DRAFT

ENGINEERING ASSESSMENT REPORT

A Contaminant Release Control Feasibility Assessment

Prepared for

KAISER
ALUMINUM

MEAD WORKS
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Chapter 1
INTRODUCTION AND BACKGROUND

INTRODUCTION

Kaiser Aluminum & Chemical Corporation (Kaiser) operates an aluminum smelting plant at its Mead Works facility near Spokane, Washington. The now-discontinued practice of open storage of spent potlining has resulted in the release of cyanide to soil and groundwater.

Kaiser discovered the release to groundwater in 1978 and notified local authorities of the situation. The Washington State Department of Ecology's Industrial Section assumed jurisdiction and oversaw ensuing investigations and remedial actions. Subsequent to the passage of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Mead Works was included on the National Priorities List (NPL) of sites to receive federal attention.

Kaiser has taken a number of corrective actions and is monitoring their effectiveness. The various corrective actions, monitoring programs, and investigations predate federal guidelines for action under CERCLA; so most of the remedial investigation and feasibility study (RI/FS) documentation that normally precedes corrective action has not been prepared. Most of this background information is disseminated among various reports, documents, and files and is not readily available from a single source.

The primary purpose of this Engineering Assessment Report is to consolidate the information into a single document and to identify and evaluate various remedial measures that may be needed to mitigate potential impacts of this release. The report summarizes available data from the various investigations and the results of remedial measures that have been conducted to date. A report describing much of the site history was prepared to supplement this one and is included as Appendix A. This background report was prepared by Hart Crowser, Inc., and is titled "Site Characterization Analysis."

The Engineering Assessment Report is organized in the following manner:

Chapter 1--Introduction and Background
Chapter 2--Technology Screening
Chapter 3--Detailed Alternatives Assessment

DESCRIPTION OF ALUMINUM SMELTING

Aluminum smelting involves electrolytic reduction of aluminum oxide (Al_2O_3) to elemental aluminum in a molten cryolite (Na_3AlF_6) bath. The process takes place in a reduction cell, or "pot," which consists of a reinforced steel shell generally containing a carbon-based cathode surrounded by insulating material. High temperatures result from electrical resistance heating, which keeps the cryolite bath and the produced aluminum in a molten state. The carbon cathode contains steel collector bars for conducting electric current. These collector bars extend through the negative pole of the power supply.

The cathode holds the molten aluminum and electrolyte bath during electrolytic smelting while serving as the cathode in the reaction. The anodes are made of carbon and are attached to the cell by a superstructure that suspends them in the molten electrolyte.

Smelting occurs when aluminum oxide is fed into the electrolyte and current is passed through the bath. Electrolysis breaks down the aluminum oxide into aluminum metal and oxygen, which combines with carbon from the anode to form carbon dioxide and carbon monoxide. Thus, the anode carbon is consumed in the process, but cathode carbon is not.

The molten elemental aluminum sinks to the bottom of the pot and is removed periodically for casting. A typical pot may operate 2 to 5 years before it needs to be removed for repairs. A pot fails when iron is detected in the aluminum, when cell voltage increases, or when the shell leaks molten aluminum or electrolyte. When the shell fails, the insulating layer and the carbon blocks are removed and the steel shell relined. The removed lining is called "spent potlining," and the carbonaceous fraction may contain cyanide, which is created when atmospheric nitrogen reacts directly with the carbon.

There have been many potliner designs used in the aluminum industry both before and after the discovery of the cyanide release at the Mead Works. The description above is intentionally general to encompass designs used at other facilities as well as those at Mead.

BACKGROUND INFORMATION

FACILITY DESCRIPTION

Kaiser Aluminum's Mead Works is a prebake aluminum smelter located about 7 miles from downtown Spokane and 1 mile from Mead, in Spokane County. Its location with respect to Mead and Spokane is shown in the Site Characterization Analysis report, Figure 1. Among other systems, the plant operates eight potlines, an anode fabrication plant with bake ovens, dry air scrubbers, pot reworking facilities, indoor storage facilities for (new) spent potlining, and miscellaneous other essential and peripheral facilities. The plant was built in 1942 and incorporated waste management and disposal practices consistent with that era. A plan view of the Mead Works is shown in Figure 1-1.

The plant is located within a glacial outwash valley about 2-1/2 miles from the Little Spokane River and has a surface elevation of about 2,000 feet. The land surface slopes gradually from Mead Works toward the Little Spokane River, and natural groundwater beneath the facility flows in a similar direction. Further information about Mead Works and its surroundings is contained in the Site Characterization Analysis report, Sections 1.1, 2.1, 2.3, and 2.4 and Figures 1, 3, and 6.

WASTE HANDLING PRIOR TO DISCOVERY OF RELEASE

Historically, there have been several wastes generated during aluminum manufacture at the Mead Works. The primary wastes associated with production were:

- Spent potlining
- Pot soaking liquor
- Sludges from process off-gas scrubbing systems
- Anode butt tailings remaining when the used anodes are tumbled prior to crushing and recycling
- Brick and rubble pile

This section describes past management of these waste products.

Spent Potlining

In the past, spent potlining was removed from the pot shells and stored in the northwest corner of the plant property. (Figure 1-1 shows an "asphalt covered" potlining pile in this area, but spent potlining was exposed to atmospheric precipitation from the early 1940s until 1979.) Use of this area for potlining disposal was discontinued in 1979 when the potlining was consolidated into a pile, graded, and covered with plastic. The pile was subsequently paved with asphalt in 1979. The pile currently is reported to have a volume of approximately 94,000 cubic yards and a weight of about 128,000 tons (Site Characterization Analysis report, Section 4.1.2.1). Typical characteristics of spent potlining generated before 1986 are shown in Table 1-1.

Table 1-1
TYPICAL CHEMICAL CHARACTERISTICS OF SPENT POTLINING FOR CONSTITUENTS ABOVE 1 PERCENT

Ingredients	Approximate Composition (% by weight)
Carbon	33
Fluoride	16
Sodium	14
Aluminum	15
Calcium	2
Silicon	2
Oxide, etc.	17

Physical Data

- o Solid.
- o Black to grey.
- o Characteristic ammonia odor when damp.
- o pH approximately 11.0.
- o Specific gravity 2.5.
- o Solubility in water 3 to 4 percent.

Source: Kaiser Aluminum & Chemical Corporation. Material Safety Data Sheet. January 1986.

A significant fraction of the total spent potlining generated at the site since the mid-1950s has been reprocessed and recycled to the pots in order to maintain the required fluoride concentration in the baths. The amount of spent lining that could be recycled was limited by the level of impurities in the recovered material and by the number of potlines that were in service (i.e., the aluminum production rate).

Pot Soaking Liquor

Until late 1978 the pots were soaked with water for the purpose of loosening the potlining material from the steel shells. Failed pots were taken offline and transported to the pot digging slab located on the southeast side of the (now-asphalt covered) potlining pile (see Figure 1-1). Here the pots were soaked with water for several days. This soaking enabled easier removal of spent potlining material from the shells. The pot soaking water was drained to the ground or sometimes to the sludge bed (between 1965 and 1978). Spent potlining was removed following soaking and was disposed of in the waste pile as discussed above.

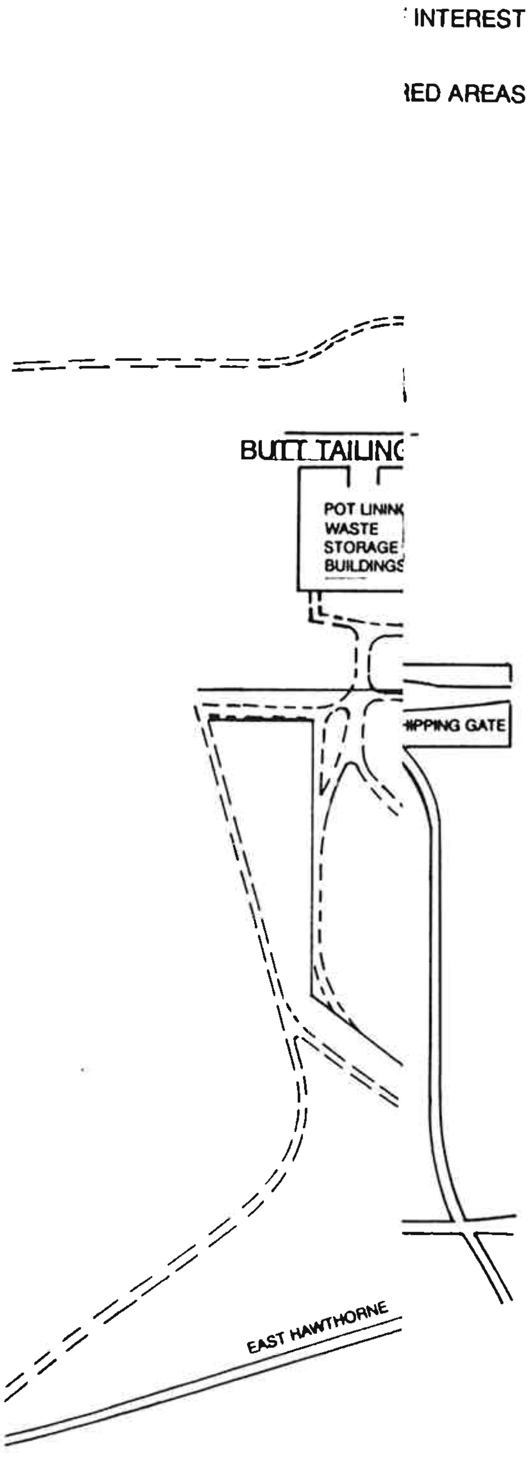


FIGURE 1-1

PLAN VIEW OF KAISER ALUMINUM AND CHEMICAL CORPORATION — MEAD WORKS

The practice of pot soaking was discontinued in 1978 when cyanide contamination was found in groundwater beneath the Mead Works.

Wet-Air Scrubber Sludge

Wet-air scrubber sludges were generated during the era of wet scrubbing of process off-gases. Wet scrubbing was conducted to remove various constituents, primarily fluoride, from the off-gas prior to atmospheric release. A calcium carbonate or calcium oxide slurry was sprayed through the off-gas in a venturi scrubber to precipitate calcium fluoride. The calcium fluoride precipitate formed a sludge, which was then placed in the sludge bed shown in Figure 1-1. Wet scrubbing was discontinued in 1974 and upgraded to a dry scrubbing system, eliminating the need to dispose of scrubber sludges at the facility.

Anode Butt Tailings

This pile was generated by screening the fines from a tumbling machine that was used to clean anode butts during the period of approximately 1960 to 1982. The pile has not been found to contain any cyanide-bearing wastes, and samples of material from the butt tailings pile are not "dangerous waste" under Washington State Department of Ecology criteria, based on aquatic toxicity and other tests (see Appendix B).

Brick and Rubble Pile

The brick and rubble pile (rubble pile) located immediately northwest of the asphalt-covered spent potlining pile, received refractor brick from the carbon plant bake ovens, general industrial waste, miscellaneous construction rubble, and periodic soil cover. The rubble pile contains metal, brick, wood, and some potlining material in the eastern portion of the pile and scattered in isolated pockets elsewhere (Site Characterization Analysis report, Sections 1.1, 4.1.1, and 4.1.2.2). The quantity of spent potlining in the rubble pile is small compared to the asphalt-covered spent potlining pile. The spent potlining is deeply buried beneath the mound of rubble making percolation of precipitation through the pile difficult, and limiting potential contact between spent potlining and water (Site Characterization Analysis report, Section 4.1.2.2).

DISCOVERY OF RELEASE

Cyanide contamination was found in groundwater in the vicinity of Kaiser's Mead Works in early 1978. An investigation carried out under Kaiser's initiative showed that contamination was present in domestic wells northwest of the plant, and these findings were reported to the Spokane County Health Department. The Health Department established a more extensive sampling program in the affected area northwest of the Mead Works.

The suspected source of the cyanide was spent potlining wastes from aluminum production (Site Characterization Analysis report, Chapter 5.0). Kaiser arranged for alternative potable water supplies to be provided to persons whose residential wells were contaminated with cyanide.

These early investigations included other indicator parameters of groundwater contamination in addition to cyanide. The most significant of these constituents was iron. The presence of elevated iron concentrations in cyanide-containing groundwater samples provided the first direct evidence that the cyanide was complexed as ferrocyanide. Robinson and Noble (May 1979) report that approximately 90 percent of the cyanide is present as ferrocyanide. Ongoing monitoring since the initial discovery of the release has shown that, on the average, ferrocyanide comprises closer to 95 percent of the cyanide present in groundwater and, at high total cyanide concentrations, over 99 percent may be present in iron-complexed form (Site Characterization Analysis report, Table 7).

Among other parameters tested during these early investigations, elevated fluoride concentrations and high specific (electrical) conductance were attributed to the operations at the Mead Works. The occurrence of nitrate was attributed to discharge from local septic tanks and the application of fertilizer to the uplands east of Mead (Robinson and Noble, May 1979), but nitrogen-containing compounds in spent potlining leachate also may have contributed nitrate (Site Characterization Analysis report, Section 4.2). Other constituents have been reported at elevated levels in regional groundwater in isolated samples, but their infrequent occurrence and a lack of significant presence in recent sampling do not correspond with the cyanide release. Cyanide is considered the most reliable indicator of leachate migration beneath the site (Site Characterization Analysis report, Section 4.2).

IMPROVEMENTS IN WASTE MANAGEMENT

Several improvements in waste management techniques have occurred at the Mead Works since the cyanide release was discovered. These changes were initiated by Kaiser Aluminum as steps toward preventing future releases. New waste management techniques include:

- Removal of spent potlining from pot shells without presoaking ("dry removal")

- Spent potlining removal in a covered building
- Indoor storage of spent potlining
- Elimination of wet scrubber sludge
- Advancements in pot design

Dry removal of spent potlining occurs in two steps. Failed pots are taken offline and brought into a building where loose cryolite bath and silicon carbide side wall brick are mechanically removed. The pots are then turned over, and the carbonaceous and refractory portions of the spent potlining are removed. This material is hauled to the potlining storage buildings for storage prior to reuse or disposal.

The spent potlining storage buildings are used to prevent contact between atmospheric precipitation and spent potlining. Each building has a storage capacity of approximately 30,000 tons. The buildings are totally enclosed and have 10-foot-high concrete walls all around with an asphalt floor underlain by a PVC flexible membrane liner (FML). One building is used currently for potlining storage. The second building presently is for processing, classification, and storage prior to resale or reuse.

There is no longer any air scrubber sludge produced. Dry scrubbing has replaced wet scrubbing for use in removing fluorides from process off-gas. This change occurred in 1974. Fluoride-containing off-gas is passed now through a fluidized bed of aluminum oxide. The scrubbed gas is conveyed to a baghouse for particulate removal, after which it is vented to the atmosphere. The aluminum oxide-fluoride complex is removed continuously from the scrubber and recycled back into pots for aluminum manufacture.

Advancements in the design of pots for aluminum manufacture have taken place both before and after the discovery of cyanide release. The newer designs give pots a longer service life and improved performance, thereby reducing the generation rate of spent potlining. The new designs, installed since 1985, also are not as prone to cyanide formation because they are more airtight. This limits the accessibility of atmospheric nitrogen to the carbonaceous cathode, which reduces the cyanide formation potential.

Kaiser has implemented other corrective measures in addition to improving waste handling practices. Kaiser's remedial actions will be summarized elsewhere in this chapter.

NATURE AND EXTENT OF CYANIDE RELEASE

Investigations conducted subsequent to the initial discovery of groundwater contamination in 1978 have confirmed that the cyanide originated from wastes stored at the Mead Works. This section summarizes the available data describing the nature and extent of the contamination in groundwater and in potential sources at the Mead facility. Most of the information discussed below was compiled by Hart Crowser in its Site Characterization Analysis report; Chapters 4.0 and 5.0, should be consulted for further details.

SUMMARY OF INVESTIGATION

Various site investigations have been performed at the Mead Works since cyanide was first discovered in groundwater in 1978. These investigations, summarized in Table 1-2, were undertaken for Kaiser by specialists in various technical disciplines. Findings of these studies have provided the basis to understand the nature and cause(s) of the groundwater contamination problem and to identify effective remedial measures affecting contaminant migration.

NATURE OF CONTAMINATION

Contaminants of Concern

The initial groundwater investigation and subsequent investigations and monitoring programs have confirmed that cyanide is present in groundwater within a well-defined plume extending from the vicinity of the (asphalt-covered) spent potlining pile (Figure 1-1) to the Little Spokane River (Figure 1-2). Because of concern about its possible effects on human health and aquatic life in the Little Spokane River, cyanide has been a contaminant of concern. Since fluoride also is associated with primary aluminum production, the samples collected for routine monitoring of cyanide normally also have been tested for fluoride. However, no fluoride concentrations above the primary drinking water standard published by the U.S. Environmental Protection Agency have been found in groundwater offsite from the Mead Works (Site Characterization Analysis report, Sections 4.2 and 5.1.2.2). Ambient water quality criteria have not been established for fluoride. Consequently, cyanide is the contaminant of concern associated with Kaiser Aluminum & Chemical Corporation's Mead Works.

Iron-Complexed Cyanide

Early investigations into cyanide release from the Mead Works showed that most of the cyanide in contaminated groundwater was complexed with iron (Robinson and Noble, May 1979). Subsequent investigations and routine monitoring confirmed

Table 1-2
SUMMARY OF INVESTIGATIVE ACTIVITIES AT KAISER MEAD 1977 TO PRESENT

Date	Activity
1977	Kaiser installed groundwater monitoring wells TH-1 and TH-2 at plant site.
April 1978	Robinson and Noble, Inc., report indicating elevated levels of cyanide, fluoride, nitrate, and sulfate in wells TH-1 and TH-2.
May 1978 to August 1978	Groundwater samples collected from network of 18 private wells and springs around the Mead Works and 2 onsite wells (by Robinson and Noble, Inc.). Analyses indicate cyanide present northwest of plant.
August 1978	Spokane County groundwater monitoring network added to existing network. Analyses indicate cyanide groundwater contamination in the vicinity of the plant site.
October 1978 to December 1978	Six additional monitoring wells constructed (TH-3, 3A, 4, 5, 6, 7).
July 1979	Monitoring well TH-8 installed at plant site; highest cyanide concentrations found in this well.
August 1980	Ecological survey of the Little Spokane River completed by researchers from University of Michigan. No significant impacts identified.
Summer 1980	Monitoring wells and borings ES-1 through ES-10 completed; samples collected and analyzed to further define sources and extent of groundwater contamination.
April 1981	Completed a study of methods to treat cyanide in groundwater.
1981-82	Twenty additional monitoring wells and borings constructed to better define extent of plume and to investigate suspected areas of contamination (wells HC-1, 1A, 2, 2A, 3 through 9, 9A, and 10 through 18 and borings D-1 through D-3).

Table 1-2
(continued)

Date	Activity
1981 to Present	Ongoing monitoring to assess effectiveness of remedial actions.
1982	Leak test of storm and sanitary sewer lines on north side of plant and water lines throughout the plant.
1983	Assessment of the potential for uncovered potlining waste to contaminate groundwater beneath the Mead Works.
August 1985	Completed an assessment of alternatives to control infiltration and cyanide transport.
1986	A groundwater extraction well inventory update was conducted to supplement the 1978 survey performed by the Spokane County Health Department.

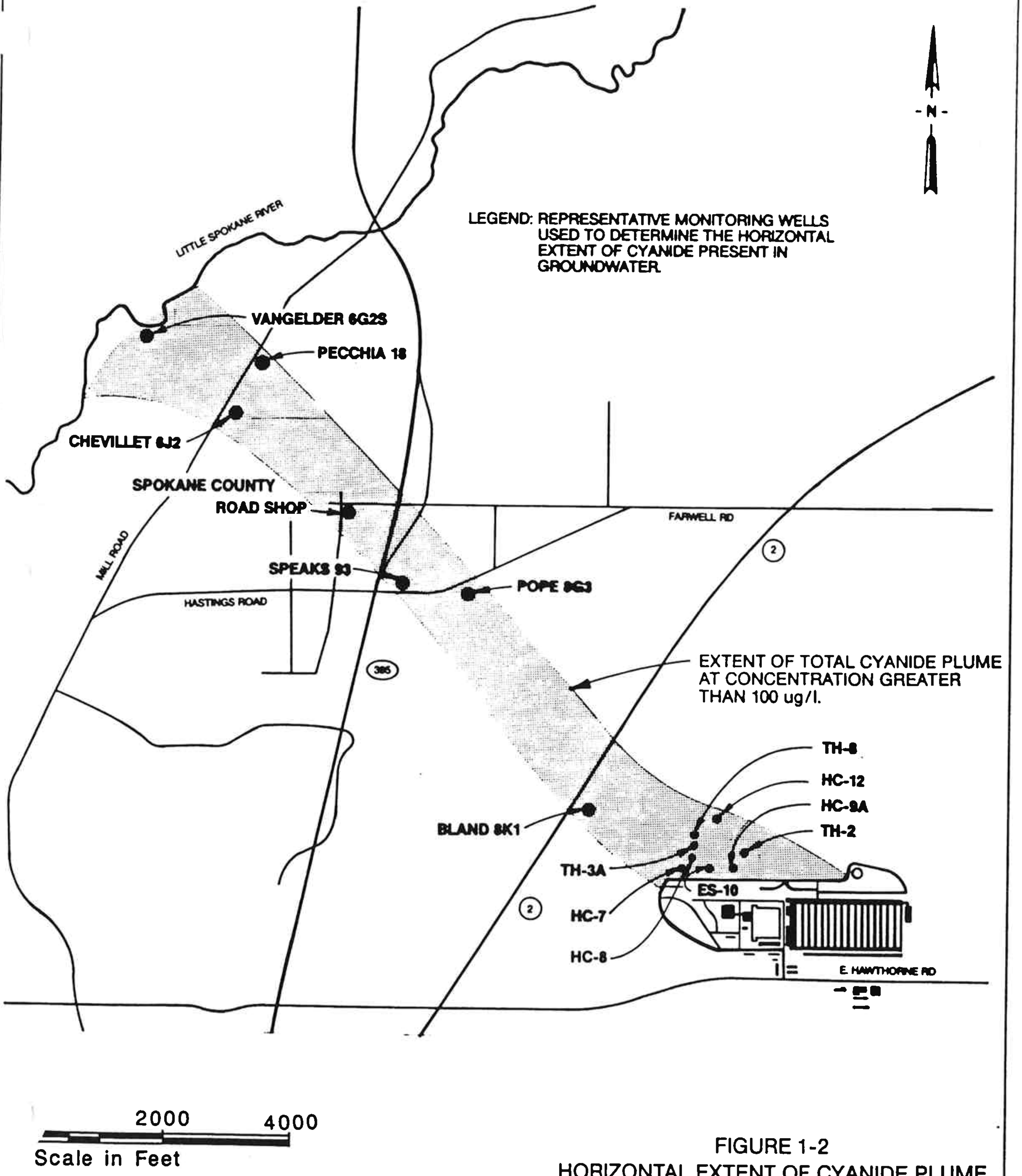


FIGURE 1-2
HORIZONTAL EXTENT OF CYANIDE PLUME
(FROM SITE CHARACTERIZATION
ANALYSIS REPORT)

the earlier findings: analyses for total cyanide (Standard Methods, 16th edition, Method 412B, modified for use with a Technicon analyzer) and free cyanide (ASTM Method D 4282-83) repeatedly have shown that only a small percentage of the cyanide was "free." The numerical difference between total cyanide and free cyanide represents cyanide that is bound or complexed. Cyanide data that are summarized in the Site Characterization Analysis report and that are present in depth in reports cited in that document confirm that the cyanide is complexed.

The occurrence of cyanide in the iron-complexed form in contaminated groundwater beneath Mead has significance in human health and aquatic toxicity issues that will be discussed later in this chapter.

Affected Medium

Groundwater in a plume extending from the Mead Works to the Little Spokane River is a widely recognized and acknowledged affected medium involved in the transport of contamination. The connection between past practices in the handling of spent potlining and the contamination of groundwater has been established (Site Characterization Analysis report, Chapter 1.0). Surface water resources (other than the Little Spokane River, which intercepts groundwater) are unaffected, as evidenced by samples from the Little Spokane River, upstream of the contaminated seepage area (see Appendix C, Ecological Survey of the Little Spokane River in Relation to Cyanide Inputs, Tables 3 and 4; Site Characterization Analysis report, Section 4.1).

The second affected medium is subsurface soil, principally the soil column beneath the spent potlining pile, where the total cyanide concentration exceeds at least 4,500 μg/g. Lower concentrations of total cyanide have been found in other areas such as the sludge bed; but concentrations decrease rapidly with depth, and these areas do not appear to be contributing appreciable quantities to the groundwater (Site Characterization Analysis report, Sections 4.1.3, 4.1.4, and 5.1). The other candidate transport medium, air, can be ruled out as a significant factor in the dissemination of cyanide because the iron complex in which the cyanide occurs is nonvolatile and does not dissociate readily to release free cyanide. (Even free cyanide would not volatilize from the pile because of the high pH of spent potlining.)

EXTENT IN GROUNDWATER

Horizontal Extent of Plume

The plume of cyanide-contaminated groundwater extends northwest from the Mead Works to the regional groundwater discharge at the Little Spokane River. Figure 1-2 depicts the horizontal extent of the plume for total cyanide concentrations exceeding 100 ug/l. The plume width at these concentrations increases from about 800 feet at the plant site to approximately 1,500 feet at the Little Spokane River, about 2-1/2 miles away.

Vertical Extent of Plume

Cyanide concentration in groundwater varies with aquifer depth. The regional aquifer beneath the Mead Works extends downward from the water table (which occurs at a depth of about 145 feet) to a depth of about 270 to 280 feet. The aquifer can be discussed in terms of three zones designated Zones A, B, and C (see Figure 1-3). Each zone is separated from the others by silt/clay layers of varied thicknesses. Cyanide contamination is greatest in Zone A (upper zone) with lesser amounts in Zone B and further reduced levels in Zone C.

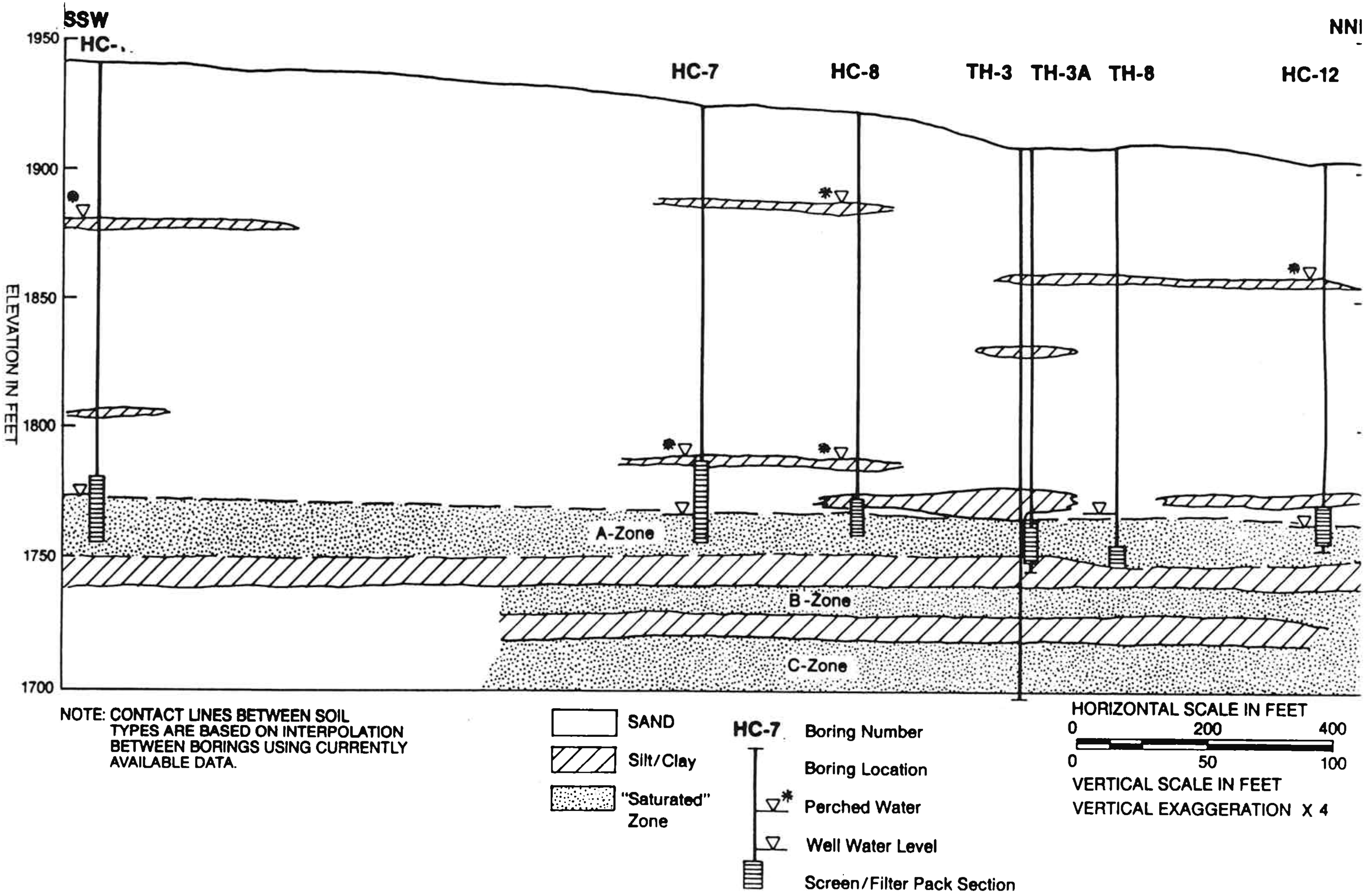
Quality Improvement With Time

Groundwater quality has improved as a result of remedial activities that have occurred at the Mead Works. Table 1-3 shows the reduction in cyanide concentrations at representative onsite wells. The locations of these wells are shown in Figure 1-2. Cyanide concentrations in these wells have declined between 46 and 99 percent over the past several years. Similar reductions in the fluoride concentration have occurred, also.

Table 1-3
TOTAL CYANIDE CONCENTRATION DECREASES IN GROUNDWATER

Well Number	Peak Year	Average Concentration for Peak Year (ppb)	1987 Concentration (ppb)	Percent Decline
ES-10	1981	74,000	4,000	95
HC-7	1981	45,000	2,500	94
HC-8	1981	55,700	1,200	98
TH-2	1982	3,000	25	99
HC-12	1984	73,600	39,800	46
HC-9A	1984	66,900	30,000	55
TH-3A	1982	182,600	62,800	66
TH-8	1982	262,700	96,400	63

Source: Site Characterization Analysis report, Table 5.



NOTE: CONTACT LINES BETWEEN SOIL TYPES ARE BASED ON INTERPOLATION BETWEEN BORINGS USING CURRENTLY AVAILABLE DATA.

FIGURE 1-3

SCHEMATIC GEOLOGIC CROSS SECTION NNE TO SSW THROUGH WEST END OF THE RUBBLE PILE (FROM SITE CHARACTERIZATION ANALYSIS REPORT)

SOURCES OF LEACHATE

Two equally significant factors must be considered in discussing the sources of leachate and its introduction into the regional aquifer. These factors are the sources of soluble cyanide and the sources of water that can transport the cyanide to the groundwater system. These factors are discussed separately below.

Sources of Cyanide

Sources of cyanide at the Mead Works may be divided into originating sources and secondary sources. The originating and secondary cyanide sources are:

Originating:

- Spent potlining pile
- Rubble pile
- Area 2

Secondary:

- Sludge bed
- Wet-air scrubber liquor
- Subsurface soil

Each of the sources is described briefly below.

Originating Sources. Information compiled to date shows that the primary source of cyanide is spent potlining (SPL) waste and that the cyanide is entering the groundwater in the vicinity of the spent potlining pile (Site Characterization Analysis report, Section 5.1). Spent potlining is the only source known to have a cyanide concentration high enough to yield amounts sufficient to produce the cyanide concentrations found in groundwater in the late 1970s and early 1980s.

Cyanide concentrations in SPL leachate have approached 1,000,000 micrograms per liter (Site Characterization Analysis report, Sections 4.1 and 5.2), and cyanide has been measured in the near-surface soils beneath the SPL pile at high concentrations (Site Characterization Analysis report, Section 5.1.2 and Figure 20). The mechanism by which cyanide migrated from the SPL to the groundwater has been described in the Site Characterization Analysis report (Section 5.1) and can be summarized as follows:

- Water from various sources (pot soaking liquor, ponded runoff, drainage from spent potlining, etc.) extracted contaminants from the SPL and carried them into the subsurface soil.

- Water from the above sources or from other sources (perched groundwater from a leaking settling basin, leaking pipes, etc.) passed through contaminated soil during its migration into the groundwater system.

This interpretation is supported by the location of the head of the contaminated groundwater plume in proximity to the SPL disposal area (Site Characterization Analysis report, Figures 25 and 34), and by the fact that covering the spent potlining pile failed to improve groundwater quality beneath the Mead facility. Groundwater quality only improved after water that was interacting with cyanide-contaminated subsurface soil was eliminated following the relocation of the wastewater settling lagoon, Tharpe Lake (see below and see Site Characterization Analysis report, Sections 1.3, 4.1.1, 4.1.2.1, 4.1.3, 5.1.1, and 5.1.2).

The rubble pile (Figure 1-1) abuts the northwest portion of the asphalt-covered spent potlining, and it is known to contain some spent potlining waste (Site Characterization Analysis report, Section 4.1.2). The quantities of spent potlining are far smaller than those in the SPL pile, however, and rubble, debris, and soil layers have been placed over the spent potlining material, protecting it from direct exposure to precipitation, snowmelt, and runoff (Site Characterization Analysis report, Section 4.1.2.2, Figure 29). Considering the limited potential for natural recharge in the region and the 30- to 40-foot depth of rubble on the pile, it is not considered likely that the rubble pile contributes sufficient quantities of contaminants or mobilizing water to affect the quality of groundwater beneath the Mead Works (Site Characterization Analysis report, Sections 3.3 and 5.2).

Area 2, immediately east of the asphalt-covered spent potlining pile, contains buried spent potlining waste that was discovered during preparations for paving. The area has been paved to prevent mobilization of cyanide during storm events or by runoff ponding. Area 2 is shown in Figure 1-1.

<u>Secondary Sources</u>. Contaminated soil beneath the asphalt-covered spent potlining pile contains cyanide concentrations of at least 4,500 micrograms per gram (parts per million) (Site Characterization Analysis report, Section 5.1.2, Figures 17 and 20, and A-31 through A-34). Subsurface soil beneath the asphalt-covered spent potlining pile has far higher cyanide concentrations than any other soil tested to date. Only spent potlining has a higher cyanide concentration than the subsurface soil below the covered pile. Consequently, subsurface soil beneath the covered spent potlining pile is regarded as a significant reservoir of cyanide even though it is a secondary source. Since the

cyanide-contaminated leachate has had to pass through the 145-foot soil column beneath the site, contaminated soil must extend to that same depth. This contaminated soil column is believed to be the major source of cyanide remaining after the SPL pile was covered that can become remobilized by pipe leaks and by infiltration during stormwater ponding (Site Characterization Analysis report, Section 5.1).

The sludge bed (Figure 1-1) was operated as a repository for sludges from the now-abandoned wet-air pollution control system. Cyanide was introduced into the sludge bed through two practices, both of which have been discontinued for about a decade:

- o Pot soaking liquor was introduced into the wet-air scrubber system for makeup, and cyanide entered the sludge bed in liquid associated with the scrubber sludge.
- o Pot soaking liquor occasionally was discharged directly to the sludge bed after the wet-air pollution control system was decomissioned in 1974.

Soil samples from beneath the sludge bed generally show a rapid decrease in cyanide concentration with increasing depth over a span of about 10 feet. Groundwater wells downgradient of the sludge bed but upgradient of the (asphalt-covered) spent potlining pile typically show cyanide concentrations below 100 micrograms per liter. These observations show that the sludge bed contains some cyanide but its contribution to regional groundwater contamination is negligible compared to soil beneath the spent potlining pile (Site Characterization Analysis report, Sections 4.1.4 and 5.1.1 and Table 2).

Prior to the abandonment of the wet-air scrubber system in 1974, occasional leaks and spills of air scrubber liquor had contaminated soil with cyanide. Spillage in the northeast portion of the plant is believed responsible for low-level and declining cyanide concentrations in Well ES-9 (Site Characterization Analysis report, Section 5.1.2.2). With the abandonment of the wet-air scrubber system in 1974, the potential for recontamination by this mechanism no longer exists. Soil contaminated by this mechanism is not considered a significant contributor of cyanide to groundwater.

In summary, spent potlining was the source from which cyanide originated; however, covering the spent potlining to prevent leaching and infiltration failed to significantly improve water quality in the aquifer. It has been shown that soil beneath the old potlining disposal area (i.e., beneath the covered spent potlining pile) contains cyanide, and is the immediate source from which cyanide contamination in the aquifer originates.

Sources of Water To Transport Cyanide

Water capable of transporting cyanide through the subsurface soil to the regional aquifer may come from a variety of sources. Some of the sources are mentioned as a matter of historical interest, while others may recur. The known or potential sources of water that may be responsible for mobilizing cyanide are:

- Pot soaking liquor (pot soaking discontinued in 1978)
- Natural infiltration (storms and snowmelt)
- Tharp Lake (wastewater settling lagoon, now abandoned)
- Treated sanitary wastewater discharge to the sludge bed (discontinued in 1978)
- Ponded stormwater runoff in Area 2 and Area 4 (see Figure 1-1)
- Pipe leaks (pressure and gravity systems)

Prior to August 1978, failed pots were soaked with water to facilitate the removal of old potlining material. Water-soaked potlining that was disposed of in the vicinity of the existing asphalt-covered spent potlining is thought to have contained free liquid, which carried soluble cyanide into the subsurface soil. This practice continued for more than 30 years and appears to have provided the primary means for cyanide to reach an intermediate aquitard, and subsequently, the regional aquifer. For a while, pot soaking liquor was discharged occasionally to the sludge bed, but this practice was short-lived and does not appear to have caused large quantities of cyanide to reach the deep aquifer, as has happened in the vicinity of the covered spent potlining pile (Site Characterization Analysis report, Sections 1.3, 4.1, 4.2, 4.3, 5.1, and 5.2).

Several studies of natural recharge in the Greater Spokane area have concluded that too little natural precipitation falls to contribute significantly to the regional groundwater system (Site Characterization Analysis report, Sections 3.3, 5.1.2, and 5.2). Excluding the accumulation of ponded stormwater runoff (discussed below), natural precipitation apparently does not constitute a water source capable of transporting cyanide into the regional aquifer in the concentrations that have been found.

Kaiser's consultant, Hart Crowser, recognized that, if natural recharge could not explain the transport of cyanide to the groundwater, another mechanism must be responsible. A nearby settling pond (Tharp Lake) is known now to have been leaking, and water was mounding at an intermediate depth. The mounded water moved laterally as it encountered an aquitard at approximately 60 feet below ground surface, and water migrated into the contaminated subsurface soil beneath the pot dumping and (old) potlining disposal area. There it picked up cyanide and gradually drained through the aquitard into the regional aquifer. This source of mobilizing water is no longer available because the settling pond has been relocated approximately 1,000 yards to the north (Site Characterization Analysis report, Sections 3.3, 4.3, and 5.1 and Figure 10).

Between 1971 and 1974, treated sanitary wastewater from the facility was discharged to the sludge bed, along with sludge from the wet air scrubber system (Site Characterization Analysis report, Section 4.1.4). Wet scrubbing of process offgases was discontinued in September 1974, but treated sanitary wastewater discharge to the sludge bed continued until August 1978, when the practice was discontinued. Following the cessation of aqueous discharge to the sludge beds cyanide concentrations in nearby TH-1 decreased tenfold, a decline that is attributed to the elimination of free liquids in the sludge bed (Site Characterization Analysis report, Section 5.1.1). The sludge bed no longer appears to be a significant source of water for cyanide mobilization.

Standing water has been observed immediately west of the asphalt-covered spent potlining pile in periods of high storm runoff. The low-lying portion of this area has been asphalt paved and is designated "Area 4" in Figure 1-1. Should standing water accumulate in Area 4, the asphalt would inhibit infiltration immediately adjacent to the covered potlining pile (Site Characterization Analysis report, Sections 1.3 and 5.1.3). Similar ponding was also observed in an area now known to be underlain with spent potlining residues, Area 2. Like Area 4, Area 2 has been asphalt paved to control infiltration.

On at least one occasion cyanide concentration increase in groundwater monitoring wells was traced to leakage in the pressure piping system near the covered potlining pile. The cyanide concentration resumed its decline after the leak was repaired. Consequently, other leaking pressurized water pipes or gravity lines could constitute potential water sources (Site Characterization Analysis report, Section 5.1.3).

In summary, five of six potential sources of water that could transport cyanide into the regional aquifer have been eliminated through remedial actions and changes in plant operation (pot soaking, settling pond leakage, sludge bed abandonment, ponded runoff) or have been found insufficient to transport the observed quantities of cyanide (natural infiltration). The sixth water source, leaking pipes and drainage lines, is the primary remaining potential source of water for cyanide mobilization.

HUMAN HEALTH AND ENVIRONMENTAL CONSIDERATIONS

SUMMARY OF REMEDIAL ACTIONS

Kaiser Aluminum & Chemical Corporation performed a succession of remedial actions as investigations provided a progressively clearer understanding of the sources and transport of cyanide. The earliest action was implemented in 1978 when users of wells that contained cyanide were provided with alternative water supplies. This initial action was taken to protect human health, based on the limited information available at the time. The remedial actions Kaiser has taken to date are described in the Site Characterization Analysis report (Section 1.3 and elsewhere) and are summarized in Table 1-4.

PUBLIC AWARENESS

The discovery that cyanide had reached a portion of the regional aquifer was made in 1978, prior to passage of the 1980 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). That act placed many requirements on parties who were responsible for the release of hazardous constituents, including the requirement to alert the public to the potential risk.

Kaiser took a series of steps to make the public aware that a release had occurred and that a public health risk may exist. The principal steps in Kaiser's public information program are summarized as follows:

- In August 1978 the Spokane County Health Department was notified that a cyanide release had taken place and that residential wells were affected.
- The public was notified about the cyanide contamination of groundwater, and replacement water supplies and medical checkups were made available in September 1978.
- Results of early investigations concerning the nature and extent of groundwater contamination were released and reported through local news media between 1978 and 1982.

Table 1-4
SUMMARY OF REMEDIAL ACTIONS AT KAISER MEAD 1978 TO PRESENT

Date	Activity	Reason for Action Taken
August 1978	Discharge of pot soaking water stopped. Discharge of sewage effluent to the sludge bed stopped.	Groundwater contamination discovered beneath the Mead Works. Waste handling practices thought to be responsible were discontinued.
September 1978	Bottled water to residents. Physical offered to residents.	Cyanide contamination was discovered in residential wells. Potential for health effects prompted action.
October 1978	Pot soaking operations discontinued.	By order of state (Department of Ecology) and county health department to prevent further pot soaking liquor releases.
January 1979	Potlining waste pile reshaped and covered with plastic.	Suspected primary cyanide source was isolated to prevent leachate generation and transport.
April 1979	Potlining waste pile paved and temporary storage slab with leachate collection constructed for new wastes.	Temporary source isolation converted to permanent design. New potlining waste from ongoing operations temporarily stored on asphalt pad, pending construction of new storage building.
November 1979	Public water supply hookups to residences completed.	Public water supply lines extended to vicinity of affected residences. Total abandonment of contaminated wells now feasible.
September 1981	New settling basin completed. Old settling basin (Tharp Lake) abandoned and filled.	Covering spent potlining had failed to improve groundwater contamination. Tharp Lake recognized as source of water transporting cyanide to the regional aquifer.
November 1981	Potlining storage building constructed. Waste stored on temporary pad moved into building.	This action was a continuation of Kaiser's plan for isolating cyanide-containing potlining waste begun in January 1979.
June 1983	Pipe leak repaired.	Increasing cyanide concentrations in monitoring wells were caused by a pipe leak.
1984	Second potlining storage building put into service.	Spent potlining storage and handling space requirements greater than capacity of a single building.
January 1986	Discontinued use of outdoor pot cleaning slab.	Pot dismantling moved indoors to minimize dust dispersal and to eliminate the need for collection and treatment of rainwater.
April 1986	Covered Area 2 with asphalt.	Ponding was observed during heavy runoff events. Area paved to prevent contaminant transport.
October 1986	Abandoned water handling system closed. Paving completed over Area 3 and old pot cleaning slab.	Area 3 paved to prevent infiltration of ponded water during heavy runoff. Abandoned water handling system (old pot soaking facility) closed concurrently.
November 1987	Covered Area 4 with asphalt.	Area 4 paved to prevent infiltration of ponded water during heavy runoff.

