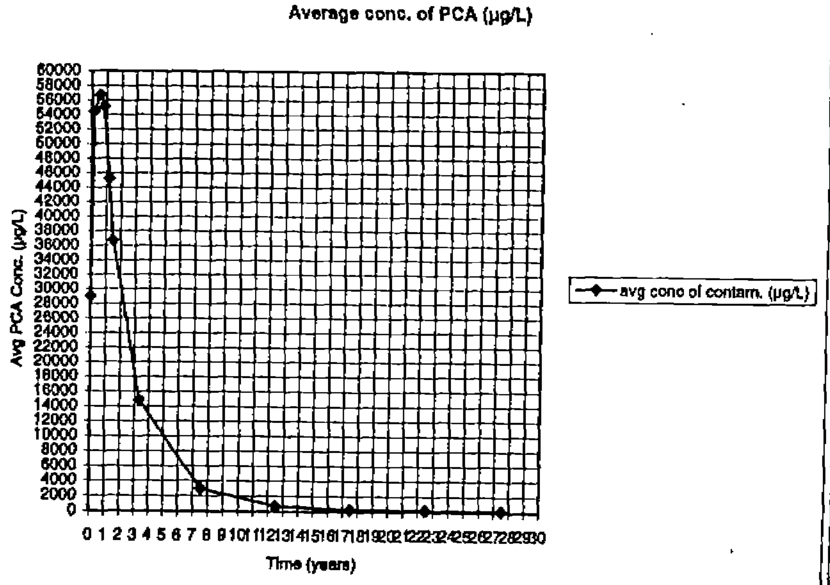
soil vapor extraction

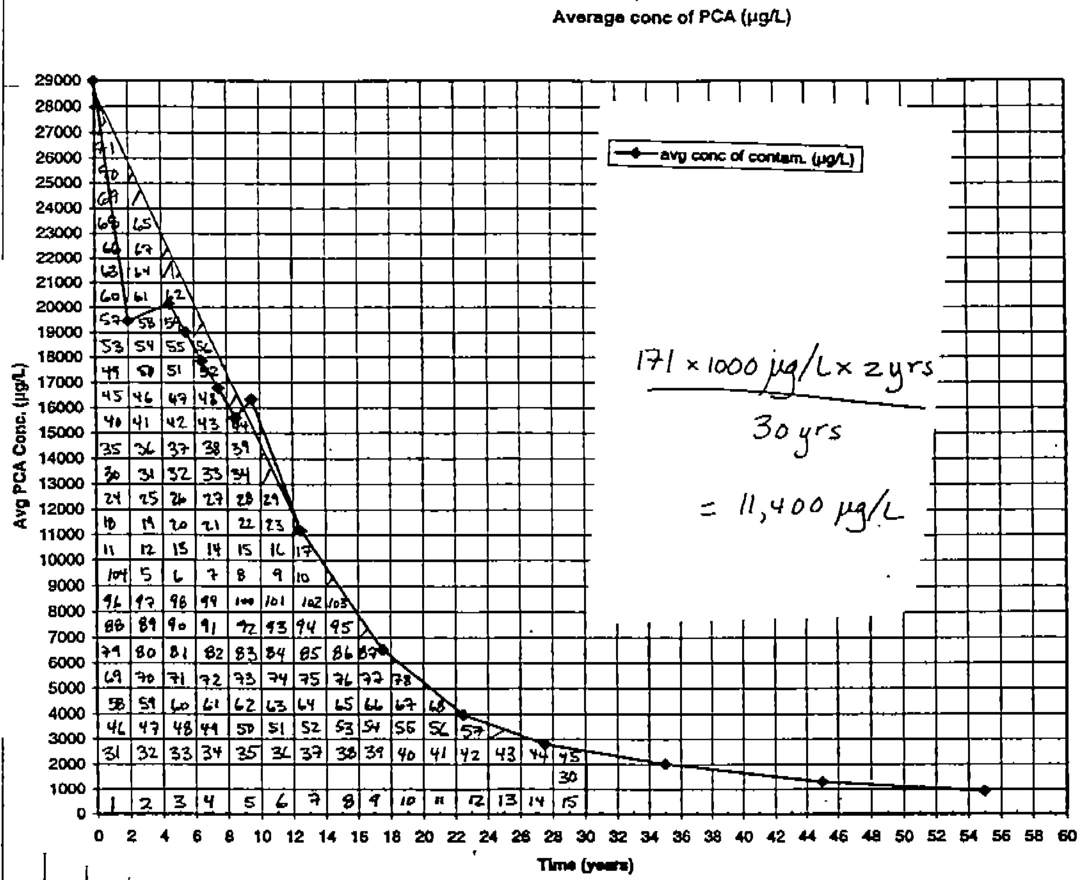
ear	Total mass of contam. removed (g)	delta time (yr)	delta contam. mass (g)	volume of water removed at rate of 181 cf/yr (cf)	delta water volume (cf)	avg conc of contam. (g/cf)	Time (year)	avg conc of contam. (µg/L)
0	0			0			0	29000
4	145,644	4	145644.3	264260	264260	0.55114	2	19461
5	183,341	1	37696.2	330325	66065	0.570593	4.5	20148
6	218,954	1	35613.7	396390	66065	0.539071	5.5	19035
7	252,388	1	33433.3	462455	66065	0.506067	6.5	17869
8	283,805	1	31417.6	528520	66065	0.475556	7.5	16792
9	313,012	1	29206.5	594585	66065	0.442087	8.5	15610
10	343,587	1	30574.9	660650	66065	0.4628	9.5	16341
15	448,081	5	104494	990975	330325	0.316337	12.5	11170
20	509,194	5	61113.1	1321300	330325	0.185009	17.5	6533
25	546,374	5	37179.9	1651625	330325	0.112556	22.5	3974
30	572,733	5	26359.4	1981950	330325	0.079798	27.5	2818
40	610,663	10	37930	2642600	660650	0.057413	35	2027
50	635,329	10	24666.1	3303250	660650	0.037336	45	1318
60	652,807	10	17478.3	3963900	660650	0.026456	55	934