- A series of newsletters informing residents of progress in the program to bring public water supplies to their property was distributed during 1978 and 1979.
- Results of periodic groundwater monitoring were made available to residents located along the migration pathway of cyanide-contaminated groundwater (1981 to present).
- In 1984 the Department of Ecology conducted a public meeting to discuss its investigation of the situation.
- In 1986 Kaiser conducted a house-to-house sampling campaign of residences with groundwater wells and discussed the trends revealed by the ongoing groundwater monitoring program.

Kaiser's proactive approach to promoting public awareness about groundwater contamination, particularly through the 1986 well sampling campaign, has provided an effective program. The program's effectiveness and credibility have been reinforced by Kaiser's early actions to protect human health by providing alternative drinking water supplies to affected residents, by offering medical examinations to determine whether health effects had occurred, and by taking steps at the Mead Works to provide long-term control against the further release of contamination.

FERROCYANIDE TOXICITY

The early remedial actions Kaiser undertook to protect public health were carried out with a sense of urgency prompted by cyanide's reputation for toxicity. As data on the speciation of cyanide in the contaminated groundwater began to accumulate from the earliest field investigations, the cyanide was shown to be present predominantly in the iron-complexed form known as ferrocyanide (Robinson and Noble, 1979; Site Characterization Analysis report, Table 7). Subsequent published accounts and field investigations have shown that ferrocyanide poses a far lower human health risk than do other forms of cyanide.

Toxicity to Humans

It is generally recognized that free or weakly dissociated cyanide is toxic to humans. The U.S. EPA (1984 and 1987) recently has evaluated the health effects of free cyanide and, based on its health effects assessment (U.S. EPA, 1984), established an allowable daily intake (oral) (ADI) for cyanide of 1.5 milligrams per day (mg/d) as CN^-, implicitly recognizing that other forms of cyanide, such as iron-complexed forms, exhibit a low toxicity. The ADI of 1.5 mg/d would be obtained by drinking 2 liters of water per day with 700 parts per billion (ppb) of cyanide as CN^-. (Parts per billion are equivalent to micrograms per liter, µg/l, in this discussion.) More recently, EPA (1987) in a health advisory has recommended that drinking water concentrations of free cyanide (as a lifetime health advisory) should not exceed 154 µg/l if consumed at 2 liters per day over a lifetime by a 70-kilogram (kg) adult or 220 µg/l of CN^- if consumed at 1 liter per day by a 10-kg child for any duration. If drinking water is the only source of cyanide, the drinking water equivalent level (DWEL) is 770 ppb, based on a reference dose of 0.022 mg/kg-day.

In contrast, the toxicity of strongly complexed cyanide such as ferro- and ferricyanide was not considered to contribute significantly to cyanide toxicity to humans; only free cyanide was considered in establishing health criteria (U.S. EPA, 1984 and 1987). The low toxicity of iron-complexed cyanides is exemplified best by the large doses that can be ingested safely by animals and humans. For example, the oral LD 50s of sodium cyanide and potassium cyanide to rats are 6.44 and 10 milligrams per kilogram (mg/kg) body weight, respectively (Sax, 1984). By contrast, the oral LD 50 of potassium ferricyanide is about 1,600 mg/kg body weight for rats (NIOSH, 1978) or 1,600 to 3,200 mg/kg (Fassett, 1958). This compares favorably with ordinary table salt (sodium chloride), which has an oral LD 50 of 3,000 mg/kg body weight for rats (NIOSH, 1978). This means that potassium ferricyanide is comparable to table salt in toxicity.

A further indication of the low toxicity of iron cyanide is provided by the fact that sodium ferrocyanide decahydrate (prussiate of sodium) is allowed in table salt as an anticaking agent (21 CFR 172.490).

Ferro- and ferricyanide salts have been tested as a renal challenge (to test kidney function). These iron-complexed cyanide salts worked reasonably well for demonstrating kidney failure and had no apparent toxic effects (Steiglitz and Knight, 1934; Plotz and Rothenberger, 1939; Kleeman and Epstein, 1956).

Ferrocyanides are used also as a clinical treatment to promote the excretion of radioactive substances following accidental radiation poisoning of humans. The relative toxicity of four metals-ferrocyanides and their efficacy at promoting excretion of cesium-134 were evaluated by Brenot and Rinaldi (1967). The oral LD50s they reported for rats were 4,090 mg/kg, 1,130 mg/kg, 891 mg/kg, and 903 mg/kg for cobalt, ferric, bismuth, and calcium ferrocyanide, respectively.

In the Soviet Union human health-based concentration limits have been established for potassium ferricyanide in reservoirs (Smirnova, Pavlenko, and Oleinik, 1967). The value is 1.25 milligrams per liter (mg/l) based on a harmless dose of 0.0625 mg/kg to a test animal.

In general, the toxicity of solutions of complexed cyanides increases as the amount of free cyanide increases (Huiatt et al., 1983).

The highest concentration of free cyanide in the groundwater plume that was observed in offsite wells in August through November 1986 was 96 µg/l (Well 195)(Site Characterization Analysis report, Table 7). Most offsite wells had concentrations of free cyanide of less than 20 µg/l. Given that most of the cyanide in those wells was reportedly iron complexed (Site Characterization Analysis report, Table 7) with low toxicity, the potential for exposure to toxic concentrations of cyanide in groundwater would be low even if the wells were used for potable water.

Aquatic Toxicity

There is extensive literature that indicates that the toxicity of iron-complexed cyanide to aquatic life is very low compared to free cyanide (Broderius, 1973; American Fisheries Society, 1979; Duderoff, 1976; Ecological Analysts, 1979). Most authors feel that cyanide toxicity is attributable almost entirely to free cyanide. However, the interpretation of potential effects of discharges of cyanides to surface waters is complicated by the fact that iron-complexed cyanides can be photolyzed to release free cyanide (Broderius, 1973; American Fisheries Society, 1979; Ecological Analysts, 1979).

Because of the potential for photolytic production of free cyanide, the U.S. EPA has established an ambient water quality criterion of 5.2 µg/l for total cyanide.

Concentrations of total cyanide in springs discharging to the Little Spokane River have been shown to increase total cyanide in the river to values several fold higher than the EPA ambient water quality criteria. To evaluate potential effects of cyanide on animals in the Little Spokane River, Kaiser sponsored a study of fish and invertebrates in the river above and below points of discharge of cyanide [Hartung and Meier, 1980 (Appendix C)]. That study confirmed the presence of total cyanide in excess of the water quality criterion, but also demonstrated that there were no apparent effects on the biota in the river.

The study by Hartung and Meier consisted of a fish census by electroshocking and estimating populations by a marked-recapture technique. Benthic invertebrates were also sampled. Community parameters above and below cyanide discharges were compared. Differences in biota along the river were attributed to variations in habitat. Fish, which are generally more sensitive to cyanides than are invertebrates, were not affected adversely. The community composition in areas with excess cyanide was compared with the composition in areas upstream of cyanide discharges. The coefficient of similarity (Cs) reported by Hartung and Meier (1980) suggests that the cyanide had no significant effect on the river, but the computational method contained an error. Their reported values should be divided by two to be corrected (Hartung, personal communication, March 3, 1988). The index used is similar to the Jicard index and is somewhat sensitive to having an equal-catch-per-unit effort in both study areas. However, the conclusions of Hartung and Meier concerning no effects of cyanides appear to be valid. Those conclusions are supported by the presence of the more sensitive salmonid species in the contaminated reaches of the river.

The studies to date in the Little Spokane River indicate that the cyanide has had no discernible effect on aquatic life despite the fact that measured total cyanide concentrations exceed the 5.2-µg/l ambient water quality criterion. The apparent lack of toxic effects of cyanide in the Little Spokane River may be because the rate of dispersion and dilution of the iron-complexed cyanides that are discharged from groundwater are more rapid than the photolytic production of free cyanide; therefore, the measured total cyanide is not all biologically active. Ultimately, large quantities of groundwater from the Spokane aquifer empty into the Little Spokane River a few hundred yards below the contaminated plume (Site Characterization Assessment report, Sections 2.4 and 4.4), further reducing any potential impact from the contamination.

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

Remedial actions conducted on National Priority List (NPL) sites must comply with all applicable or relevant and appropriate federal and duly promulgated state environmental and public health laws. Congress established this requirement in Section 121(d) of the 1986 Superfund Amendments and Reauthorization Act (SARA). These laws are known as Applicable or Relevant and Appropriate Requirements (ARARs). There is a distinction between "applicable" and "relevant and appropriate."

"Applicable" means that all jurisdictional prerequisites of the law or requirement are satisfied. "Relevant and appropriate" means that not all of the prerequisites are satisfied but that the conditions on the site are similar to those governed by the law or requirement. The EPA decides, with input from the state, which requirements are applicable or relevant and appropriate to a site on a case-by-case basis.

ARARs apply only to actions or conditions that are located entirely onsite. Section 121(e) of CERCLA states that no federal, state, or local permit is required for remedial actions conducted entirely onsite. Therefore, actions conducted entirely onsite must meet only the substantive, and not the administrative, requirements of the ARARs.

ARARs may be divided into three categories:

- Chemical-specific ARARs
- Location-specific ARARs
- Action-specific ARARs

These terms are described below.

Chemical-specific ARARs include those laws and requirements that regulate the release to the environment of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. The requirements for cyanide and fluoride were examined in connection with the Mead Works.

Location-specific ARARs are those requirements that relate to the geographic or physical position of the site. These requirements may limit the type of remedial actions that can be implemented and may impose additional constraints on the cleanup action. Flood-plain restrictions and the protection of endangered species are among the location-specific potential ARARs.

Action-specific ARARs are requirements that define acceptable treatment and disposal procedures for hazardous substances. These requirements generally set performance or design standards for specific activities related to the management of hazardous wastes. Appendix D provides a compilation of action-specific ARARs that may apply to alternative remedial actions that are discussed in Chapter 3.

By identifying potential ARARs at an early stage, the remedial alternatives can be developed to meet the ARARs and can then be evaluated and compared more accurately. This discussion covers only the potential federal ARARs. State requirements that are more stringent than the corresponding federal requirements will be identified by the Washington Department of Ecology (Ecology). These potential state ARARs will be evaluated at a later date.

CHEMICAL-SPECIFIC ARARs

The major regulations that contribute to the list of potential chemical-specific ARARs included in the EPA draft guidance are the Safe Drinking Water Act (SDWA) and the Resource Conservation and Recovery Act (RCRA). These regulations all describe chemical-specific standards for water. The SDWA maximum contaminant level (MCL) standards are based on human use of water for drinking, cooking, bathing, etc. Economic considerations and technical feasibility of treatment process are included in the justification for these levels. These are enforceable standards that may be applicable to the discharge of any liquid to surface water or groundwater that can be classified as a source or potential source of drinking water. [The RCRA maximum concentration limits (MCLs) apply to groundwater contamination from a RCRA facility.]

Review of these potential chemical-specific ARARs resulted in the identification of one possible ARAR. The Safe Drinking Water Act maximum contaminant level (SDWA MCL) for fluoride is 4 mg/l.

The SDWA MCLs regulate the concentrations of contaminants in a public water system. Since the groundwater in the areas can be classified as a present or potential source of drinking water, the MCLs may be applicable to water from the facility that enters the groundwater. Although the MCLs are enforceable at the point of usage (at the tap), they may be applied to the groundwater itself since groundwater traditionally receives little or no treatment prior to distribution. The MCLs also may be applicable to the discharge of the groundwater to the Little Spokane River if the river is or could be considered to be a source of public drinking water.

LOCATION-SPECIFIC ARARs

Table 1-5 has been prepared using the proposed EPA draft guidance and includes the location-specific requirements identified by EPA as potential ARARs for CERCLA remedial actions. Location-specific ARARs are concerned with the area in which the site is located. Actions may be required to preserve or protect aspects of the environment or cultural resources of the area that may be threatened by the existence of the site or by the remedial actions to be undertaken at the site.

The major regulations that form the list of potential location-specific ARARs include RCRA, the National Archaeological and Historical Preservation Act, the National Historic Preservation Act, the Endangered Species Act, the Clean Water Act, the Wilderness Act, the Fish and Wildlife

Table 1-5
(Continued)

	Location	Requirement	Prerequisite(s)	Citation	ARAR	Comments
11.	Area affecting stream or river	Action to protect fish or wildlife.	Diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife	Fish and Wildlife Coordination Act (16 USCC 661 et seq.); 40 CFR 6.302	Not ARAR	No actions which would adversely impact the Little Spokane River are contemplated.
12.	Within area affecting national wild, scenic, or recreational river	Avoid taking or assisting in action that will have direct adverse effect on scenic river.	Activities that affect or may affect any of the rivers specified in Section 1276(a)	Scenic Rivers Act (16 U.S.C. 1271 et seq. Section 7(a)); 40 CFR 6.302(e)	Not ARAR	No national wild or scenic rivers are located on the site or will be impacted by site remediation.
13.	Within coastal zone	Conduct activities in manner consistent with approved state management programs.	Activities affecting the coastal zone including lands thereunder and adjacent shorelands	Coastal Zone Management Act (16 USC Section 1451 et seq.)	Not ARAR	The site is an inland area with no direct access to coastal areas.
14.	Oceans or waters of the United States	Action to dispose of dredge and fill material into ocean waters is prohibited without a permit.	Oceans and waters of the United States Sanctuary Act, Section 103	Clean Water Act Section 404 40 CFR 125 Subpart M; Marine Protection Resources	Not ARAR	No dredging actions are envisioned.

Table 1-5
POTENTIAL LOCATION-SPECIFIC ARARs
KAISER ALUMINUM/MEAD WORKS

	Location	Requirement	Prerequisite(s)	Citation	ARAR	Comments
1.	Within 61 meters (200 feet) of a fault displaced in Holocene time	New treatment, storage, or disposal of hazardous waste prohibited.	RCRA hazardous waste; treatment, storage, or disposal	40 CFR 264.18(a)	Not ARAR	There is no evidence of an active fault within 61 meters of the site.
2.	Within 100-year flood plain	Facility must be designed, constructed, operated, and maintained to avoid washout.	RCRA hazardous waste; treatment, storage, or disposal	40 CFR 264.18(b)	Not ARAR	The Kaiser facility is not located within a 100-year flood plain.
3.	Within flood plain	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values.	Action that will occur in a flood plain; i.e., lowlands and relatively flat areas adjoining inland and coastal waters and other flood-prone areas	Executive Order 11988, Protection of Floodplains, (40 CFR 6, Appendix A)	Not ARAR	The Kaiser facility site is not located within a flood plain.
4.	Within salt dome formation, underground mine, or cave	Placement of noncontainerized or bulk liquid hazardous waste prohibited.	RCRA hazardous waste; placement	40 CFR 264.18(c)	Not ARAR	The Kaiser facility site does not contain any salt dome formations, underground mines, or caves used for waste disposal. No such disposal is planned for the site wastes.
5.	Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Action to recover and preserve artifacts.	Alteration of terrain that threatens significant scientific, prehistorical, historical, or archeological data	National Archaeological and Historical Preservation Act (16 USC Section 469); 36 CFR Part 65	Not ARAR	No known scientific, prehistoric, or historic artifacts present at the site.
6.	Historic project owned or controlled by federal agency	Action to preserve historic properties; planning of action to minimize harm to national historic landmarks.	Property included in or eligible for the National Register of Historic Places	National Historic Preservation Act, Section 106 (16 USC 470 et seq.); 36 CFR Part 800	Not ARAR	The Kaiser facility is not included in the National Register of Historic Places.
7.	Critical habitat upon which endangered species or threatened species depends	Action to conserve endangered species or threatened species, including consultation with the Department of the Interior.	Determination of endangered species or threatened species	Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR Part 200, 50 CFR Part 402	Not ARAR	No endangered species are known to exist on the site.
8.	Wetland	Action to minimize the destruction, loss, or degradation of wetlands.	Wetland as defined by Executive Order 11990, Section 7	Executive Order 11990, Protection of Wetlands, (40 CFR 6, Appendix A)	Not ARAR	The site is not defined as a wetland.
		Action to prohibit discharge of dredged or fill material into wetland without permit.		Clean Water Act, Section 404; 40 CFR Parts 230 and 231		
9.	Wilderness area	Area must be administered in such a manner as will leave it unimpaired as wilderness and to preserve its wilderness character.	Federally owned area designated as wilderness area	Wilderness Act (16 USC 1131 et seq.); 50 CFR 35.1 et seq.	Not ARAR	The site has not been designated as a Federal Wilderness Area.
10.	Wildlife refuge	Only actions allowed under the provisions of 16 USC Section 668 dd(c) may be undertaken in areas that are part of the National Wildlife Refuge System.	Area designated as part of National Wildlife Refuge System	16 USC 668 dd et seq.; 50 CFR Part 27	Not ARAR	The site has not been designated as a National Wildlife Refuge.

Coordination Act, the Scenic Rivers Act, the Coastal Zone Management Act, the Marine Protection Resources and Sanctuary Act, and the Executive Orders on the Protection of Wetlands and the Protection of Floodplains.

As indicated in Table 1-5, none of the proposed location-specific ARARs identified in the EPA draft guidance appears to be applicable or relevant and appropriate to the Mead Works.

ACTION-SPECIFIC ARARs

A tabulation of action-specific ARARs that may pertain to remedial alternatives that are described later in the report is contained in Appendix D. This appendix should be consulted for action-specific ARARs when remedial alternatives in Chapter 3 are evaluated.

WAIVERS

CERCLA Section 121 specifies that there are six situations under which the ARARs requirements may be waived by EPA. The waivers apply only to the attainment of an ARAR. The requirement that remedies the protection of human health and the environment may not be waived. The situations eligible for waivers include:

1. Interim Remedies. A portion of a remedy need not satisfy all ARARs as long as the completed remedial action will satisfy the ARARs.

2. Greater Risk to Human Health or the Environment. Compliance with the ARARs would result in greater risk to human health or the environment than would alternative actions.

3. Technical Impracticability. Compliance with the ARARs is technically impracticable from an engineering perspective.

4. Equivalent Standard of Performance. The remedial action selected will attain a standard of performance equivalent to that required by the ARAR using another method or approach.

5. Inconsistent Application of State Requirements. A state requirement will not be treated as an ARAR if the state consistently has not applied the requirement in similar circumstances on other remedial actions.

6. Fund Balancing. Applies only to remedial actions being financed by Superfund.

The waivers would be evaluated, if necessary, after selection of the remedial action alternatives.

CRITERIA TO BE CONSIDERED (TBCs)

In addition to ARARs, there are several environmental and public health criteria, guidelines, goals, and industry standards that are evaluated in the development and selection of remedial alternatives. While these guidelines are not enforceable regulations and therefore are not ARARs, they are useful and important sources of information. The EPA has designated such guidelines as criteria to be considered (TBC) in the RI/FS process.

The EPA has classified the Clean Water Act ambient water quality criteria (CWA AWQC) as TBCs rather than ARARs. The ambient water quality criteria are designed to protect aquatic life. These criteria are expressed on the bases of acute and chronic toxicity levels. Although the ambient water quality criteria, themselves, are not enforceable, offsite discharges to surface water or to groundwater that discharges to surface water may be required to meet these criteria under NPDES permits.

The AWQC for cyanide in fresh water is 5.2 µg/l for chronic exposure and 22 µg/l for acute exposure. These criteria should be considered in the selection of remedial action alternatives. Alternatives that would result in these concentrations being met in the Little Spokane River should be favored.

SUMMARY OF CURRENT STATUS

This section draws upon information presented in the preceding portions of Chapter 1 in order to state succinctly the technical issues that are involved in groundwater contamination originating at Kaiser's Mead Works. The following items summarize the current understanding of the situation at the time this report was prepared.

- Cyanide is the contaminant of concern that has migrated from sources at the Mead Works.
- The cyanide is found primarily in an iron complex (ferrocyanide).
- Substantial abatement in the quantity of cyanide leaving the Mead Works has been realized through past remedial actions taken at the sources.

- Human health is not believed to be at risk because residences along the affected plume are connected to the public water supply.
- The human health risk from cyanide is lower than originally thought in 1978 because the cyanide is now known to be present predominantly in an iron-complexed form.
- No human exposure standard for cyanide has been found among federal ARARs.
- An ecological investigation of the Little Spokane River has indicated that the cyanide entering the river has not affected indigenous aquatic populations.
- A recommended federal criterion for cyanide in fresh water (5.2-µg/l chronic exposure for aquatic organisms--cyanide assumed to be in free form) is exceeded by up to a factor of 10 in the Little Spokane River.

Based on the foregoing understanding of the current status and considering the physical environment at Mead and of the affected environment, it appears that a potential cleanup target is 5.2-µg/l cyanide in the Little Spokane River. Means to achieve this degree of cleanup fall into two categories: source control and contaminated plume management. Source control can be subdivided further into two categories: (1) cyanide source management and (2) control of water that can infiltrate and transport cyanide from cyanide sources.

Ten years of field investigation have shown that the original cyanide source was spent potlining, now isolated by asphalt cover. The asphalt-covered spent potlining pile is the largest reservoir of cyanide at the Mead Works; but its isolation was insufficient to eliminate groundwater contamination.

Like the spent potlining pile, Area 2 contains spent potlining, which is protected by an asphalt cover. Unlike the spent potlining pile, however, Area 2 contains a smaller amount of waste material but had been subject to ponding during storm runoff events. Area 2 may be as important as a collection point for ponded stormwater, which could transport contaminants in subsurface soil into the regional aquifer, as it is an originating source of cyanide. The rubble pile also contains small quantities of spent potlining compared to the covered pile, but while it is a potential source of cyanide, no mechanism has been identified by which the cyanide could be transported into the subsurface soil and the regional aquifer.

The most important cyanide source at the Mead Works is contaminated soil beneath the asphalt-covered spent potlining pile. The degree of soil contamination is second only to the spent potlining pile, above, and far outweighs other known originating sources at the facility. Contaminated subsurface soil is the primary medium that can affect groundwater quality, through a mechanism of infiltration from various water sources. The other secondary sources, spilled wet-air scrubber liquor and the air emissions control system sludge bed, showed little potential for significant groundwater contamination and are not considered further.

The cyanide sources to be addressed in the development of remedial alternatives, therefore, are:

- o The spent potlining pile (originating source)
- o Area 2 (originating source)
- o Subsurface soil beneath the spent potlining pile (secondary source)

The number of potential sources for recharge water that might transport cyanide into the regional groundwater system are limited to three, as described in a previous section of this chapter:

- o Ponding in Area 2
- o Ponding in Area 4
- o Leakage of buried pressure or gravity pipes in the vicinity of a cyanide source

Direct precipitation is not considered sufficient to promote cyanide transport to the groundwater system, unless assisted by ponding.

The remainder of the report will deal with means of controlling the cyanide sources, sources of recharge water identified above, and means of managing groundwater once it has become contaminated.

Chapter 2
TECHNOLOGY SCREENING

This chapter discusses the procedures used to identify and screen technologies for possible incorporation into remedial alternatives for controlling cyanide contamination from the Kaiser Aluminum and Chemical Corporation's (KACC) Mead Works. Technologies were evaluated for both the onsite contaminant source(s)(source operable units) and the groundwater (groundwater/plume operable unit). It should be explained that "source" refers to both sources of cyanide and any seasonal, permanent, or occasional sources of water that could mobilize the cyanide. The term "operable unit" refers to any discrete part of a remedial action that functions independently as a unit and contributes to preventing or minimizing rebase or threat of release.

TECHNOLOGY IDENTIFICATION AND INITIAL SCREENING

Potentially applicable remedial technologies were identified after first evaluating the cyanide contamination in potential sources at the site and in groundwater. A summary of the site nature and extent of contamination is provided in Chapter 1. Based on these data, the potential remedial actions were divided into source-related and plume-related operable units.

Source-related technologies were directed mainly at cleanup actions for the spent potlining pile with consideration also given to other, less contaminated sources including potential water infiltration sources and source areas. Groundwater remediation technologies were focused on actions to clean up the cyanide-contaminated plume extending from the Mead site to the Little Spokane River.

Potentially applicable technologies for source and groundwater remediation at Mead were selected initially from those listed in Table 2-1. The technologies listed in Table 2-1 were compiled from two references:

1. Guidance on Feasibility Studies Under CERCLA, document published by the U.S. Environmental Protection Agency Report No. EPA/540/G-85/003 (June 1985).

2. A Study of Hazardous Waste Management Priorities for Categories of Waste in Washington State by the Washington State Department of Ecology, Ecology Document No. 86-7 (July 1986).

The first document provides a general list of technologies that typically are considered for site remedial actions.

Table 2-1
TYPICAL REMEDIAL TECHNOLOGIES

Technology	Screening Results First Level
A. Air Pollution Controls	
o Capping	Selected for further consideration
- Synthetic membranes	
- Clay	
- Asphalt	
- Multimedia cap	
- Concrete	
- Chemical sealants/stabilizers	
o Dust Control Measures	Selected for further consideration in conjunction with waste removal technologies
- Polymers	
- Water	
B. Surface Water Controls	
o Capping (see Item A above)	Selected for further consideration
o Upgrade existing caps	Selected for further consideration
o Reroute, repair, or replace existing pipelines, and relocate wastewater treatment plant	Selected for further consideration
o Pipeline leak monitoring	Selected for further consideration
o Grading	Provided as a component of capping technology
- Scarification	
- Tracking	
- Contour furrowing	
o Revegetation	Considered as a component of capping technology
- Grasses	
- Legumes	
- Shrubs	
- Trees, conifers	
- Trees, hardwoods	

Table 2-1
(continued)

Technology	Screening Results First Level
o Groundwater pumping (generally used with capping and treatment) Function options - Extraction and injection - Extraction alone - Injection alone Equipment and Material Options - Well points - Deep wells - Suction wells - Ejector wells	Components selected for further consideration
o Subsurface Collection Drains - French drains - Tile drains - Pipe drains (dual media drains)	Not applicable to this site
o Groundwater Monitoring	Selected for further consideration
D. <u>Gas Mitigation Controls</u>	
o Capping (gas barriers) (see Item A)	Not applicable to this site
o Gas collection and/or recovery - Passive pipe vents - Passive trench vents - Active gas collection systems	Not applicable to this site

Table 2-1
(continued)

Technology	Screening Results First Level
E. Excavation and Removal of Waste and Soil	
o Excavation and removal - Backhoe - Cranes and attachments - Front-end loaders - Scrapers - Pumps - Industrial vacuums - Drum grapplers - Forklifts and attachments	Components selected for further consideration
o Grading (see Item B)	Considered as a component of capping
o Capping (see Item A)	Selected for further consideration
o Revegetation (see Item B)	Considered as a component of capping
F. Removal and Containment of Contaminated Sediments	
o Sediment removal Mechanical dredging - Clamshell - Dragline - Backhoe Hydraulic dredging - Plain suction - Cutterhead - Dustpan Pneumatic dredging - Airlift - Pneuma - Oozer	Site does not contain contaminated sediments; not applicable to this site

Table 2-1
(continued)

Technology	Screening Results First Level
o Sediment turbidity controls and containment	Not applicable to this site
- Curtain barriers	
- Cofferdams	
- Pneumatic barriers	
- Capping	
G. <u>In Situ Treatment</u>	
o Hydrolysis	Components selected for further consideration
o Oxidation	
o Reduction	
o Soil aeration	
o Solvent flushing	
o Neutralization	
o Polymerization	
o Sulfide precipitation	
o Bioreclamation	
o Permeable treatment beds	
o Chemical dechlorination	
o Vitrification	
H. <u>Direct Waste Treatment</u>	
o Incineration	Components selected for further consideration
- Rotary kiln	
- Fluidized bed	
- Multiple hearth	
- Molten salt	
- Cement kiln	
- In situ vitrification	
o Potlining--specific treatments	Components selected for further consideration
- Incineration by fluidized bed combustion	
- Pyrohydrolysis	
- Pyrosulfolysis	
- Carbon recovery by steam hydrolysis or hot-water leach	
- Carbon reuse as anode material	

Table 2-1
(continued)

Technology	Screening Results First Level
- Alcan membrane process	
- Alcoa aluminum sulfate/ sulfuric acid process	
- Alcan Deutschman process	
- Cyclonic smelting	
- Incineration followed by sodiumcarbonate addition	
o Potlining--specific recycle/resale	Components selected for further consideration
- Recycle in-plant (dry roasting)	
- Recycle in-plant (wet processing)	
- Resale for steelmaking	
- Resale for mineral wool production	
- Resale for cement kiln fuel	
o Gaseous waste treatment	Considered as a component of other direct waste treatment technologies
- Activated carbon	
- Flares	
- Afterburners	
o Treatment of aqueous and liquid waste streams and groundwater	Components selected for further consideration
Biological treatment	
- Activated sludge	
- Trickling filters	
- Aerated lagoons	
- Waste stabilization ponds	
- Rotating biological disks	
- Fluidized bed bioreactors	
Chemical treatment	
- Neutralization	
- Precipitation	
- Oxidation	
- Hydrolysis	
- Reduction	
- Chemical dechlorination	
- Ultraviolet/ozonation	

Table 2-1
(continued)

Technology	Screening Results First Level
o Solidification, stabilization, or fixation - Cement-based - Lime-based - Thermoplastic - Organic polymer - Self-cementing techniques - Surface encapsulation - Glassification - Solidification (i.e., fly ash, polymers, sawdust) - Grouting	Components selected for further consideration
I. Land Disposal Storage	
o Landfills onsite/offsite o Surface impoundments o Land application o Waste piles o Deep-well injection o Temporary storage	Components selected for further consideration
J. Contaminated Water Supplies and Sewer Lines	
o In situ cleaning o Removal and replacement o Alternative drinking water supplies - Cisterns or tanks - Deeper or upgradient wells - Municipal water systems - Relocation of intake o Individual treatment units	Not relevant under existing site conditions (some components previously implemented)

Sources: U.S. Environmental Protection Agency. Guidance on Feasibility Studies Under CERCLA. EPA/540/6-85/003. June 1985.

Washington State Department of Ecology. A Study of Hazardous Waste Management Priorities for Categories of Waste in Washington State. Ecology Document Number 86-7. July 1986.

Technologies listed in the second document relate to treatment of spent potlining from aluminum reduction facilities.

Potentially applicable technologies were selected during an initial screening of the technologies in Table 2-1. This initial screening process consisted of identifying technologies that had potential applicability to sources or affected media associated with the Mead Works. Screening involved comparing the listed technologies to known waste characteristics and site data. Typical site- and waste-related characteristics that are considered in the selection of remedial technologies are listed in Table 2-2. In this initial screening exercise, technology applicability was judged primarily on the basis of the waste type and toxicity, known contamination sources, known migration and potential exposure routes, and the physical condition of the waste piles stored onsite.

TECHNOLOGY DISCUSSIONS

The technologies that had potential usefulness for the Mead site were classified according to their applicability to sources or the contaminated plume associated with the Mead Works.

I. SOURCE-RELATED TECHNOLOGIES

A. General

Excavation. Excavation is the process of physically digging and removing contaminated solids from their existing emplacements. Use of this technology would be required in any remedial alternative involving handling of the waste sources. Generally, the method of excavation is selected by a given contractor and depends on the type of equipment the contractor has available. For removal of waste deposits on the ground surface, bulldozers, front-end loaders, and haul trucks would be the likeliest equipment used. Source excavation at the Mead site would require that dust from the spent potlining be controlled. This probably would be implemented by spraying the waste piles and the filled haul trucks with water during the process. Tight covers over the truck beds also might be necessary during any transport to minimize dust release.

Excavation of sufficient cyanide-contaminated soil to prevent groundwater contamination during occasional recharge episodes such as pipe leaks would involve removing a soil column approximately 145 feet deep. This hydraulically unsaturated soil consists of clean to silty, fine-to-medium and fine-to-coarse sand with occasional interbedded clayey silt to silty clay layers (Site Characterization Analysis report,

Table 2-2
CHARACTERISTICS THAT MAY AFFECT TECHNOLOGY SELECTION

Site Characteristics

- Source volume
- Source area
- Source configuration
- Disposal methods
- Climate (precipitation, temperature, evaporation)
- Soil texture and permeability
- Soil moisture
- Slope
- Drainage
- Vegetation
- Depth of bedrock
- Depth to aquacludes
- Degree of contamination
- Direction and rate of groundwater flow
- Receptors
- Drinking water wells
- Surface waters
- Ecological areas
- Existing land use
- Depths of groundwater or plume

Waste Characteristics

- Quantity/concentration
- Chemical composition
- Acute toxicity
- Persistence
- Biodegradability
- Radioactivity
- Ignitability
- Reactivity/corrosivity
- Infectiousness
- Solubility
- Volatility
- Density
- Partition coefficient
- Compatibility with other chemicals
- Treatability

Source: U.S. Environmental Protection Agency. Guidance on Feasibility Studies Under CERCLA. EPA/540/6-85/003. June 1985.

Section 3.1.1). Excavation of this contaminated soil to the lateral extent of contamination is considered infeasible because of the large volume of contaminated soil and the problems of disposal, replacement and temporary support of the excavation. Extending the excavation zone sufficiently to overcome slope stability problems also appears infeasible because of the proximity of the contaminated zone to physical structures on the plant site. It is estimated that a minimum of 3.28 million cubic yards of soil would require excavation and disposal if soil excavation were to be pursued.

Excavation of the spent potlining pile was retained for additional evaluation, but subsurface soil excavation was not retained for further consideration.

Onsite Disposal. This technology would keep the waste materials onsite but in an approved waste storage area. Generally, this would require excavating the source materials and depositing them in a lined waste disposal area meeting RCRA performance standards and with a cover cap that meets RCRA performance criteria. A closure plan with a written environmental monitoring and release response plan included would be required. Groundwater monitoring would be an essential element in the closure plan. This technology option is not retained because spent potlining waste is now a listed hazardous waste and because an additional onsite source of potential releases would be created. Restrictions on siting landfills over sole-source aquifers would apply also.

Offsite Disposal in RCRA-Permitted Landfill. Potlining wastes have been designated recently as a RCRA hazardous waste. Because of this, offsite disposal at a RCRA-permitted landfill would be necessary. There are two and possibly three landfills in the Northwest where spent potlining may be disposed of. Implementation of this remedy would require excavation with associated dust control, hauling, waste compatibility testing, and probably capping of the excavated area after waste removal to control cyanide migration in contaminated subsurface soil. This option is retained for further consideration.

B. Infiltration Control

These technologies minimize the amount of direct rainfall, stormwater drainage, or plant pipe leakage that is allowed to percolate into the subsurface soil. Use of these technologies controls the leaching of contaminants from the waste sources and their migration into groundwater.

Grouting. Grouting would be most applicable for use on the rubble and brick pile. Grout may consist of mixtures of cement and water with admixtures of clay and chemicals to control fluidity or may consist of chemicals that form a gel or rubbery compound in the ground. The grout would be injected in a liquid state into voids in waste piles. The grout would be allowed to harden, subsequently reducing the permeability of these waste piles and preparing the piles for an impermeable cap. There is difficulty in implementing this technology with waste piles such as the rubble pile that have such large void volumes. The large voids and the variability in porosity make control of grout injection difficult, and limited equipment and personnel access to the sides of the waste piles compounds the problem. This option was not retained for further consideration.

Capping. Installing new caps over the waste sources at the site generally would be performed to RCRA (40 CFR Part 264) and Washington Department of Ecology performance standards. Various cap design options are possible, all of which would meet the required performance standards. The cap should be designed to limit liquid infiltration, promote surface drainage, minimize erosion, and accommodate possible future subsidence. A likelihood in the use of this technology is that the waste piles would be graded to obtain flatter and smoother surfaces for capping. Capping of cyanide sources and infiltration areas is retained for further consideration.

Upgrade Existing Caps. In this option the existing asphalt cap over the spent potlining pile would be upgraded to conform to RCRA performance requirements. Cracks in the existing cap would be repaired with new asphalt and surface water run-on routed away from the capped area, as is now practiced. A program to monitor the integrity of the cap and to repair it as necessary would be developed. The usefulness of performing a cap upgrade for the spent potlining pile is questionable as the present cap appears to be functioning well and recently has had the cracks in it repaired. Further, this cap presently meets RCRA and Washington Department of Ecology performance standards as identified in the Code of Federal Regulations (40 CFR part 264) for site closure.

Reroute, Replace, or Repair Existing Water Pipelines and the Sanitary Treatment Plant. Potential leakage from existing pipelines in the vicinity of the spent potlining pile could percolate through contaminated subsurface soil and cause continued groundwater contamination. Water lines, sanitary sewer lines, and storm drainage pipelines would be rerouted away from the potlining pile, replaced, or repaired in order to remove these potential sources of leachate. Rerouting is applicable for the larger sized storm drain pipe and several small water and sewer pipelines. Direct parallel replacement or repair by slip lining with polyethylene pipe is possible for other water, sewer, and storm drain pipe where rerouting is not possible because of their services to existing plant facilities. These options are retained for further consideration.

Pipeline Leak Monitoring. This technology calls for hydraulically testing the structural integrity of water, sewer, and storm drain pipe in the vicinity of the potlining pile. Leak testing has occurred in the past at the Mead Works. The approaches used in previous testing of pressurized water lines involved:

- Identifying the pipe segment to be tested and any vital services on the line requiring special consideration
- Identifying secondary services on the line segment to be tested and disconnecting these services or estimating their consumption
- Closing isolation valves where possible
- Connecting a fill line to the segment to be tested and blocking the end of the segment
- Pumping water into the pipe segment through a water meter and periodically measuring the volume of water consumed

Sonic (i.e., acoustic) leak detection was tested in 1982 at the Mead Works and found to be infeasible.

Video testing in addition to hydraulic testing might be used to investigate leakage of sewer lines and storm drains. If pipe leaks are discovered, the leaking pipe segment would be repaired as necessary. This option is retained for further consideration.

C. Vertical Barriers

Vertical barriers would be used to isolate contaminated subsoil beneath the waste pile(s) from groundwater to control the transport of cyanide into the main plume.

Sheet Piles. Sheet piles are relatively flat and wide in cross section so that, when driven side by side, they form a cutoff wall. Because they are physically driven down from the surface, their use is limited to a fairly shallow depth. Effective use of the sheet piles is contingent upon keying the wall into an impermeable layer of subsoil. This technology would be difficult to implement, given the 60-foot depth from surface of the first significant aquitard. This option is not further considered because of its implementability at depths where it would be effective.

Slurry Wall. Slurry walls can be described as permanent "membranes" constructed in subsurface soil. In this process a vertical wall trench is excavated by a trenching machine, a "clam shell," or by drilling a series of overlapping, large-diameter vertical holes. The trench is maintained during and after excavation by backfilling with a bentonite clay mud. The mud is displaced finally by concrete, and the finished subsurface installation is a concrete wall with mud-impregnated soil on the outside. Construction is by a variety of drilling and digging methods, depending on the particular equipment used. Slurry walls usually are limited to a depth of less than 50 feet, but walls to several hundred feet have been built. Slurry wall effectiveness is contingent upon keying the wall into an impermeable layer of subsoil. Implementability is doubtful at Mead because of the nature of the subsoil, the depth to groundwater (approximately 150 feet), and the apparent absence of an impermeable zone to key into. This option was not considered further.

Grout Curtain. A grout curtain is a barrier comprised of soil with grout-filled voids. The curtain is created by drilling vertical holes and grouting successive intervals of the holes with cement-based or chemical grouts. The grout holes are spaced closely in a linear array, and several lines of grout holes may be used to obtain a reasonably continuous and thick zone of grouted soil. The continuity of the grouting is checked by noting grout movement into ungrouted holes and by core drilling into the grouted zone. The feasibility of installing a grout curtain at Mead is doubtful because of the subsoil conditions, depth to groundwater, and absence of an identified zone to key into. This option was not retained.

D. Direct Waste Treatment

Recycle In-Plant (Dry roasting). Crushed and ground spent potlining is combusted in a multiple-hearth furnace to burn off the carbon. The remaining high-fluoride fraction is returned to the aluminum production process. The quantity of spent potlining that can be processed in this manner is limited because of impurities in the high-fluoride fraction, which contaminate the cryolite bath. This option has been dedicated at the Mead Works to the current generation of spent potlinings, which consumes the smelter's capacity to use the material. It must be noted that the smelter's capacity to use this material is less than the current generation rate of spent potlining. No further consideration is given to this option, beyond current practice.

Recycle In-Plant (Wet processing). Crushed and ground spent potlining is placed in a caustic bath, and the soluble cryolite fraction is extracted. Cyanide is not destroyed in this process, and it is associated with the liquid phase and the carbonaceous solid fraction, both of which require disposal. The dissolved cryolite is reprecipitated by reducing the pH, and the cryolite is separated, dried, and stored for eventual reuse. Recent surpluses of cryolite on the market have reduced demand for this product, making resale difficult. This option is not considered further.

Resale for Steelmaking. Spent potlining has found limited use in the steelmaking industry in the past 2 or 3 years. Its main use is as a substitute for the fluxing agent, fluorspar. Potlining recycled in this manner must be crushed and ground to between 1/4 and 3 inches in size. It is then placed in the furnace at an appropriate time during the "heat" and burned. The Mead facility had established a working relationship with a steel company for this use; however, the steel company has discontinued the use of this material because of detrimental effects that potlining has on the refractory lining of their furnace. No further consideration is given to this option.

Resale for Mineral Wool Production. Spent potlining may be used as an alternative feedstock in the production of mineral wool because of its low melting refractory components coupled with its benefit as a supplemental fuel. This technology has been pilot tested, but industry standards have not been established. Potlining is crushed and ground to between 2 and 6 inches in size and is then burned in a cupola with other feedstock. Fluorides and other inorganics are incorporated into the mineral wool product. Cyanides are destroyed during combustion. The process has not been fully accepted by the mineral wool manufacturing industry, and air emissions are a possibility. Spent potlining resale for reuse is purchaser controlled, and the listing of this material as a hazardous waste makes it unattractive for secondary uses. This option is not considered further.

Resale as a Fuel Supplement in a Cement Kiln. The high carbon content in spent potlining makes it suitable as a fuel supplement in a cement kiln. Cement clinker is produced by burning finely ground raw cement mix in a rotary kiln at approximately 2,700°F. Volatile components in the cement are driven off, and partial melting occurs, leading to nodulation of the feed into round balls known as "clinkers." Test burns by others have shown that substitution of small amounts of spent potlining in the feed (approximately 2 to 4 percent by weight) would result in reduced fossil fuel costs with no adverse effects on cement quality, kiln operation, or equipment. Cyanide destruction was nearly complete, and fluoride emissions in the stack were negligible. The Mead facility's experience with this option has not been successful. A test burn through a third party was contracted for at a cement kiln in Inkom, Idaho. However, because of adverse public reaction, no test runs could be performed. This option is not retained for further consideration.

Incineration by Fluidized Bed Combustion. In this process, spent potlining is burned in a circulating fluidized bed combustor at approximately 1,400°F with the result being destruction of cyanide. Air is used for combustion and fluidizing the bed. Coarse solids are removed from the bottom of the combustion chamber while fines are recirculated in a high-temperature loop that helps to control combustion temperature while keeping the bed expanded. Use of this technology at the Mead site would require processing of spent potlining prior to incineration. Material processing would include excavation followed by scrap metal removal and crushing to approximately 1/4-inch-size solids. Process off-gas could contain high levels of fluorides, which would require scrubbing. Leachable fluorides in the process ash may limit the number of acceptable landfill locations where residues could be placed. This option has been under active development recently and is retained for further consideration.

Pyrohydrolysis. In this process, spent potlining is burned in a circulating fluidized bed reactor at approximately 2,200°F, resulting in nearly complete cyanide destruction. Steam is injected into the combustor, reacting with the fluorides to produce hydrogen fluoride gas. The off-gas is scrubbed in an absorption tower, resulting in a 25 percent hydrogen fluoride solution that may be sold on the open market. In the pyrohydrolysis process itself coarse solids are removed from the bottom of the combustion chamber while fine solids are recirculated into the bed to control combustion temperature and to keep the bed expanded. Combustion ash contains sodium and aluminum values suitable for reuse in the Bayer process for bauxite refining. However, the great distances to the remaining Bayer plants that are still operating in this country limit the viability of this approach, and residues would be disposed of by landfilling. This option is retained for further consideration.

Pyrosulfolysis. This process is similar to that described for pyrohydrolysis except that air, sulphur dioxide, and steam are injected into a circulating fluidized bed reactor operating at approximately 1,300°F to 1,650°F. Cyanide destruction is achieved while producing hydrofluoric acid for possible resale for manufacture of aluminum fluoride or other fluoride chemicals. An ash low in cyanide and fluoride is produced that may be acceptable for landfill disposal. The process is relatively experimental, however, and has not been demonstrated at other than a laboratory testing level. This option is not considered further because of its early stage of development.

Carbon Recovery by Steam Hydrolysis or Hot-Water Leach. This process is being employed currently on a limited scale by Alcan at one plant in Canada. Spent potlining is crushed and ground to between 1/2 inch and 3/4 inch. It is then either placed in an autoclave, sparged with steam, or boiled with hot water to hydrolyze the cyanide. The resulting product is then screened to recover the treated carbon, which is returned to the plant as carbon paste for the production of carbon sidewall blocks. Presently, ALCAN is recycling only a portion of its potlining and has no additional capacity. In addition, carbon sidewall blocks are not used in aluminum production at the Mead Works, thus limiting the usefulness of this technology for waste potlining at Kaiser-Mead. This option is not considered further.

Carbon Reuse as Anode Material. This process attempts to reuse the carbon in spent potlining for anodes in Soderberg plants. Crushed and processed spent potlining is mixed with anode paste at concentrations of less than 10 percent of the total anode mass. The resulting paste is then placed inside a container on top of an operating Soderberg cell. As the anode is consumed, the paste falls down into the cell and is slowly baked hard in the process. At the low percentage additions of spent potlining currently being mixed into the anode paste, there is insufficient Northwest plant capacity to consume the quantity of spent potlining at the Mead site. The process is most applicable to reuse of new spent potlining currently being generated by the aluminum industry that has fewer process contaminants. Mead is a prebake plant; so carbon use in anode paste is not applicable. Moreover, experimental testwork by others has been abandoned because of poor anode quality. This option is not considered further because Mead is not a Soderberg plant, the reuse quantity is limited, and carbon reuse as anode material is experimental.

In Situ Vitrification. In situ vitrification involves the passage of electrical current through a melt of the waste undergoing fixation. This process is proprietary to Battelle Northwest Laboratories and usually is contemplated for soils contaminated with radioactive compounds. Electrodes are placed in the material to be treated at a predetermined spacing; the area to be heated is treated with a graphite to impart electrical conductivity; and electrical current is applied. As the treated material begins to melt, it becomes electrically conductive, thereby accelerating the process. After the waste is completely melted, current flow is stopped, and the molten mass is allowed to cool into an immobile glassy state. There is no known commercial experience with this process, and there are concerns about uncontrolled combustion, gaseous and particulate emissions containing fluoride and hydrocarbons, and contaminant within controllable zones within the spent potlining pile. This process is not considered further.

Alcan Membrane Process. There are several possible versions of this process. In the basic process, ground potlining is first digested in caustic to produce a solution of sodium fluoride (NaF) and sodium aluminate ($NaAlO_2$). Liquids are then decanted off to an evaporator to crystallize out the sodium fluoride. Solids from the decanter go to disposal. The sodium fluoride crystals from the evaporator are washed in caustic and are dissolved in boiling water. This solution is then passed through a water-splitting membrane to produce solutions of hydrogen fluoride and sodium hydroxide. The hydrogen fluoride solution can then be reacted with solid Al_2O_3-$3H_2O$ to produce aluminum fluoride (AlF_3) for resale. Cyanide present in the potlining is extracted into the caustic and discharged along with sodium aluminate from the evaporator. Cyanide can be destroyed by returning the sodium aluminate to a Bayer plant. This process has not been demonstrated beyond a pilot-scale operation, and work reportedly has been discontinued at Alcan. This option is not considered further because of its reliance on a nearby Bayer plant and its early stage of development (especially the bipolar "water-splitting" membranes. Carbonaceous byproducts stream disposal appears to be an unresolved issue.

Alcoa Aluminum Sulfate/Sulfuric Acid Leach Process. This process uses a two-step digestion of spent potlining in an aluminum sulfate and sulfuric acid bath to volatilize cyanide and to extract fluoride (aluminum fluoride) and sodium fluoride. Bath effluent requires treatment to remove free fluoride. Solids that require disposal are produced. The process has been tested only on a small scale and is not technically proven. Full-scale operations would require material excavation, size reduction processing, and an acid plant for hydrofluoric acid production. This option is not considered further because of its early stage of development.

Alcan Deutschman Process. Spent potlining is treated in a two-step process. Crushed and prepared potlining is heated in the presence of water or steam to hydrolyze cyanide. Solids are then reacted with sulfuric acid and either calcium hydroxide or calcium oxide to precipitate fluoride as CaF_2. Cyanide removals of over 99 percent have been achieved in pilot testing. Fluoride levels in ash may be low enough for acceptable ash disposal in nonhazardous waste landfills. Material preparation including size reduction and scrap metal removal would be required prior to treatment. This technology is still experimental and has not been demonstrated in a large-scale continuous process. This option is not considered further because of its early stage of development.

Cyclonic Smelting. Spent potlining is incinerated in a cyclone smelter similar to those used at copper plants. Potlining is melted at high temperature, thereby oxidizing cyanide and driving off fluorides. This technology is still experimental, and there currently is no published literature describing the process. Fluoride scrubbing of the off-gas as well as material processing and size reduction likely would be required. This option is not considered further because of limited reporting of tests and its early stage of development.

Incineration Followed by Sodium Carbonate Addition. Little information is available on this process, but it is thought to be a variation of dry roasting. The process is experimental and reportedly has experienced some problems at this stage of development. This option is not considered further.

II. PLUME-RELATED TECHNOLOGIES

A. Groundwater Extraction

Groundwater extraction is the process of removing water from saturated subsoil for the purpose of intercepting a contaminated plume, inhibiting plume migration, or removing water for treatment.

Extraction Wells. Extraction wells would be used to pump groundwater from the uppermost saturated zone in the deep aquifer in the vicinity of the Mead site in order to provide water with a treatable concentration of ferrocyanide. These wells would be located along the centerline to withdraw contaminated groundwater for surface treatment and/or disposal. It is envisioned that three extraction wells would be located at 500-foot intervals along the plume centerline, with the first placed near TH-8. Each well would produce at a rate of about 70 to 85 gpm (total 200 gpm for all three wells). It is estimated that this groundwater extraction rate would produce groundwater with cyanide above the minimum treatable concentration but would not exceed the sewer capacity at the point of discharge.

B. Groundwater Treatment

Biological Treatment. This technology normally would involve the use of several unit processes. First, wastewater would be fed into a basin with a large population of acclimated microbes attached to rotating biological contactors. Wastewater would then flow into a clarifier where any sloughed solids would be settled, and the supernatant would overflow to other polishing treatment steps such as filtering. Solids would be removed from the clarifier and dewatered in a filter press or other suitable device. Attempts to apply biological treatment to aluminum industry wastewaters have been unsuccessful to date; consequently, this option is not considered further.

Treatment by Ion Exchange. The ion exchange process employs an anion exchange resin that has high ferrocyanide selectivity. The Rohm and Haas Company has developed several resins for this purpose. In this process, contaminated water is passed through a properly conditioned column of ion exchange resin. The resin adsorbs ferrocyanide and releases the anion that was bound formerly to the resin. Once the resin is exhausted, it is regenerated by replacing the ferrocyanide ions with hydroxide ions by treatment with sodium hydroxide. A subsequent replacement of the OH^- anion with SO_4^{-2} anion from sulfuric acid completes the regeneration cycle. This process is suitable for only complex cyanide; therefore, free cyanide in the water must be complexed before it can be treated. Because the operating cycle time decreases as feedwater ferrocyanide concentrations increase, this process would be most suitable for polishing the effluent from another process such as chemical precipitation. The effectiveness of ion exchange diminishes as the dissolved solids content of the water increases. Regeneration waste contains a high concentration of cyanide that must either be treated to destroy the cyanide or disposed of by other methods. This option is not considered further because previous testing showed that ion exchange removed little cyanide in addition to what could be precipitated.

Physical Treatment by Reverse Osmosis. Reverse osmosis is used frequently in the desalinization of brackish water and seawater. This technology uses a semipermeable membrane that inhibits the passage of dissolved solids but allows water to pass. Feedwater is fed under pressure into the reverse osmosis unit where it is separated by the membrane into a waste brine stream and low-salinity product water. Product water recovery constitutes generally 30 to 85 percent of the feed. The waste brine solution must be disposed of. Reverse osmosis only concentrates the cyanide into a smaller liquid stream; it does not destroy cyanide. If this technology were used, the waste brine would contain concentrated cyanide that would require further treatment or disposal. This option is not considered further.

Chemical Treatment by Precipitation. Precipitation treatment for iron cyanides has been used in a full-scale, continuous process to reduce the cyanide concentration in aluminum plant wastewater. In precipitation treatment, ferrous and ferric salts (usually ferrous sulfate and ferric chloride, respectively) are added to the wastewater and insoluble iron cyanide compounds precipitate, reducing the total cyanide content to a level between about 1 to 3 mg/l. The process would be carried out using a conventional water treatment plant consisting of rapid mixing, reaction, gravity settling, and filtration. Treated water leaving the filter would be discharged either to a publicly owned treatment works (POTW) or to a receiving stream if sufficient treatment has been obtained. Sludge precipitated in the reactor and collected in the clarifier would be dewatered by conventional techniques such as a filter press, centrifuge, or drying bed and disposed of in a suitable landfill. This option is retained for further consideration.

Chemical Treatment by Oxidation. In an oxidation process, groundwater containing ferrocyanide would be pumped from the ground and treated in one of several processes. Among the potential choices are hot alkaline chlorination and ultraviolet-catalyzed ozone. Neither of these processes has been used for aluminum industry wastewater at a commercial scale for a variety of technical, economic, and environmental reasons. As an example, hot alkaline chlorination uses about 1,000 mg/l of excess chlorine, but residual cyanide concentrations fall in the same range as for the chemical precipitation process. And ultraviolet/ozone treatment is hampered by the accumulation of iron oxide deposits on the optical surfaces after only a short period of operation. This option is not retained for further consideration.

C. Treated Wastewater Discharge to Local POTW

Treated wastewater produced at the onsite groundwater treatment system would be discharged to the City of Spokane municipal wastewater treatment system. A force main constructed at the plant site would be necessary to convey the treated groundwater to a preselected discharge point into the city's sanitary sewer system. This option is retained for further consideration.

D. Groundwater Monitoring

Currently, there is an ongoing groundwater monitoring program in force at the Mead Works. Groundwater samples are collected from selected wells and analyzed to monitor changes in groundwater contaminant concentrations. Specific wells would be identified and sampled four times per year. Selection of the wells for sampling would be dependent on the remedial alternative to be implemented. The wells would be selected to model, as accurately as possible, the effects of remedial action that is to be implemented. It is assumed that no new wells would be constructed. This option is retained for further consideration.

DETAILED TECHNOLOGY SCREENING

The technology alternatives identified above were evaluated in moderate detail and screened on the basis of their technical, economic, and institutional feasibility and their impacts on public health, welfare, and the environment. This screening process was intended to eliminate technologies that may prove infeasible to implement or that rely on processes that are unlikely to perform satisfactorily or reliably.

Technical criteria included evaluation of performance, reliability, and implementability as discussed below.

- Performance. Performance was assessed on the basis of effectiveness and useful life. Effectiveness was evaluated in terms of the degree to which the technology would prevent or minimize the release of hazardous substances to current or future receptors. Useful life was related to the length of time that the level of effectiveness could be maintained.

- Reliability. Reliability was assessed on the basis of operation, maintenance, and demonstrated performance. Operation and maintenance were evaluated in terms of labor availability, frequency, necessity, and equipment complexity. Demonstrated performance included consideration of proven performance, probability of failure, and pilot testing needs.

- Implementability. Implementability was based on the ease of installation and time for implementation. Ease of installation was related to constructibility of the technology, applicability to site conditions, external conditions such as the need for permits and access to offsite disposal facilities, and equipment availability. The time for implementation was assumed to be the time to achieve beneficial results.

Technologies that were deemed to be unreliable or to perform poorly or that were not fully demonstrated were excluded from further consideration during the screening process.

Public health and welfare, environmental, and institutional screening criteria are described as follows:

- Effects on Public Health and Welfare. Short-term (i.e., construction-related) and long-term health risks from exposure to contaminants were considered. Short- or long-term effects could include odor, noise, and air pollution; disruption of households, businesses, and services; use of natural resources; alteration of natural environments, transportation corridors, and urban facilities; relocation of households, businesses, and services; and aesthetic changes. For the purposes of this screening effort, these effects were evaluated on exposure or no-exposure conditions only.

Table 2-3
INTERIM SCREENING OF SOURCE-RELATED TECHNOLOGIES

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
1. Excavation and onsite disposal	Proven technology. Relatively rapid implementation. Excavation is possible for potlining pile, but subsurface soil excavation is not feasible because of depth and slope stability considerations. Waste materials will be exposed to leaching during excavation. Dust control will be necessary to prevent windborne migration. Liner and cap needed in excavation and disposal areas to control leachate. An additional waste source area is created, requiring monitoring and maintenance. A liner leak detection program is necessary to detect liner failure.	Regulatory limitations on moving the contaminated material. Must dedicate part of existing site to permanent disposal of the materials. Restrictions on construction of new hazardous waste landfills over sole-source aquifers probably apply.	Capital cost high. O&M cost low.	No. New source created; landfill siting over sole-source aquifers may apply.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria: Technical	Screening Criteria: Public Health, Environment, Institutional	Screening Criteria: Relative Cost	Retained for Further Consideration
2. Excavation and offsite disposal	Proven technology. Excavation is possible for potlining, but excavation of subsurface soil is not feasible because of the depth of the soil column and poor slope stability during excavation. Waste materials will be exposed to leaching during excavation. Dust control will be necessary to prevent windborne migration. Offsite landfills may not accept the excavated material.	Eliminates contaminants at primary source. Contaminants are not treated. Short-term public health impact from noise, odor, and dust.	High capital cost. No O&M cost.	Yes.
3. Excavation and recycle in-plant (dry roasting of potlining)	Proven technology. Relatively rapid implementation. An ongoing program with potlining generated since 1952; process established. No further capacity in existing equipment.	May be sanctioned under reuse provisions within RCRA.	Capital cost high. O&M cost high.	No. Already practiced on currently generated material. Impurities limit degree of recycle back to the pots.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
4. Excavation and recycle in-plant (wet processing of potlining)	Proven technology. Relatively rapid implementation. An established process but process feasibility is market dependent. Currently, there is little domestic market for reclaimed product and, therefore, limited resale value. Feedstock and product variability and purity unpredictable.	Wastewater and waste solids are produced which still contain cyanide; these require treatment and disposal.	Capital cost high. O&M cost high.	No. No demand for the recovered cryolite; disposal of cyanide-containing carbon slurry a deterrent.
5. Excavation and resale (for steelmaking, mineral wool production, and/or cement kiln fuel)	Demonstrated technologies. Relatively rapid implementation. Feasibility of these processes is market dependent. Generally, there is insufficient Northwest capacity to absorb the necessary quantity of waste. Uncontrolled quality of the waste piles will limit market acceptance of the waste. Product specifications are developed by purchaser.	Listing as a hazardous waste will place restrictions on the sale of spent potlining from aluminum production and may eliminate this option.	O&M cost low.	No. Marketability determined by potential uers, not by Kaiser. Listing as a hazardous waste may block future resale for secondary uses.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
6. Excavation and Incineration (FBC typ.)	Demonstrated on a limited scale. Relatively rapid implementation. Process will require onsite storage facilities and waste preparation by size reduction, preclassification, or other method. Process developed for feedstocks of type under consideration.	Regulatory classification of treatment residues needs to be verified (air, water, solids). Permitting may be difficult.	Capital cost high. O&M cost high.	Yes.
7. Excavation and pyrohydrolysis and burial of residues	Developing technology. Process fundamentals understood; no known demonstration or prototype plant experience. Process economic feasibility is dependent on Bayer plants available to take product as feedstock. Process economics are unfavorable in the Northwest because there are no Bayer plants in existence. Fluoride recovery is inefficient compared to other recycling processes.	Vapor-phase hydrogen fluoride needs high capture efficiency. Personnel hazard potential. Regulatory constraints may preclude acceptance of the waste into the Bayer process.	Capital cost high. O&M cost high.	Yes.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
8. Excavation, pyrosulfolysis, and burial of residues	Developing technology. Process fundamentals understood at laboratory scale only; no known demonstration or prototype plant experience. Technical feasibility is dependent on quality of feedstock, and difficult agglomeration problems have occurred during testing. Uncontrolled quality in waste pile may preclude acceptability of waste in process. Fluoride is recovered during the process.	Sulfur dioxide and hydrogen fluoride air controls probably would be needed. Residue disposal is required.	Capital cost high. O&M cost high.	No. Early stage of development. Commercial-scale feasibility uncertain.
9. Excavation, carbon recovery by either steam hydrolysis or hot-water leach, residue disposal	Commercial in Canada but not commonly used in the U.S. Recovered carbon is reusable only for carbon sidewall blocks, which are not used at Kaiser Mead plant. Only a portion of the waste can be recycled; a large amount of residues remain.	Residues require offsite disposal. A generated wastewater stream requires treatment and disposal.	Capital cost moderately high. O&M cost high.	No. Sidewall blocks from recovered carbon not used at the Mead Works.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
10. Excavation, carbon recovery as anode material	Experimental technology. Laboratory tests indicate difficulties in obtaining a satisfactory anode at anything but low addition levels. Feasibility of process for large waste volumes is unlikely. Useful only in Soderberg plant, whereas Mead is a prebake plant.	May be sanctioned under reuse provisions within RCRA.	Capital cost low with existing Soderberg plant. O&M cost high.	No. Mead Works is not a Soderberg facility; reuse quantity limited.
11. In situ vitrification, onsite disposal	Process not proven on spent potlining wastes. Reaction may not be controllable with high carbon wastes such as spent potlining. Excessive fuming may cause formidable technical problems. Method not yet practiced commercially. Proprietary process of Battelle Pacific Northwest Laboratories.	Gaseous emissions, air controls probably would be needed. Final product may require offsite disposal.	High capital cost. High O&M cost.	No. No known commercial experience. Intended for soil, not carbonaceous wastes. Concerns about emissions, combustion, and process control and confinement.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
12. Excavation, Alcan membrane process	Technology development discontinued. Small-scale pilot project completed but no followup development. Economic projections are not promising: requires Bayer process for reuse of reaction products.	Gaseous emissions require treatment.	High capital cost. High O&M.	No. Early stage of development; reliance on Bayer plant; byproduct disposal.
13. Excavation, Alcoa aluminum sulfate/ sulfuric acid leach process	Unproven technology. Process fundamentals understood, but process has not been technically demonstrated. Significant technical difficulties. Economically unattractive.	Personnel hazard potential.	High capital cost. High O&M.	No. Early stage of development; cyanide volatilization.
14. Excavation, Alcan Deutschman process	Developing technology. Process fundamentals understood at laboratory level but not technically demonstrated at larger scale. No apparent aqueous waste stream. Uncontrolled quality in waste pile may preclude acceptability of waste in process.	Ash disposal may be a problem. Personnel hazard potential.	High capital cost; low O&M.	No. Early stage of development.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
15. Excavation, cyclonic smelting furnace, disposal of residues	Experimental process. Research has not been published yet. Process is not yet commercial. Apparent logistical and product use problems.	Unknown.	Unknown.	No. Early stage of development; no known process documentation.
16. Excavation, incineration followed by sodium carbonate addition	Unproven process. Experimental. Process is not commercial, and little information is available to evaluate its use.	Unknown.	Unknown.	No. Information limited; early stage of development.
17. Grouting	Chemical or foaming cement grouts can be used to fill the void spaces in the waste. Volume of voids is high. Proportion of voids varies widely, making injection control difficult.	Uncertainty about the control provided by the grout.	High capital cost. Low O&M cost.	No. Implementation difficult because of limited side access and large voids.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
18. Cap	Cement, asphalt concrete, and soil caps are not 100 percent impermeable while synthetic membrane and multimedia caps may be close to 100 percent impermeable. Soil, membrane, and multimedia caps are more appropriate to flat areas or low slopes. Piles must be graded to get flatter, smoother slopes in preparation for placement of cap. Cement, asphalt, or soil caps may crack if settling occurs under new loading.	Contaminants remain onsite. Rapid implementation.	Moderate capital cost. Low O&M cost.	Yes.
19. Upgrade (existing) caps	Existing asphalt caps require periodic maintenance. Further hydration potential eliminated with cap maintenance. Upgrade undertaken only to achieve RCRA performance standards.	Reopening capped area might change regulatory status of the covered areas.	Potentially moderate capital cost. Low O&M cost.	No. Existing caps meet RCRA performance standards.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
20. Reroute water lines/relocate wastewater treatment plant	Technically feasible and straightforward to implement.	No significant considerations identified.	Capital cost moderately high. O&M cost unchanged from current status.	Yes.
21. Pipeline leak monitoring program	Established methods available. Periodic leak investigation (not continuous, online) is feasible at present. Methods for pressure piping more definitive than those for gravity drainage systems. May need to coordinate with water-level measurements in monitoring well system.	No restrictions identified.	O&M cost low to moderate, depending on frequency.	Yes.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
22. Vertical barriers	Rapid implementation. Barrier must fully penetrate the pervious subsoils and embed in an impervious soil unit. Required depth is too deep for steel sheet piles. Required depth of barrier, nature of subsoils, and quality requirements suggest a slurry wall is more appropriate than a grout curtain. A full circumference wall may be required. A slurry wall would not be completely impervious, and drainage would pool within the wall until the water developed sufficient head to cause flow through the more porous areas of wall.	May affect local groundwater flow.	High capital cost. Low O&M cost unless the barrier is breached and reconstruction is required.	No. Coarse subsoil, depth to groundwater, and uncertain depth to impermeable material impose difficulties.

Table 2-4
INTERIM SCREENING OF PLUME-RELATED TECHNOLOGIES

	Screening Criteria			
Corrective Measure Technology	Technical	Public Health, Environment, Institutional	Relative Cost	Retained for Further Consideration
1. Extraction wells	Proven technology. Pumping may change groundwater flow patterns. Duration of pumping could be long.	Rights-of-way and access. Treated water disposal.	Capital costs are moderate. O&M cost is moderate.	Yes.
2. Biological treatment	Poor results in trying to biologically treat cyanide-containing wastewater from aluminum reduction facilities. Extensive development work would be required.	Cyanide destroyed instead of concentrated.	Moderate capital cost. Low-to-moderate O&M cost.	No. Process is unsuccessful, so far, with aluminum plant wastewaters.
3. Physical treatments (reverse osmosis, ion exchange)	Liquid waste stream enriched in cyanide, posing a disposal problem. Development work may be required. Not specific to cyanide. Free cyanide would be poorly removed.	Cyanide-rich wastewater to be disposed of.	Moderate-to-high capital cost; moderate to high O&M cost.	No. Concentrated liquid waste stream remains, which requires disposal. Neither process feasible as a stand-alone process with Mead groundwater.

Table 2-4
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
4. Chemical treatment (precipitation)	Prussian blue precipitation process specific for cyanide. Difficult to reduce cyanide below 1 to 3 mg/l concentration. Demonstrated on wastewaters from aluminum reduction facilities.	Waste solids to dispose of (may be nonhazardous).	Moderate capital cost. Moderate O&M cost.	Yes.
5. Chemical treatment (oxidation)	Oxidation processes have proved ineffective with ferrocyanide.	Releases to air of ozone or chlorine may need to be controlled.	High capital cost. High O&M cost.	No. Oxidation ineffective with iron-complexed cyanide.
6. Treated wastewater discharge to local POTW	Proven technology. Likely will require installation of new onsite pump station along with force main to sanitary sewer.	Possible leakage from city-owned sanitary sewer lines. Possible leakage from holding basins in city system, such as Lidgerwood Lagoon.	Medium capital cost. Medium O&M cost.	Yes.
7. Groundwater monitoring	Ongoing program with monitoring wells already in place. System appears responsive to changes in groundwater regime.		Low capital cost. Low O&M cost.	Yes.

- <u>Environmental Effects</u>. Short- and long-term effects on the environment that were considered include toxic effects on plant and animal life from exposure to contamination, alteration of wildlife habitat, and effects on threatened and endangered species.

- <u>Institutional Effects</u>. Institutional effects evaluated were related to surface and groundwater quality standards; air quality, odor, and noise standards; land acquisition, land use, and zoning; and federal, state, and local laws or policies.

Costs were included in the evaluation only for comparison purposes and reflect judgment based on engineering experience at other sites and installations. Relative costs, designated as either low, medium, or high, were used to enable a qualitative comparison between technologies. Both capital and operation and maintenance costs were considered.

The use of relative costs is accepted by the U.S. EPA for technology screening. These estimates were developed only for the purpose of screening technologies and do not reflect the entire cost of implementing a technology. These costs are appropriate only for comparison between alternative measures applied in a particular area. Any other use of these estimates is not appropriate and would be misleading.

The screening criteria were used to evaluate corrective measures relative to other technologies accomplishing the same objective. Since each technology does not address all treatment objectives, the technology evaluation assumes that other technologies necessary to meet the objective are implemented concurrently. The effect of combining technologies will be considered in the detailed analyses of alternatives.

The results of the detailed screening are presented in Tables 2-3 and 2-4. Technologies considered to have some merit for use at the Mead Works are identified with a "yes" written under the "retained for further consideration" column. These technologies are combined into remedial alternatives in the next section of this chapter.

REMEDIAL ALTERNATIVES

Remedial alternatives for sources and for groundwater were developed separately by combining the technologies remaining after interim screening into integrated remedial actions. Each retained technology is contained in at least one alternative. The remedial alternatives are identified and described briefly in this chapter but are more fully developed and evaluated in the following chapter. In the sections, the remedial alternatives are identified according to their applicability to the source operable units or the plume operable unit.

I. SOURCE-RELATED OPERABLE UNIT

The technologies that are incorporated into each of the source-related remedial alternatives are shown in matrix form in Table 2-5. The scope of activities associated with each remedial alternative in the table is discussed below.

Alternative 1. Excavate the spent potlining pile and dispose of this material offsite in a permitted hazardous waste disposal facility. Install a RCRA cap over the location of the excavated spent potlining (SPL) pile and the currently uncapped part of Area 4. Conduct a leak monitoring program for water, sanitary sewer, and storm drainage piping and repair or replace leaking pipe as necessary (see Figure 2-1). Conduct quarterly groundwater monitoring.

Alternative 1A. Same as Alternative 1 above except eliminate the leak monitoring program with pipe repair or replacement and substitute a task to relocate existing water, sanitary sewer, and storm drain piping, and the sanitary treatment plant.

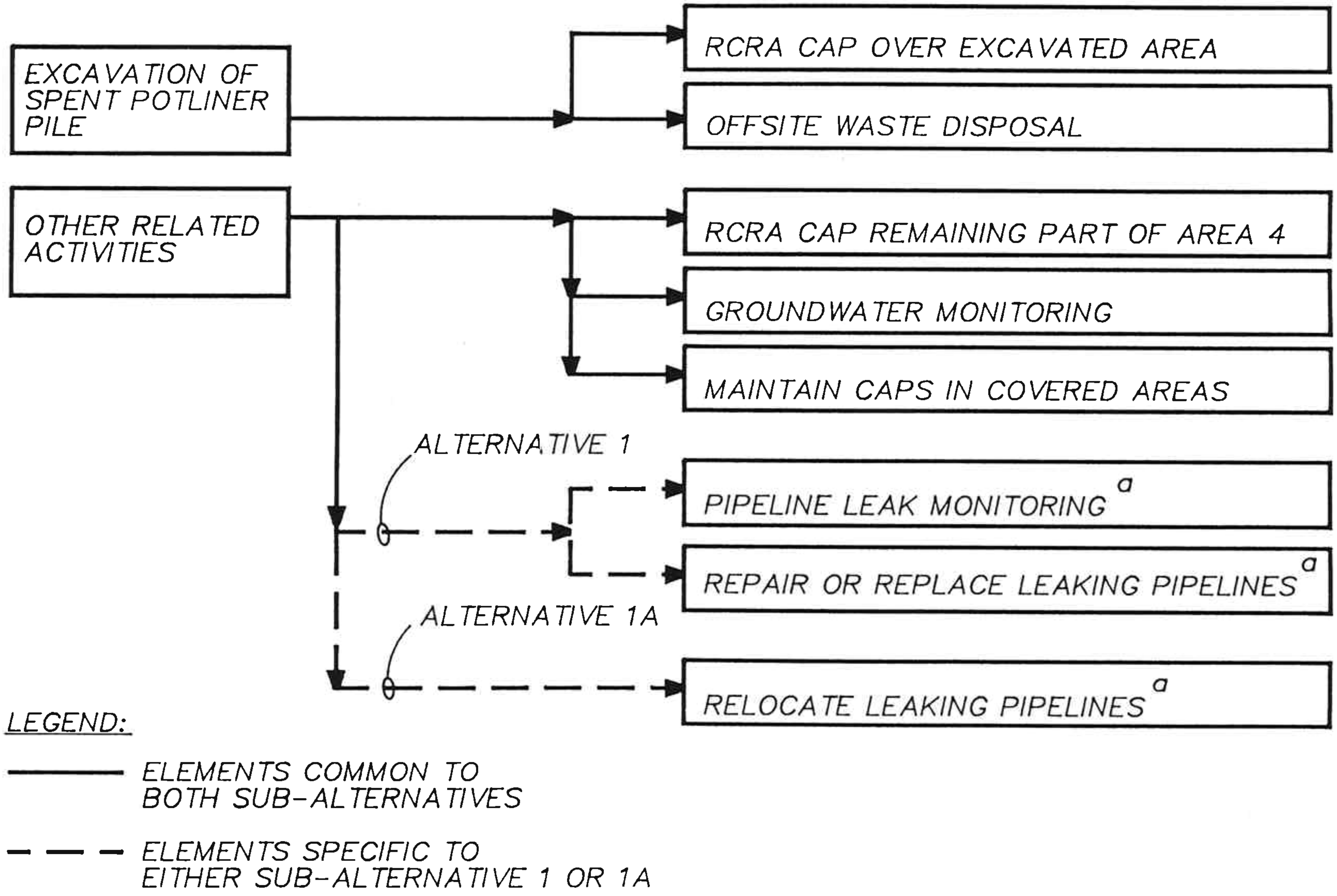
Alternative 2. Excavate the spent potlining pile and incinerate onsite (see Figure 2-2). Incinerate the existing asphalt cap over the spent potlining pile with potlining wastes. Install RCRA cap over the location of excavated SPL pile and the currently uncapped part of Area 4. Conduct a leak monitoring program for water, sewer, and storm drainage piping and repair or replace leaking pipe as necessary. Conduct quarterly groundwater monitoring.

Alternative 2A. Same as Alternative 2 above except eliminate the leak monitoring program with pipe repair or replacement and substitute a task to relocate existing water, sanitary sewer, and storm drain piping, and the sanitary treatment plant.

Alternative 3. Excavate the spent potlining pile and treat onsite, using pyrohydrolysis (see Figure 2-3). Dispose of the existing asphalt cap over the spent potlining pile at an offsite permitted hazardous waste landfill. Install a RCRA cap over the location of the excavated SPL pile and the currently uncapped part of Area 4. Conduct a leak monitoring program for water, sanitary sewer, and storm drainage piping. Repair or replace leaking pipe as necessary and conduct quarterly groundwater monitoring.

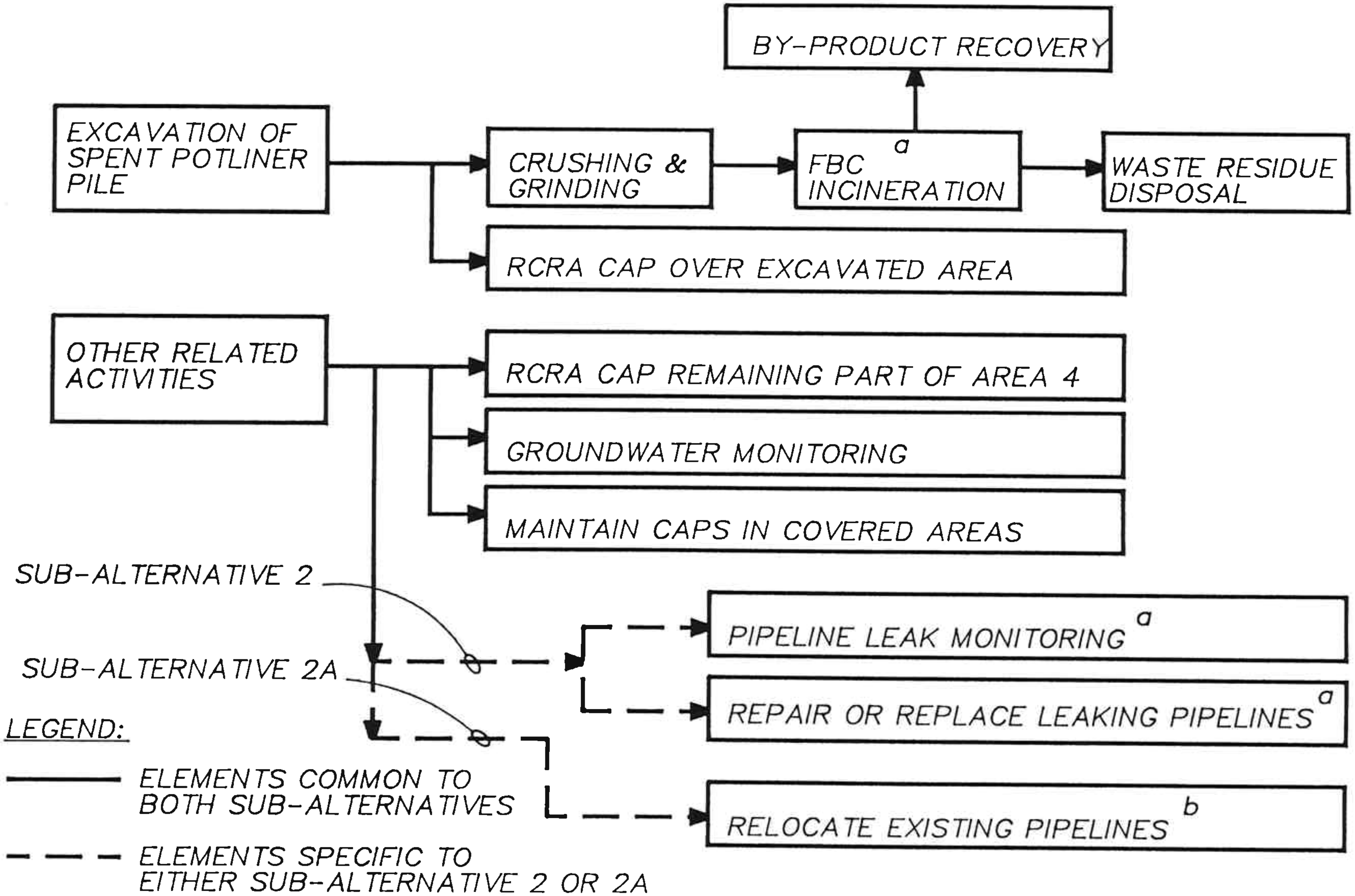
Table 2-5
POTENTIAL REMEDIAL ALTERNATIVES FOR THE SOURCE-RELATED OPERABLE UNIT AT KAISER-MEAD

Technology	Alt. 1	Alt. 1A	Alt. 2	Alt. 2A	Alt. 3	Alt. 3A	Alt. 4	Alt. 4A	Alt. 5
1. Excavation	X	X	X	X	X	X			
2. Offsite disposal	X	X			X	X			
3. Incineration			X	X					
4. Pyrohydrolysis					X	X			
5. RCRA cover cap	X	X	X	X	X	X	X	X	
6. Pipeline leak monitoring	X		X		X		X		X
7. Repair or replace leaking pipelines	X		X		X		X		X
8. Relocate leaking water, sanitary sewer, and storm drainage pipelines and water treatment plant		X		X		X		X	
9. Groundwater monitoring	X	X	X	X	X	X	X	X	X



[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT

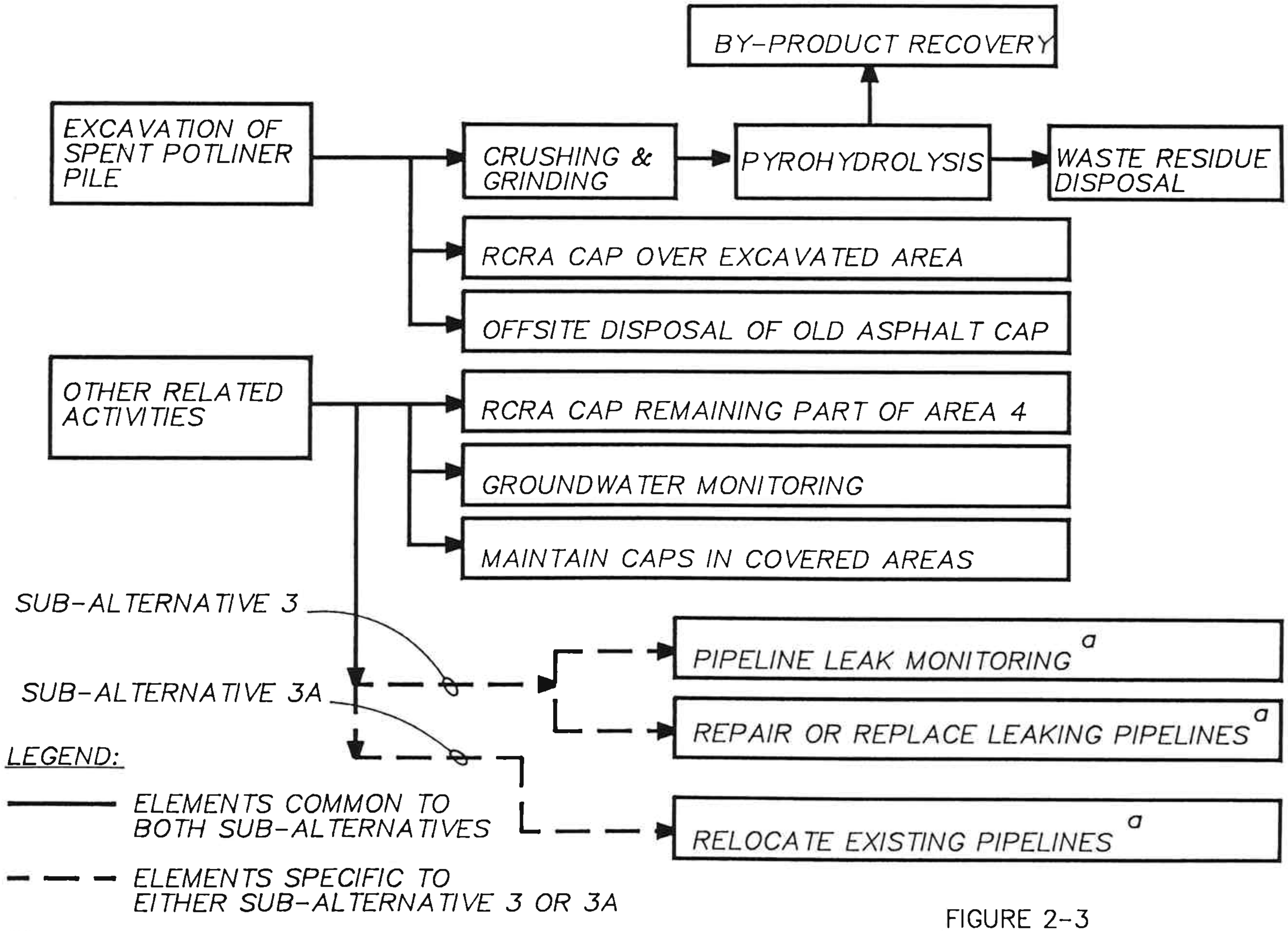
FIGURE 2-1
ALTERNATIVES 1 AND 1A:
OFFSITE DISPOSAL



[a] FBC STANDS FOR FLUIDIZED BED COMBUSTION.

[b] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

FIGURE 2-2
ALTERNATIVES 2 AND 2A
INCINERATION



[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

FIGURE 2-3
ALTERNATIVES 3 AND 3A
PYROHYDROLYSIS

Alternative 3A--Same as Alternative 3 above except eliminate the leak monitoring program with pipe repair or replacement and substitute a task to relocate existing water, sanitary sewer, and storm drain piping and the sanitary treatment plant.

Alternative 4. Install a new cap over the uncapped part of Area 4. Conduct a leak monitoring program for existing water, sanitary sewer, and storm drain piping and repair or replace leaking pipe as necessary (see Figure 2-4). Conduct a quarterly groundwater monitoring program.

Alternative 4A. Same as above except eliminate the leak monitoring program with pipe repair or replacement and substitute a task to relocate existing water, sanitary sewer, and storm drain piping and the sanitary treatment plant.

Alternative 5. Leave waste piles in place and maintain existing caps over the spent potlining pile and Areas 2 and 4 (see Figure 2-5). Conduct a leak monitoring program for water, sanitary sewer, and storm drainage piping and repair or replace leaking pipe. Conduct quarterly groundwater monitoring.

II. PLUME-RELATED OPERABLE UNIT

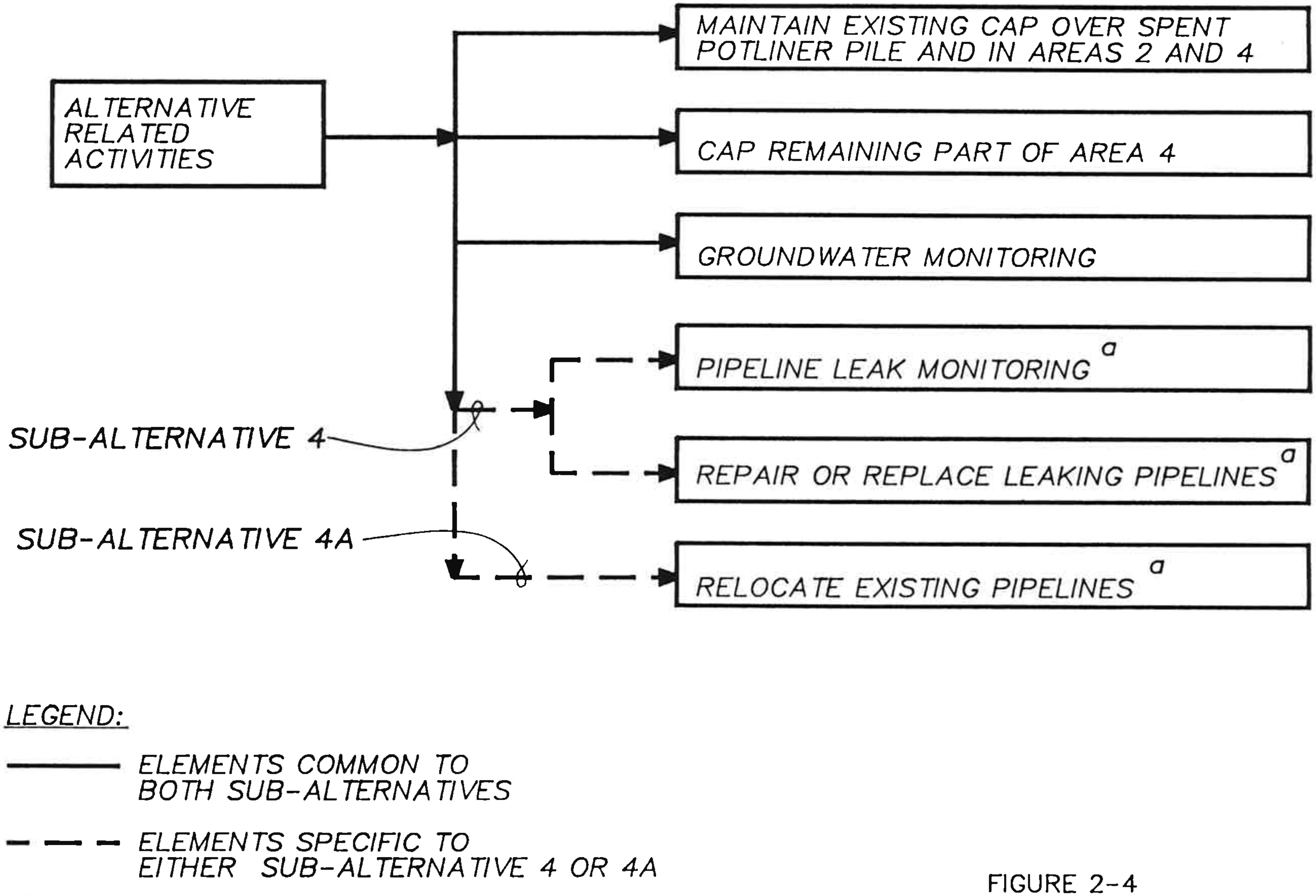
The technologies to be incorporated into each of the potential plume-related remedial alternatives are summarized in Table 2-6. Details regarding the work scope to be incorporated within each remedial alternative are discussed below.