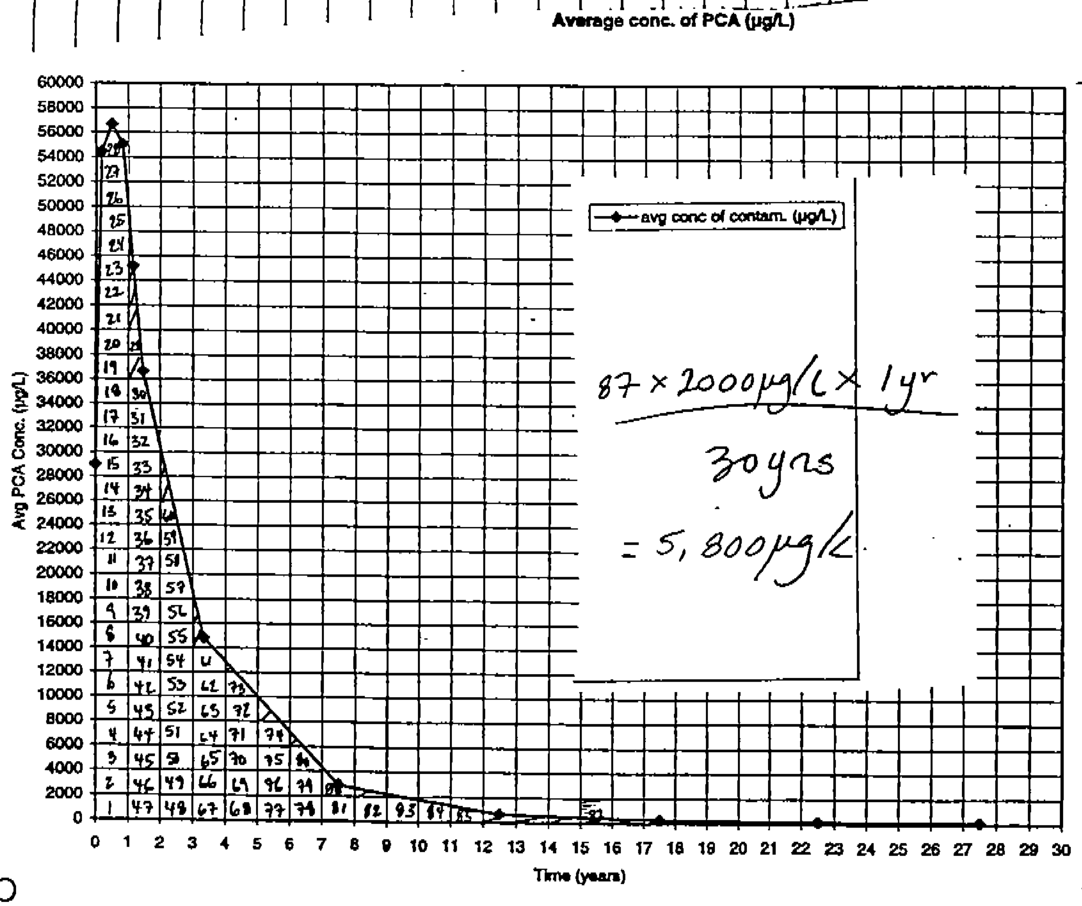
Soil flushing

Year	Total mass of contam. removed (g)	delta time (yr)	delta contam. mass (g)	volume of water removed at rate of 1026 cf/yr (cf)	delta water volume (cf)	avg conc of contam. (g/cf)	Time (year)	avg conc of contam. (µg/L)
0	0			0			0	29000
0.33	189,911	0.329	189911	123120	123120	1.542487	0.164384	54465
0.66	387,559	0.329	197648	246240	123120	1.605328	0.493151	56684
0.99	579,508	0.329	191949	369360	123120	1.55904	0.821918	55050
1.32	737,081	0.329	157573	492480	123120	1.279833	1.150685	45191
1.64	864,933	0.329	127852	615600	123120	1.038434	1.479452	36667
5	1,392,760	3.356	527827	1872450	1256850	0.41996	3.321918	14829
10	1,547,476	5	154716	3744900	1872450	0.082628	7.5	2918
15	1,582,963	5	35487	5617350	1872450	0.018952	12.5	669
20	1,597,756	5	14793	7489800	1872450	0.0079	17.5	279
25	1,606,367	5	8611	9362250	1872450	0.004599	22.5	162
30	1,612,924	5	6557	11234700	1872450	0.003502	27.5	124





171 × 1000 µg/L × 2yrs
30 yrs
= 11,400 µg/L



87 × 2000µg/L × 1yr
30yrs
= 5,800µg/L

Reaction wall

Change drains to reaction wall

set gate I Bound in MT3D to
Constant Conc cell
w/ starting conc = 0

Files use

fspum+6, for flow → fsgate1

fsilgt3 for MT3D → fswall1
this has &trans4 w/ starting conc.

drains 1-3 25 cells/cry
drain 4 15 cells/cry

no flow BC except cell 12 & 13
7 & 8

gatesat

raw	col	col
11	23	24
20	"	"
29	"	"
38	18	19

dm

didnt converge
read in heads & rerun

soln is 4.86% off
read in heads & rerun
soln failed to converge → soln 1.75% off
read in heads & change conv criteria to 0.01 from 0.006