Alternative G-1. Pump groundwater with greater than 5-mg/l total cyanide from the regional aquifer beneath the Mead site, using extraction wells. Treat this groundwater, using Prussian blue precipitation in an onsite wastewater treatment system. Discharge effluent by force main to local POTW (City of Spokane).

Alternative G-2. Leave groundwater in place and continue periodic groundwater monitoring program.

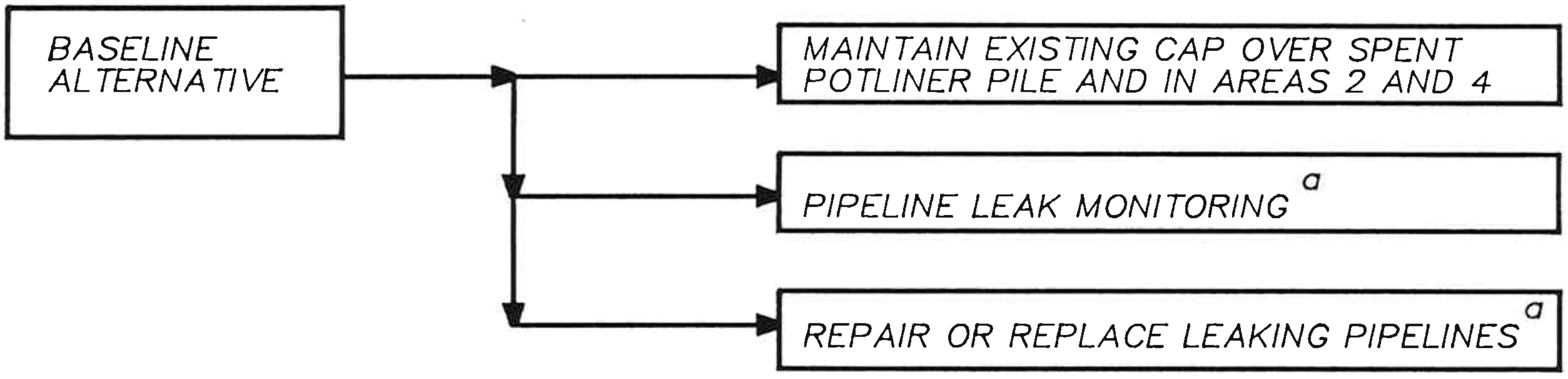
ALTERNATIVE DEVELOPMENT

Five remedial alternatives have been developed for source operable units, and two alternatives have been developed for the groundwater plume operable unit. These alternatives are further developed, evaluated, and compared in the next chapter.



[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

FIGURE 2-4
ALTERNATIVES 4 AND 4A
SOURCE CONTROL



[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

FIGURE 2-5
ALTERNATIVE 5
BASELINE

Table 2-6
POTENTIAL REMEDIAL ALTERNATIVES FOR THE PLUME-RELATED OPERABLE UNIT AT KAISER-MEAD

Technology	Alt. G-1	Alt. G-2
1. Extraction wells	X	
2. Groundwater treatment by chemical precipitation	X	
3. Treated effluent discharge to POTW	X	
4. Groundwater monitoring	X	X

Chapter 3
REMEDIAL ALTERNATIVE ASSESSMENT

INTRODUCTION

Several remedial alternatives for controlling the migration of cyanide from onsite sources were identified in Chapter 2. Additionally, two alternatives and their respective technologies were identified for the management of ferrocyanide-contaminated groundwater. To define adequately the degree of applicability of the identified technologies to both source and plume (groundwater) operable units, a more in-depth analysis was made of the individual technologies that make up the remedial alternatives.

EVALUATION CRITERIA

All remedial alternatives identified in Chapter 2 (and their component technologies) were analyzed for their applicability to the specific cyanide and water sources at the Mead Works. The characteristics of spent potlining and its principal component of interest, cyanide, also were weighed in the evaluations. Specifically, all alternatives and their components were evaluated in the following five areas.

1. Technical feasibility including performance, permanence, reliability, and implementability
2. Environmental effects including reduction of ferrocyanide discharge to the Little Spokane River
3. Public health effects including human exposure on- and offsite during implementation of remedial alternatives
4. Institutional requirements including compliance with ARARs and TBCs
5. Cost including capital and operation and maintenance (O&M) and present-worth analysis

Because several of the identified alternatives contain identical technological components, these individual technologies are reviewed and assessed according to the criteria listed above. The individual technologies are summarized below.

Source control operations:

1. Excavation of the spent potlining (SPL) pile
2. Offsite disposal of SPL at a regulated landfill

3. Onsite CBC incineration

4. Onsite pyrohydrolysis

5a. RCRA capping of exposed SPL area (following excavation of SPL)

5b. RCRA capping of exposed part of Area 4

6. Pipe leak testing and monitoring

7. Replacement or slip lining of leaking pipes and structures

8. Relocation of water and sewer lines, the treatment plant, and storm drains away from the SPL pile

9. Quarterly groundwater monitoring

Plume control operations:

1. Groundwater extraction
2. Ferrocyanide precipitation
3. Treated effluent discharge to POTW
4. Periodic groundwater monitoring

The final section of this chapter will summarize the identified alternatives by compiling the individual technologies and analyzing the overall effects relative to the five evaluation criteria.

TECHNOLOGY ASSESSMENT

SOURCE-RELATED TECHNOLOGIES

Technology No. 1: Excavation of the Spent Potlining (SPL) Pile

The greatest volume of waste potlining is located in an asphalt-covered pile directly northwest of the Kaiser facility. The pile is approximately 650 to 700 feet long by 150 to 300 feet wide with heights ranging from 10 to 40 feet. The estimated volume of the pile is 94,700 cubic yards with a weight of 128,000 tons. The average total cyanide content is estimated at 0.2 percent or 2,000 parts per million (ppm).

The following analysis will examine excavation only, without regard to final disposition of the excavated material. In contrast, offsite transportation will be discussed with offsite disposal below.

Technical Feasibility. Excavation of the spent potlining could be accomplished readily, using standard heavy-duty construction equipment. Because of the bulky nature of the waste pile (odd-size distribution) and presence of abrasives and tramp iron, wear on the equipment is expected to exceed the norm. Maintenance and downtime also are expected to exceed levels normally found in earth-moving operations. However, excavation could proceed at a rate far in excess of the capability of any operation to receive the waste. The time necessary to excavate the pile completely is dependent on the receiving facility capacity. Assuming offsite disposal at a regulated landfill, the time requirement could be as little as 12 months with continuous landfill operation. With onsite treatment options, excavation would be limited by receiving capacity and could require from 3-1/2 to 13 years.

Environmental Effects. During the excavation operation, removal of the asphalt cover would be required. By exposing waste potlining to the elements, i.e., precipitation and wind, increased dispersion to the environment is anticipated. Standard dust control measures (water spray) would be of limited use because of the possible leaching of ferrocyanide to the underlying soil and mobilization of ferrocyanide already present in the underlying soil column. Windbreaks or other enclosure controls would be required.

Controlling infiltration of precipitation could require recovering the exposed section of the pile at the end of each work period as well as stopping all excavation work during periods of rain and snow. With implementation of all required controls for windblown dispersion and water infiltration, it is expected that a minimal increase in ferrocyanide dispersion to the environment would occur; however, groundwater quality could deteriorate during excavation since the protective cover would not be in place.

Removal of the SPL pile as a contaminant source would be expected, at first glance, to bring short-term improvements in groundwater quality. However, because of a number of factors, most notably the depth to groundwater (approximately 145 feet) and volume of contaminated soil underlying the SPL pile (more than 900,000 cubic yards), removal of the SPL pile is not expected to contribute to significant improvement in groundwater quality. Additionally, upon analysis of the prevailing precipitation patterns and underlying soil conditions, it is evident that natural surface water infiltration in the vicinity of the SPL pile is not a significant mechanism for aquifer recharge or for mobilization of ferrocyanide present in the soil column beneath the SPL pile. Evidence of this is that capping of the SPL failed to improve the groundwater quality. Grading of the SPL pile and subsequent installation of the asphalt cap in 1979 have minimized or eliminated direct contact of the waste material with precipitation, thereby controlling mobilization of ferrocyanide from the SPL pile to the underlying soils.

After complete removal of the SPL pile, a permanent RCRA cap would be required to control water infiltration. This subject is discussed separately in a following section.

Public Health Effects. An increase in dispersion of ferrocyanide to the environment, as discussed above, would increase the chances of adverse public health effects. The degree to which the public health would be impacted is a function of the amount of additional dispersion, its pathway, and characteristics of the receptor. Assuming minimal increase in dispersion by implementation of proper engineering controls during excavation, coupled with the known properties of ferrocyanide--i.e., stability in alkali and mild acids, its low level of toxicity, and expected dilution--no additional adverse public health effects are anticipated.

Equipment operators involved in the actual excavation process would be exposed more directly and, as such, may be required to conform to standard Level C site safety requirements. This involves use of cartridge respirators and protective clothing. Standard hygiene practices (no eating, drinking, smoking, etc.) also would be required.

Public health effects resulting from removal of the SPL pile as a source are expected to be negligible because residences located along the contaminated plume pathway have been provided with uncontaminated water supplies. This issue will be discussed in the following technology assessment section on offsite disposal.

Institutional Requirements. It is not clear that the SPL pile needs to be excavated as a part of existing regulatory requirements. During the time period of placement of the waste potlining at its current location, no regulations were in force or proposed prohibiting storage or disposal in this manner. Although the waste pile lies above a sole-source aquifer, it is exempt from compliance with existing State of Washington dangerous waste regulations prohibiting construction of new waste disposal facilities above sole-source aquifers [WAC 173-303-420(6)] because of the time period of placement. Current regulations do not require "exhuming" existing solid or dangerous waste disposal sites solely because they lie above sole-source aquifers.

The current actions being pursued by Kaiser are CERCLA/SARA guided. Should the SPL waste pile be excavated, these activities then would be controlled by applicable or relevant and appropriate requirements (ARARs)(see Appendix D).

The following listed requirements would be "applicable" since the SPL pile is a "listed" RCRA hazardous waste (K 088--spent potliners from primary aluminum reduction).

1. Area from which materials are excavated may require cleanup to levels established by closure requirements (40 CFR 264, disposal and closure requirements).
2. Devise fugitive and odor emission control plan for this action if existing site plan is inadequate (CAA Section 101 and 40 CFR 52).
3. File an air pollution emission notice (APEN) with the state to include estimates for each emitted pollutant (40 CFR 52).

These ARARs are considered to be attainable, with the possible exception of Item 1 because of the unknown cleanup levels that may be required. A significant number of additional ARARs exists for activities subsequent to excavation; these will be discussed in subsequent sections.

Economics. The costs associated with excavating the SPL pile are dependent on the rate at which it is removed. As stated earlier, the excavation can proceed at a rate far in excess of the receiving facility capacity. Consequently, the equipment would tend to be under-used, and unit costs would exceed those normally experienced during earth-moving operations. Additionally, unit costs could be increased further because of operator safety requirements, contaminant dispersion controls, and practical restrictions against working during periods of inclement weather to protect against environmental degradation.

With the above-mentioned constraints, excavation is estimated to cost $4.30 per ton at an excavation rate of 40,000 tons per year (tpy). The total cost would be about $550,000. This cost assumes no project management or regulatory-compliance-related costs, which will be incorporated into the costs of operating the receiving facility or technology. The expected range in unit costs because of variance in removal rates is from $1.30 per ton (1-year removal period) to over $15.00 per ton for receiving rates of 10,000 tpy. No potential long-range costs are incurred by excavation alone. These costs are associated with the receiving facility or technology. However, the exposed area would require capping to prohibit infiltration. These associated costs are addressed in a following section.

Technology No. 2: Offsite Disposal at a Regulated Landfill

Spent potlining is now a Subtitle C RCRA hazardous waste. As such, SPL that is transported to other states is subject to all the requirements imposed on transport and disposal of Subtitle C RCRA wastes. Because of this classification of SPL, disposal in a RCRA-regulated landfill is required and can be accomplished only outside the state of Washington. Three permitted disposal facilities are located within reasonable distances of Spokane.

1. Chem-Security, Arlington, Oregon (240 miles)
2. Envirosafe, Grand View, Idaho (420 miles)
3. USPCI, Grassy Mountain, Utah (560 miles)

The following analysis not only will examine offsite land disposal but also will address the required transportation of the waste.

Technical Feasibility. Several million pounds of Subtitle C RCRA wastes are transported and disposed of on a daily basis at operating RCRA and TSCA landfills. The "mechanics" of land disposal are well-known, and if undertaken by personnel skilled in the construction industry, relatively few technical implementation problems should be encountered.

Environmental Effects. As discussed in the previous technology assessment on excavation, any handling of the SPL increases the chances for dispersion to the environment. Truck-loading operations would require some form of dust control, most likely windbreaks or total enclosure of the loading operation. These measures, if properly installed and used, would eliminate adverse impacts on the environment because of material handling at the site.

Two major concerns relative to environmental impact are effects of reburial of the SPL waste material offsite and effects of the possible release of SPL to the environment during transport. Each of these areas is discussed in detail in the following paragraphs.

Reburial of the excavated SPL offsite at a regulated hazardous waste landfill needs to be analyzed for the potential of contribution to contaminant discharge at the receiving facility. Placement of SPL in engineered landfills with leachate collection and treatment systems raises questions about the facility's ability to treat the collected leachate. Ferrocyanide treatment by conventional cyanide destruction methods is ineffective and may result in unacceptable discharge levels.

Possible adverse environmental effects of transport of SPL can result because of three occurrences: (1) dispersion or "tracking" of waste by adherence to the transport truck's frame and tires, (2) dispersion because of wind during transport, and (3) a major release because of an accident. The first two listed items can be controlled largely by proper cleaning and decontamination of the truck undercarriage and tires and proper use and maintenance of tarps. The likelihood of a major accident, and the possible release of truck contents, can be estimated based on total mileage to the disposal facility (240 to 560 miles), number of trips required (6,400), and the average accident rate for truck transport (0.13 releasing accident per million truck-miles, NTIS Report No. PB85-224468). Based on this calculation, there is a small but finite possibility of waste material being released to the environment certainly during transport to the disposal facility. The degree to which the release would affect the environment cannot be estimated because of uncertainties about release location, speed of cleanup, weather conditions, etc.

Public Health Effects. Public health concerns largely parallel the environmental concerns outlined above. To summarize, offsite transportation and disposal can be expected to impart the following public health effects.

1. SPL pile removal from site: no change in groundwater quality; therefore, no effect on public health, either positive or negative

2. Truck loading: potential minimal negative effect

3. Transport: potential negative effect in all three categories identified above

4. Offsite reburial: likely negative effect

In addition, large-scale truck movements are likely to pose a public nuisance because of noise and increased local traffic that could raise the accident rate.

Institutional Requirements. RCRA hazardous waste management requirements have jurisdiction over wastes generated or managed after November 19, 1980. Should the SPL pile be excavated for disposal offsite, the waste material would be under RCRA control, and redisposal would be fully regulated.

Transportation of the SPL would be required to comply fully with 40 CFR 263 and 49 CFR since the material in the pile has become a listed RCRA hazardous waste (K 088).

Economics. The costs associated with offsite disposal at a RCRA landfill are presented in Table 3-1.

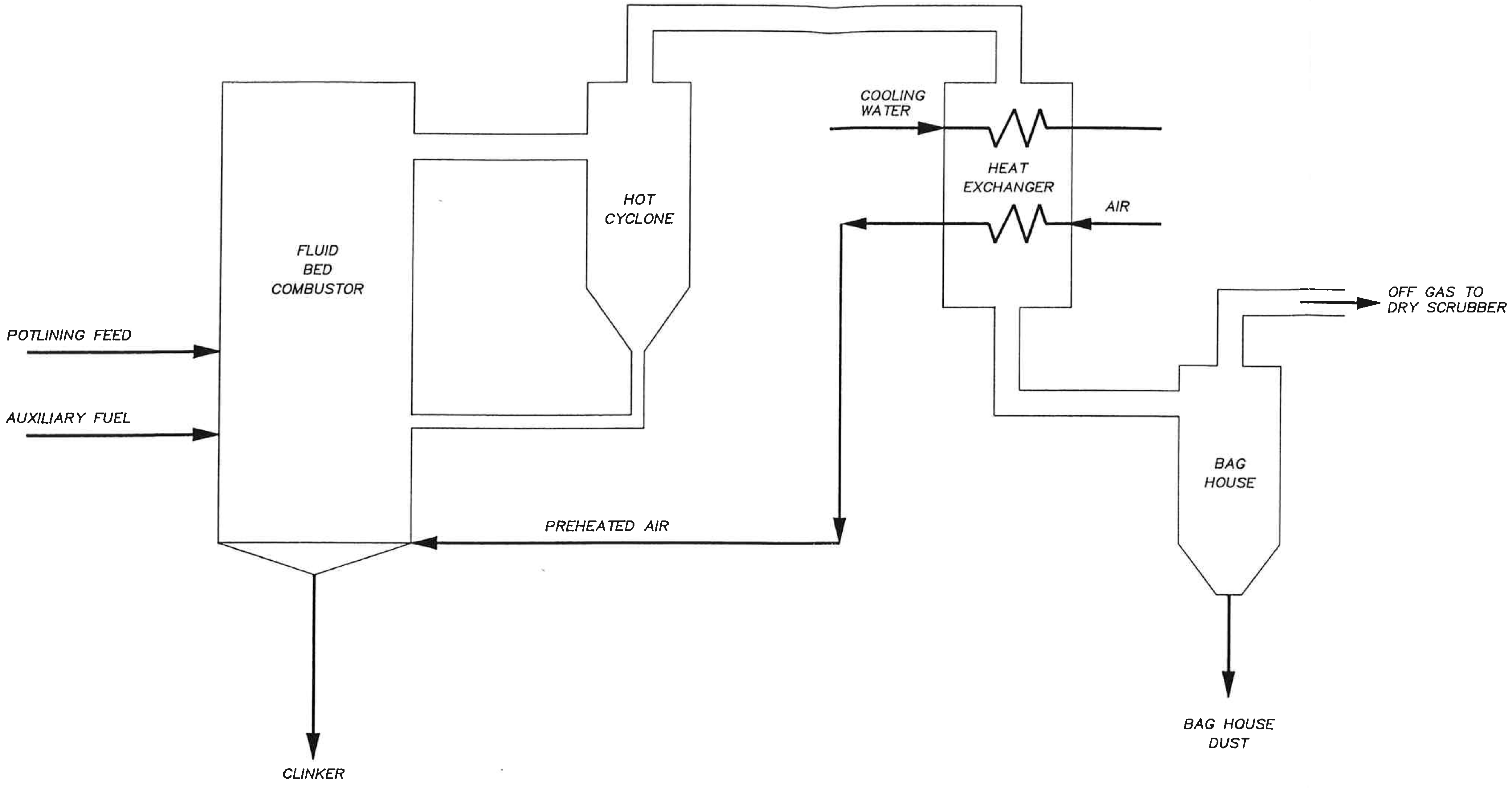


FIGURE 3-1
FLUID BED
COMBUSTION PROCESS SCHEMATIC

(TYP OF 4 TRAINS)

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Table 3-1
OFFSITE DISPOSAL COST ESTIMATE

RCRA Facility	Disposal Cost ($/ton)	Transport Cost ($/ton)	State Tax ($/ton)	Total ($/ton)
Chem-Security Arlington, Oregon	124	30	20	164
Envirosafe Grand View, Idaho	114	53	20	187
USPCI, Grassy Mountain, Utah	120	70	9	199

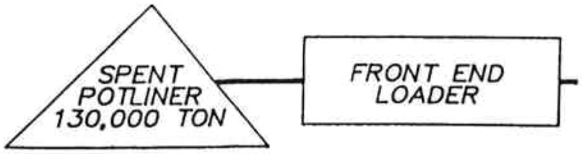
Based on the figures in the table, assuming no land disposal restrictions and no escalation in disposal costs, the 128,000 tons of SPL could be removed in under 4 years at a cost of approximately $21 million.

Offsite disposal of the SPL pile would require construction of a RCRA cap over the exposed area to isolate contaminated subsurface soil from infiltration. These costs are not included but are addressed in a following section.

Potential long-range costs of transport or offsite disposal liabilities have not been estimated and are not included.

Technology No. 3: Onsite CBC Incineration

Circulating bed combustion (CBC), as developed by GA Technologies and marketed by Ogden Environmental Services, Inc., involves burning of finely crushed (minus 1/4-inch) SPL in a fluidized bed reactor at approximately 1,500°F. A process flow schematic of the CBC system is shown in Figure 3-1. The cyanide contained in the SPL is reported by Ogden to be "completely" destroyed during the incineration process. Because of the low slagging temperature of the SPL, a proprietary additive is introduced with the SPL feed to improve handling characteristics. Effluents from the process include flue gas with hydrogen fluoride concentrations as high as 2,400 ppm. Inorganic constituents including fluoride, sodium, and aluminum remain in the ash or clinker from the combustion unit. Clinker mass is estimated to be from 70 to 100 percent of the SPL feed mass, dependent on the quantity of additive fed to the combustor.



NOTES:

a. ROTEX TWIN SCREEN FOR FLUID BED COMBUSTION, TRIPLE SCREEN FOR PYROHYDROLYSIS

b. +1mm RECYCLE FOR PYROHYDROLYSIS ONLY

c. SINGLE TRAIN REQUIRED FOR FLUID BED COMBUSTION, THREE TRAINS REQUIRED FOR PYROHYDROLYSIS.

d. STREAM SPLITTER FOR PYROHYDROLYSIS ONLY.

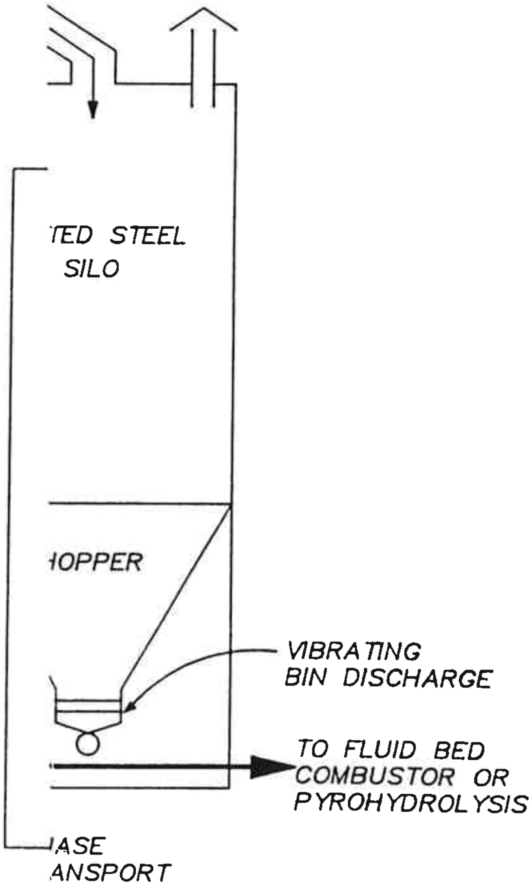


FIGURE 3-2
SPENT POTLINER
SIZE REDUCTION SYSTEMS FOR
FLUID BED COMBUSTION
AND PYROHYDROLYSIS

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Ogden Environmental Services, Inc., currently markets a 10,000-ton-per-year modular mobile unit. Analysis of this technology is based upon use of four parallel units for a combined capacity of 40,000 tpy.

Technical Feasibility. CBC, as applied to SPL, has been demonstrated on a pilot scale only. Demonstrations of commercial-size units (10,000 tpy) were proposed but did not occur. The main technological concerns with CBC incineration of SPL are listed below.

1. Required feed characteristics: The SPL must be processed by crushing and screening to a minus 1/4-inch particle size. All tramp iron must be removed, as well as aluminum "slabs" and nodules. A process schematic of the size reduction portion of a CBC system is shown in Figure 3-2.

2. Temperature control in the reactor: An adequate time/temperature environment must be maintained in the reactor to destroy the cyanide fully. However, increases in temperature above the 1,250°F to 1,450°F range cause slagging of the SPL and subsequent collapse of the fluidized bed. This occurrence causes interruption of the process and significant downtime. Use of a proprietary additive is reported to control this problem at the expense of increased clinker mass.

3. Clinker/ash composition: Fluoride and sodium present in the ash are leachable and therefore may pose as a significant disposal problem. Additionally, early CBC pilot studies reported leachable cyanide concentrations of approximately 10 ppm in the ash. With ash production estimated at 70 to 100 percent of SPL feed mass, the claimed nonhazardous nature of this stream would require verification prior to commercial application.

4. Flue gas composition: Hydrogen fluoride concentrations of 2,400 ppm have been reported in pilot-scale testing. This stream would require careful handling because of its potential health effects.

5. Abrasive nature of SPL: High alumina content is expected to increase maintenance requirements for all systems handling the SPL solids over typical maintenance requirements for equipment of this type handling less abrasive natural materials.

Although CBC units have demonstrated success with feedstocks such as coal, considerable development and demonstration work with SPL would be required before construction and successful operation of a full-scale commercial unit could be undertaken. Successful long-term continuous operation at 10,000 tpy with SPL should precede any construction of a commercial unit in order to demonstrate mechanical integrity, assure cyanide destruction, verify general process performance, and establish an online factor. The online factor is important for forecasting the time required to process the SPL pile.

Environmental Effects. The environmental effects of SPL processing by CBC are contingent largely on the adequacy of handling the effluent streams. Assuming the ash stream is nonhazardous, with no leachable constituents in excess of criteria, and disposal is permitted in a nearby non-RCRA landfill, the environmental effects are similar to those associated with operation of a municipal solid waste landfill. Should the ash be a dangerous or hazardous waste requiring out-of-state disposal at a RCRA facility, the same concerns addressed in the above offsite disposal discussion would apply, with the exception that cyanide treatment of any leachate would not apply. Designation of CBC-processed SPL as a hazardous waste would eradicate the economic viability of this technical option.

Flue gas handling, expected to be by dry scrubbing with aluminum oxide for production of aluminum fluoride, could be accomplished with no significant adverse environmental effects as long as the system remained intact. Structural failure of a system processing hydrofluoric acid (HF) at 2,400 ppm could harm local vegetation, depending on the degree of failure and the subsequent quantity of HF released.

One area yet to be addressed is the required size reduction processing of the SPL feed stream. Although the designed system would incorporate fugitive emission controls, operational experience at crushing and sizing facilities indicates that particulate emissions are likely to occur. "Housekeeping" at these types of operations is a significant problem and could cause release of small amounts of cyanide to the environment.

Public Health Effects. Public health effects are consistent with the concerns expressed relative to environmental effects. In summary, the following areas may impact public health:

1. Ash disposal: Potential negative effect whether disposed at sanitary/industrial landfill or RCRA facility.

2. Flue gas: Potential major impact if HF emissions occur. Plant workers are at greatest risk.

3. SPL pile removal: Limited effect on groundwater quality because a 145-foot contaminated soil column remains. Therefore, essentially no net effect on public health is expected. Minimal adverse impact because of handling.

4. SPL size reduction processing: Likely minimal adverse impact because of fugitive emissions. Plant operators would be required to use safety equipment.

Institutional Requirements. The SPL is considered a RCRA hazardous waste; so the following listed requirements would be "applicable."

1. Analysis of waste feed (40 CFR 264.341)

2. Disposal of all hazardous wastes and residues including ash, scrubber water, and sludge (40 CFR 264.351)

3. Monitor operational parameters including combustion temperature, waste feed rate, combustion gas velocity, and carbon monoxide content of off-gas (40 CFR 264.343)

4. Devise fugitive and odor emission control plan (CAA Section 101 and 40 CFR 52)

5. File an air pollution emission notice (APEN) with state to include estimates of emissions for each pollutant expected (40 CFR 52)

In addition, standards for miscellaneous treatment units (40 CFR 264, Subpart X) also may apply.

These ARARs are considered to be attainable.

Economics. Table 3-2 summarizes the capital, annual and unit costs associated with construction, operation, and maintenance of four parallel 10,000-tpy circulating bed combustors. The following assumptions were used in the economic analysis.

1. Capital costs include 8 percent of fixed capital cost as a startup allowance.

2. Maintenance estimates are 6 to 9 percent of fixed capital cost per year.

3. Ash disposal costs reflect disposal at a nonhazardous waste landfill. Costs for disposal at a RCRA facility were not used.

4. Flue gas scrubbed with existing equipment in plant.

5. Interest rate at 9 percent, inflation at 4 percent per year.

6. Capital costs annualized over 4 years with unit costs calculated on 128,000-ton basis.

7. O&M costs annualized over 4 years with unit costs calculated on a 40,000-tpy basis.

8. No dismantling or disassembly costs included.

9. No legal, insurance, land or permitting costs included.

10. No credits are included for recoverable commodities.

Table 3-2
40,000-TON-PER-YEAR CIRCULATING BED COMBUSTION COST ESTIMATE

Process Component	Capital Cost ($000's)	Annual Cost ($000's)	Unit Cost ($/ton)
Size Reduction Eqt.			
Procure and construct	1,310	404	12.65
Operation	--	356	8.90
Maintenance	--	92	2.30
Subtotals	1,310	852	23.85
Circulating Bed Combustors (four)			
Procure and construct	16,815	5,190	162.20
Operation	--	4,542	113.55
Ash Disposal	--	1,087	27.18
Maintenance	--	1,071	26.80
Subtotals	16,815	10,891	329.73
CBC TOTALS	18,125	12,742	353.58

Based on the figures above, assuming CBC technical feasibility and reliability, the 128,000 tons of SPL could be treated in about 4 years.

Excavation and onsite processing of the SPL pile would require construction of a RCRA cap over the exposed area. These costs are not included but are addressed in a later section.

Technology No. 4: Onsite Pyrohydrolysis

Pyrohydrolysis, as developed by Lurgi GmbH, F.R.G., involves reaction of very finely ground SPL (minus 1 mm) with steam in a 2,100°F to 2,200°F circulating fluid bed reactor (Figure 3-3). Supplementary fuel (coal) fires the process although self-sustaining operation has been achieved on a pilot scale. During combustion the carbon content is reported to be completely oxidized to carbon dioxide, with complete destruction of the cyanide also claimed. Process effluents include sodium and aluminum (as sodium aluminate) in the bed ash (clinker) and hydrogen fluoride gas (HF) in the off-gas. Sodium fluoride (NaF) is, produced, also as a fugitive dust from the off-gas handling equipment. The proposed process would use these effluent streams as feedstocks for the Bayer process and aluminum fluoride production, respectively. The NaF stream requires treatment with lime to produce dilute caustic, which is used as a feedstock for the Bayer process. Calcium fluoride is generated as a byproduct sludge in this slaking process. Unfortunately, the Kaiser facility in Mead does not incorporate the Bayer process, and transport of the clinker and dilute caustic out of state would be required to recover any value from this effluent stream.

For the purposes of this evaluation, it is assumed that the clinker and calcium fluoride effluent streams will not be recovered but can be handled as nonhazardous wastes. Also, because of the short life of the project, aluminum fluoride will not be produced; instead, dilute hydrofluoric acid, which is considered to be readily marketable, would be recovered. All the additional operations associated with aluminum fluoride synthesis in the Lurgi process have been eliminated.

The sizing basis used for this analysis is 40,000 tpy. This capacity was selected to facilitate comparison with CBC technology, and considerable predesign information was readily available for a 40,000-tpy facility.

Technical Feasibility. The basis for design of an operating pyrohydrolysis unit is pilot-scale research performed in 1981 in Germany by a cooperative effort of Lurgi, Kaiser, and VAW, a German aluminum producer. Based upon 1981 market conditions, considerable interest was expressed in the process because of its reported ability to recover valuable chemicals from spent potlining that could be used in aluminum production. However, with changes in market conditions and in the aluminum industry, most notably the cessation of construction of new facilities and decreased production at existing facilities, the pyrohydrolysis process was not pursued to demonstration or commercial scale. Scale-up problems are a major concern in construction and operation of a full-scale facility.

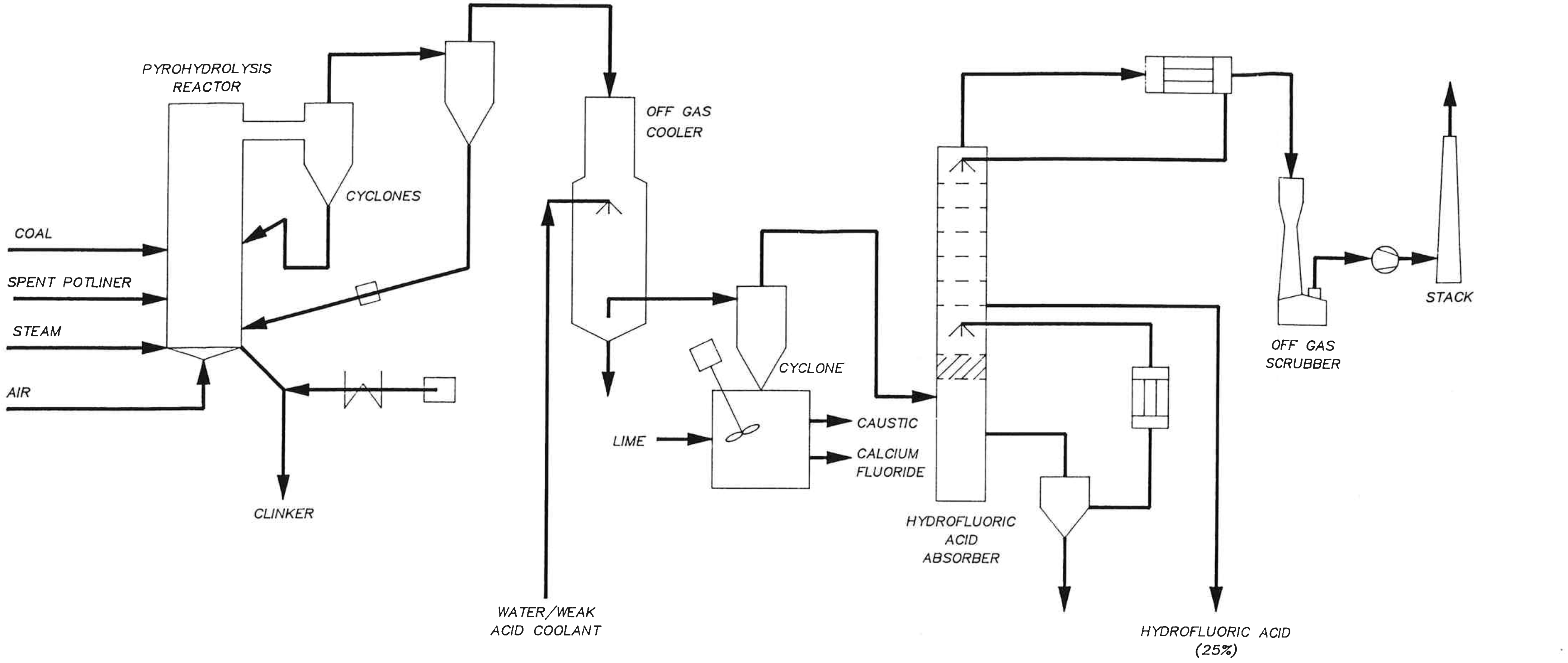

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FIGURE 3-3
PYROHYDROLYSIS PROCESS SCHEMATIC

Other technical problems exist with the ability of the unit to handle both cathode carbon (first cut) and insulating portions (second cut) of the SPL. No research has been reported for soil-contaminated feed streams with silica.

Based on the limited operational experience to date, technical feasibility is questionable. Construction and operation of "one-of-" or "first-of-a-kind" processes is usually extremely difficult with poor reliability and extended downtime.

Environmental Effects. Environmental effects associated with the implementation of the pyrohydrolysis process are consistent with the concerns expressed in the preceding section on CBC. In summary, the following impacts have been identified.

1. Ash (clinker) and calcium fluoride disposal: If nonhazardous and disposed at a nearby sanitary/industrial landfill, the environmental effects would be negative, similar to disposal of municipal solid waste. Because the clinker and calcium fluoride streams amount to over 60 percent by weight of the SPL feed stream, significant quantities would require disposal. If the ash is considered RCRA hazardous, requiring out-of-state disposal at an RCRA facility, the concerns addressed previously in offsite disposal would apply with the exception that cyanide treatment in leachate would not be a concern.

2. Hydrogen fluoride off-gas: Expert handling would be required because of its high hazard potential and the toxicity of fluoride to plants.

3. Groundwater quality: No effect on groundwater quality is anticipated.

4. Fugitive emissions: The size reduction equipment required typically produces fugitive particulate emissions that could disseminate spent potlining dust into areas where contaminant leaching could occur.

5. Dilute caustic stream: For the purposes of this evaluation, the caustic stream would be neutralized and discharged under the current NPDES permit. Assuming compliance with effluent discharge criteria, no adverse environmental effects are anticipated.

Public Health Effects. Public health effects are consistent with the concerns expressed relative to environmental effects. In summary, the following areas may impact public health.

1. Ash and calcium fluoride disposal: Potential minor negative effect whether disposed at a sanitary/industrial landfill or RCRA facility.

2. Hydrogen fluoride stream: Potential major impact if accident or equipment failure occurs. Exposure risks to plant personnel are the most significant concern, but there is also a risk to the population in the surrounding area, a risk during shipment, and the potential for damage to plants.

3. Groundwater quality: No effect expected on public health, either positive or negative.

4. Fugitive emissions: Minimal adverse impact if controls are used and maintained.

5. Dilute caustic stream: No effect on public health.

Institutional Requirements. Because potlining is a listed hazardous waste, the following listed requirements would be "applicable."

1. Analysis of waste feed (40 CFR 264.341)

2. Dispose of all hazardous waste and residues including ash, scrubber water, and sludge (40 CFR 264.351)

3. Monitor operational parameters including combustion temperature, waste feed rate, combustion gas velocity, and carbon monoxide content of off-gas (40 CFR 264.343)

4. Standards for miscellaneous treatment units (40 CFR 264, Subpart X)

5. Devise fugitive and odor emission control plan (CAA Section 101 and 40 CFR 52)

6. File an air pollution emission notice (APEN) with state to include estimation of emission rates for each pollutant expected (40 CFR 52)

The applicable or relevant and appropriate requirements are considered to be attainable.

Economics. Table 3-3 summarizes the capital, annual, and unit costs associated with construction, operation, and maintenance of a 40,000-tpy pyrohydrolysis system. The following assumptions were used in the economic analysis.

1. Capital costs include 8 percent of fixed capital cost as startup allowance.
2. Maintenance estimates are 6 to 9 percent per year of fixed capital cost.
3. Ash and calcium fluoride disposal costs at a solid waste facility included.
4. Interest rate 9 percent and inflation 4 percent per year.
5. Capital costs annualized over 4 years with unit costs calculated on 128,000-ton basis.
6. O&M costs annualized over 4 years with unit costs calculated on 40,000-tpy basis.
7. No dismantling or disassembly costs included.
8. No legal, insurance, land, or permitting costs included.

Technologies No. 5a and No. 5b: RCRA Capping Of Exposed SPL Area (No. 5a) and Unpaved Portion of Area 4 (No. 5b)

After removal of the SPL pile for offsite disposal or onsite treatment, the underlying soils would be exposed. Because of potential water infiltration and subsequent mobilization of the ferrocyanide, installation of a RCRA cap over this area was assessed. The area potentially to be capped measures approximately 300 feet by 700 feet with a generally level grade.

Area 4 is located directly west of the SPL pile and south of the rubble pile, measuring approximately 250 feet by 150 feet. It is bordered on the south edge by G Avenue. A portion of this area currently is exposed. Because of potential water infiltration in this area, installation of a RCRA cap was assessed.

Table 3-3
40,000-TON-PER-YEAR PYROHYDROLYSIS COST ESTIMATE

Process Component	Capital Cost ($000's)	Annual Cost ($000's)	Unit Cost ($/ton)
Size Reduction Eqt.			
Procure and construct	2,634	813	25.40
Operation	--	452	11.30
Maintenance	--	187	4.70
Subtotals	2,634	1,452	41.40
Pyrohydrolysis			
Procure and construct	24,500	7,560	236.25
Operation	--	1,932	48.30
Solids disposal	--	872	21.80
Maintenance	--	1,560	39.00
Hydrofluoric acid (25%) credit		(1,760)	(44.00)
Subtotals	24,500	10,164	301.35
PYROHYDROLYSIS TOTALS	27,134	11,616	342.75

Technical Feasibility. Installation of RCRA caps over the exposed SPL area following excavation and the exposed part of Area 4 can be implemented readily with performance requirements attained. The caps would be asphalt and would have good reliability with little maintenance.

Environmental Effects. Because natural surface water infiltration is not considered to be a significant mobilizing force for ferrocyanide contained in the soils underlying the SPL pile, installation of RCRA caps is not expected to alter or accelerate the general trend of decreasing total cyanide concentrations observed in the aquifer. However, should large quantities of water inundate either of these areas because of natural or manmade causes, the potential for increased leaching of ferrocyanide is reduced or eliminated by grading and installation of the caps. Additionally, installation of the caps would eliminate the potential for windblown dispersion during dry conditions.

Public Health Effects. Since no significant effect on groundwater quality is anticipated by installation of either RCRA cap, no effect on public health, either positive or negative, is expected relative to groundwater. Because the RCRA caps would protect against water infiltration during flooding of the areas (an improbable occurrence), some protection of the public health may be provided by installation of these caps. However, no contaminated groundwater is being used for drinking purposes, and a short-term increase of leached ferrocyanide entering the aquifer may have little effect.

Protection from windblown particulate matter would be provided by cap installation. However, only during extremely dusty conditions could any release of contaminant occur.

These areas are not used for plant operations (i.e., no vehicular traffic). Therefore, offsite dispersion of dust is not considered to be a problem.

Institutional Requirements. RCRA capping of the exposed area beneath the removed SPL pile may be regulated by a number of action-specific ARARs. The SPL pile is considered a RCRA hazardous waste; so the following requirements would be "applicable."

1. The area from which materials are excavated may require cleanup to levels established by closure requirements (40 CFR 264, disposal and closure requirements).

2. Placement of a cap over waste requires a cover designed and constructed to meet 40 CFR 264.258(b). Such a cap must:

   - Provide long-term minimization of migration of liquids through the capped area

   - Function with minimum maintenance

   - Promote drainage and minimize erosion or abrasion of the cover

   - Accommodate settling and subsidence so that the cover's integrity is maintained

   - Have a permeability less than or equal to the permeability of any bottom-liner system or natural subsoils present

3. Restrict postclosure use of property as necessary to prevent damage to the cover [40 CFR 264.117(c)]

4. Prevent run-on and runoff from damaging cover [40 CFR 264.228(b) and 264.310(b)]

5. Protect and maintain benchmarks used to locate waste [40 CFR 264.310(b)]

The listed ARARs are considered to be attainable with the possible exception of the cleanup of the waste area to levels established by closure requirements (Item 1 above). At this time it is unknown what cleanup levels would be required.