Soln is 1.75% off but good enough for this purpose

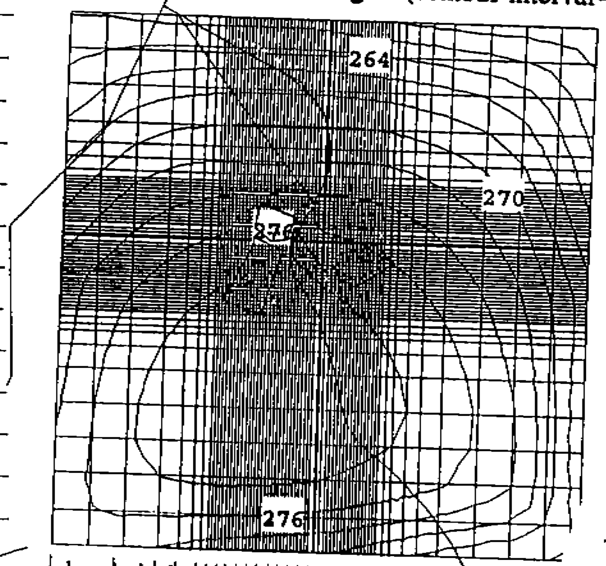
---

fswall1
soln is -15.6 % off

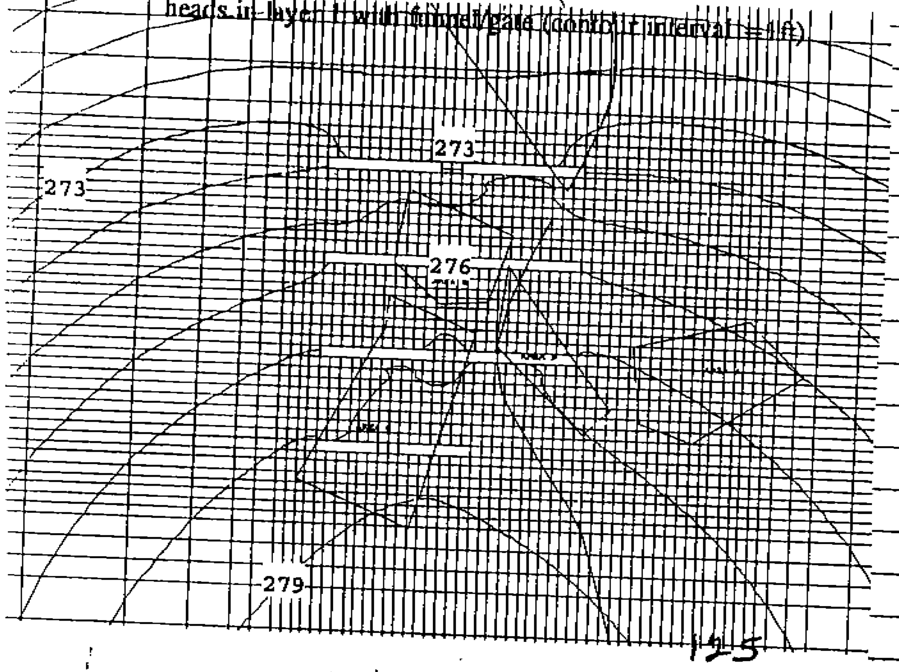
~~Layer 4 low conc in 5 yrs ~ 1ppb~~
~~Layer 3 " " ~600 ppb~~
~~Layer 1 -352647 ppb?~~

~~Run for 20 yrs = 7300~~
~~Layer 4 low conc in yr 20 ~ 300b~~
~~Layer 3 as high as 3000~~
~~Run for.~~

heads in layer 1 with funnel/gate (contour interval=2ft)



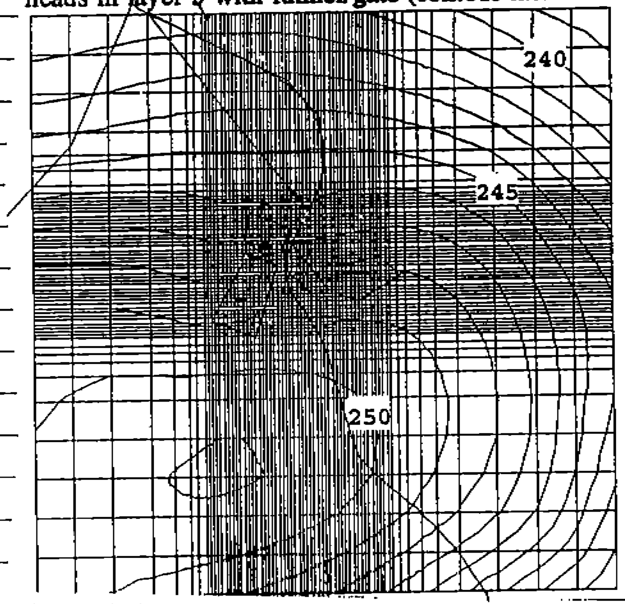
heads in layer 1 with funnel/gate (contour interval =1ft)



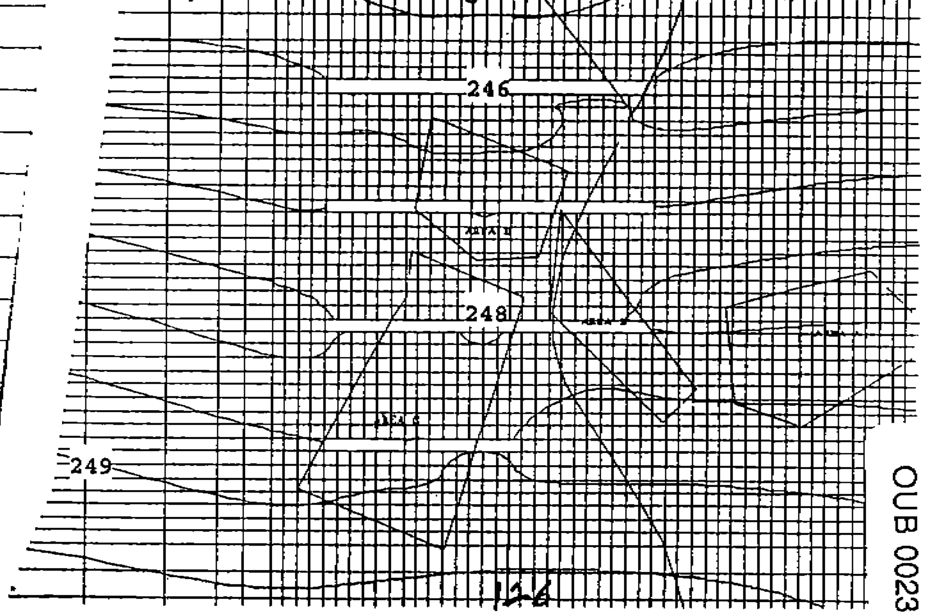
125

2

heads in layer 3 with funnel/gate (contour interval =1ft)



layer 2 heads with funnel/gate (contour interval=0.5ft)



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compare flushing + reaction wall

at

3 + 5 + 10 yrs

1095 1825 3650

MAX Conc PPB

3years 5yrs 10yrs

L1 L3 L4 L1 L3 L4 L1 L3 L4

reaction Wall

9000 max
=8732 <50ppb max~2ppb
Contain
3cells>1000

lush

max ~880 <5ppb max~4
cells>800

0 cells>800

20yrs

L1 L3 L4 L2

L3:
~~more area >1000 ppb than 5 yrs
lots >1000
max = 2000?
Found And~~
max=2000
~34 cells >800

8cells >800
max=1702

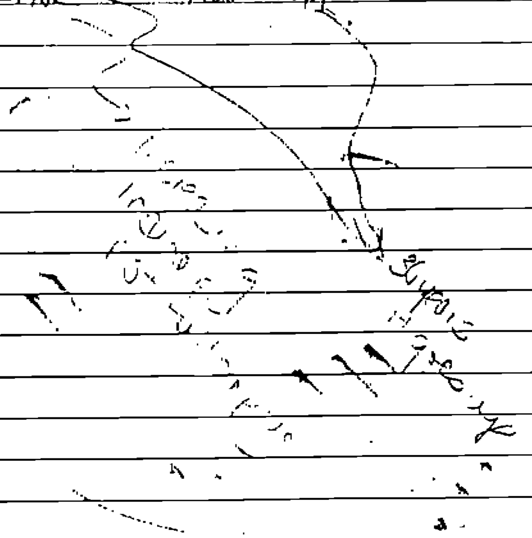
L4:
conc: are increasing
7-10ppb
2 cells >10ppb