Economics. Installation of a 4-inch-thick, contoured asphalt RCRA cap over the exposed SPL area is estimated to cost $285,000. Annual maintenance expenses are estimated at $21,000 for sealing of the asphalt.

Installation of a 4-inch-thick, contoured asphalt RCRA cap over the exposed portion of Area 4 is estimated to cost $50,000. Annual maintenance expenses are estimated at $3,750 for sealing of the asphalt.

An associated cost would be incurred by the required construction of runoff and run-on controls. Asphalt-lined storm drainage ditches could be used, at an estimated additional cost of $7,000 (SPL area) and $3,000 (Area 4). Collected surface water would be discharged to existing storm drains.

Technology No. 6: Leak Testing and Monitoring

Leak testing or monitoring would involve identification of all pipes and associated equipment (manholes, valves, etc.) for storm, sewer, and potable water within a reasonable distance of the SPL pile and checking for leakage. Two methods could be used for determination of gravity pipe integrity. First, actual leakage rates could be measured by closing off pipe sections, filling with water, and monitoring the reduction in water level, if any. This testing method is applicable to gravity water systems and was used in a limited testing program performed in this fashion at Kaiser in 1982 on pipes within a 600-foot distance of the SPL pile. The second testing method involves monitoring soil or gravel moisture content to identify areas with moisture levels above background or anticipated levels. Although this test method may identify areas of leakage, it cannot quantify volume of leakage.

Portions of the pressurized water system also can be isolated and leakage estimated by measuring the flow rate of pressurized water from elsewhere in the system that is required to maintain a nominal pressure within the isolated section. A method similar to this was used in 1982 to leak-test water pipes within about 600 feet of the asphalt-covered SPL pile.

The pipe lengths located within 600 feet of the SPL pile are summarized in Table 3-4. This listing includes the majority of pipe within this zone as well as other pipes crossing beneath the abandoned sludge bed and pipe segments beginning within the 600-foot zone but extending outside this area.

Technical Feasibility. Leak testing and monitoring could be implemented readily. As mentioned previously, moisture monitoring would not quantify the volume of leakage but may be the only testing procedure available where shutdown of required systems for testing is not feasible. Therefore, an integrated testing program, using both detection methods, may be best suited for operating systems.

Environmental Effects. It is possible that increased mobilization of ferrocyanide will occur because of increased pipe leakage during high-volume leak testing. However, the short duration of the tests should minimize this consequence.

Public Health Effects. The possible increased water leakage to the subsoils during high-volume leak testing, and possible subsequent mobilization of ferrocyanide, should not impact groundwater quality because of the short duration of the tests and limited quantity (length) of pipe tested at any one time. Therefore, no significant adverse effects on public health are anticipated when coupled with the fact that the contaminated groundwater is not being used as a drinking water supply.

Institutional Requirements. No requirements, applicable, relevant, appropriate, or otherwise, have been identified for the subject leak testing and monitoring program.

Economics. The scope of the leak testing and monitoring program is outlined below.

1. Test pipe segments including those evaluated in the 1982 study

2. Install moisture detectors at suspected or identified infiltration points

The estimated cost to perform the above items is $75,000. Associated costs (pipe repair, replacement, or relocation) are addressed in the following sections.

Table 3-4
PIPE LENGTH SUMMARY

Pipeline	Diameter (inches)	Length (feet)
Storm	42	600
	36	1,191
	30	771
	27	224
	21	283
	18	466
	15	649
	12	1,260
	8	431
	6	242
Subtotal		6,117
Sanitary	12	561
	10	1,438
	6	2,108
	4	52
Subtotal		4,159
Water	10	2,150
	8	100
	6	200
	3	500
	1.5	200
	1	100
Subtotal		3,250
TOTAL		13,526

Technology No. 7: Slip Lining or Replacement of Leaking Pipes

There are two main alternatives for reducing or eliminating water infiltration from pipes should the leak testing and monitoring program indicate losses of significant volumes of water to the subsoils. They are repair by slip lining with polyethylene pipe and parallel replacement with new pipe.

Technical Feasibility. The options outlined above are technically feasible to a large degree with some exceptions as discussed in the following paragraphs.

Installation of polyethylene slip linings allows pipe repair to be made with a minimum of ground surface disturbance. It often enables repairs to be performed to pipe segments that would be inaccessible for other repair procedures. The resulting pipe integrity is excellent. The disadvantages of this approach include:

- The line to be repaired must be removed from service for extended periods of time, and alternative service must be provided for essential processes and facilities during the slip lining installation.
- The liner reduces the hydraulic capacity of the pipe.

Parallel replacement of faulty pipe segments minimizes the need to disrupt service during construction. It also provides for full hydraulic capacity should the same diameter pipe be installed, as well as the option of installing larger or smaller pipe in some cases. Structural integrity, if properly installed, is excellent. Disadvantages of this approach include:

- Major ground-surface disruptions with impacts on vehicular and pedestrian traffic, especially when access to active work areas is affected.
- Major surface restoration is required, which could involve adjacent buildings and structures.
- Conflict with other existing underground utilities is anticipated.

Environmental Effects. By eliminating significant leakages, a major mechanism for potential ferrocyanide transport to the aquifer would be eliminated. Based on the prevailing precipitation patterns and soil hydrology, it was concluded that natural water infiltration was insignificant both for groundwater recharge and for mobilization of contaminants contained in soils underlying the SPL pile. However, contaminant mobilization could be caused by water infiltration from other sources, such as pipe leakage. It is anticipated that the current trend of decline in cyanide concentrations observed in the aquifer could be accelerated by eliminating this source of water infiltration if it were, in fact, occurring.

Although a general decrease in ferrocyanide concentration in the Little Spokane River would be expected because of the reduced mobilization of cyanide to the aquifer at the Kaiser facility, no harmful aquatic effects have yet been demonstrated at present levels of contamination. (The University of Michigan study in Appendix C was unable to document any harmful effects on aquatic life because of discharge of low-level concentrations of ferrocyanide.) Therefore, no demonstrable benefit to the environment (the Little Spokane River) would be expected by implementing either of these options.

Using the groundwater concentration of cyanide at the point of discharge to the Little Spokane River as a measure of groundwater quality, it is anticipated that no increase in the observed steady improvement of groundwater quality would result for a period of years.

Public Health Effects. Minimal improvement in the protection of public health is expected from an increased decline in the cyanide concentration in the aquifer. Since contaminated groundwater currently is not being extracted for human consumption, no effects are anticipated because of this exposure mechanism. Accidental ingestion of water from the Little Spokane River constitutes a potential exposure mechanism, but the toxicity of ferrocyanide is low compared to free cyanide, and the quantities involved are likely to be low and of short duration.

Institutional Requirements. Implementation of pipe leakage control measures is not governed by any identified requirements or regulations.

Economics. Table 3-5 summarizes the estimated costs associated with the pipe slip lining and parallel replacement options discussed previously.

Technology No. 8: Relocation of Water- and Sewerlines, the Wastewater Treatment Plant, and Storm Drains

The relocation of water- and sewerlines, the wastewater treatment plant, and storm drains to a sufficient distance away from the SPL pile is intended to eliminate the potential for leakage and the transport of cyanide in subsurface soil into the groundwater. The piping would be relocated sufficiently far from the main source of available cyanide (contaminated subsurface soil) so that cyanide remobilization would not occur even if pipe leakage occurred.

Technical Feasibility. Relocation or rerouting of pipes is least difficult for the major stormwater lines. Relocation of sewer or potable waterlines also would require relocation of the facilities they service, which, in the case of the sewerlines, includes the wastewater treatment plant. The stormwater lines considered as candidates for relocation are the main 30- and 36-inch-diameter discharge lines leading from the Mead Works to the stormwater lagoon. They could be rerouted from their current location between the sludge bed and the SPL pile over to the east side of the sludge bed, then north to their intersection with an existing stormwater

Table 3-5
COST SUMMARY FOR REPAIR OR REPLACEMENT OF LEAKING PIPES

	Pipe Diameter (inches)	Pipe Length (feet)	Estimated Unit Cost ($/lin ft)	Total Cost ($)
Polyethylene Slip Lining				
Stormwater	42	600	152	91,200
	36	1,191	114	135,800
	30	771	84	64,800
	27	224	73	16,400
	21	283	58	16,400
	18	466	55	25,600
Subtotals		3,535		350,200
Sanitary sewer	12	561	37	20,800
	10	1,438	36	51,800
	6	2,108	39	82,200
Subtotals		4,107		154,800
Potable water	10	2,150	50	108,500
	8	100	44	4,400
	6	200	38	7,600
Subtotals		2,450		119,500
Slip Lining Totals		10,092		624,500
Parallel Replacement				
Stormwater	Same pipe segments as slip lining			441,400
Sanitary sewer	Same pipe segments as slip lining			236,200
Potable water	Same pipe segments as slip lining			142,500
Parallel Replacement Total				820,100

drain. The new routing would remove the potential leakage from these lines from within the zone of influence, for purposes of estimation, assumed to be within 600 feet of the SPL pile (Matt Dalton, personal communication). The existing lines would be abandoned in place.

Relocation of the existing wastewater treatment plant would enable the abandonment of a 10-inch and a 12-inch sanitary sewerline as well as a 3-inch potable water pipeline. Further, relocation would eliminate water possibly leaking from the treatment tanks at the plant.

Because the existing wastewater treatment plant is of older design and concrete construction, it has been assumed that this plant would be abaoned in-place and a new packaged plant constructed on the east side of the sludge bed. New influent and effluent pump stations would be constructed, and new effluent pipeline to convey treated wastewater to the existing settling basin would be installed.

No other facilities are candidates for relocation because they move water from the point of collection to the main storm lines discussed above. Leakage from these lines must be eliminated by either repair or replacement.

Environmental Effects. Relocating piping away from areas where leakage could cause cyanide remobilization would diminish a major mechanism for cyanide transport. It is anticipated that the current trend of declining cyanide concentrations in groundwater would continue resulting in eventual reduction of the cyanide concentration in the Little Spokane River.

Similar to the situation for slip lining or replacing leaking pipes in their present locations, no measurable effect on aquatic life is likely to be observed in the Little Spokane River if this remedy were implemented because there is no apparent effect at current cyanide concentration in the river.

Public Health Effects. Minimal improvement in the protection of public health is expected by relocating pipes away from the SPL pile. Since contaminated groundwater is not currently being extracted for human consumption, no effects are expected because of this exposure pathway.

Institutional Requirements. Relocation of water, sewer, and large storm drain lines and the wastewater treatment plant away from the SPL pile is not governed by any identified requirements or regulations.

Economics. Table 3-6 summarizes the estimated costs associated with the relocation of the water, sewer, and storm drain lines and the treatment plant.

Technology No. 9: Periodic Groundwater Monitoring

This activity involves continuation of the groundwater monitoring effort without any substantial changes in scope from previous work performed. Activities that would be performed include sampling of several indicator monitoring wells and springs quarterly and compilation and evaluation of the data and submittal of reports, all on a semiannual basis.

Technical Feasibility. Periodic groundwater monitoring and reporting are technically feasible.

Environmental Effects. No effects on the environment are anticipated because of groundwater monitoring.

Public Health Effects. No effects on the public health and safety are anticipated because of groundwater monitoring.

Institutional Requirements. Groundwater monitoring provisions of RCRA (40 CFR 264) may be relevent and appropriate.

Economics. The current groundwater monitoring effort is estimated to cost $120,000 per year, inclusive of all analytical requirements.

PLUME-RELATED TECHNOLOGIES

Technology No. 1: Groundwater Extraction

Extraction of contaminated groundwater would involve drilling, installing, and developing three recovery wells located downgradient from the SPL pile spaced at approximately 500-foot intervals on the plume centerline. Pumping rates for the wells would be approximately 60 to 80 gpm, with extracted groundwater piped back to a treatment facility in the vicinity of the plant.

Technical Feasibility. Based upon a semianalytical groundwater model (RESSQ), the well configurations and pumping rates described above should be sufficient to create a capture zone larger than the existing contaminant plume. The model was based on the following aquifer parameters (Site Characterization Analysis report, Sections 3.1.2 and 3.2).

- Thickness of aquifer--12.5 feet (range 10 to 15 feet)
- Porosity--0.25

Table 3-6
COST SUMMARY FOR RELOCATION OF WATER, SEWER, AND STORM DRAIN LINES AND THE TREATMENT PLANT

I. Storm Drain Lines

Pipe Diameter (inches)	Pipe Length (feet)	Estimated Unit Cost ($/lin ft)	Total Cost ($)
42	2,000	115	334,000
36	150	142	21,300
30	1,500	115	172,500
TOTAL			527,800

II. Treatment Plant, Sanitary Sewer, and Water Lines

Major Equipment Item	Estimated Cost ($)
Packaged Biological Treatment System Installed	402,500
Influent Pump Station (equipment and controls)	20,000
Effluent Pump Station (equipment and controls)	20,000
Maintenance Building	40,000
12-Inch Sewerlines With Manholes (1,000 feet)	63,000
18-Inch Sewerlines With Manholes (500 feet)	37,500
8-Inch Effluent Pipeline (2,500 feet)	87,500
3-Inch Water Pipeline	15,500
Asphalt Drive and Paving (2,000 ft^2)	8,900
Major Equipment Foundations	7,000
Electrical Installation	25,000
Subtotal	726,900
Abandonment of Existing System (Demolition, backfill, revegetate, landfill demolition debris, equipment salvage)	100,000
Subtotal	826,900
Mobilization, Bonds, and Insurance	41,400
Engineering, Legal, and Administrative	181,900
Contingency	248,000
TOTAL CAPITAL COST	1,298,200

- Hydraulic conductivity--3,300 gpd/square foot (range 1,800 to 4,800 gpd/square foot)
- Hydraulic gradient--0.003
- Pore water velocity--1,950 ft/yr

Drilling, installation, and development of the required recovery wells can be accomplished readily.

Environmental Effects. It is anticipated that implementation of this technology would improve the quality of the downgradient aquifer. However, it cannot be assured that ambient water quality standards would be met.

Based upon the research performed by the University of Michigan on the Little Spokane River aquatic environment in the vicinity of the contaminated plume outfall, the improved groundwater quality expected to be observed eventually at the outfall will not produce any noticeable improvements in this environment. Environmental quality improvements could be assessed only by performing chemical analyses for cyanide and not directly from the state of health of the aquatic environment.

Public Health Effects. Since contaminated groundwater currently is not being extracted for human consumption, no improvement in public health is anticipated relative to this exposure mechanism. Ingestion of water from the Little Spokane River is not considered to pose a public health problem because the cyanide concentration is far below levels that would cause human health effects, referenced in Chapter 1.

Institutional Requirements. The CWA AWQC (chronic freshwater exposure limit for cyanide of 5.2 μg/l) discussed previously is "to be considered" in connection with controlling cyanide released into the Little Spokane River. No requirements were identified for groundwater extraction only. This is discussed further in the following section on chemical treatment.

Economics. A cost estimate was developed for construction and operation of the groundwater extraction system as outlined above. The estimated capital cost is $45,000 with an annual operating cost of $25,000. No land costs are included should right-of-way costs be incurred to accommodate offsite well placement.

Technology No. 2: Chemical Treatment

The groundwater extraction system would be designed to produce a 200-gpm groundwater stream requiring treatment for removal of dissolved cyanide. The estimated average total cyanide concentration of this 200-gpm water supply is 45 to 50 mg/l, with typically over 90 to 95 percent of the cyanide existing as ferrocyanide, $Fe(CN)_6^{4-}$. Ferrocyanide is chemically very stable and therefore resistant to the conventional cyanide oxidation techniques. The treatment process evaluated in the following sections is based upon the reaction of dissolved ferrocyanide at pH 6.0 with excess ferrous sulfate to form a precipitate (Figure 3-4). Additional chemicals also are involved to aid in the flocculation and settling of the precipitate.

Technical Feasibility. Previous research performed by CH2M HILL indicates that dissolved ferrocyanide might be removed effectively down to levels of 2 to 4 ppm by precipitation with ferrous sulfate. Additionally, the ferrocyanide precipitation is performed easily in conventional wastewater treatment equipment. Effluent streams from the process include the treated groundwater (<4 ppm cyanide and pH 6.0) and the dewatered precipitate sludge. This sludge is considered to be RCRA hazardous for the purposes of this evaluation although the expected characteristics of the sludge should allow for a nonhazardous classification.

No technical impediments have been identified for construction and operation of a 200-gpm groundwater treatment facility as described. Operation should prove to be reliable.

Environmental Effects. Operation of the treatment facility is not anticipated to produce any adverse environmental effects. Only one hazardous chemical is used in treatment (sulfuric acid), with storage and feed systems designed to minimize handling or exposure risks. Fugitive emissions are not anticipated. The dewatered ferrocyanide precipitate would be disposed offsite at a RCRA landfill if necessary.

Environmental effects associated with discharge of the treated effluent are addressed in the technology assessment section of Technology No. 3, below.

Public Health Effects. No adverse public health effects are anticipated by construction and operation of the described system.

Institutional Requirements. Should the dissolved ferrocyanide be considered a RCRA hazardous waste, the following requirements would be "applicable." If a nonhazardous waste, these requirements may be "relevant and appropriate."

1. Standards for treatment in tanks (40 CFR 264, Subpart J) or for treatment in miscellaneous units (40 CFR 264, Subpart X) to satisfy environmental performance standards by protection of groundwater, surface water, and air quality and by limiting surface and subsurface migration.

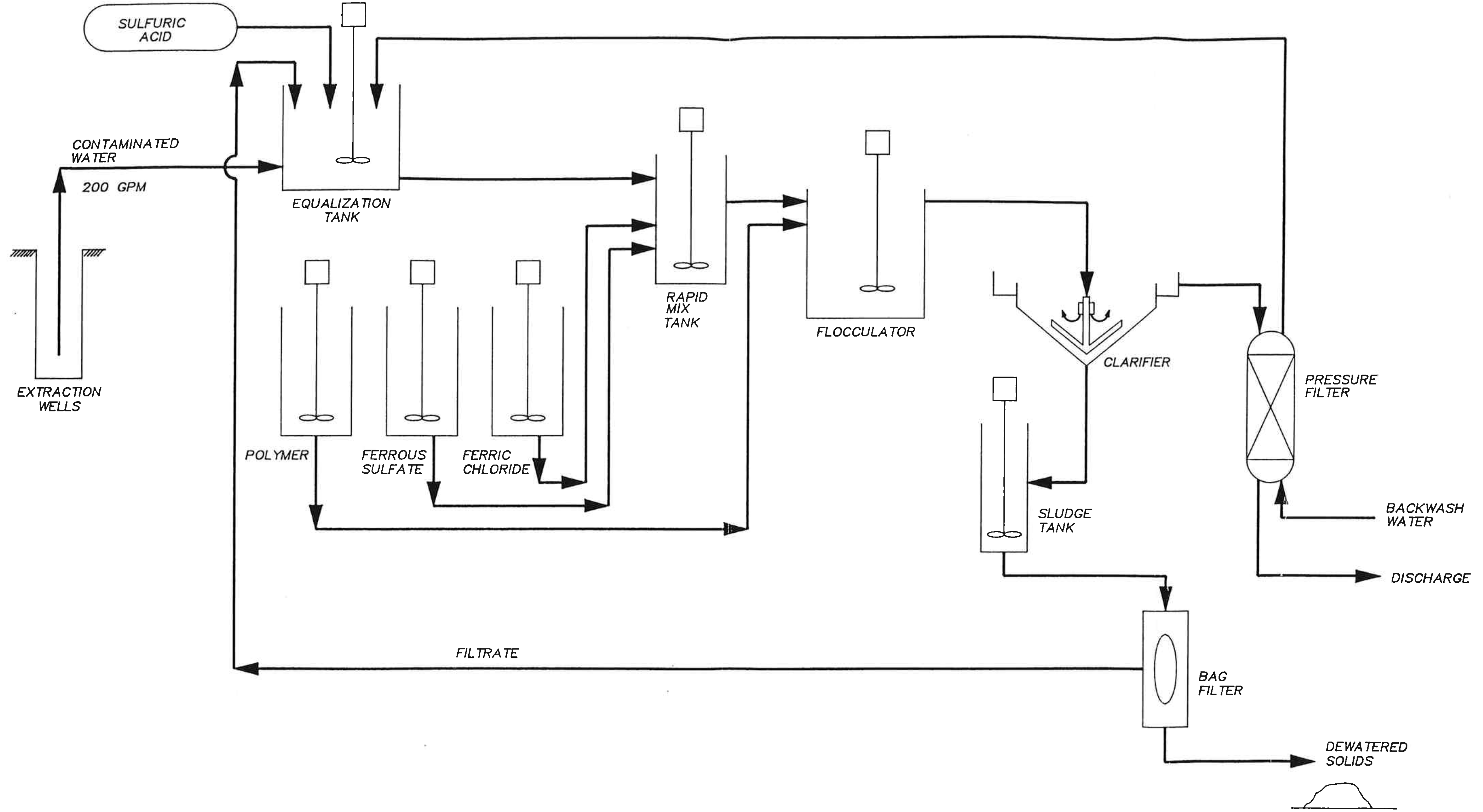

FIGURE 3-4
CYANIDE PRECIPITATION PROCESS SCHEMATIC

2. Devise fugitive and odor emission control plan (CAA Section 101 and 40 CFR 52)

3. File an air pollution emission notice (APEN) with state to include estimates for each emission (40 CFR 52)

These ARARs are considered to be attainable, should they be applied to Mead facility remedial activities.

Economics. Table 3-7 summarizes the estimated costs for construction, startup, and operation of the 200-gpm groundwater treatment facility as previously described. Operation costs include RCRA disposal of the ferrocyanide precipitate. Annual costs were calculated over 20 years with 9 percent interest and 4 percent inflation.

Table 3-7
200-GALLON-PER-MINUTE GROUNDWATER TREATMENT FACILITY

Process Component	Capital Cost ($000s)	Annual Cost ($000s)	Unit Cost ($/Kgal.)
Groundwater Treatment			
Procure and construct	2,160	237	2.26
Operation	--	691	6.58
Maintenance	--	328	3.12
TOTALS	2,160	1,256	11.96

Based on treatment for 20 years, a total expenditure of approximately $13 million would be required to build and operate the groundwater treatment system.

Technology No. 3: Treated Effluent Discharge to the POTW

Effluent from the groundwater treatment facility would be transported by pipeline to the nearest available and approved pump station, most probably the main station located at the southeast corner of Holland and Colton. From there it would be conveyed through existing city lines to the POTW. Discharge flow rates are not expected to exceed 210 gpm, and cyanide concentrations, before dilution, are not expected to exceed 4 ppm. Ferrocyanide is not readily decomposed by aerobic biological processes, and it is expected to pass through the POTW unattenuated, albeit diluted. (Direct discharge of treated water at the Mead Works would cause the NPDES discharge permit limit for cyanide to be violated. Consequently, direct discharge was not evaluated.)

Technical Feasibility. No technical implementation problems are anticipated in construction of the required transport line. However, the capability to treat the low-level cyanide stream does not exist at the POTW, with the only probable effect being further dilution.

It is anticipated that sufficient capacity exists at the main pump station and POTW to accommodate the additional 210-gpm maximum flow.

Environmental Effects. The impact of transporting the low-level cyanide effluent over the required distance to the pump station (approximately 1.5 miles) and subsequent transport of the diluted stream to the POTW is dependent on the leakage from these piping systems. The cyanide levels (∿4 mg/l prior to dilution) are well above CWA AWQC.

Environmental effects related to the POTW discharge are not anticipated to be a factor because of the high dilution of the cyanide stream.

Excavation and trenching would be required for installation of the transport pipe.

Public Health Effects. Effects on public health and safety are expected to be small. Pipe leakage (if any) and its location relative to drinking water sources would govern the type and seriousness of any effects.

The low toxicity of ferrocyanide at low concentration (∿4 mg/l) provides a margin of safety compared to the potential health effects that might occur if the cyanide were free.

The only likely effects on public health and safety would be those normally associated with pipeline construction.

Institutional Requirements. No requirements were identified for the actual construction of the transport line. However, several ARARs were identified relative to discharge to a POTW.

The following requirement is applicable to discharge of any waste to a POTW:

1. Pollutants that pass through the POTW without treatment, interfere with POTW operation, or contaminate POTW sludge are prohibited (40 CFR 403.5).

Additionally, the following are specific prohibitions precluding the discharge of pollutants to POTWs if:

1. Flow is obstructed, resulting in interference in the operation of the POTW.

2. The discharged material is corrosive (pH <5.0).

3. The material is discharged at a flow rate and/or concentration that will result in interference with POTW operations.

Dischargers also must comply with local POTW pretreatment requirements including POTW specific pollutants, spill prevention program requirements, and reporting and monitoring requirements (40 CFR 403.5 and local POTW regulations).

Because of the possible interpretation of these requirements, most notably the requirement that pollutants not pass through without treatment being effected, it is not expected that discharge to the local POTW would be permitted.

Economics. Based on a total pipe length of 1.5 miles to the nearest available pump station at the intersection of Holland and Colton, it is estimated that installation of a 4-inch transport line along public rights-of-way would cost $475,000. Construction of a small midway pump station would cost an additional $35,000. Purchase of land rights and costs associated with interruption of public utilities are not included. Annual costs associated with operation of the midway pump station and maintenance of the transport line are estimated at $25,000.

REMEDIAL ALTERNATIVES SUMMARY--SOURCE OPERABLE UNITS

The individual technologies evaluated in the previous technology assessment section must now be combined into the selected remedial alternatives for evaluation as total systems. The same evaluation criteria used in the previous technology-specific evaluations were used to evaluate the remedial alternatives, but at a much reduced level of detail. Tables presenting capsule summaries (present worth, source control, and groundwater migration control) follow the discussions.

ALTERNATIVE NO. 1

Technology Components

1. Excavation of the SPL pile
2. Offsite disposal
5a. RCRA capping of exposed SPL area
5b. RCRA capping of exposed portion of Area 4
6. Leak testing/monitoring
7. or 8. Leaking pipe remediation
9. Periodic groundwater monitoring

Feasibility

All components were judged to be technically feasible with relatively rapid implementation possible, limited mainly by the receiving capacity of the disposal facility. Reliability was rated very high with a minimum of maintenance requirements.

Environmental Effects

Offsite disposal and subsequent capping activities were not expected to provide for any immediate downgradient reduction in cyanide levels because contaminated subsurface soil remains in place. Excavation of contaminated subsurface to its full 145-foot depth is considered infeasible. Implementation of leaking pipe remedial actions could yield reductions in cyanide in groundwater near the Mead Works, but effects on the Little Spokane River would materialize slowly.

The overall effect on the environment of the Little Spokane River is not expected to be significant or noticeable except by chemical analysis.

With proper engineering controls, the technological components could be implemented with minimal adverse effects on the environment in the area of the Mead Works. Offsite adverse effects during transport and after disposal were judged to be a possibility.

Public Health Effects

No significant public health and safety effects were identified, positive or negative, except for the potential for exposure during transport and improper disposal offsite.

The anticipated decrease in cyanide concentration in groundwater and the Little Spokane River resulting from implementation of leaking pipe remedial measures was not viewed as significantly improving the protection of public health.

Institutional Requirements

While many ARARs were identified for this alternative, only two were judged to be potentially unattainable. Uncertainty about attainability arises from a lack of information on the possible requirements.

- Possible land disposal restrictions
- Cleanup levels required for closure

No ARARs were identified requiring implementation of this alternative.

Economics

Table 3-8 presents the costs associated with this alternative.

Table 3-8
ALTERNATIVE NO. 1 COST SUMMARY

Technology Component	Capital Cost ($000s)	Annual O&M Cost ($000s)
Excavation	--	172
Offsite Disposal	--	6,560
RCRA Cap, SPL Area	292	21
RCRA Cap, Area 4	53	4
Leak Testing	--	75
Quarterly Groundwater Monitoring	--	120
Subtotals	345	6,952
Leaking Pipe Remediation	625 to 1,298	--
ALTERNATIVE NO. 1 TOTALS	970 to 1,643	6,952

ALTERNATIVE NO. 2

Technology Components

1. Excavation of the SPL pile
3. Onsite CBC incineration
5a. RCRA capping of exposed SPL area
5b. RCRA capping of exposed portion of Area 4
6. Leak testing/monitoring
7. or 8. Leaking pipe remediation
9. Periodic groundwater monitoring

Feasibility

All components except CBC incineration were judged to be technically feasible. Implementation of CBC incineration to SPL wastes has not been demonstrated on a commercial scale, and significant technical and operational concerns exist. Reliability is considered tenuous, with large expenditures anticipated for startup, operation, and maintenance.

Environmental Effects

Incineration onsite and subsequent capping activities were not expected to provide for any immediate downgradient reductions in cyanide levels, while implementation of leaking pipe remedial measures may yield significant reductions in cyanide near the Mead Works.

Emissions from the CBC incineration were considered to be a problem area with particulate matter and hydrogen fluoride emissions a strong possibility. The ability to achieve a 99.99 percent DRE, if applied, has not been demonstrated in a commercial-scale system.

The overall effect on the environment of the Little Spokane River is not expected to be significant; only a low-level, µg/l chemical analysis for cyanide could be used as an indicator for improvement of environmental quality.

Public Health Effects

Substantial public health and safety concerns are expected to be raised relative to the siting and operation of the incinerator. Disposal of residues (ash and off-gas) also was cited as a potential public health concern.

The anticipated reduction in cyanide concentrations in groundwater and the Little Spokane River resulting from implementation of leaking pipe remedial measures was not viewed as significantly improving the protection of public health.

Institutional Requirements

While many ARARs were identified for this alternative, only two were judged to be possibly unattainable, largely because of a lack of data available relative to full-scale CBC systems and unknown closure requirements.

- The 99.99 percent DRE
- Cleanup levels required for closure

No ARARs that would require implementation of this alternative were identified.

Economics

Table 3-9 presents the capital and O&M costs associated with this alternative.

Table 3-9
ALTERNATIVE NO. 2 COST SUMMARY

Technology Component	Capital Cost ($000s)	Annual O&M Cost ($000s)
Excavation	--	172
CBC Incineration	18,125	7,148
RCRA Cap, SPL area	292	21
RCRA Cap, Area 4	53	4
Leak Testing	--	75
Periodic Groundwater Monitoring	--	120
Subtotals	18,470	7,540
Leaking Pipe Remediation	625 to 1,298	--
ALTERNATIVE NO. 2 TOTALS	19,095 to 19,768	7,540

ALTERNATIVE NO. 3

Technology Components

1. Excavation of the SPL pile
4. Onsite pyrohydrolysis
5a. RCRA capping of exposed SPL area
5b. RCRA capping of the exposed portion of Area 4
6. Leak testing/monitoring
7. or 8. Leaking pipe remediation
9. Periodic groundwater monitoring

Feasibility

The construction, operation, and maintenance of a commercial-size pyrohydrolysis unit for SPL treatment has not been demonstrated and, as such, is judged to be inherently risky. Significant problems during implementation are expected.

All other components were judged to be feasible.

Environmental Effects

Onsite pyrohydrolysis and subsequent capping of exposed and adjacent areas were not expected to yield immediate downgradient reductions in cyanide concentrations because subsurface soil would remain in place. Implementation of leaking pipe remedial actions may yield short-term reductions in cyanide beneath the Mead Works.

Operation of a full-scale pyrohydrolysis unit may cause adverse environmental effects in the event of system failure. Assuming successful operation and proper handling of the effluent streams, no significant environmental impact is anticipated, but there is insufficient precedent to support these assumptions.

Public Health Effects

Substantial public health and safety concerns are expected to be raised relative to the siting and operation of a pyrohydrolysis system. Disposal of residues (ash and off-gas) also was cited as a potential public health concern.

The anticipated reductions in downgradient cyanide concentrations because of leaking pipe remedial measures were not viewed as significantly improving the protection of public health.

Institutional Requirements

The ability of pyrohydrolysis to meet a 99.99 percent DRE has not been demonstrated with SPL wastes on a commercial scale.

The unknown requirements for cleanup levels for site closure may present an unattainable situation.

No ARARs that would require implementation of this alternative were identified.

Economics

Table 3-10 presents the costs associated with this alternative.

ALTERNATIVE NO. 4

Technology Components

5b. RCRA capping of the exposed portion of Area 4
6. Leak testing/monitoring
7. or 8. Leaking pipe remediation
9. Periodic groundwater monitoring

Feasibility

All components were judged to be technically feasible, with rapid implementation possible.

Table 3-10
ALTERNATIVE NO. 3 COST SUMMARY

Technology Component	Capital Cost ($000s)	O&M Annual Cost ($000s)
Excavation	--	172
Pyrohydrolysis	27,134	3,243
RCRA Cap, SPL Area	292	21
RCRA Cap, Area 4	53	4
Leak Testing	--	75
Periodic Groundwater Monitoring	--	120
Subtotals	27,479	3,635
Leaking Pipe Remediation	625 to 1,298	--
ALTERNATIVE NO. 3 TOTALS	28,104 to 28,777	3,635

Environmental Effects

No significant reductions in downgradient cyanide concentrations are anticipated because of implementation of Alternative No. 4 unless leaking pipe remediation actions are conducted. In this case, immediate reductions are possible if leakage is currently an active mechanism for cyanide transport.

No adverse environmental effects to be caused by implementation of these technologies are anticipated.

Public Health Effects

No significant public health effects were identified, positive or negative, relative to this alternative. The anticipated accelerated decline in downgradient cyanide concentrations was not viewed as significantly improving the protection of public health.

Institutional Requirements

No ARARs that were considered unattainable were identified. Additionally, no ARARs requiring implementation were found.

Economics

Table 3-11 presents the capital and annual O&M costs associated with this alternative.

Table 3-11
ALTERNATIVE NO. 4 COST SUMMARY

Technology Component	Capital Cost ($000s)	Annual O&M Cost ($000s)
RCRA Cap, Area 4	53	4
Leak Testing/Monitoring	--	75
Periodic Groundwater Monitoring	--	120
SPL Cap Maintenance	--	21
Subtotals	53	220
Leaking Pipe Remediation	624 to 1,298	--
ALTERNATIVE NO. 4 TOTALS	677 to 1,351	220

ALTERNATIVE NO. 5

Technology Components

6. Leak testing/monitoring
7. or 8. Leaking pipe remediation
9. Periodic groundwater monitoring

Feasibility

All components were judged to be technically feasible, with rapid implementation possible.

Environmental Effects

No significant effects, positive or negative, are anticipated by implementation of this alternative with the exception of leaking pipe remedial actions, which may produce immediate reductions in downgradient cyanide concentrations.

Public Health Effects

No significant public health effects were identified, positive or negative, relative to this alternative. The anticipated accelerated decline in downgradient cyanide concentrations was not viewed as significantly improving the protection of public health.

Institutional Requirements

No ARARs that were considered unattainable were identified. Additionally, no ARARs requiring implementation were found.

Economics

Table 3-12 presents the capital and annual O&M costs associated with Alternative No. 5.

Table 3-12
ALTERNATIVE NO. 5 COST SUMMARY

Technology Component	Capital Cost ($000s)	Annual O&M Cost ($000s)
Leak Testing/Monitoring	--	75
Periodic Groundwater Monitoring	--	120
SPL Cap Maintenance	--	21
Subtotals	--	216
Leaking Pipe Remediation	624 to 1,298	--
ALTERNATIVE NO. 5 TOTALS	624 to 1,298	216

REMEDIAL ALTERNATIVES SUMMARY--PLUME OPERABLE UNITS

ALTERNATIVE NO. G-1

Technology Components

1. Groundwater extraction
2. Cyanide treatment by chemical precipitation
3. Treated effluent discharge to POTW
4. Periodic groundwater monitoring

Feasibility

All components were judged to be technically feasible, with reliable performance predicted. Cyanide discharge levels of 2 to 4 ppm should be obtained.

Environmental Effects

Significant reductions in downgradient cyanide concentrations are anticipated by implementation of this alternative. However, it is not anticipated that CWA Ambient Water Quality Criteria would be obtained for cyanide (5.2 µg/l for chronic freshwater exposure).

No adverse environmental effects prohibiting implementation of this alternative were identified.

Public Health Effects

Although downgradient cyanide concentrations are expected to decline at an accelerated rate because of implementation of this alternative, no significant improvement in protection of the public health is anticipated.

No adverse public health effects expected to be caused by implementation were identified.

Institutional Requirements

Many ARARs for discharges to POTW that may impede implementation of this alternative were identified.

Economics

Table 3-13 presents the capital and annual O&M costs associated with this alternative.

Table 3-13
ALTERNATIVE NO. G-1 COST SUMMARY

Technology Component	Capital Cost ($000s)	Annual O&M Cost ($000s)
Groundwater Extraction	45	25
Chemical Treatment	2,160	1,019
Effluent Discharge to POTW	475	35
Periodic Groundwater Monitoring	--	120
ALTERNATIVE NO. 1 TOTALS	2,680	1,199

ALTERNATIVE NO. G-2

Technology Components: Periodic Groundwater Monitoring

Continuation of the current groundwater monitoring effort has been discussed in previous sections.

PRESENT WORTH ANALYSIS

Tables 3-14 and 3-15 present the capital, annual O&M, and present worth cost estimates for the source operable unit and plume operable unit alternatives, respectively.

Table 3-14
PRESENT WORTH ANALYSIS OF SOURCE OPERABLE REMEDIAL ALTERNATIVES

Alternative	Description	Cost Estimates ($000s) Capital	Cost Estimates ($000s) Annual O&M	Present Worth at 9% Discount ($000s)[a]
1	Excavation, offsite disposal, RCRA capping of exposed SPL area and Area 4, leak testing and monitoring, and periodic groundwater monitoring	345	6,952	24,599
2	Excavation, onsite CBC incineration, RCRA capping of exposed SPL area and Area 4, leak testing and monitoring, and periodic groundwater monitoring	18,470	7,450	44,629
3	Excavation, onsite pyrohydrolysis, RCRA capping of exposed SPL area and Area 4, leak testing and monitoring, and periodic groundwater monitoring	27,479	3,635	40,987
4	RCRA capping of Area 4, leak testing and monitoring, periodic groundwater monitoring	53	220	2,497
5	Leak testing and monitoring, periodic groundwater monitoring	--	216	2,400
Piping Subalternatives:	o Polyethylene slip lining	624	--	624
	o Parallel replacement	820	--	820
	o Piping relocation	1,298	--	1,298

---

[a] Present worth of annuity factor for 4 years = 3.24. Excludes cost for leaking pipe remediation in Alternatives 1 through 5. Present worth for leak testing, cap maintenance, and groundwater monitoring compoennts was treated as perpetuities, separate from other O&M components:factor = 11.11.

Table 3-15
PRESENT WORTH ANALYSIS OF PLUME OPERABLE REMEDIAL ALTERNATIVES

Alternative	Description	Cost Estimates ($000s)		Present Worth at 9% Discount ($000s)[a]
		Capital	Annual O&M	
G-1	Groundwater extraction, chemical treatment, discharge to POTW, and periodic groundwater monitoring	2,680	1,199	13,863
G-2	Periodic groundwater monitoring	--	120	1,333

---

[a] Present worth of annuity factor for 20 years = 9.129. Present worth for groundwater monitoring treated as a perpetuity, separate from other O&M components:factor = 11.11.

All source operable alternatives possess expected project lives of 4 years, while plume operable alternatives have 20-year estimated project lives.

The order-of-magnitude estimates in this report were performed at the "screening" level of accuracy. Screening cost estimates were generated during the alternative assessment process. These estimates are used to eliminate from further analysis those alternatives that have costs significantly greater than competing alternatives within each evaluation category. The absolute accuracy of screening cost estimates is not critical at the current level of evaluation. The focus here is to produce comparative estimates with relative accuracy upon which to base cost decisions among alternatives.

Screening-level costing detail is used for the purpose of screening the relative magnitude of the costs involved in implementing each alternative under consideration. This order-of-magnitude estimate normally considers major capital cost items. Operating and maintenance (O&M) costs may affect the overall cost of an alternative significantly; therefore, O&M costs were included in the screening process. Cost estimates reported throughout this report were developed only for the purpose of screening the various alternatives and not necessarily to reflect the entire cost of implementing a particular alternative. Estimates of this type show the relative magnitude of the costs for an alternative and are appropriate only for comparison between alternative measures. Any other use of these numbers is not appropriate and will be misleading.

It should be clearly understood that the order-of-magnitude cost estimates presented in this report have been prepared for guidance in project evaluation and implementation on the basis of the information available at the time of the estimate. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project schedule, the firm selected for final engineering design, and other variable factors. As a result, the final project costs will vary from the estimates presented herein. Because of these factors, funding needs must be reviewed carefully prior to making specific financial decisions or establishing final budgets.

COMPARISON OF ALTERNATIVES

Comparison matrixes that display economic, environmental, public health, and institutional evaluation results were prepared for the source operable unit alternatives (Table 3-16) and for the plume operable unit alternatives

Table 3-16
SOURCE OPERABLE UNIT REMEDIAL ALTERNATIVE SUMMARY

Alternative	Cost ($000s)		Feasibility	Environmental Effects	Public Health Effects	Institutional Requirements	Other
	Capital	Present Worth[a]					
1. Excavation, offsite disposal, RCRA capping of exposed SPL area and Area 4, leak testing and monitoring, and periodic groundwater monitoring	345	24,599	No concerns	Minimal improvement in the protection of groundwater and the Little Spokane River; possible increase in dust, contaminated runoff, infiltration during excavation	Minimal improvement in exposure protection; possible negative effect because of truck traffic and dust	Most ARARs attainable; possible cleanup-level complications	Pipe options discretionary
2. Excavation, onsite CBC incineration, RCRA capping of exposed SPL area and Area 4, leak testing and monitoring, and periodic groundwater monitoring	18,470	44,629	Not demonstrated at this scale with SPL	Minimal improvement in protection of groundwater and Little Spokane River; increased air emissions expected; possible infiltration during excavation	Minimal improvement in exposure protection; possible negative impact because of air emissions	Air pollution emission notice (APEN) required for each pollutant	Possible public resistance to incinerator siting; ash must be proved nonhazardous; pipe options discretionary
3. Excavation, onsite pyrohydrolysis, RCRA capping of exposed SPL area and Area 4, leak testing and monitoring, and periodic goundwater monitoring	27,479	40,987	Not demonstrated at this scale with SPL	Minimal improvement in protection of groundwater and the Little Spokane River; increased air emissions expected; possible infiltration during excavation	Minimal improvement in exposure protection; possible negative impact because of air emissions	Air pollution emission notice (APEN) required for each pollutant	Possible public resistance to incinerator siting; economics depend on market for recovered hydrogen fluoride; ash must be proved nonhazardous; pipe options discretionary
4. Leak testing and monitoring, periodic groundwater monitoring, and maintenance of existing SPL RCRA cap	53	2,497	No concerns	Long-term improvement in protection of groundwater and the Little Spokane River	Minimal improvement in exposure protection	No concerns	Pipe options discretionary
Subalternatives							
o Polyethylene slip lining of storm, sanitary, and potable water pipes	624	624	Service interruptions	Increased protection of groundwater and Little Spokane River	Minimal improvement in expsure protection	No concerns	Extended service interruptions
o Parallel replacement of of storm, sanitary, and potable water pipes	820	820	Possible disruption of underground utilities	Increased protection of groundwater and Little Spokane River	Minimal improvement in exposure protection	No concerns	Considerable surface restoration required
o Relocation of pressurized water, stormwater, sewer, and treatment plant lines	1,298	1,298	Possible disruption of underground utilities	Increased protection of groundwater and Little Spokane River	Minimal improvement in exposure protection	No concerns	Complete relocation of all piping may be infeasible

---

[a] Leaking pipe remediation not included in present worth summary of Alternatives 1 through 4.

(Table 3-17). These tables provide a concise summary of the way key issues were evaluated in preceding sections of Chapter 3.

Table 3-17
PLUME OPERABLE UNIT REMEDIAL ALTERNATIVE SUMMARY

Alternative	Cost ($000s)		Feasibility	Environmental Effects	Public Health Effects	Institutional Requirements	Other
	Capital	Present Worth[a]					
1. Groundwater extraction, chemical treatment, discharge to POTW, and periodic groundwater monitoring	2,680	13,863	Treatment of 2 to 4 ppm total CN possible; extraction limited to unconfined aquifer	Increased protection of groundwater and the Little Spokane River	Minimal improvement in exposure protection; short-term nuisance because of discharge line installation	Discharge to POTW may be restricted; will not attain CWA AWQC	POTW treatment of ferrocyanide ineffective
2. Periodic groundwater monitoring	--	1,333	No concerns	None	None	None	No-action alternative

---

[a] Present worth of annuity factor for 20 years = 8.514.

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21 CFR 72.490

Appendix A

SITE CHARACTERIZATION ANALYSIS

HARTCROWSER

Earth and Environmental Technologies

Site Characterization Analysis
KACC - Mead Plant
Spokane County, Washington

Prepared for
Kaiser Aluminum & Chemical Corporation

December 1988
J-948-05

1910 Fairview Avenue East Seattle, Washington 98102-3699 206.324.9530

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WELL AND BORING DATA

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SELECTED HYDROLOGIC DATA

J-948-05

SITE CHARACTERIZATION ANALYSIS
KAISER ALUMINUM & CHEMICAL CORPORATION
MEAD PLANT
SPOKANE COUNTY, WASHINGTON

1.0 INTRODUCTION

This report presents the results of our site characterization analysis at the Kaiser Aluminum & Chemical Corporation's Mead Plant (KACC-Mead), located north of Spokane, Washington (Figure 1). In August of 1978 cyanide was detected in several private wells located to the northwest of the plant (Robinson and Noble, 1978, 1979b). The suspected source of the cyanide was potlining waste material generated during aluminum reduction processes.

The purpose of our work was to complete a comprehensive survey, review, and analysis of available site information so that the need for, and type of, additional remedial action can be assessed. The primary issue associated with the site is the contamination of groundwater, so much of our report is devoted to the characterization of the hydrogeology and water quality conditions beneath and in the vicinity of the site. Other information is also presented.

We prepared this report using existing available data through mid-1987 including data obtained by KACC-Mead as part of their ongoing water quality monitoring program. Data collected during later periods are summarized in biennial monitoring reports. Sources of information included:

Hart Crowser, Inc.;
KACC-Mead;
Washington State Department of Ecology;
Spokane County Department of Health;
Robinson & Noble, Inc.;

United States Geological Survey; and
Other published information.

A list of references is contained at the end of this report. Selected data used in this report are contained in the Appendices.

This report has been prepared for the exclusive use of Kaiser Aluminum & Chemical Corporation and their consultant, CH2M Hill, for specific application to the project area and purpose using generally accepted professional practice for the nature of the work completed. No other warranty, express or implied, is made.

1.1 SITE DESCRIPTION

The Mead plant lies within Section 16, Township 26 North, Range 43 East about seven (7) miles from downtown Spokane and one (1) mile southwest of Mead in Spokane County, Washington (Figure 1). The Little Spokane River is situated 2.5 miles northwest of this 240-acre plant.

Potlining and other waste materials have been handled on 25 to 30 acres located within the northwest portion of the plant. In this area the major site features (Figure 2) include:

- an asphalt covered pile of waste potlining materials;
- a rubble pile containing metal, brick, wood, and some potlining material;
- a butt tailings pile;
- a sludge bed where wet scrubber and other effluent were deposited;
- an abandoned settling basin (Tharp Lake);
- an abandoned temporary potlining storage area;
- an abandoned holding pond which received runoff from the temporary potlining storage area;

- potlining storage buildings;
- sewage treatment plant; and
- several asphalt paved areas (areas 2, 3, and 4).

1.2 PROJECT HISTORY AND STUDY AREA INVESTIGATIONS

After the cyanide was detected in 1978, an assessment program was implemented to define:

- The specific source and transport mechanisms of cyanide and other constituents (such as fluoride) to the underlying aquifer;
- Water quality impacts; and
- Appropriate remedial actions.

The assessments were conducted by:

- Robinson and Noble, Inc., (1977 through 1979) completed the initial work. They drilled and installed nine (9) monitoring wells (TH-1 through TH-8 and TH-3A), conducted groundwater sampling of both the newly installed monitoring wells and downgradient wells/springs, and supervised the installation of a replacement well (Pope Well-8G3).

- Engineering-Science, Inc., and Hart Crowser, Inc., (1979 through 1981) were retained to complete additional assessments. Engineering-Science completed a survey of the site while Hart Crowser compiled available data to complete a hydrogeologic assessment including the results of a well inventory completed by the Spokane Health Department in 1978. Twenty-eight (28) additional wells were installed (ES-1 through ES-8 by Engineering-Science and ES-9, ES-10, and HC-1 to HC-18 by Hart Crowser). Analysis of soil samples for cyanide, fluoride, and moisture content and pumping tests in wells ES-9 and ES-10 were also completed.

- Hart Crowser, Inc., (1981 to present) has been assisting KACC-Mead in collecting and analyzing hydrogeologic and other data. This on-going work includes preparing semi-annual monitoring reports and assessing the need for additional remedial action. A five (5) year summary report (1981 to January 1987) was prepared in May 1987 (Hart Crowser, 1987).

- Hart Crowser, Inc., (1983) assessed the potential for uncovered potlining waste to contaminate groundwater at the Mead plant.

- Dr. Rolf Hartung (1980) completed an environmental assessment of the Little Spokane River.

- CH2M Hill (1981) completed a study of methods to treat cyanide in groundwater at the Mead Plant.

- CH2M Hill (1982) completed a survey of the piping systems beneath the plant to identify leaking pipes.

- CH2M Hill (1985) completed an assessment of alternatives to control infiltration of water into site soils.

- KACC-Mead (1978 to present) has provided on-going monitoring and laboratory support. Kaiser staff have been responsible for the majority of the water sampling and chemical analysis that has been completed as part of this project. They routinely analyze water samples for total and free cyanide, and fluoride. They also analyzed soil samples for cyanide and fluoride that were collected as part of the drilling activities.

- Other Reports have been prepared as part of geologic and water quality investigation of the Spokane Aquifer system. Several of the more important reports include those by Crosby et al (1971a, b, c), Bolke and Vaccaro (1979), and published work conducted as part of the "208" Water Quality Management Program (Spokane County, 1978, 1979; Todd, 1975).

1.3 PAST REMEDIAL ACTIONS

The results of the technical assessments provided the basis for KACC-Mead to implement a series of remedial actions:

- 1978: Alternative water supplies were provided for users of wells which had been adversely affected by cyanide migration to and within the underlying aquifer.

- Spent potlining handling practices were changed to minimize the possibility of leachate generation from plant activities or by exposure to precipitation.

  - August 1978: Pot soaking operations and effluent discharge to the sludge bed ceased.
  - January 1979: Exposed potlining was graded and covered with plastic.
  - April 1979: Exposed potlining waste was covered with asphalt.
  - September 1981: An unlined and leaking settling basin (Tharp Lake) was drained and abandoned.

- Selected areas were graded and covered with asphalt to reduce the possibility of infiltration of concentrated volumes of snowmelt or stormwater runoff. Drainage systems were installed to move surface water out of the spent potlining handling area.

  - April 1986: Area 2 was paved with asphalt.
  - April 1986: Pot cleaning slab was closed.
  - October 1986: Area 3 was paved.
  - November 1987: Area 4 was paved.

- Stored spent potlining was moved out of the temporary storage area into storage buildings.

  - 1981: Potlining was moved into the first storage building.
  - 1984: A second building was constructed and put into operation.

- Several pipe leaks repaired.
  - June 1983
  - December 1987

- An updated field well inventory was completed by KACC-Mead during 1986. This inventory supplements the inventory of wells completed by the Spokane County Health Department in 1978.

KACC-Mead is supporting an ongoing monitoring program to assess how the remedial actions are affecting groundwater quality and to provide the basis to implement other actions, as required. This monitoring program includes the sampling of selected wells, springs, and surface waters located on and downgradient of the plant site and the routine chemical analysis of the water samples for total and free cyanide, and fluoride by KACC-Mead.

Ongoing technical analyses of the data are being conducted by Hart Crowser, Inc. These ongoing analyses are documented in biannual monitoring summary reports which have been prepared since December of 1982. The ongoing monitoring efforts indicate that the remedial actions implemented by KACC-Mead have substantially improved the groundwater quality beneath and downgradient of the plant site.

2.0 PHYSICAL CHARACTERISTICS OF STUDY AREA

2.1 SURFACE FEATURES

The plant is located within a glacial outwash valley (Figure 3). Land surface elevations slope gently downward in a northerly direction from slightly over 2,050 feet at the Spokane City line to about 1,920 feet at the plant, to less than 1,600 feet in the Little Spokane River Valley. The topography rises to over 2,300 feet two (2) miles west and one (1) mile east of the plant.

2.2 METEOROLOGY

Average annual precipitation as measured at the Spokane Airport and in Spokane is 16.4 and 17.3 inches, respectively (Crosby, 1971c), 70 percent of which generally falls between the first of October and the end of April (Spokane County, 1979). Figure 4 shows a histogram of annual precipitation at the Spokane Airport for the period 1941 to 1987.

Summer temperatures at the airport range between 80 to 90 degrees F during the day with night time lows of 45 to 60 degrees F. Winter highs range from 25 to 45 degrees F with lows of 15 to 25 degrees F (Spokane County, 1979).

2.3 SURFACE WATER HYDROLOGY

The Little Spokane River is situated about 2.5 miles northwest of the plant. The river flows in a southwesterly direction toward Dartford and then flows in a westerly direction toward Long Lake (Figure 1). Flows in the river are measured by a USGS gaging station located at Dartford (Figure 1). River flows range between 100 and 300 cubic feet per second (cfs) during relatively low precipitation periods (summer and fall) and peak between 600 and 900 cfs during high runoff periods (later winter and early spring). Substantial groundwater discharge into the river occurs downstream of the gaging station which is discussed in a following section.

A second surface water drainage course, Deadman Creek, is located to the northeast of the plant (Figure 3). This creek flows into the Little Spokane River about 1-1/2 miles to the northeast of the USGS gaging station near Dartford. Deadman Creek is called Peone Creek in the monitoring records of KACC-Mead.

KACC-Mead stormwater and non-contact cooling water flows into Deadman (Peone) Creek via a buried discharge line which extends to the north and northeast of the plant (Figure 3). Before discharge to the creek, plant discharge water flows through a settling basin.

2.4 HYDROGEOLOGY

Figure 5 shows wells and springs located in the vicinity of the Mead facility. Further information is tabulated in Appendix B. Selected well and spring locations are shown on other figures to support the following discussion.

2.4.1 Well Numbering System

Well and sampling locations shown on the figures in our report have been numbered in three (3) ways. Water supply wells and springs are designated using the United States Geological Survey numbering system which designates locations by Township, Range, and Section, and location within the section by an assigned letter and, if more than one well or spring, an additional number. Where the USGS system is used the Township and Range are omitted because the location is referenced to a figure.

Monitoring wells or borings drilled as part of this project are identified by letters (TH-, ES-, HC-, or D-) and then by sequential number. TH- and

ES-designated wells/borings were drilled under contract to Robinson and Noble, Inc., and Engineering-Science, Inc., respectively. HC- and D-series wells or borings were drilled under contract to Hart Crowser, Inc.

2.4.2 Regional Hydrogeologic Setting

The KACC-Mead Plant lies above the Hillyard Trough portion (Figure 3) of the Spokane-Rathdrum Prairie Aquifer which roughly extends from Pend Oreille Lake in Idaho to Long Lake, Washington (Bolke and Vaccaro, 1979). This aquifer is the major source of water to the area and has been designated by the Environmental Protection Agency (EPA) as a "sole source" water supply (Spokane County, 1979).

The aquifer materials consist of glaciofluvial sands and gravels with cobbles, boulders, and scattered clay and silt lenses which were deposited in a pre-existing bedrock valley (Cline, 1969; Drost and Seitz, 1978). In the Hillyard Trough the materials are generally finer (as compared to those to the east) with the aquifer being comprised predominantly of stratified sand with some gravel, silt, and boulders.

The aquifer extends westward from the state line to the east side of the City of Spokane and then turns northerly toward Long Lake. Five Mile Prairie splits the aquifer into two (2) portions just northwest of Spokane (Figure 3). The aquifer boundaries in the Hillyard Trough are comprised of flow basalts or granitic intrusives except for the area from approximately one half mile south of Mead to the southeastern part of Section 4 where the boundary is composed of glaciolacustrine deposits which lie beneath Peone Prairie.

Groundwater flows generally parallel to the trend of the filled-in valley. In 1978 flow volumes were estimated to be 970 and 350 cubic feet per second (cfs) at the state line and Hillyard Trough, respectively. However, later estimates are about one half these values (Spokane County, 1979).

Figure 6 shows two (2) schematic geologic cross sections showing the general subsurface conditions and approximate water table position in the Hillyard Trough. The cross section and well locations we used in the preparation of the cross sections are shown on Figure 3. The glaciofluvial materials can be divided into two (2) units which include a "low" permeability clay and silt with occasional sand and gravel zones (regional aquitard) overlain by a variable thickness of a more permeable sand and gravel with minor interbedded clays and silts (regional aquifer).

In the vicinity of the plant site and extending west to east the aquifer ranges in thickness between 80 feet at well 7P1 to 120 feet at well 16G1 located near the plant site. The depth to water is between approximately 45 and 145 feet along this profile. In a southeast to northwest direction the aquifer thins from 120 feet at the plant site (well 16G1) to 70 feet at well 8G3 to 35 feet or less between well 8G3 and the Little Spokane River. The depth to water also decreases westward from the plant from about 145 feet to the surface where groundwater is discharged by springs along the Little Spokane River.

2.5 DEMOGRAPHY AND LAND USE

The KACC-Mead Plant is located about seven (7) miles north of Spokane. Land use in the area is mixed consisting of commercial, industrial, and residential (urban to rural) (Golder, 1985).

The area immediately adjacent to the plant is zoned industrial. The closest residential neighborhoods are situated to the northwest of the plant (approximately 1,500 feet) (Figure 5).

Municipal and private wells are used to provide water in the area. Private well systems which were adversely impacted by contaminant migration from the plant were replaced by municipal supplies (except for Pope) as part of the past remedial actions implemented by Kaiser. A replacement well was drilled for Pope. These systems are located to the northwest of the plant within the general area shown for the cyanide plume (Figure 5).

3.0 PROJECT AREA HYDROGEOLOGY

We have interpreted the project area hydrogeology using data from borings and wells drilled on and downgradient of the plant site. Well locations are shown on Figures 5 and 7 while pertinent well data are summarized in Appendices A and B.

3.1 GEOLOGY

The subsurface environment in the project area can be divided into three (3) zones as shown on Figures 8, 9, and 10:

3.1.1 Unsaturated Zone

This zone extends from ground surface to the water table which lies at a depth of about 145 feet. The unsaturated zone consists of clean to silty, fine to medium, and fine to coarse SAND with occasional interbedded clayey SILT to silty CLAY layers. The finer grained SILT/CLAY layers range in thickness from less than 6 inches to several feet and at least one layer appears to be relatively continuous beneath the site.

3.1.2 Regional Aquifer

The regional aquifer extends downward from the water table (about 145 feet) to a depth of about 270 to 280 feet where relatively low permeability deposits (regional aquitard) exist based on the geologic logs of water supply wells. The top 35 feet of the aquifer is vertically stratified. Three (3) sandy to silty sandy zones terms "A", "B", and "C" separated by sandy SILT/CLAY layers are defined for discussion purposes.

- Zone A, the highest elevation zone, ranges in thickness from 5 feet at TH-6 to 21 feet at ES-10 with a typical thickness of about 10 to 15 feet. This zone is composed of silty SAND, and fine to coarse SAND. Grain size data for Zone A materials are contained in Appendix C, on Figures C-6 and C-7.

- Zone B underlies Zone A and is separated from Zone A by a sandy SILT/CLAY layer which typically ranges in thickness from 5 to 10 feet. Zone B ranges in thickness from about 20 feet at TH-6 to 5 feet at ES-10 with a typical thickness of about 15 feet. This middle zone is composed of a relatively clean, fine to coarse SAND.

- Zone C lies beneath Zone B and is separated from Zone B by a sandy CLAY layer which typically ranges in thickness from 1 to 7 feet. Zone C is composed of fine to medium SAND which grades into SAND and GRAVEL at deeper depths. The geologic logs of borings and water supply wells indicate that this zone is about 70 to 80 feet thick beneath the plant site. Grain size data for Zone C materials are presented in Appendix C, on Figure C-8.

3.1.3 Regional Aquitard

The regional aquifer is underlain by finer grained deposits of SILT and CLAY interbedded with occasional lenses and layers of sand, and sand and gravel. The top of this zone lies at a depth of about 270 to 280 feet beneath the plant site and defines the bottom of the regional aquifer.

3.2 HYDROLOGY

Water level measurements made in several wells which are screened in differing zones at the same location indicate that hydraulic head varies between zones (Figure 11). The highest head was measured within Zone A. Lower hydraulic heads were measured in Zones B and C (as compared to Zone A), with lower heads measured in Zone B as compared to Zone C. We interpret the differential heads to be caused by the low permeability

Q = KiA
Q/A = Ki
$v = Ki$
$v_s = Ki/n_e$

layers which separate the zones and by variations in hydraulic conductivity between each zone. The data indicate to us that Zone B likely has a higher hydraulic conductivity as compared to Zone A and the upper portion of Zone C.

241 – 643 ft/day
0.085 – 0.23 cm/s

We estimate the hydraulic conductivity of Zone A to range between 1,800 and 4,800 gallons per day per square foot (gpd-ft^2) based on pumping tests we conducted in wells ES-9 and ES-10 (Appendix C). Lower hydraulic conductivities (1,800 to 2,800 gpd-ft^2) were estimated at ES-10 as compared to the values we estimated at ES-9 (4,100 to 4,800 gpd-ft^2).

Water level measurements made by us and KACC-Mead personnel in wells which are screened within Zone A beneath the plant indicate that the slope of the water table is to the northwest (Figures 12 and 13) which is consistent with our interpretation of the regional groundwater flow direction (Figure 3). Flow directions have not changed substantially from 1982 to the present as shown by a comparison of Figures 12 and 13 which show A-Zone groundwater contour maps for 1982 and June 1988. We estimate the hydraulic gradient to be about 0.003 based on the contour maps.

However, the June 1988 map (Figure 13) does differ from the earlier map (Figure 12). A groundwater "high" is indicated to be present in the vicinity of ES-5 which may have been caused by a pipe leak. The leak has been repaired and conditions are being monitored.

The linear advective groundwater flow velocity within the A-Zone near ES-10 ranges between 3 and 4 feet per day (ft/day). This estimate was made by us using a modified form of Darcy's Law, v=Ki/u, where:

v = linear advective groundwater flow velocity,
K = hydraulic conductivity (2,300 gpd-ft^2), = 308 ft/d = 0.11 cm/s
i = hydraulic gradient (0.003), and
u = soil porosity (0.25). ne? or n?

However, lower cyanide flow velocities than those estimated using hydraulic data are likely present in Zone A. Since 1981 aquifer water quality monitoring indicates that cyanide has occasionally increased and then declined because of recharge events such as pipe leaks. The timing of the cyanide concentrations peaks in wells along the flow path indicate cyanide flow velocities on the order of 1 to 2 feet per day.

Higher groundwater flow velocities exist in other portions of the aquifer (as compared to Zone A beneath the plant) where hydraulic conductivities and gradients are higher. Estimated flow velocities for the regional aquifer northwest of the plant developed by us (Hart Crowser, 1980) and the USGS and Army Corps of Engineers (Spokane County, 1979) are greater than 40 feet per day.

Groundwater flow conditions within the Hillyard Trough portion of the Spokane Aquifer are relatively constant over a year. From June 1979 to June 1980 (Figure 11) water levels in Zones A, B, and C fluctuated in well TH-6 about 0.5 to 1.7 feet. Precipitation data for this period are also on Figure 11. This range of water level fluctuation compares with a seasonal and yearly change of less than 5 feet for Well 26/43-19A (Figure 3), measured since 1932 (Drost and Sietz, 1978).

3.3 RECHARGE AND DISCHARGE

The major recharge to the aquifer occurs to the east of Spokane where runoff from precipitation, falling on mountainous areas, infiltrates into the aquifer (Drost and Sietz, 1978). In the Hillyard Trough the USGS (Drost and Sietz, 1978) estimated that 23 cfs flows from Peone Prairie and Orchard Prairie located on the east side of the trough in addition to the flow from the southeast. Little, if any, recharge occurs locally under natural conditions.

Discharge of groundwater migrating through the trough occurs from subsurface and spring flow into the Little Spokane River (Figure 3). The discharge flow has been estimated by the USGS at 310 cfs (Drost and Sietz, 1978) but actually may be about half this estimate (Spokane County, 1979).

Previous studies have arrived at conflicting conclusions concerning local recharge conditions in the Spokane area. Crosby (1971 a, b, c) stated that recharge from precipitation could not be demonstrated. Crosby's conclusion was based on a 6-year study which included laboratory and infiltration testing, and geophysical logging. He found that soils in the Spokane valley are in a state of high moisture deficiency and that maximum moisture penetration from snowmelt is less than 25 feet.

Todd (1975) concluded, however, that recharge could occur from precipitation but would be limited to late winter in average and above average precipitation years. Todd's conclusion is supported by analyses completed by Robinson & Noble (1979b) during their early work to assess the causes of cyanide migration to the aquifer beneath the KACC-Mead plant. If their conclusions are representative of site conditions then little recharge would have occurred in 22 of the past 46 years as shown on Figure 4.

Robinson & Noble (1979b) analyzed precipitation data for the years 1941 to 1970 (Appendix C) using the Thornthwaite method. They analyzed data for the driest (1976) and the wettest (1948) years as well as the average over this 29-year period. Their work indicates that water surpluses (water available for recharge and/or runoff) were present during average and wettest precipitation conditions:

	Precipitation Rate in Inches	Water Surplus in Inches
Driest Year (1976)	11.22	0
29-Year Average	17.42	3.8
Wettest Year (1948)	26.07	10.31

Water surpluses were calculated to be present during the late winter and early spring (January through March) except in wet years where surpluses may be present in April and May. The possibility that some of the estimated water surpluses recharge the aquifer is reduced because of frost (frozen ground) which will promote runoff. It also should be noted that the Thornthwaite method overestimates water surpluses as compared to other methods (Dunn and Leopold, 1978).

Hart Crowser (1983) analyzed the unsaturated zone flow characteristics beneath the plant. The purpose of our work was to estimate the amount of natural recharge by assessing the soil moisture conditions beneath the plant. Soil moisture retention curves were prepared by laboratory testing (porous plate) to estimate the hydraulic conductivities of site soils at various moisture contents using the procedures of Jackson (1972). Our work indicates that the amount of water migrating to the aquifer within the deeper soil column is small, on the order of less than 0.1 inches per year.

We conclude after review of the work associated with assessing natural recharge that local precipitation likely contributes a small amount of recharge to the aquifer over the long-term. However, groundwater monitoring data and other hydrologic and water quality analyses indicate that cyanide transport to the aquifer was caused by recharge from plant activities rather than by evenly distributed infiltration of precipitation. This finding will be further discussed in a later report section.

3.4 WATER SUPPLIES

The KACC-Mead plant is located over the Spokane Aquifer which is the primary source of municipal, industrial, and domestic water supply for the region. When cyanide was first discovered in the aquifer the Spokane County Health Department completed a well inventory (in 1978) within the northern portion of the Hillyard Trough. More recently (summer 1986) KACC-Mead personnel conducted an inventory update.

The results of the 1978 inventory are documented in a Hart Crowser report (Hart Crowser, 1980). Figures 5 and 7 show the locations of wells and springs that were identified in the 1986 inventory. Data on the wells and springs in the Mead sampling area are summarized in Appendix B.

The majority of wells tap the upper portions of the Spokane Aquifer and are used for domestic purposes. Several wells are screened in relatively permeable portions of the regional aquitard such as Well 8G3 (Pope replacement well) and Well 6H1 (Anderson Well) (Figure 3).

Several industrial wells exist on the KACC-Mead plant (Figure 2) which provide water for cooling and other purposes. At one time six (6) wells were used but four (4) are currently active:

- Well No. 1 (16D1)
- Well No. 2 (16D2)
- Well No. 5 (16F2)
- Well No. 6 (16F3)

Combined pumpage from the wells varies from about 2.5 to 3.5 million gallons per day depending on the season. Summer pumping rates are higher as compared to winter pumping rates. These wells are screened in the lower portions of Spokane Aquifer at depths of between 200 and 290 feet.

Several municipal wells exist west and northwest of the plant (Figure 5):

- Whitworth Well No. 3A (7K1)
- Whitworth Well No. 3 (7P1)
- Whitworth Well No. 3B (7G2)
- Spokane Suburban Well 3-5 (8B4) - formerly Washington Water Power 3-5
- Spokane Suburban Well 3-7 (4P1) - formerly Mead School District Well
- Spokane Suburban Well 3-BP (32J and 32J2)

These wells are also screened in the lower portions of the Spokane Aquifer and are pumped at varying rates of several hundred gallons per minute (gpm) up to a thousand or so gpm.

The potential for wells to be adversely affected by the plume is dependent upon the well's downgradient position, both horizontally and vertically, relative to the position of the plume. The Pope replacement well (well 8G3) is located within the areal extent of the plume (Figure 14) but is screened in a zone which lies beneath the bottom of the plume (Figure 24). Water quality analyses of samples obtained from this well confirm that plume migration has not adversely effected this well.

An analysis of the "capture width boundary" for the Whitworth municipal well (7G2) was made (Hart Crowser, 1980) to assess whether pumpage from this well would cause cyanide to migrate to the well. Water within the capture boundary flows to the well while water flowing outside the boundary will not be pumped by the well. The estimated capture boundary is shown on Figure 14 which indicates that pumpage from the well should not cause cyanide to migrate into the well. Monitoring of water quality since 1980 has not detected cyanide or other plume constituents in this well.

Low concentrations of <u>total</u> cyanide have been detected in Spokane Suburban Water District well (8B4). These concentrations have been in the range of 1 to 5 ppb or less (not detected) total cyanide since mid-1985 (Figure 48 and Hart Crowser, 1987). This is the closest municipal well to the cyanide plume. The variability in the data is likely the result of how and when the well has been sampled. The district is currently assessing the feasibility of increasing pumping from this well. Preliminary data from this testing (November 1988) indicate that total cyanide concentrations of 3 ppb were measured in samples obtained during the test. Cyanide concentrations did not change during pumping (about 800 gpm) for 22 hours. Hart Crowser (under contract to KACC-Mead) is participating in work to assess whether increased pumping will cause cyanide concentrations to increase in pumped water from this well.

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 POSSIBLE SOURCES

The KACC-Mead aluminum reduction plant started operations in the early 1940s. Prior to this time the site was undeveloped.

Spent potliner is generated during aluminum reduction operations when the reduction cell cathode (pot) fails. The pot shells are reused after the cathode and insulating material are removed. Spent potlining has typically been managed within the northwest portion of the plant.

When water contacts spent potlining a leachate is formed which consists of cyanide, fluoride, and other constituents. In December 1978 EPA Region X analyzed a leachate sample, the results of which are presented in a letter dated March 12, 1979, from EPA to the Spokane Health District. These results are tabulated in Table 1. Various metals were detected as were cyanide (0.13 mg/L) and fluoride (2,720 mg/L). We consider the reported concentration of cyanide to be low (if a total cyanide value) based on other available data. KACC-Mead analyses of total cyanide concentrations of potlining leachate are on the order of 700 to 1,000 ppm.

4.1.1 Waste Handling History

Aerial photographs were obtained to assess the specific areas within the plant where potlining wastes were handled. Photographs for various years were evaluated:

- August 3, 1938
- October 11, 1946
- August 30, 1950
- September 1956
- July 10, 1957
- July 14, 1959
- April 18, 1962
- May 8, 1967
- July 5, 1972
- July 21, 1978
- May 20, 1979
- May 27, 1983

We prepared Figures 15 and 16 to illustrate where potlining was handled on the plant.

- <u>1946 to 1959</u>: Figure 15 summarizes our assessment for the years 1946 to 1959. The dominant features we observed in the photographs for this period included deposits of both spent potlining and rubble. Initial deposition occurred within the northern portion of the area (after 1946) and generally spread southward. In the 1946 photograph some stockpiled material is evident in a pile northwest of the baking furnace building.

  Spent potlining appears to be present in varying thicknesses. Within the north part of the area the thicknesses appear to be relatively thin. Interviews with plant employees indicated that spent potlining in this area were deposited in a single layer by end-dumping from trucks. Thicker deposits were present in the southern part of this area. Several outlying piles were also observed adjacent to the railroad tracks. We understand that a portion of the spent potlining generated at this time were shipped off-site.

  Other plant wastes, such as wood and brick, were deposited immediately west of the spent potlining material. These materials form the base of the existing rubble pile.

- <u>1962 to 1972</u>: Figure 16 summarizes our assessment for the years 1962 to 1972. The same general features were present in the photographs for this period as for the 1946 to 1959 photographs. Spent potlining was present in both "thin" and "thick" layers and rubble deposits were present in the adjacent area. The area of the rubble pile had expanded to the west and northeast. The outlying piles of spent potlining were no longer present in the photographs after 1962.

  The photographs support our interviews with plant employees who indicated to us that potlining was generally managed within the northwest portion of the plant. We did not observe similar piles of other materials in other portions of the plant.

- 1978 to present: Spent potlining management practices were modified by KACC-Mead after cyanide was discovered in the aquifer. The locations of features described below are presented on Figure 2.

  - Pot soaking operations and effluent discharge to the wet scrubber/sewage disposal pond were discontinued in August 1978. Prior to August 1978 the pots were soaked to remove the spent potlining. This activity generated a liquid containing cyanide and other constituents which was discharged to the ground or to the sludge bed (from 1964 to 1978). Pot soaking and lining removal occurred on a concrete slab located on the southeast side of the existing asphalt covered pile.

  - Exposed spent potlining was graded to form a single pile and was covered with asphalt to minimize contact with precipitation. Precipitation falling on the pile is collected and discharged through the plant stormwater disposal system. These activities were completed in August 1979.

  - A temporary potlining handling area was constructed which consisted of asphalt paving with an underdrain system. Water collected by the underdrains was directed to a plastic-lined holding pond. Potlining was stored in this area from 1978 to 1981. The plastic-lined pond has been removed.

  - Two (2) potlining storage buildings were constructed. The first building was constructed in 1981, while the second building was constructed in 1984. Potlining which was stored on the temporary handling area was moved into the first storage building in 1981.

- Spent potlining materials are currently removed from the failed pots by mechanical means in a covered area (Building 32H) and are stored in the buildings.

4.1.2 Extent of Existing Spent Potlining Materials

Spent potlining materials remain on the plant in several areas outside the operating storage buildings (Figures 17, 18, and 19):

4.1.2.1 Asphalt Covered Pile

The greatest volume of spent potlining is present in the asphalt covered pile. KACC-Mead estimated that the covered pile has the following characteristics (Robinson & Noble, 1979b):

o Volume	94,700 cubic yards
o Weight	128,000 tons
o Average Cyanide Content	0.2 percent

Spent potlining beneath the asphalt cover was not a direct source of aquifer contamination, even before covering with asphalt. Recharge analyses indicate that precipitation is not high enough to cause the measured cyanide concentrations in the underlying aquifer. This finding is supported by monitoring data collected after the pile was covered with asphalt in 1979. After covering, little change in aquifer water quality conditions was detected and another "source" was identified as discussed later in this report.

4.1.2.2 Rubble Pile

Review of historical aerial photographs, interviews, and field sampling activities completed by Hart Crowser discovered that spent potlining is present beneath the eastern portion of the rubble pile. Some isolated potlining deposits are also present within other portions of the pile.

Spent potlining was encountered during drilling of borings D-1 to D-3 (Figure 19). Thicknesses ranged from 3 feet in D-1 to 12 feet in D-3.

The presence of potlining material beneath the rubble pile is consistent with our analysis of the available aerial photographs. This analysis indicates that the rubble pile expanded eastward into the potlining handling area.

Spent potlining beneath the rubble pile is not considered to be a source of cyanide to the underlying aquifer. This finding is based on several lines of evidence:

- The source strength of the spent potlining material in the rubble pile is, for the most part, much lower than for the potlining beneath the asphalt covered pile. For the mass of spent potlining lying at the bottom of the rubble pile the average cyanide concentration is 30 to 50 times lower than that present in the asphalt covered pile (about 190 ug/g as compared to 6,350 ug/g).

- Cyanide migration into soil immediately beneath the spent potlining in the rubble pile is substantially less than that measured beneath the asphalt covered pile or beneath Area 2. For example, cyanide concentrations above 100 ug/g were detected only within a depth of 5 feet below potlining beneath the rubble pile (Figure 19) as compared with depths of more than 40 to 80 feet beneath the asphalt covered pile (ES-1 and ES-2/Figures A-31/A-32) and Area 2 (HC-18/Figure A-30). This potlining is the oldest potlining on the plant which indicates that if substantial water were contacting the waste, the deepest migration should have occurred. The covering of the potlining with rubble has apparently reduced water contact with the potlining and limited downward migration.

- Unsaturated zone analyses (Hart Crowser, 1983) indicate that deep soils beneath the area are very dry and have an unsaturated hydraulic conductivity of 10-8 to 10-9 cm/sec. The distribution of moisture contents indicates that downward water migration occurs but coupled with the low unsaturated hydraulic conductivity is less than 0.1 inch per year. This work is supported by the work of Crosby et al (1968, 1971a, 1971b) who concluded that groundwater recharge within the Spokane Valley is very unlikely.

- While recharge estimates using the Thornthwaite method indicate that some recharge may occur during average and above average precipitation years, the method is limited especially in deep aquifer conditions. It also should be noted that this method may overestimate recharge by 100 percent or more as compared to other methods which use similar data (Dunn and Leopold, 1978).

- Potlining weathers to an amorphous fine-grained material. This condition coupled with the apparent slope of the potlining (Figure 19) will shed water which percolates through the rubble pile to the sides of the pile further reducing the potential for contact with potlining.

4.1.2.3 Spent Potlining between Asphalt Covered Pile and Sludge Bed

During preparations for paving of the area between the sludge bed and asphalt covered pile, spent potlining was discovered. Samples obtained during the drilling of boring HC-18 (Hart Crowser, 1983) and excavation of several test pits revealed spent potlining thicknesses on the order of five (5) to six (6) feet.

Water quality monitoring indicates that this spent potlining was a source of cyanide to the aquifer because of its location in a low area where stormwater runoff and snowmelt collected and infiltrated in substantial quantities. This area has been paved (Area 2 on Figure 2) and no longer is a source of cyanide to the underlying aquifer.

4.1.3 Soils and Vadose Zone

Soil samples collected during drilling on the plant were analyzed by the KACC-Mead laboratory for cyanide and fluoride content. The results of their analyses are presented on the boring logs in Appendix A.

The highest soil cyanide and fluoride concentrations were measured in soil samples obtained within the potlining handling area. Soil cyanide concentrations in samples obtained above a depth of about fifty (50) feet are generally shown on Figure 17. Concentrations greater than 100 ug/g were measured in borings ES-1, ES-2, and ES-4 (asphalt covered pile), D-3 (rubble pile), and HC-18 (between asphalt covered pile and the sludge bed). Concentrations declined to between 10 and 100 ug/g in borings completed relatively close to the existing potlining materials and to less than 10 ug/g cyanide in more outlying borings. Samples obtained immediately beneath portions of the potlining in the rubble pile (D-1 and D-2) were also found to be less than 10 ug/g.

Cyanide concentrations in soil below a depth of about 50 feet are generally less than 100 ug/g and the highest concentrations are within the historic potlining handling area (Figure 18).

Soil cyanide concentrations beneath potlining material generally decline with depth. For example, samples obtained from D-3 declined in cyanide concentration from over 945 ug/g to less than 10 ug/g over a depth interval of less than 10 feet (Figure 19). Declines in cyanide concentration with depth were also measured in samples from borings such as HC-18 (Appendix A) and ES-1 (Figure 20).

Soil beneath the spent potlining handling area represents the primary source of cyanide contamination of the underlying aquifer because they are (or were) within the migration pathway of plant induced recharge sources of sufficient volume to transport cyanide to the water table. These water sources include infiltration from a settling basin (now abandoned), pipe leakage, and infiltration of ponded runoff or snowmelt which are discussed in Section 5 of our report.

4.1.4 Sludge Bed: Construction, Operation, and Results of Sampling

The sludge bed is located to the east of the area where spent potlining was handled (Figure 2). Twelve (12) to twenty-seven (27) feet of sludge are reported to be present in the area. Sludge sampling indicates that the sludge bed contains cyanide although this possible source is not considered to be contributing significant quantities of cyanide to the underlying aquifer (see section 5.2).

Construction: The present day sludge bed was constructed in four steps (Kaiser memo, September 27, 1978) (Figure 21):

- 1952: A four(4)-foot-deep bed was constructed level with an existing road.
- 1960: The dike on the original bed was heightened an additional four (4) feet.
- 1964: A new bed was constructed northeast of the original bed.
- 1967: Modifications were made which resulted in the present day sludge bed configuration.

Operation: During portions of its operating history pot soaking liquor was introduced into the sludge bed. This is likely the source of the cyanide found in the sludge samples (Kaiser memo, January 8, 1979):

- 1964 to 1974: Pot soaking liquor was pumped into the wet scrubber water treatment system which discharged to the sludge bed.

- 1974 to 1978: In September 1974, the wet scrubber water treatment system was abandoned but pot soaking liquor was occasionally pumped into the southwest corner of the sludge bed. This practice was stopped in 1978.

- 1971 to 1978: Waste water from the sewage treatment plant was discharged to the southwest corner of the sludge bed.

Results of Sludge Bed Sampling: Thirty (30) sludge bed samples were obtained from the approximate locations shown on Figure 22. The source of this information are two (2) Kaiser Interoffice Memoranda dated October 24, 1978 and January 8, 1979.

Most of the samples were analyzed for water soluble and total cyanide. The results are summarized in Table 2.

Cyanide was detected at each of the sampled locations. The highest concentrations were detected in the vicinity of the pot soaking and sewage inlets near the southwest corner of the sludge bed. In this area average total soil cyanide concentrations ranged between about 190 and 380 parts per million (ppm) as compared to less than 100 ppm at the other sampling locations (Figure 22).

HC-17 was installed during July of 1982. Soil samples were obtained and analyzed for cyanide and fluoride to a depth of about 160 feet (Appendix A). About seven (7) feet of sludge was encountered during drilling. Analysis of soil samples obtained below the sludge (starting at about ten (10) feet) did not detect cyanide above the detection limit of one (1) microgram per gram.

4.2 AQUIFER WATER QUALITY: AFFECTED BY CYANIDE AND OTHER CONSTITUENTS

In 1978 cyanide was discovered in the aquifer beneath the KACC-Mead plant. Other monitoring parameters including fluoride, nitrate, iron, and specific conductance were measured to be at concentrations substantially above background (Robinson & Noble, 1979b).

The highest cyanide concentrations of groundwater samples have been obtained from well TH-8 (located on Figures 5 and 7). A sample collected in August 1979 (Mead number E717) displayed a cyanide concentration of 180 ppm (180,000 parts per billion (ppb)). Samples from well TH-8 have always displayed the highest cyanide concentrations so we assume that this well produces groundwater samples which have been most affected by leachate migration to the aquifer from the plant.

The groundwater sample from TH-8 was also analyzed for other constituents by Water Management Associates, Inc. (Tacoma, WA) the results of which are presented in Table 3. Total arsenic, iron, manganese, mercury, selenium, fluoride, and nitrate (as N) concentrations exceeded drinking water standards.

Groundwater samples were obtained from wells TH-8 and ES-10 in August 1981 for analysis of polynuclear aromatic hydrocarbons (PNAs) using EPA method 610. The samples were submitted to AM Test Inc. in Seattle. No PNAs were detected in these samples (detection limit was reported to be 5 micrograms per liter).

A recent sampling (July 1986) by a contractor working for the Washington State Department of Ecology (Golder Associates, Inc., 1988) sampled three (3) wells on the KACC-Mead plant site (this work was being completed as part of the Market Street site assessments.) Analyses for volatile compounds typical of petroleum fuels (such as benzene, toluene, ethylbenzene, and xylenes) were analyzed for, and were not detected in the samples.

Six (6) wells and one (1) spring downgradient of the plant were sampled before 1980. Analyses for total metals and selected other constituents were made (Table 3). The samples met drinking water standards except for iron (Speaks, Spokane County Road Shop, and Chevillet wells) and iron and arsenic in the Van Gelder Spring (discussed below). The iron concentrations in the wells and spring do not represent a potential health risk. The concentrations exceed a secondary drinking water standard which was set for aesthetics purposes.

The predominant constituents of the sample from TH-8 were cyanide (180 ppm), fluoride (104 ppm), nitrate (591 ppm), iron (79.6 ppm), and sodium (2,160 ppm). These constituents are present in or could be produced (nitrite/ammonia to nitrate) by potlining leachate.

Both total and free cyanide are routinely analyzed by KACC-Mead as part of their monitoring program. Robinson and Noble (1979a) report that about 10 percent of the total cyanide concentration is free cyanide. Actual percentages vary from this generalization.

Table 7 presents selected data for total and free cyanide. While several of the percentages exceed 10 percent the average free cyanide concentration for the data set shown is actually closer to 5 percent. Lower percentages of free cyanide are present for those samples having the highest total cyanide concentration. For example, well TH-8 has a free cyanide concentration of 390 ppb which is less than 1 percent of the total cyanide concentration of about 100,800 ppb.

Total cyanide concentration is considered by us to be a reliable indicator of leachate migration within the aquifer beneath the site based on the following:

- Cyanide is a major constituent of potlining leachate;
- It is highly soluble and mobile in the groundwater environment; and
- It is not typically present in groundwater and has been consistently detected beneath and downgradient of the plant.

The available water quality data are most extensive and complete for cyanide and fluoride. KACC-Mead laboratory personnel have completed over 6,000 cyanide and/or fluoride analyses through April 1988 which we focus on in the following discussion (4.3).

4.2.1 Questionable Arsenic Concentrations

We regard the arsenic concentration reported in the Van Gelder Spring (Table 3) as highly questionable and not representative of arsenic concentrations in groundwater at this location. Our conclusion is based on arsenic concentrations in well TH-8, comparison of well TH-8 and Van Gelder Spring total cyanide concentrations, and recent (September 1988) sampling.

- Well TH-8 has displayed the highest cyanide concentrations and is assumed to yield groundwater samples which have been most impacted by potlining leachate. The arsenic concentration in well TH-8 was measured at 0.085 mg/L which compares with a concentration of 0.068 mg/L in the Van Gelder Spring. This represents a decline of about 20 percent.

- Total cyanide concentrations in samples from well TH-8 in 1978 to 1980 were measured to range between 200,000 and 300,000 ppb as compared to 1,500 to 1,700 ppb measured in the Van Gelder Spring. This represents a concentration decline of about 99 percent between the plant and the spring discharge location.

- The decline in total cyanide concentration is attributed largely to dilution within the aquifer. We would expect more than a 20 percent decline in arsenic concentrations between the two (2) locations based solely on aquifer dilution. It is more likely that the arsenic concentrations at Van Gelder would be approaching aquifer background concentration.

- Recent sampling and analysis of a Van Gelder spring sample indicated arsenic concentrations of 0.008 mg/L (total) and less than 0.003 mg/L dissolved (Table 4). These concentrations are similar to the concentrations measured in upgradient well HC-14.

4.3 CYANIDE PLUME MIGRATION

The hydrogeologic and water quality conditions beneath and downgradient of the plant through the first half of 1980 are summarized by Hart Crowser in our September 1980 report. The cyanide plume position was estimated using cyanide analyses and water level measurements from selected wells (Figure 14). Wells where samples had greater than 100 ppb <u>total</u> cyanide were considered to be within the plume.