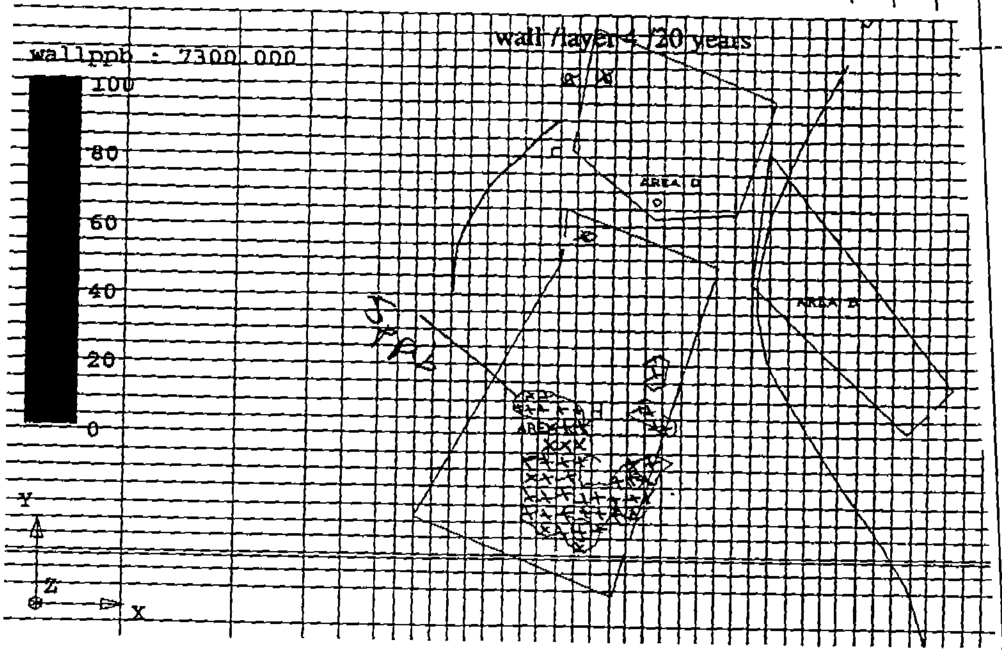
4 cells >10ppb

Plot 50, 1000 + 10,000 ppb, 5000, 10

100 show 0-5000
500
1000

layer 3 more
salg+3 → not much [illegible]
conc increase > than reaction wall
in layer at 30 or flush at 30
[illegible]
layer 3 [illegible] 25 [illegible]
[illegible] cells > 1000