As illustrated on Figure 14, a cyanide plume extends to the northwest from the plant to the Little Spokane River. The plume width is about 800 feet at the plant and widens to about 1,500 feet where groundwater discharges into the river. Total cyanide concentrations beneath the plant were measured to be greater than 250,000 ppb in well TH-8 and declined to about 1,500 to 1,600 ppb near the river, a reduction of over 99 percent.

Cyanide analyses completed on groundwater samples obtained from wells which tap Zone A, B, or C indicate that Zone A has the highest cyanide concentrations and that concentrations decrease in Zones B and C. For example, in well TH-6 during 1979 to 1980 (Figure 23), Zone A showed a concentration range of 10,000 to 30,000 ppb, Zone B showed a concentration range of 1,000 to 10,000 ppb, while Zone C showed a range of between 40 and 500 ppb total cyanide.

A vertical section of the cyanide flow pathway is shown on Figure 24. This figure is based on cyanide analyses completed on groundwater samples from wells in the vicinity and downgradient of the plant; analyses of groundwater samples obtained during the drilling of the Pope replacement well (Robinson & Noble, 1979d); and analyses from springs containing cyanide.

We interpret the geologic data to indicate that the aquitards beneath the plant "pinch out" somewhere between the plant and the Pope well (well 8G3). Flow from Zone A joins the main aquifer where dilution from the lower zones occurs and then continues to the spring discharge points.

Zone A cyanide concentrations beneath the plant are shown on Figure 25 using data generally obtained during October 1981. This figure represents the "head" of the cyanide plume shown on Figure 14. The distribution of the cyanide concentrations is consistent with the northwest groundwater flow direction shown on Figure 12.

Although the highest concentrations of cyanide and fluoride are detected beneath and immediately downgradient of the potlining handling area, lower total cyanide concentrations have been measured upgradient of this area in wells ES-9, HC-15, HC-16, and HC-17 (Figure 7). Total cyanide concentrations in wells ES-9 during mid-1981 ranged between 100 and 200 ppb. This compares with an upgradient total cyanide concentration of less than 1 ppb measured in samples from HC-14.

4.4 SURFACE WATER QUALITY

Total and free cyanide concentrations have been measured at several locations in the Little Spokane River and in Deadman (Peone) Creek. Surface water sampling locations are shown on Figure 26. The measured range of cyanide concentrations for 1985 to 1988 is tabulated below.

Sampling Station	Total Cyanide Concentration in ppb (Free Cyanide Concentration in ppb)			
	1985	1986	1987	1988*
Peone (Deadman Creek)				
Above Outfall	<1 to 2 (<1)	<1 to 1 (<1)	<1 to 1 (NA)	<1 to 1 (NA)
Below Outfall	<1 to 5 (<1)	<1 to 11 (<1 to 8)	<1 to 1 (NA)	<1 to 1 (NA)
Little Spokane River				
Dartford/Minihdoka	<1 to 1 (<1)	1 (<1)	1 to 2 (NA)	1 to 2 (NA)
Pine River Park	<1 to 1 (<1)	<1 to 6 (<1)	<1 to 1 (NA)	<1 (NA)
Gaging Station	3 to 7 (<1)	1 to 5 (<1)	<1 to 4 (NA)	2 to 9 (NA)
Rivilla Park	70 to 107 (2 to 25)	9 to 132 (<1 to 16)	10 to 58 (1 to 11)	12 to 66 (2 to 9)
Below Van Gelder Spring	14 to 83 (1 to 13)	26 to 72 (1 to 4)	23 to 67 (1 to 5)	12 to 57 (2 to 8)
Below Popps	8 to 35 (<1 to 10)	8 to 34 (0 to 5)	6 to 22 (1 to 2)	12 to 28 (2 to 6)
St. Georges School	12 to 17 (6 to 13)	6 to 14 (<1 to 8)	6 to 12 (<1 to 5)	8 to 12 (10)

*Through mid-July 1988

The highest cyanide concentrations in the river are detected at Rivilla Park and below the Van Gelder Spring, which is the spring where the highest cyanide concentrations have been measured. Lower cyanide concentrations are detected in the river below this location where substantial groundwater volumes discharge into the river from springs.

Downstream locations from where the cyanide plume discharges into the river include Below Popps and St. Georges School (Figure 26). Reductions in the measured maximum total cyanide concentration of about 80 percent occur between the below Van Gelder Spring and St. Georges School sampling locations. In this river reach up to 50 percent of the base flow of the river is contributed by groundwater discharge during low flow conditions when the highest cyanide concentrations are measured in river samples.

Highest cyanide concentrations in the river occur during periods of low river flows. This is illustrated on Figure 27 when high river flows occurred in March 1987 and relatively lower cyanide concentrations were detected in the river.

5.0 CONTAMINANT FATE AND TRANSPORT

Spent potlining generated as part of the aluminum reduction process is the initial source of the cyanide and other constituents found in elevated concentrations in soil and groundwater beneath the plant. As shown on Figures 17 and 18 spent potlining is present beneath a portion of the rubble pile, beneath the asphalt covered pile, and beneath Area 2. Constituents leached from potlining are present in other media including subsurface soil and materials in the sludge bed and may also be considered potential sources.

Because spent potlining is a solid waste, for groundwater contamination to occur a media to leach soluble constituents and transport them to the water table is required. Water is the media which fulfills this requirement. Water sources can be grouped into two categories, depending on volume and recharge potential. These include water sources to "drive" contamination into soil but not cause substantial migration to the underlying aquifer and water sources which caused substantial migration to the aquifer.

To evaluate a particular source as to its potential to contaminate groundwater the nature of the source itself <u>and</u> its relationship to water sources needs to be considered. The effects of past remedial activities also should be considered to assess sources as they exist after the activities were completed. These factors are critical in assessing what additional remediation will be effective on the Mead site.

Prior to 1978 when remedial activities began our assessment indicates that the water sources and their effects on contaminant migration into soil or groundwater included:

o Water Sources to Drive Contaminants into Soil

  - Infiltration of pot-soaking liquor in pot-soaking area
  - Disposal of pot-soaking liquor into sludge bed

  - Infiltration of precipitation, ponded runoff, and dust control water which contacted exposed spent potlining material including spent potlining present beneath the rubble pile
  - Drainage of wet spent potlining material

- Water Sources to Drive Contaminants to the Water Table

  - Contact of water from leaking settling basin with contaminated soil
  - Disposal of pot-soaking liquor and sewage effluent into sludge bed
  - Water from pipe leaks which contacted contaminated soil
  - Infiltration of ponded runoff which contacted either contaminated soil or potlining (beneath Area 2)
  - Possibly infiltration of pot-soaking liquor in pot-soaking handling area if fluid volumes were large enough.

After 1978 spent potlining handling practices were changed and a series of remedial actions were completed which reduced the possibility of further migration of contaminants into soil or groundwater. After these activities were completed our assessment indicates that the remaining effective contaminant and water sources includes:

- Water Sources to Drive Contaminants into Soil

  - Infiltration of precipitation into sludge bed and rubble pile (but considered unlikely).

- Water Sources to Drive Contaminants to Water Table

  - Water from pipe leaks which contacts contaminated soil
  - Ponding of water (if present)

Review of the possible contaminant and water sources indicates that the only demonstrated condition where spent potlining contacted water which infiltrated to the aquifer occurred when ponded runoff infiltrated through potlining and soil in Area 2. This condition has been remediated by paving of Area 2 with asphalt and installation of drainage facilities. Contaminated soil which exists beneath the spent potlining handling area is considered to be the primary remaining contaminant source while pipe leakage is considered to be the primary remaining water source to leach and transport contaminants to the underlying aquifer.

The remaining portions of this section discuss further how cyanide migrated to the aquifer, the basis for remedial actions implemented by Kaiser, and the changes that occurred from these actions.

5.1 HOW CYANIDE MIGRATED TO THE AQUIFER

Cyanide migration through the unsaturated zone to the underlying aquifer was caused by:

- Effluent discharge to the sludge bed;
- Leakage of an unlined settling basin; and
- Infiltration of pipe leakage and ponded stormwater runoff.

5.1.1 Effluent Discharge to the Sludge Bed

Cyanide contained in pot soaking liquor was discharged to the sludge bed. Infiltration of wet scrubber water and sewage plant effluent into the bed caused cyanide to migrate to the water table.

The initial remedial actions implemented by Kaiser included modifying how spent potlining was handled and grading/covering the exposed piles of potlining with asphalt. The preliminary monitoring results were favorable in that Zone A groundwater concentrations began to decline in well TH-1 (Figure 28). From September 1978 to July 1980 cyanide concentrations declined from about 400 ppb to less than 40 ppb. However, total cyanide concentrations remained mostly unchanged in other wells and additional work and analysis were completed to further assess the situation. We now interpret the initial decline in the cyanide concentrations in well TH-1 to have been caused by halting disposal of pot soaking liquids and sewage effluent into the southwest corner of the sludge bed.

5.1.2 Leakage of an Unlined Settling Basin

Leakage of an unlined settling basin is the primary means that caused cyanide to migrate to the underlying aquifer. The settling basin was at first not suspected to be a major contributor to the groundwater quality conditions because:

- Water from the settling basin was low in cyanide concentration, and
- The settling basin was situated off to the side of the cyanide plume (water samples from well TH-2, located between the basin and the plume had low cyanide concentrations, generally less than 20 ppb total cyanide).

Figure 29 illustrates our model of what occurred, the major components of which are discussed below:

- Natural precipitation recharge is not sufficient to cause the high concentrations of cyanide measured in the aquifer. Water is necessary to transport cyanide to the aquifer. Our recharge analyses indicate that natural precipitation is not sufficient to transport enough cyanide to the aquifer to result in the consistently high concentrations which were observed during the early stages of the project although natural precipitation caused cyanide to migrate into soil. This conclusion is supported by the lack of decline in cyanide concentrations within Zone A after the asphalt cover was installed. Construction of the cover substantially increased runoff (which is collected and diverted out of the area) which in turn reduced the potential for recharge to occur from infiltration of precipitation through potlining and soils containing cyanide.

- A column of soil beneath the potlining handling area (centered on the asphalt covered pile) has been invaded by cyanide. The highest soil cyanide concentrations exist beneath the area where the asphalt covered pile is located (Figures 17, 18, and 20). The highest soil concentrations are present within the upper portions of the unsaturated soil column. At ES-1 the concentrations range between about 100 and 1,000 micrograms per gram (Figure 20). Downward migration was caused by infiltration of precipitation and pot soaking liquor over a long period of time. Runoff of water into closed depressions, with subsequent infiltration, was likely a major factor in causing significant downward migration.

- An aquitard consisting of silt and clay was directing leakage water from an unlined settling basin into the soil containing cyanide. During drilling an aquitard was encountered which was perching groundwater above the underlying aquifer. Three (3) to four (4) feet of perched water was measured in well HC-1A. We also measured water in well HC-6. These wells are screened on top of the aquitard 80 to 90 feet above Zone A.

- Settling basin leakage water was dissolving and transporting cyanide as the water migrated to Zone A. The settling basin contained water generated by stormwater flow and production well pumping (cooling water). Sampling and analysis of this water indicated it generally did not contain cyanide. An infiltration test indicated the basin was leaking at a rate of 50 to 60 gpm. Sampling and analysis of perched water zone samples indicated an increasing cyanide content as the water moved beneath the potlining handling area along the aquitard surface.

- Cyanide migrated downward to the aquifer and then northwest toward the spring discharge locations adjacent to the Little Spokane River. As leakage water migrated on top of the aquitard the water dissolved cyanide and percolated through the aquitard to the aquifer. Once the aquifer was reached, cyanide migrated to the northwest in the direction of groundwater flow. As shown on Figure 30, the aquitard surface is "swale like" with the low point on the surface lying beneath the area where highest soil cyanide concentrations exist. The trend of the swale is toward TH-8 where the highest aquifer cyanide concentrations are detected.

Initial development of our model was based on historical, hydrogeologic, and soil/water quality data available during the initial phases of the project. Based on these analyses and the general cyanide transport model shown on Figure 29, we recommended to KACC-Mead that leakage from the settling basin be stopped. The basin was drained and effectively abandoned on September 30, 1981. No current ponding or substantial infiltration of water occurs in the area of the old settling basin. A new basin was constructed several thousand feet to the north of the old basin location (Figures 3 and 5). Since the old settling basin was abandoned, KACC-Mead and Hart Crowser have been monitoring the groundwater conditions beneath and downgradient of the plant. Data collected as part of the ongoing monitoring program continue to support our model. Hydrologic and water quality changes occurred because of abandoning the old settling basin as discussed below.

5.1.2.1 Abandoning Leaking Settling Basin Causes Groundwater Levels to Decline

Hydrologic changes occurred within the perched water zone above the aquitard and within Zone A of the regional aquifer after the settling basin was abandoned. Figure 31 shows water levels versus time for HC-1A and HC-1 located adjacent to the old settling basin. HC-1A is screened above a depth of 50 feet and monitors water levels in the perched zone. HC-1 is screened at an approximate depth of 155 feet and monitors water levels in Zone A.

Once leakage from the settling basin was stopped the water level in HC-1A began to decline. The well became "dry" approximately two (2) to three (3) weeks after abandoning the basin. A similar response was measured in well HC-6 which is also screened directly above the aquitard.

Water levels in well HC-1 also declined. Well water levels declined about one (1) foot over a three-month period after the basin was abandoned.

Other wells screened in the Zone A also showed a water level decline in the vicinity of the abandoned settling basin. This decline is illustrated on Figure 32. Wells relatively close to the basin showed the greatest decline (about 1 foot) while wells further away showed a smaller decline (0.4 to 0.5 foot). We interpret these latter values to represent seasonal variations in the elevation of the Zone A water table.

The pattern of water level declines shown on Figure 32 indicates that a groundwater mound was present beneath the plant prior to September 30, 1981. The mound decayed after recharge from the settling basin stopped.

The decay of the groundwater mound within Zone A caused the groundwater flow direction beneath the potlining handling area to shift somewhat northward. The shifting of the groundwater flow patterns caused the head of the cyanide plume to shift which was detected using water quality data.

5.1.2.2 Abandoning the Settling Basin Improves Water Quality

Cyanide concentrations began to change after the basin was abandoned. Water quality monitoring since 1981 indicates that water quality has substantially improved because of stopping recharge from this source. The initial changes included cyanide concentrations declines, and some temporary increases in on-site wells.

o <u>Initial Water Quality Changes</u>

We divided the initial water quality changes into three (3) stages based on the first year of monitoring after the basin was abandoned (Hart Crowser, 1982). Selected water quality data are presented on Figure 33 to illustrate these initial changes.

o <u>Stage I</u> (September 1981 to July 1982) - Represents the draining of the perched water zones and soil column above the regional water table following drainage of the settling basin. The increase in cyanide concentrations in TH-1 and TH-2 is interpreted to be caused by a decrease in relatively clean recharge water infiltrating through the aquitard before migrating through soil containing cyanide, diluting water in the A-Zone, and/or by the initial shifting of the groundwater flow directions caused by reduced recharge. The decline in cyanide concentrations in wells HC-2A, HC-7, HC-9A, and ES-10 was likely caused by a reduction in cyanide moving to the water table.

o <u>Stage II</u> (August 1982 to September 1982) - We interpret Stage II as a period where the soil column has drained. The amounts of cyanide reaching the water table have substantially reduced and where cyanide concentrations in the A-Zone aquifer are responding to shifts in the groundwater flow directions. Well ES-10 is located on the far side of the plume, while well TH-2 is located on the near side of the plume from the settling basin. As the mound decayed the plume itself shifted in response the changed groundwater flow directions toward TH-2 and away from ES-10. The plume shift caused concentrations to rise in TH-2 and to fall in ES-10.

o <u>Stage III</u> (October 1982 to Present) is defined by the peaking and decline in cyanide concentrations in wells beneath and downgradient of the plant. We interpret the water quality data to mean that the groundwater flow directions have stabilized and that the aquifer is in the process of naturally purging (flushing) itself.

- Longer Term Water Quality Changes and Improvement

Cyanide: Eliminating recharge from the settling basin and natural aquifer flushing have resulted in a substantial improvement in water quality conditions beneath the plant. The available data indicate that at least a 50 percent reduction in the amount of cyanide migrating off the plant has occurred over the period from September 1981 to January 1987. Wells on the plant in the immediate vicinity of the plume have shown a net decline in total cyanide concentration of between 46 and 98 percent (Table 5).

The general water quality improvement is illustrated on Figures 25, 34, and 35. The areal extent of the plume beneath the plant is shown on Figure 25 for October 1981 (the leaking basin had just been abandoned). A similar figure for January 1987 is presented on Figure 34. As illustrated by the figures both the areal extent and maximum observed cyanide concentration have substantially declined. This declining trend is also illustrated on Figure 35 which shows a cyanide concentration profile across the area of the plume in which maximum cyanide concentrations have been detected.

Average annual total cyanide concentrations and standard deviation at several selected upgradient and downgradient well locations of the potlining pile were calculated using the available data. The results are presented on Figures 36 through 44. The trends, since 1983, of selected sampling points are graphically presented on Figures 45 through 48. The general declines in cyanide concentrations in wells indicate that aquifer flushing has been occurring after the plume shift and mound dissipation had been completed. However, several temporary aquifer recharge excursions have occurred which have increased cyanide concentrations in some of the wells. These are discussed in the following report section (5.1.3).

The average total cyanide concentration of the plume in the vicinity of the plant has reduced from approximately 97,000 ppb in October 1981 to about 34,000 ppb in January 1987. Assuming a 1,100-foot-wide plume leaving the site, a 10-foot A-Zone aquifer thickness, and a 3 feet per day average advective velocity, off-site migration of total cyanide has been reduced from 90 to 100 kilograms per day to 30 to 40 kilograms per day.

Leakage from the settling basin and discharge to the sludge bed are the primary means that cyanide migrated to the aquifer. However, cyanide has been detected upgradient of the sludge bed and potlining handling area in well ES-9 (Figure 7). We believe the source of cyanide in well ES-9 is spillage from the wet scrubber system based on interviews with past plant employees. This spillage, coupled with the infiltration of concentrated stormwater runoff, likely caused cyanide to reach to the aquifer in this portion of the plant. Monitoring of ES-9 cyanide concentrations indicates that concentrations have declined from 150 to 200 ppb total cyanide in 1981 to 10 ppb in early 1988.

<u>Fluoride</u>: Fluoride concentrations have also declined in a similar fashion as cyanide. Fluoride concentrations in Zone A beneath the plant are shown on Figures 49 and 50 for October 1981 and January 1987 (compare with Figures 25 and 34 for cyanide). The maximum concentrations and the extent of the fluoride plume have declined.

Similarly, a plot of fluoride concentrations across the highest detected concentration part of the plume shows a substantial decline (Figure 51). A similar pattern is illustrated for cyanide on Figure 35. Fluoride concentration trends for selected wells are shown on Figures 52 and 53.

Fluoride concentrations decrease substantially downgradient of the plant site. Background fluoride concentrations as measured at well HC-14 are on the order of 0.29 mg/L. Several wells on the plant exceed 2 mg/L as shown on Figure 54. Fluoride concentrations in downgradient wells are measured to be less than 2 mg/L and for the most part less than 1 mg/L.

<u>Other Constituents</u>: Other constituents have also declined since the settling basin was abandoned in 1981. Table 6 compares the results of groundwater sample analyses from well TH-8 for August 1979 and September 1988. As shown other constituents have declined. The greatest declines

were measured for nitrate (98 percent), manganese (92+ percent), selenium (72 percent), barium (59 percent), and iron (55 percent).

5.1.3 Infiltration of Pipe Leakage and Ponded Stormwater Runoff

Monitoring since 1981 has detected water quality changes not related to abandonment of the settling basin. These include recharge events caused by a pipe leak, and concentration of stormwater in a limited area which caused subsequent infiltration and mobilization of cyanide to the water table from soils beneath the potlining handling area.

A pipe leak (Hart Crowser, April 12, 1984) occurred in 1983 which caused total cyanide concentrations to increase in well HC-2A (Figures 36 and 45). Subsequent temporary increases were also observed in wells TH-2 and HC-8 (Figure 46). The pipe leak was detected in the vicinity of well HC-2A. The leak was repaired and cyanide concentrations declined.

In February 1984, HC-2A cyanide concentrations started increasing again (Figures 36 and 45). Kaiser Aluminum did not detect any pipe leaks and the cyanide concentrations peaked in mid-1984 and returned to January 1984 values in October 1984. The cause for this incident was later interpreted to have been caused by infiltration of concentrated stormwater in the low area between the covered potlining pile and sludge bed where ponded water was observed (Hart Crowser, April 4, 1985). This area (Area 2) has since been paved.

In a similar situation, the cyanide concentration in well ES-10 (Figure 46) went up and returned to previous levels over the period February through August 1986 (Hart Crowser, October 21, 1986). The available data indicate that the cause of the rise in cyanide concentrations was water infiltration in the area south or southwest of the asphalt covered pile. This area (Area 4) has since been paved.

The general trend of decline in cyanide concentration in well HC-2A and other wells indicates that the temporary excursions such as the pipe leak and infiltration of stormwater have not changed or substantially slowed the general pattern of water quality improvement.

Starting in February of 1987 cyanide concentrations again increased in well ES-10 (Figure 46). The concentrations declined after May 1988 but not to the baseline levels of 1985. KACC-Mead is currently evaluating the cause of this recent increase. The available data indicate to us that the most probable cause of the increase was or is a pipe leak. The timing of the paving of Area 4 may also be a factor. A pipe leak located near the northwest corner of the baking furnace building was repaired in December 1987. This leak may be at least a partial cause of the cyanide increased in well ES-10.

On-going monitoring continues to assess the trend in cyanide concentrations in the aquifer beneath the site. Other work is being considered to assess whether other factors, such as an undiscovered pipe leak, could be the cause of the current situation.

5.2 UNCOVERED EXISTING POTENTIAL SOURCES OF CONTAMINATION: SLUDGE BED AND RUBBLE PILE

Potlining or materials containing cyanide are present in two (2) unpaved areas; sludge bed and rubble pile. While these areas represent <u>potential</u> source areas, their contribution to aquifer contamination, if any, is substantially smaller than for soil beneath the potlining handling area.

<u>Sludge bed</u>: The sludge bed contains cyanide and is exposed to precipitation. The bed is a diked area so no runoff occurs. Infiltration through the bed is evenly distributed and runoff does not concentrate within any discrete portion of the diked area.

Wells on the downgradient site of the sludge bed (HC-1, TH-1, HC-2A) typically display total cyanide concentrations of less than 100 ppb. This concentration is at least 2,000 times less than the concentrations observed in further downgradient well TH-8.

The source strength is also characterized by the relative concentrations of cyanide in leachate from the sludge bed as compared to leachate from potlining. Leachate collected in early 1979 (Robinson & Noble, 1979b) in an underdrain pipe placed beneath the sludge bed yielded a total cyanide concentration of 1970 ppb. This compares with total cyanide concentrations of 700,000 to 900,000 ppb in leachate collected from pipes installed beneath the potlining pile (prior to covering with asphalt).

Rubble pile: Potlining is present beneath the rubble pile (Figure 19). We do not believe that this potential source contributes significant, if any, cyanide to the aquifer based on:

- Soil concentrations beneath the potlining. These concentrations decline from several hundred ug/g to less than 10 ug/g in a distance of less than 10 feet. This compares with cyanide concentration beneath the asphalt covered pile which are still greater than 100 ug/g 40 to 50 feet below the bottom of the potlining (Figure 20).

- Recharge estimates which indicate that the potential for natural recharge is low. The potential for recharge to occur through this material is further reduced because of the 30 to 40 feet of rubble which overlies the potlining.

6.0 DOWNGRADIENT GROUNDWATER QUALITY CHANGES

Data from downgradient wells and springs were compiled and analyzed to evaluate water quality conditions and changes downgradient of the plant. Well locations are shown on Figure 5 while pertinent data are shown on Figures 52 and 53 (graphical data plots) and Figures 55 through 60 (histograms). The wells are generally grouped with respect to distance from the Mead plant toward the Little Spokane River.

6.1 REGIONAL POSITION OF CYANIDE PLUME

Based on total cyanide concentration data collected during the latter part of 1986, an updated regional cyanide plume map was prepared (Figure 5). The plume boundary is defined by groundwater concentrations greater than 100 ppb total cyanide. The specific data and wells used to prepare the map are listed in Table 7.

Comparison of the plume configuration in 1986 (Figure 5) with the configuration prepared in 1980 (Figure 14) (Hart Crowser, 1980) indicates that cyanide flow paths from the plant have not substantially changed. This finding was expected since the general hydrogeologic conditions in the vicinity of the plant have not changed.

6.2 BLAND/MERRIT, TH-6A, TH-6B, TH-6C, and TH-5

The cyanide concentration trends for the Bland/Merritt, TH-6, and TH-5 wells (Figures 55, 47, and 48) are similar to the trends detected in plant wells. The Bland/Merritt well and wells TH-6A, TH-6B, and TH-6C have decreased in concentration while well TH-5 increased, then began to decrease in total cyanide concentration. This pattern is interpreted to be caused by the cyanide plume shift which in turn was caused by the abandonment of the unlined settling basin (Tharp Lake) in late 1981 (Hart Crowser, 1987).

The relatively rapid response in the Bland/Merritt and TH-6C wells is likely the result of these wells being finished in the more permeable portions of the aquifer as compared to well TH-5 and plant site wells finished in Zone A. The higher permeability materials allowed the effects of abandoning Tharp Lake to propagate downgradient more rapidly.

6.3 POPE (OLD), COLBORN, SPOKANE COUNTY SHOP, AND WWP 3-5 WELLS

The Pope (Old), Colborn, Spokane Shop, and WWP 3-5 wells are located approximately 7,000 feet downgradient of the plant site (Figure 5). The Pope (Figure 56) and Spokane County Shop (Figure 57) wells have generally declined in total cyanide concentration (since 1981) while the Colborn well (Figure 58) has increased and then appears to have decreased. This pattern is similar to other wells as discussed in the preceding paragraphs.

The data suggest that cyanide concentrations are increasing in the Spokane County Shop well (Figure 57). Additional monitoring is required to assess the nature of the changing concentrations in this well.

Data from the WWP 3-5 well (SS 3-5) indicate that cyanide concentrations have remained relatively constant (Figure 48). This well is on the periphery of the contaminant plume (Figure 5).

6.4 PRUMER/DAVIS WELL AND VAN GELDER/SMITT (LEAK) AND WANDERMERE SPRINGS

The Prumer/Davis well and Van Gelder/Smitt and Wandermere springs are located toward the end of the cyanide plume near the regional aquifer discharge area. The limited data from the Prumer/Davis well (Figure 59) show a similar pattern to the Colborn well (Figure 58) and well TH-5 (Figure 48). There is also evidence that the water quality changes have reached the Van Gelder/Smitt spring (Figure 60) in that the latest data indicate that concentrations have dropped below 1,000 ppb total cyanide.

7.0 EXPECTED WATER QUALITY IMPROVEMENTS IN THE FUTURE

Total cyanide concentration data presented on Figures 36 through 48 indicate that the groundwater quality beneath the Kaiser plant site has improved substantially since 1981. The available data indicate that the water quality conditions should continue to improve.

Several wells have established a general decline pattern after the cyanide concentration peaked in the well. These patterns appear to be dependent on the location of the well in relation to the plume. Wells on the fringes of the plume have typically declined at a greater rate than wells located more toward the plume center.

Wells on the fringes of the plume (HC-7, HC-8, TH-2, HC-12, and ES-10) over the last several years have shown an average decline rate on the order of 20 to 40 percent per year of the previous years average concentration value (Table 8). Wells located toward the center of the plume (HC-9A, TH-3A, and TH-8) have declined at a lower rate on the order of 3 to 9 percent per year of the previous years average concentration value.

The available data indicate that as the aquifer flushing continues the rate of cyanide concentration decline should increase in wells located toward the center of the plume. This may be occurring in well HC-9A (Figure 42) which declined about 25 percent between 1985 and 1986; as compared to 9 percent between 1984 and 1985. Similar decline rates should occur in wells TH-3A and TH-8 over the next year or two, although the increases observed in well ES-10 could delay these declines.

There are no data to indicate that the observed declining trends should not continue. Extrapolating the trends over the next four to five years appears to indicate that at the end of this period cyanide concentrations of wells finished within the A-Zone should be less than 20 percent of their highest observed average concentration value assuming that no substantial recharge events occur in or within the vicinity of the potlining handling area.

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Table 1 - Kaiser Potlining Leachate Analysis

Metals	Concentration in ppb (Except Where Noted)
Antimony	15
Arsenic	98
Cadmium	7
Copper	27
Manganese	16
Nickel	25
Selenium	25
Silver	13
Thallium	<1
Beryllium	1
Chromium	11
Lead	40
Mercury	0.36
Zinc	20
Calcium	250
Aluminum	94,000

Parameter	Concentration in ppb (Except Where Noted)
Cyanide	130
Phenolics (AAP)	5
Chloride	10 ppm
Fluoride	2720 ppm
Sulfide	44 ppm
Ammonia	632 ppm
Toluene	0.4
Acetone	200 (Estimated)
Phenol	0.02
Unknown	2.5×10^6 (Estimated)

All other compounds were found to be present in concentrations below established reporting limits.

EPA Region X Laboratory, December 22, 1978

Table 2 - Summary of Sludge Bed Sampling

Sample Location	Depth in Feet	Sludge Cyanide Concentration in ppm		
		Water Soluble	Total	Source
1 (Area 1)	Surface	10.5	62*	1
2 (Area 4)	0.5	37.7	610*	1
3 (Area 4)	8	20	147*	1
4 (Area 4)	Surface	36	NA	1
5 (Area 4)	5	0.31	NA	1
6 (Area 4)	10	--	NA	1
7 (Area 4)	13	0.50	NA	1
149 (Area 1)	Surface	0.8	1.7	2
250 (Area 1)	3	<0.2	42	2
251 (Area 1)	6	<0.2	0.8	2
252 (Area 1)	9	<0.2	<0.2	2
242 (Area 3)	Surface	1.4	560	2
243 (Area 3)	3	<0.2	1.2	2
244 (Area 3)	6	<0.2	0.2	2
245 (Area 3)	9	<0.2	300	2
238 (Area 3)	Surface	27.6	190	2
239 (Area 3)	3	1.8	212	2
240 (Area 3)	6	2.4	260	2
241 (Area 3)	9	1.8	108	2
151 (Area 4)	Surface	2.4	116	2
248 (Area 4)	45.5	<0.2	<0.2	2
249 (Area 4)	9-9.5	<0.2	<0.2	2
150 (Area 3)	Surface	0.3	1.8	2
152 (Area 3)	4	1.2	9.0	2
246 (Area 3)	5.5-6	<0.2	9.0	2
247 (Area 3)	9.5-10	<0.2	<0.2	2
CFT 1** (Area 2)	Surface	0.9	101	2
CFT 2** (Area 2)	3	0.9	65	2
CFT 3** (Area 2)	6	1.6	92	2
CFT 4** (Area 2)	7	0.6	84	2

NA - Not Analyzed
* - Analyses Completed by Washington State Department of Ecology
** - Analyses Completed by Kaiser CFT Laboratory

Sources:
1. Kaiser Interoffice Memo to: R.L. Alboncq, From: W.B. Eastman, Dated October 24, 1978.
2. Kaiser Interoffice Memo to: W.B. Eastman, From: D. Hirst, Dated January 8, 1979.

Table 3 - Summary of Water Quality Analyses

Parameter	TH-3	TH-8	Pope (8G1)	Speaks (93)	Pecchia (118)	Spokane Co. Roadshop (5N1)	Bland (8R1)	Chevillet (6J2)	Van Gelder (6G2S)	Drinking Water Standards
Total Cyanide		180	0.185- 0.495	<0.001- 0.009	0.245- 0.445	0.480- 1.150	0.225- 0.545	0.545- 0.890	1.328- 2.100	0.20
Arsenic	0.061	0.085	0.008	0.013	0.017	0.0072	0.006	0.0077	0.068	0.05
Barium	0.720	0.34	0.09	0.18	0.24	<0.2	<0.2	<0.2	<0.2	1.0
Cadmium	0.002	0.007	0.001	0.001	0.001	<0.002	<0.002	<0.002	<0.002	.01
Chromium	0.057	0.045	0.014	0.005	0.013	<0.04	<0.04	<0.04	<0.04	.05
Iron	17.2	79.6	0.12	0.85	0.13	0.41	0.24	0.44	0.70	.3
Lead	0.055	0.013	0.003	0.010	0.010	<0.005	<0.005	<0.005	<0.005	.05
Manganese	0.077	0.181	0.003	0.019	0.032	<0.02	<0.02	<0.02	<0.02	.05
Mercury	0.001	0.0028	0.0002	0.0002	0.0002	<0.001	<0.001	<0.001	<0.001	.002
Selenium	0.059	0.065	0.004	0.008	0.005	NA	NA	NA	NA	.01
Silver	0.003	0.007	0.001	0.001	0.001	NA	NA	NA	NA	.05
Total Hardness	65	145	143	126	172	NA	NA	NA	NA	--
Fluoride	57	104	0.03	0.1	0.1	NA	NA	NA	NA	4
Nitrate as N	274	591	2.6	2.9	2.2	NA	NA	NA	NA	10
Chloride	120	11	5	10	5	NA	NA	NA	NA	*250
Calcium	NA	8.6	NA	NA	NA	NA	NA	NA	NA	*5.0
Magnesium	NA	32.8	NA	NA	NA	NA	NA	NA	NA	*1.0
Sodium	BA	2160	NA	NA	NA	NA	NA	NA	NA	--
Antimony	NA	NA	NA	NA	NA	<0.01	<0.01	<0.01	<0.01	--
Beryllium	NA	NA	NA	NA	NA	<0.002	<0.002	<0.002	<0.002	--
Zinc	NA	NA	NA	NA	NA	0.09	0.06	0.14	0.01	--
Copper	NA	NA	NA	NA	NA	0.12	0.08	0.01	0.03	--
Specific Cond.	3750	7400	245	234	234	NA	NA	NA	NA	--
Date Sampled	11/16/78	8/1/79	7/11/79	7/11/79	7/11/79	Bef. 1980	Bef. 1980	Bef. 1980	Bef. 1980	
Source	(1)	(2)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	

(1) Robinson & Noble 1979a
(2) Robinson & Noble 1979b
Total cyanide concentration range January to May 1979.
All units mg/L except specific conductance - micromhos/cm; metal concentrations are "total" (unfiltered)
NA - Not Analyzed

Table 4 - Results of Water Quality Analyses September 1988 Sampling

		HC-14	TH-8	Merritt Bland	Pope (Old)	Spokane Co. Road Shop	Pecchia	Van Gelder Spring
(number)		---	---	(W-328)	(W-34)	(W-51)	(W-118)	(W-195)
Parameter					Parts per million (mg/L)			
Total Cyanide		0.001	94.3	0.096	0.211	0.805	0.152	0.907
Free Cyanide		NA	0.53	0.011	0.017	0.056	0.016	0.048
Fluoride		0.18	97.6	0.35	0.74	0.074	0.05	0.76
Arsenic	(T)	0.009	0.278	0.006	0.007	0.009	0.010	0.008
	(D)	<0.003	0.254	<0.003	0.004	<0.003	0.005	<0.003
Selenium	(T)	<0.003	0.018	0.004	0.004	<0.003	<0.003	<0.003
	(D)	<0.003	0.010	<0.003	<0.003	<0.003	<0.003	<0.003
Barium	(T)	0.150	0.140	<0.090	<0.090	<0.090	<0.090	0.120
	(D)	<0.090	0.120	<0.090	<0.090	<0.090	<0.090	<0.090
Cadmium	(T)	<0.0003	0.007	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
	(D)	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Chromium	(T)	0.006	0.042	0.004	<0.0006	0.004	0.002	0.005
	(D)	0.001	0.028	<0.0006	<0.0006	<0.0006	0.001	0.001
Lead	(T)	<0.0039	<0.0039	<0.0039	<0.0039	<0.0039	<0.0039	<0.0039
	(D)	<0.0039	<0.0039	<0.0039	<0.0039	<0.0039	<0.0039	<0.0039
Zinc	(T)	0.026	0.006	0.038	0.054	0.025	0.019	0.016
	(D)	0.025	0.008	0.021	0.029	0.006	0.020	<0.006
Copper	(T)	0.006	0.102	<0.0024	<0.0024	<0.0024	0.007	<0.0024
	(D)	NA	0.087	<0.0024	<0.0024	<0.0024	<0.0024	<0.0024
Iron	(T)	0.303	35.9	0.056	0.132	0.299	0.102	0.355
	(D)	<0.036	35.7	0.038	0.090	0.279	0.071	0.327
Manganese	(T)	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
	(D)	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Sodium	(T)	<6.1	1,723	7.0	19.1	29.1	10.6	44.2
	(D)	<6.1	1,666	7.0	20.0	28.6	7.6	43.8
Nitrate		20.4	10.2	2.2	1.9	3.1	1.3	2.8

NA = Not Analyzed

Source: Cyanide and Fluoride Data - KACC-Mead
Other Parameters - Hart Crowser (1988)

Table 5 - Reduction in Cyanide Concentrations

Well Number	Peak Year	Avg. Peak Conc. in ppb	1987 Conc. in ppb	Percent Decline
ES-10	1981	74,000	4,000	95
HC-7	1981	45,000	2,500	94
HC-8	1981	55,700	1,200	98
TH-2	1982	3,000	25	99
HC-12	1984	73,600	39,800	46
HC-9A	1984	66,900	30,000	55
TH-3A	1982	182,600	62,800	66
TH-8	1982	262,700	96,400	63

Source (Hart Crowser, 1987)

Table 6 - Comparison of Water Quality Data from Well TH-8

	DATE		
	August 1, 1979	September 2, 1988	Change in Percent
Total Cyanide	180	94.3	-48
Fluoride	104	97.6	-6
Arsenic	0.085	0.278	*
Barium	0.34	0.140	-59
Cadmium	0.007	0.007	0
Chromium	0.045	0.042	-6
Iron	79.6	35.9	-55
Lead	0.013	<0.0039	>-70
Manganese	0.181	<0.015	>-92
Mercury	0.0028	NA	---
Selenium	0.065	0.018	-72
Silver	0.007	NA	0
Nitrate	591	10.2	-98
Sodium	2,160	1,723	-20
Zinc	NA	0.006	---
Copper	NA	0.102	---

*The August 1, 1979 data for arsenic are highly questionable based on review of other analyses.

Table 7 - Selected Total and Free Cyanide Concentration Data August through November 1986

Well Number	Date	Total CN in ppb	Free CN in ppb	Free CN in Percent
114	08/18/86	53	3	5.7
118	09/12/86	166	10	6.0
120	09/19/86	73	5	6.8
138	11/25/86	51	2	3.9
139	08/25/86	237	18	7.6
159	08/18/86	138	12	8.7
165	08/18/86	118	9	7.6
195	08/18/86	1,461	96	6.5
328	08/18/86	202	11	5.4
34	08/18/86	134	5	3.7
35	08/18/86	123	7	5.7
36	08/18/86	311	13	4.2
4	08/19/86	212	7	3.3
45	08/18/86	185	9	4.9
51	08/18/86	241	12	5.0
6	08/18/86	130	7	5.4
2147	11/25/86	137	4	2.9
14	10/13/86	0	NA	0
15	10/17/86	0	NA	0
209	09/08/86	0	NA	0
94	09/04/86	0	NA	0
40	08/04/86	0	0	0
41	08/04/86	0	0	0
142	10/17/86	0	NA	0
98	10/15/86	4	NA	0
99	10/15/86	6	NA	0
91E	08/18/86	1	0	0
203	09/05/86	0	NA	0
202	09/05/86	12	1	8.3
44	11/25/86	16	1	6.2
ES-9	10/06/86	21	1	4.7
ES-10	10/06/86	1,164	24	2.0
TH-3A	10/08/86	64,290	561	<1.0
TH-5	10/09/86	27	3	11.0
TH-6A	10/07/86	13,996	310	2.2
TH-8	10/08/86	100,828	390	<1.0
HC-1	10/06/86	84	5	5.9
HC-2A	10/08/86	42	2	4.7
HC-7	10/09/86	1,915	210	1.1
HC-8	10/06/86	2,253	89	3.9
HC-12	10/09/86	46,800	676	1.4
HC-13	10/09/86	4	NA	---
HC-9A	10/06/81	41,378	224	<1.0
TH-1	10/06/86	67	3	4.5
TH-2	10/07/86	82	10	12.0
HC-14	10/08/86	0	NA	---

Average percent Free CN of Total CN where Total Cyanide is greater than 10 ppb = 5.3 percent.

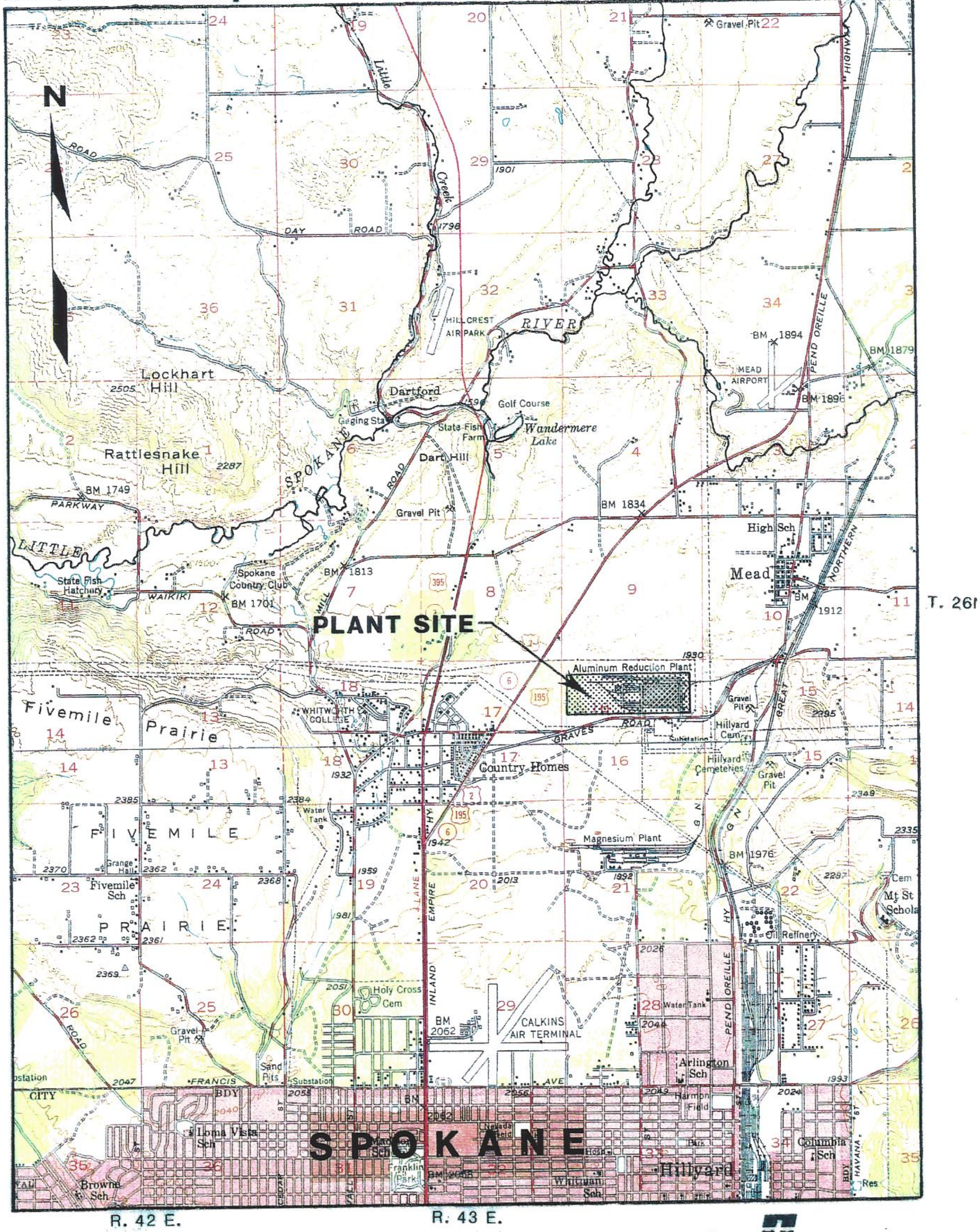
Table 8 - Percentage Decline in Average Total Cyanide Concentration Over Previous Year in Selected Wells

Well Number	Percent Decline in Average Total Cyanide Concentration 1983 to 1984	 1984 to 1985	 1985 to 1986
HC-7	37	34	21
HC-8	48	16	34
TH-2	62	37	16
HC-12	14	19	22
ES-10	28	39	--
HC-9A	--	9	25
TH-3A	31	L/1	3
TH-8	30	8	9

L/ - less than

Source (Hart Crowser, 1987)

Location Map - Plant Site Area



Base map prepared from USGS
15-minute quadrangle of Spokane,
and Deer Park, Washington, dated 1950.