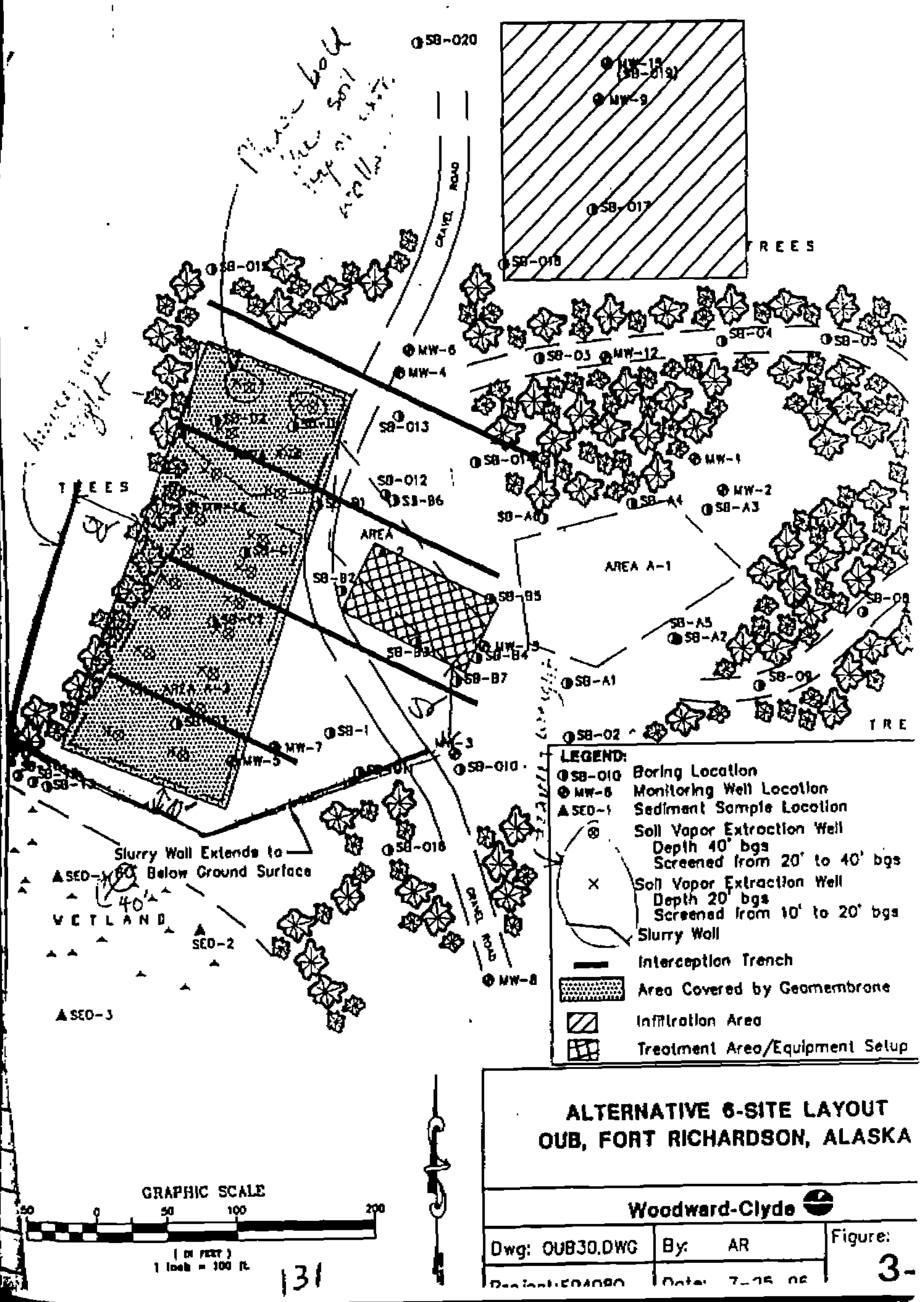


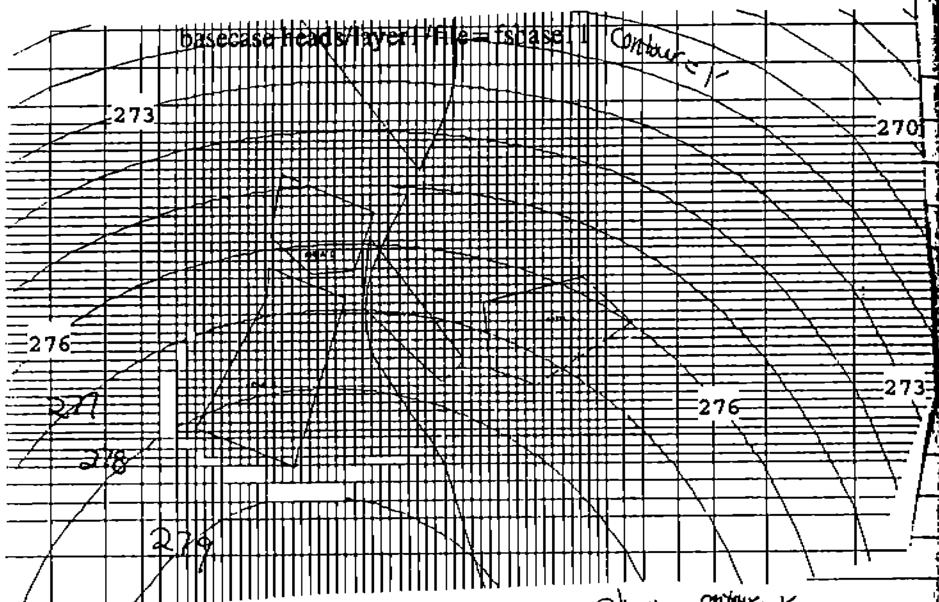


54 squar
75ppb

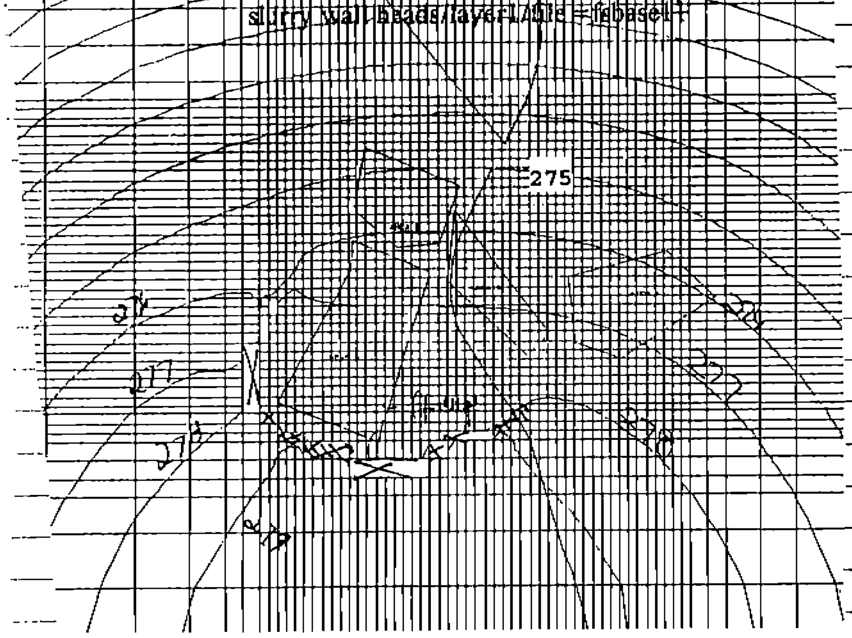
.37

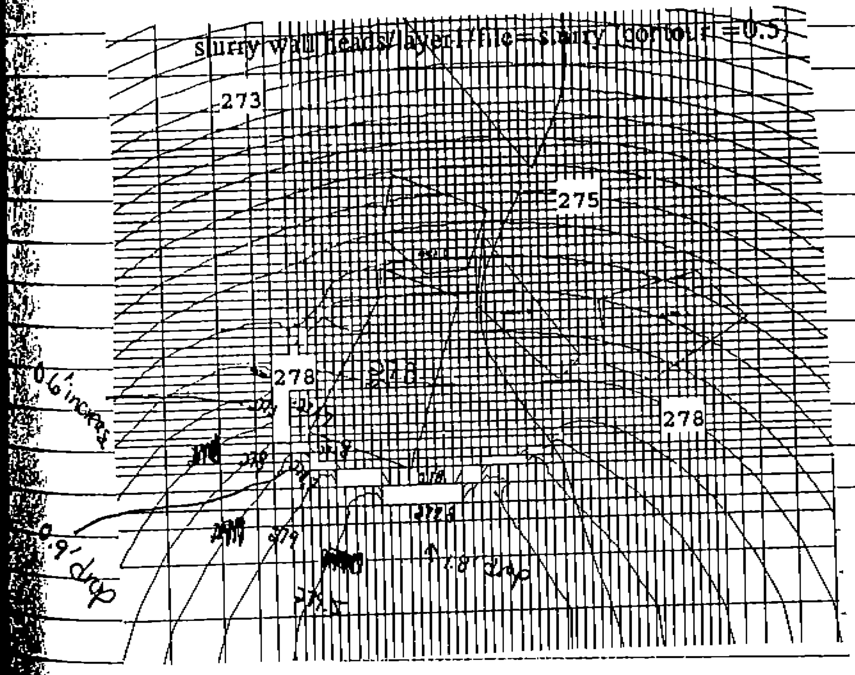
Run Slurry Wall
Slurrywall location
change fbase11' → SLURRY




basecase heads/layer1/file=fsbase1 Contour=1'

slurry contour=1'


slurry wall heads/layer1/file=fsbase1


slurry wall heads/layer1/file=slurry (contour=0.5)

well

$Q = 1000 \frac{gal}{day} =$

$\frac{1000\,gal}{day} \times \frac{}{7.48\,gal} = 133.7\ ft^3/day$

~~Abel~~
change A bas 11 → well

add well
row 38
col 25

Soln is 0% off

dried up aquifer

$Q = 250\ gal/day = 33.4\ ft^3/da$

only dried up one cell

$Q = 25\ gal/day = 3.34$
okay

$Q = 100\ gal/day = 13.37$ head at well = 275.9
okay

$Q = 200\ gal/da = 26.7$ " " 2730

$Q = 225\ gpd = 30.1\ ft^3/da$

$\frac{200\,gal}{day} \times \frac{day}{24 \times 60} = 0.14\ gpm$

Results for Writeup (Baccct)

Steady State Heads

file = fsbasell.hed

	row	col	Head
Layer 1			
drain 1	11	24	274.4
drain 4	38	19	278.2
layer 2			
drain 1	11	24	247.0
drain 4	38	19	248.9

note drains 1-3 run from col 12 to col 36 rw@pt = 24
4 runs " col 12 to 26 19

Drain (no soil flushing)

file = fspum6.sup$ head

	row	col	head
Layer 1			
drain 1	11	24	264.0
drain 4	38	19	269.0
Layer 2			
drain 1	11	24	237.0
4	38	19	240

dr

drain elev

layer 1

Drain	1	2	3	4
elev	264	264	268	269

layer 2

Drain	1	2	3	4
	237	240	240	240

conductance = 1000 ft/day

Drain (with soil flushing)

file = fspum21

	row	col	head
layer 1	11	24	264.0
drain 1	38	19	269.0
4			
layer 2			
drain 1	11	24	237.0
4	38	19	240.0

Trench (

file = fsgate1

		gate loc row	col	
layer 1	drain 1	11	24	273.9
	4	38	19	278.5
layer 2	drain 1	11	24	276.0
	4	38	19	278.6

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