0 1 2
Scale in Miles

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J-948-05 6/88
Figure 1

Plant Site Features

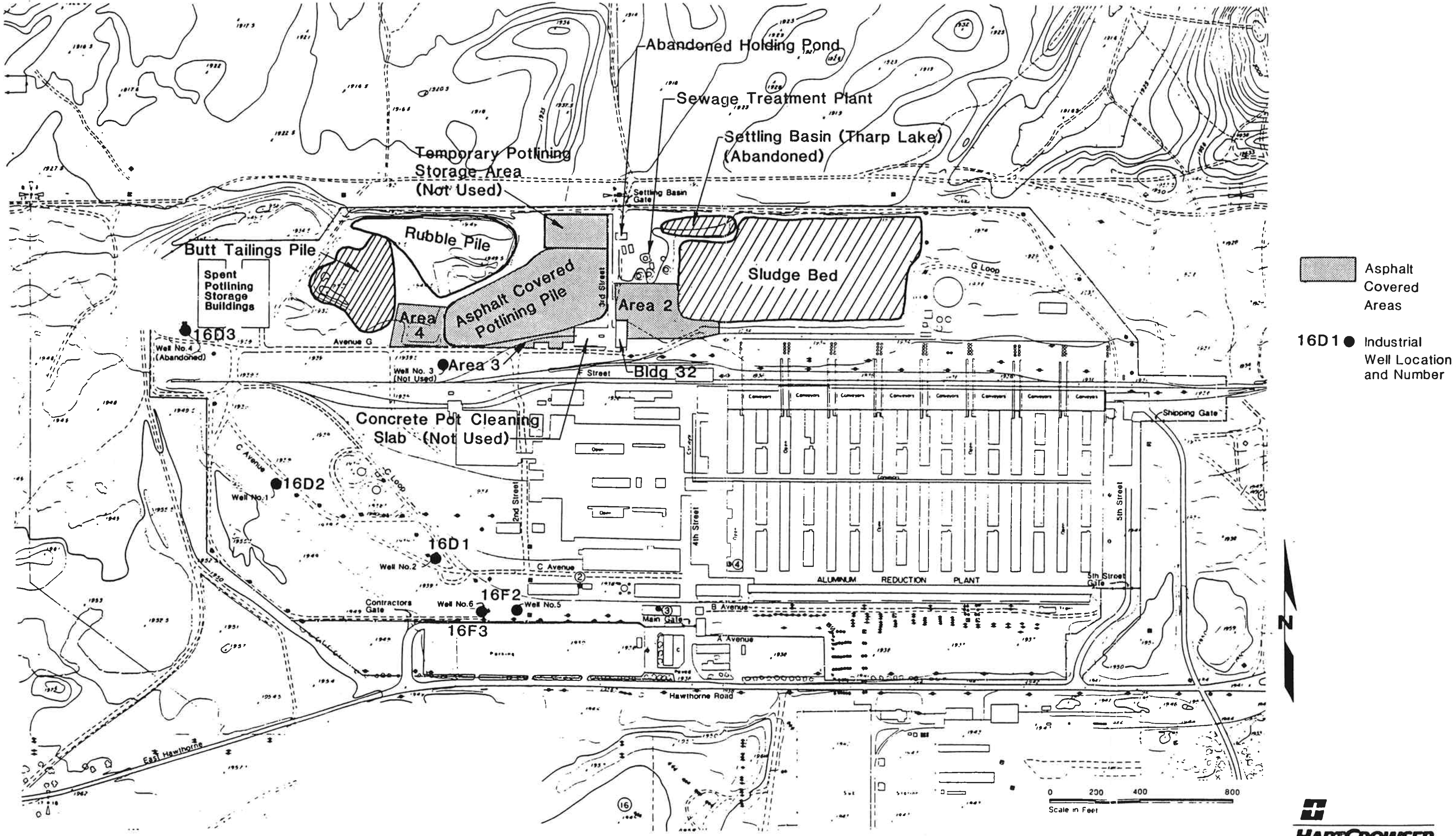

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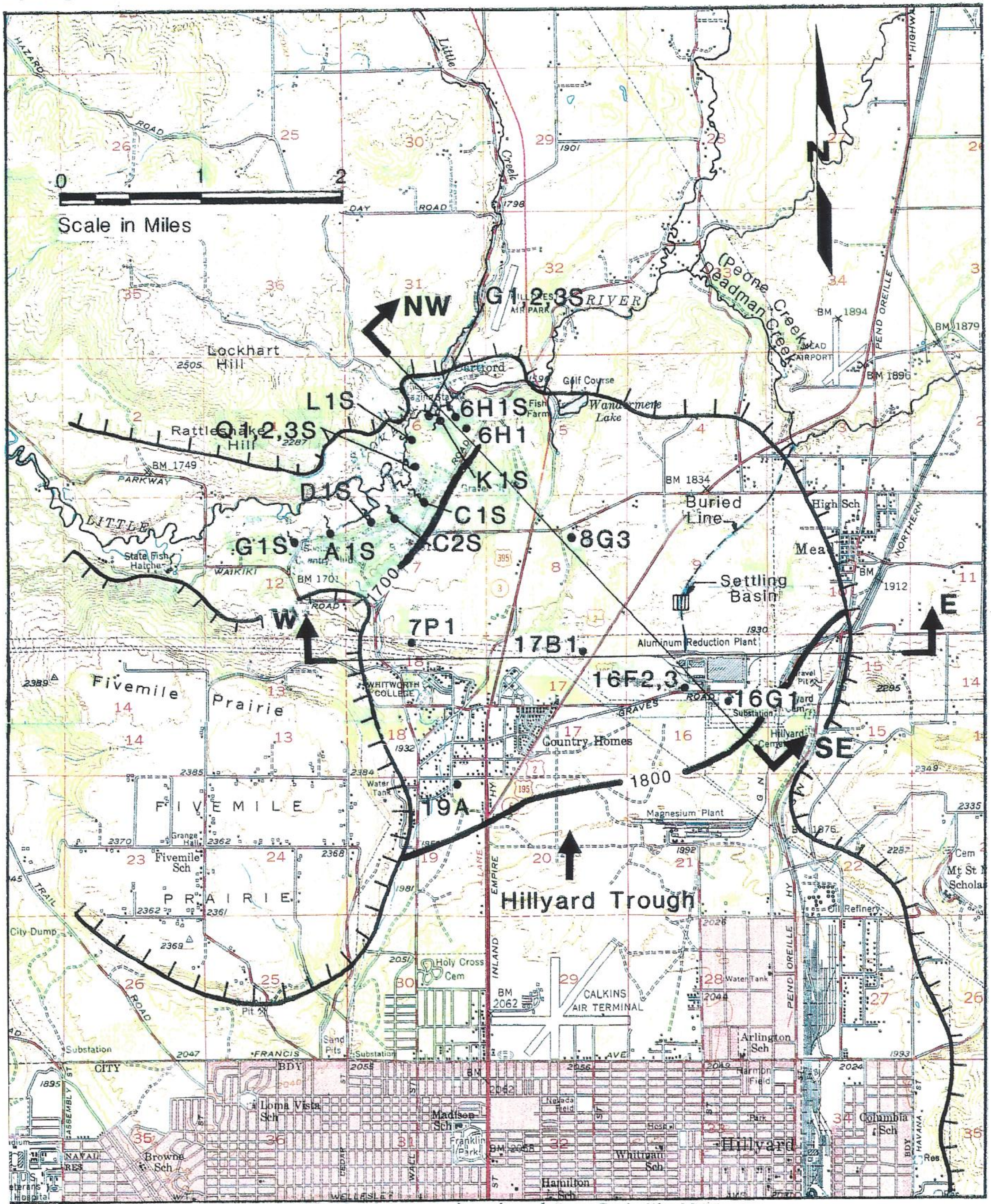
Figure 2

Hydrogeologic Environment Map Showing Cross Section, Selected Well and Spring Locations



Note: Base map prepared from USGS 15-minute quadrangles of Deer Park, Washington, dated 1949 and Spokane, Washington, dated 1950

H1 ● Well Location and Number

G2 Spring Location and Number

W E Cross Section and Designation

Aquifer Boundary

1700 Water Table Contour

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Figure 3

Total Annual Precipitation at Spokane Airport

(A few years data may be recorded in downtown Spokane)

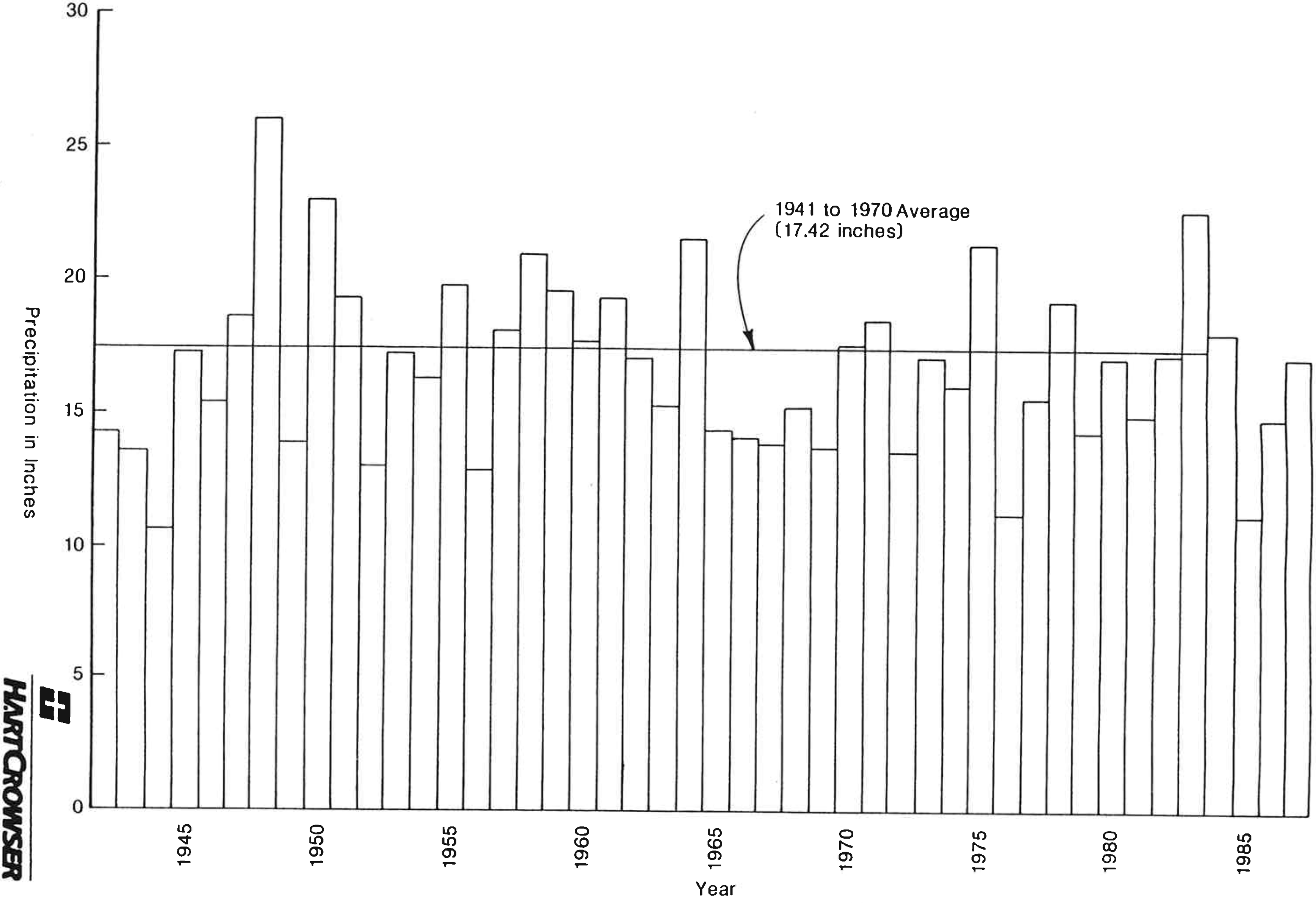

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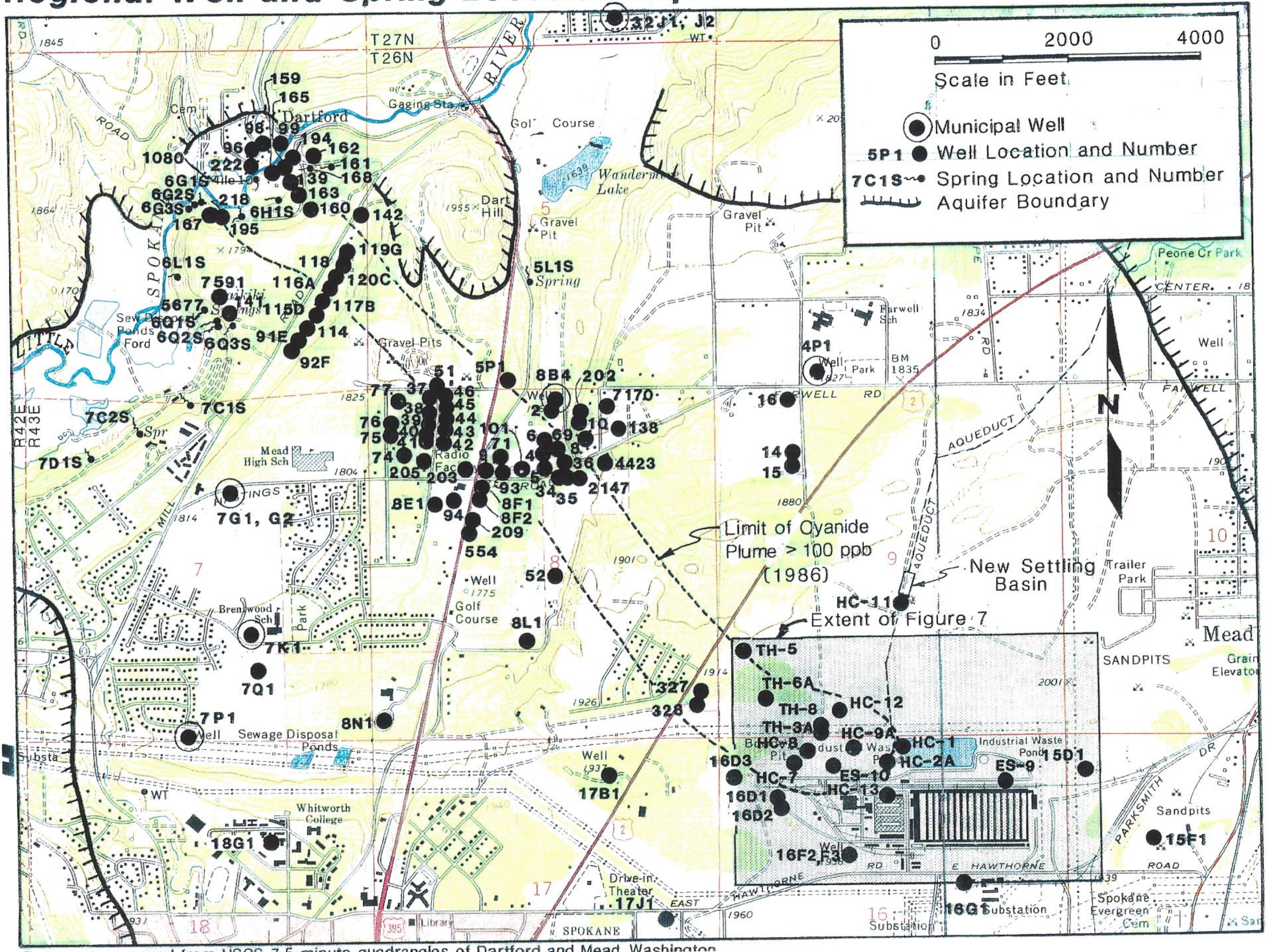
Figure 4

egional Well and Spring Location Map (1986 Inventory of Wells)



Base map prepared from USGS 7.5-minute quadrangles of Dartford and Mead, Washington

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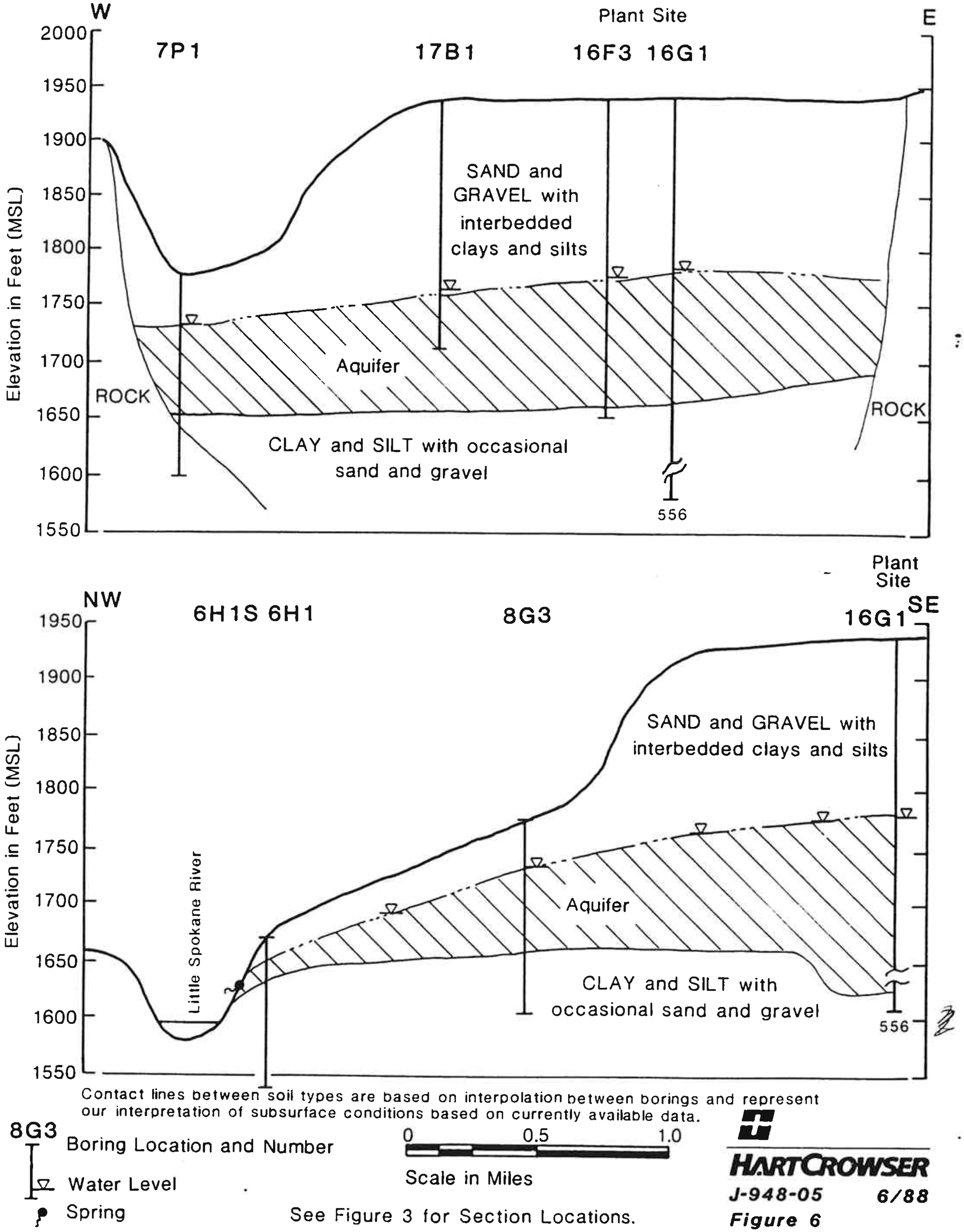
Figure 5

Schematic Geologic Cross Sections W-E and NW-SE



Contact lines between soil types are based on interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

See Figure 3 for Section Locations.

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Figure 6

Well and Boring Location Map

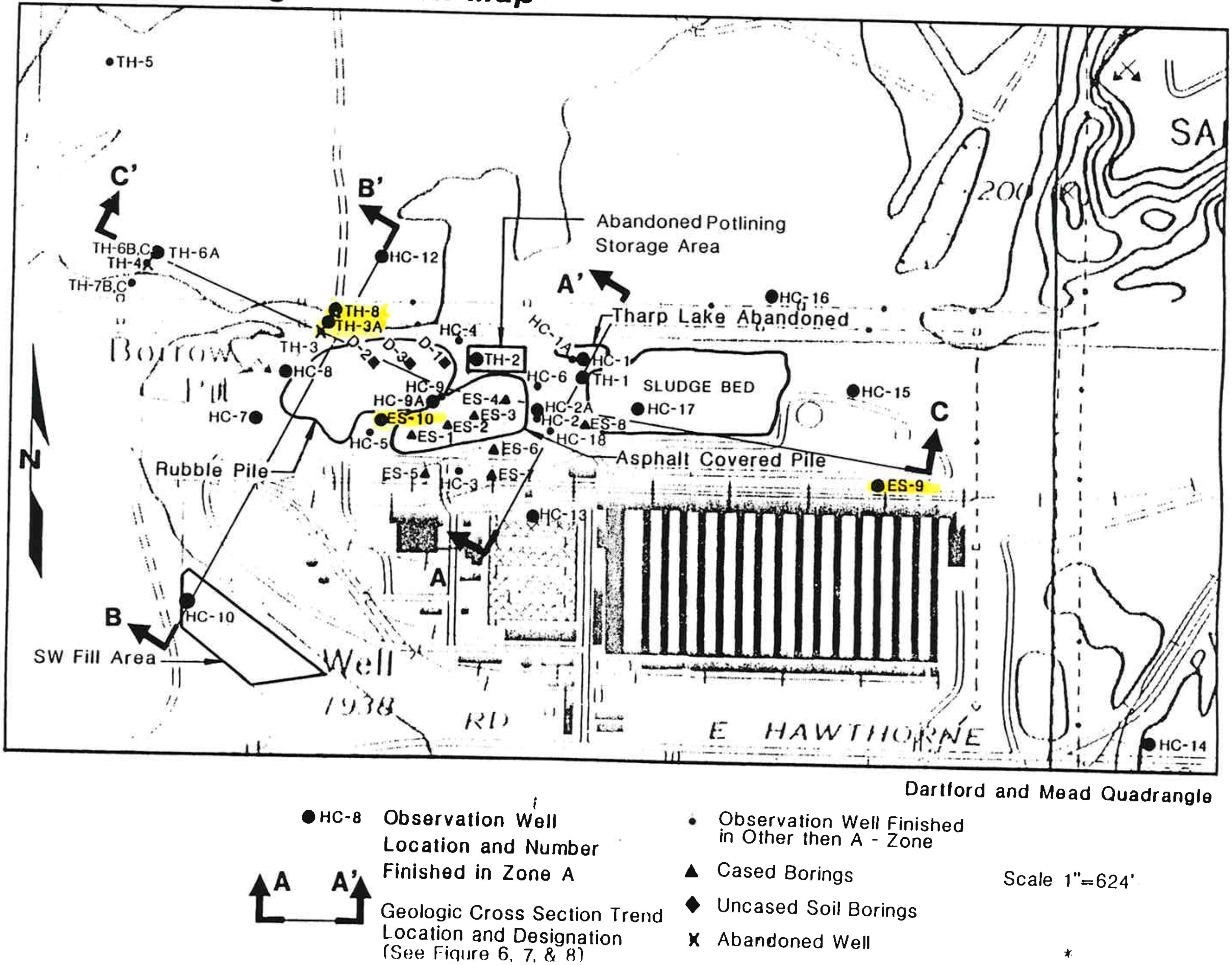

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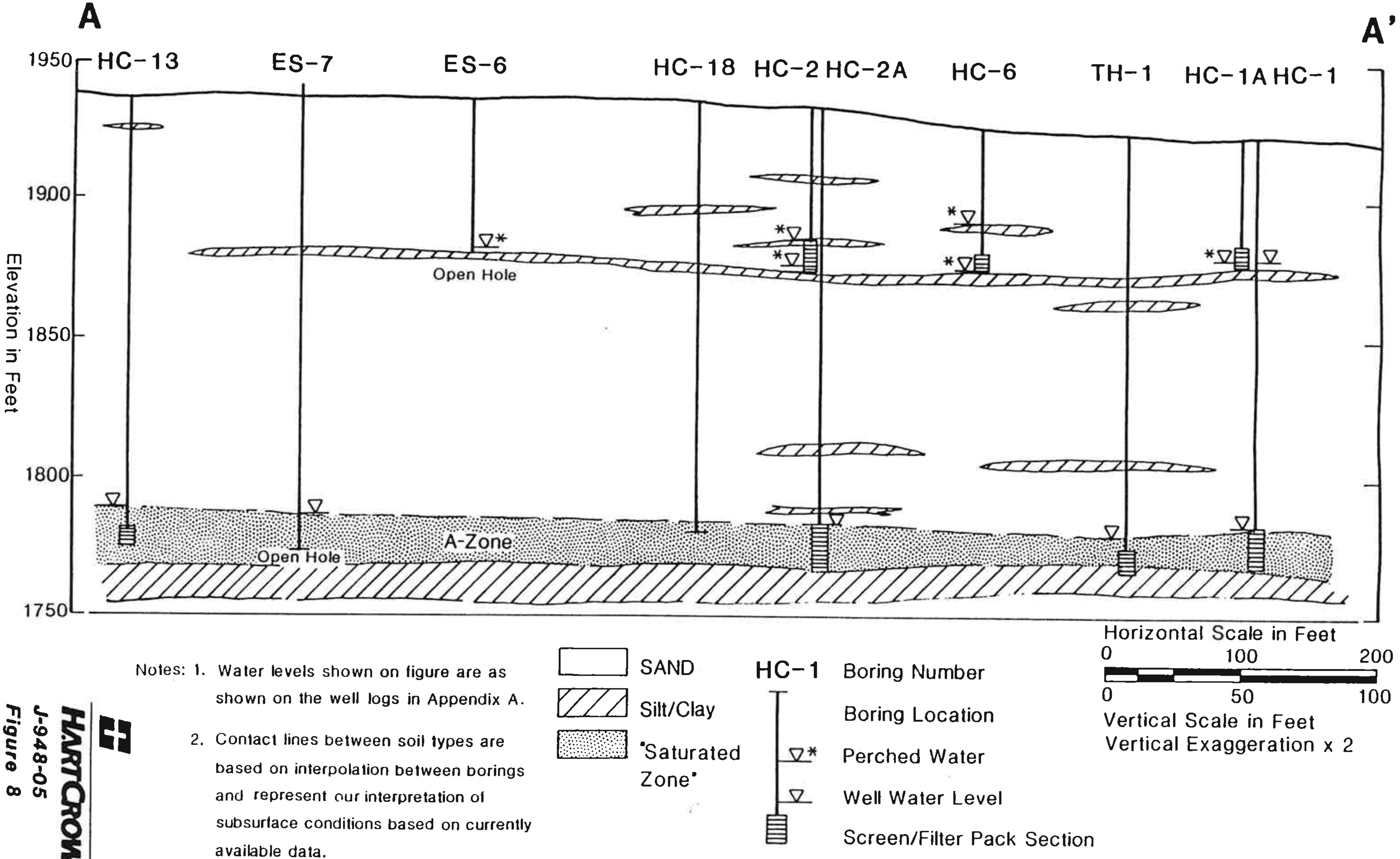
Figure 7

Schematic Geologic Cross Section A-A'



Notes: 1. Water levels shown on figure are as shown on the well logs in Appendix A.

2. Contact lines between soil types are based on interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

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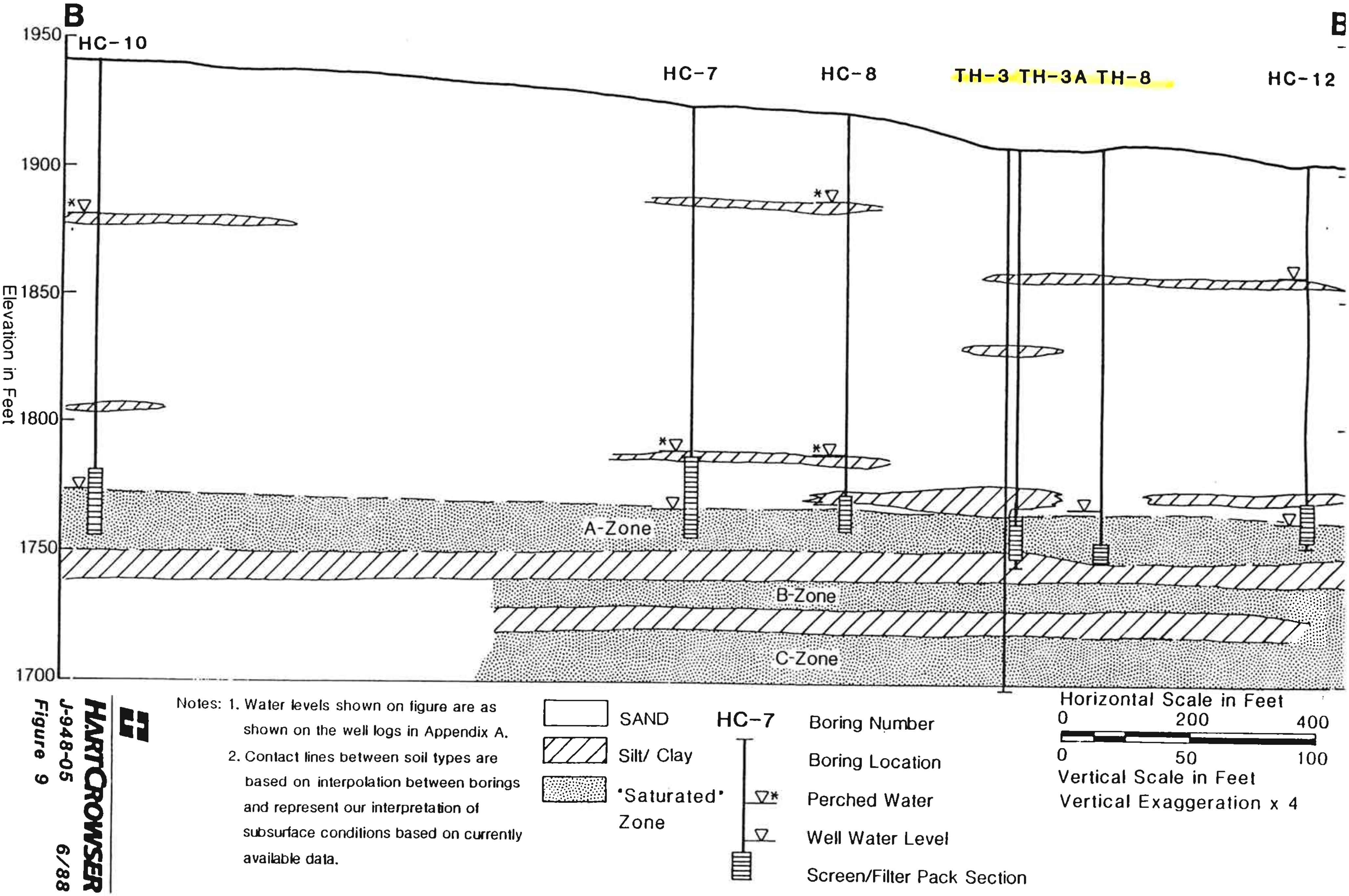
Figure 8

Sch‿matic Geologic Cross Section ‿-B'



Notes: 1. Water levels shown on figure are as shown on the well logs in Appendix A.

2. Contact lines between soil types are based on interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

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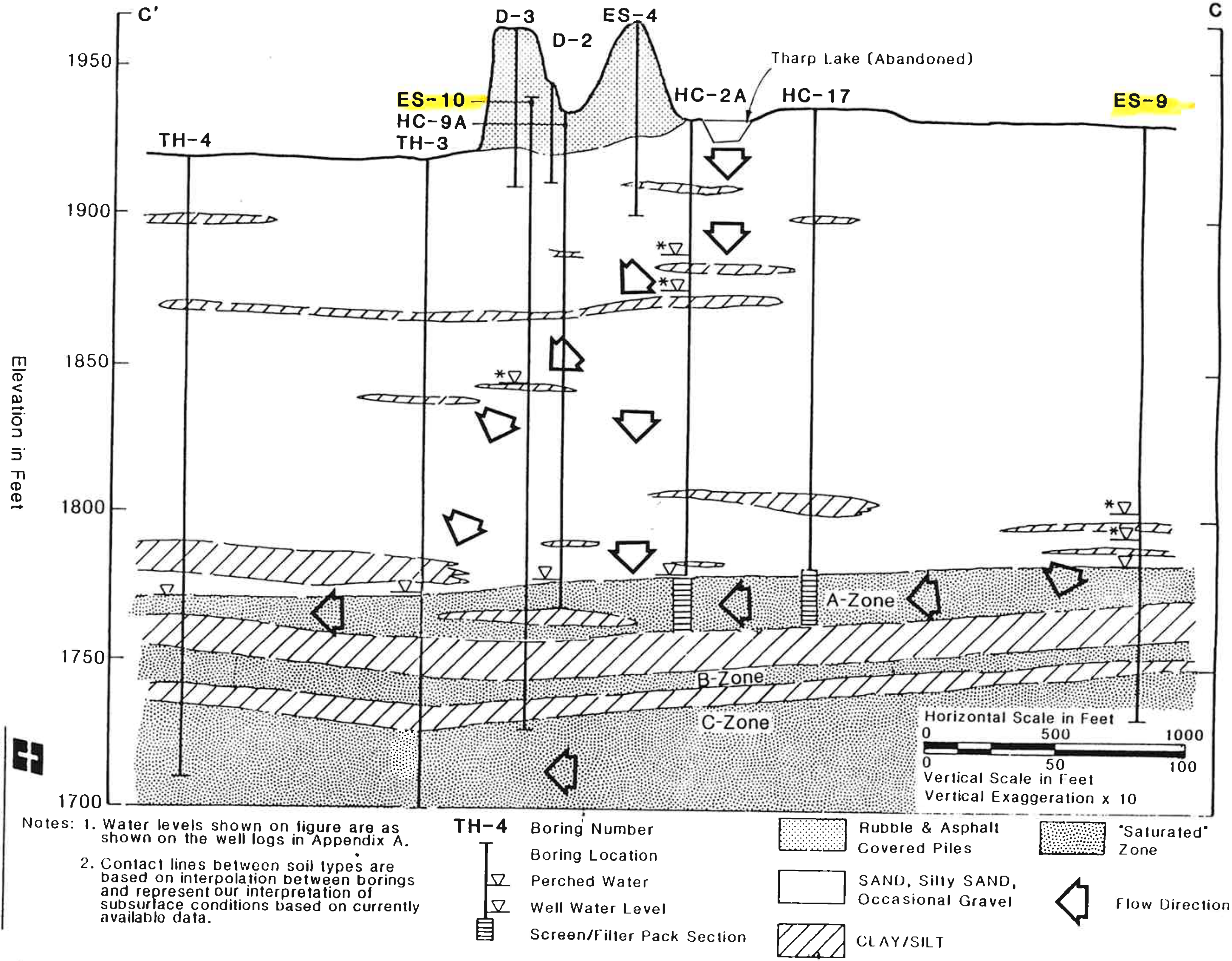
Figure 9

ematic Geologic Cross Section C-C' and Groundw. . Flow Patterns Beneath Mead Plant



Notes: 1. Water levels shown on figure are as shown on the well logs in Appendix A.

2. Contact lines between soil types are based on interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

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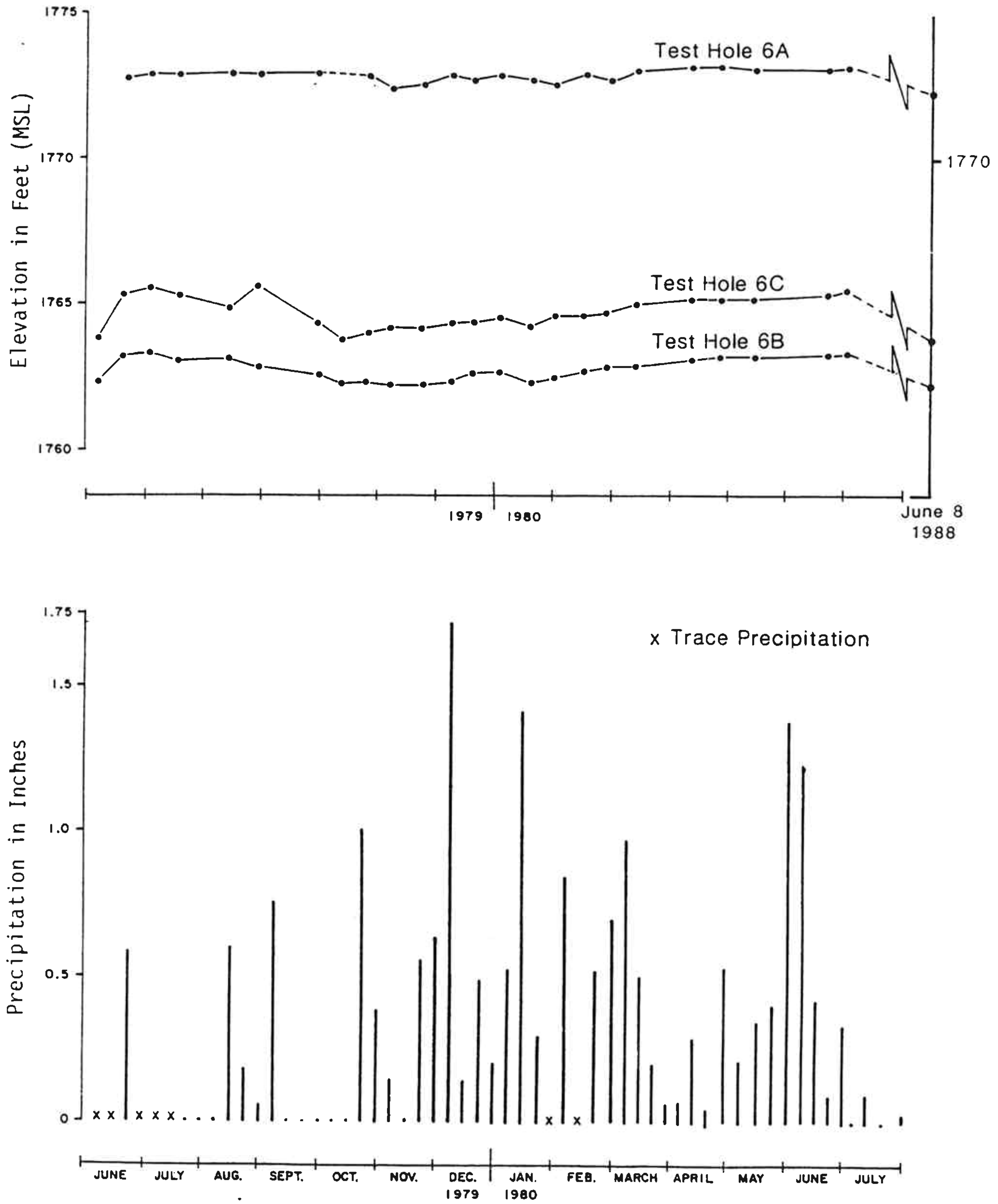
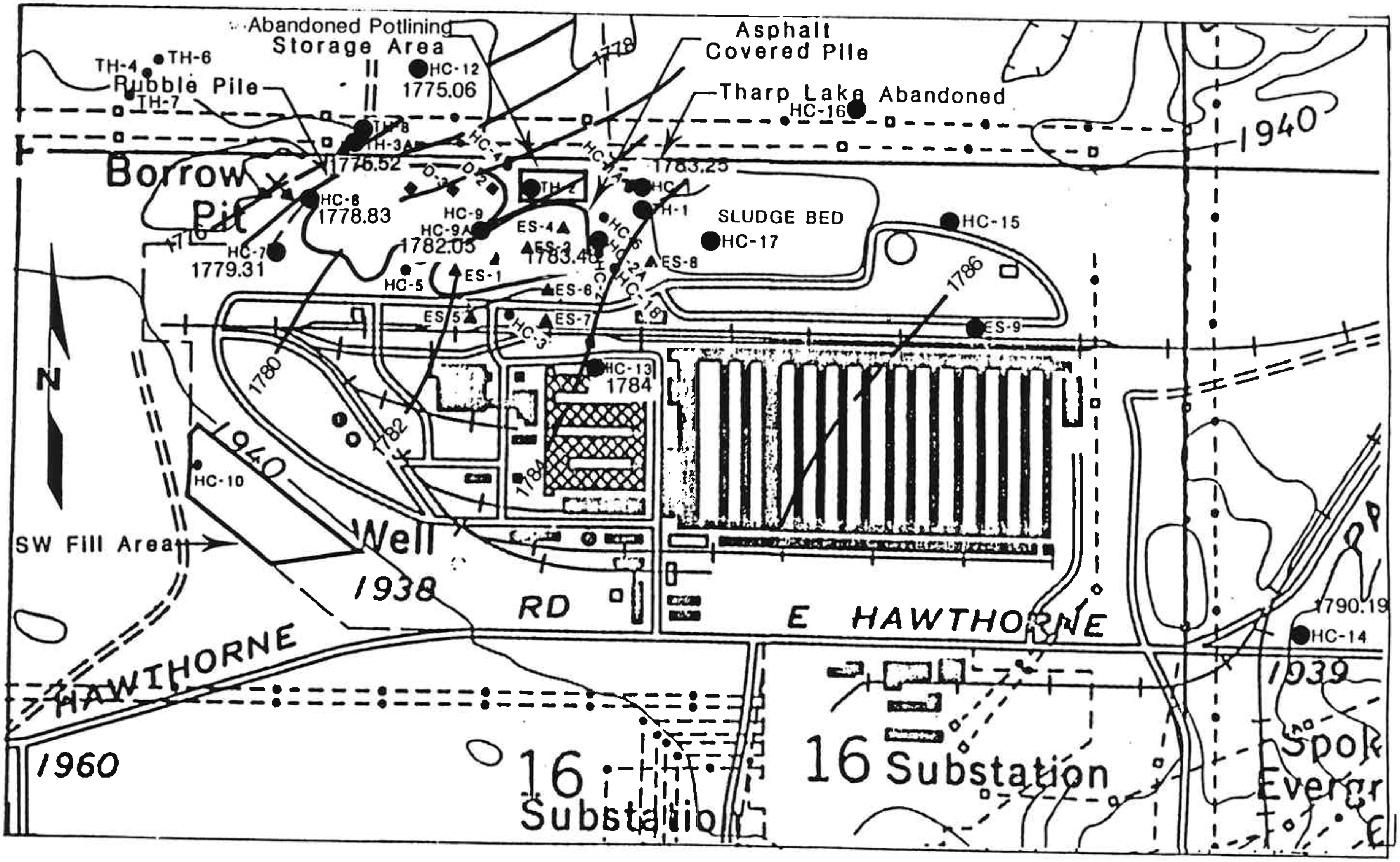
Figure 10

Water Levels in Zones A, B and C in Vicinity of Plant Site and Precipitation Data for Spokane Reporting Station



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 11

G ndwater Elevation Contour Ma Zone A September 1981



Dartford and Mead Quadrangles

Scale 1"-624'

● HC-8	Observation Well Location and Number Finished In A-Zone
1778.83	Spot Water Level Elevation in Feet
—— 1776 ——	Groundwater Elevation Contour in Feet

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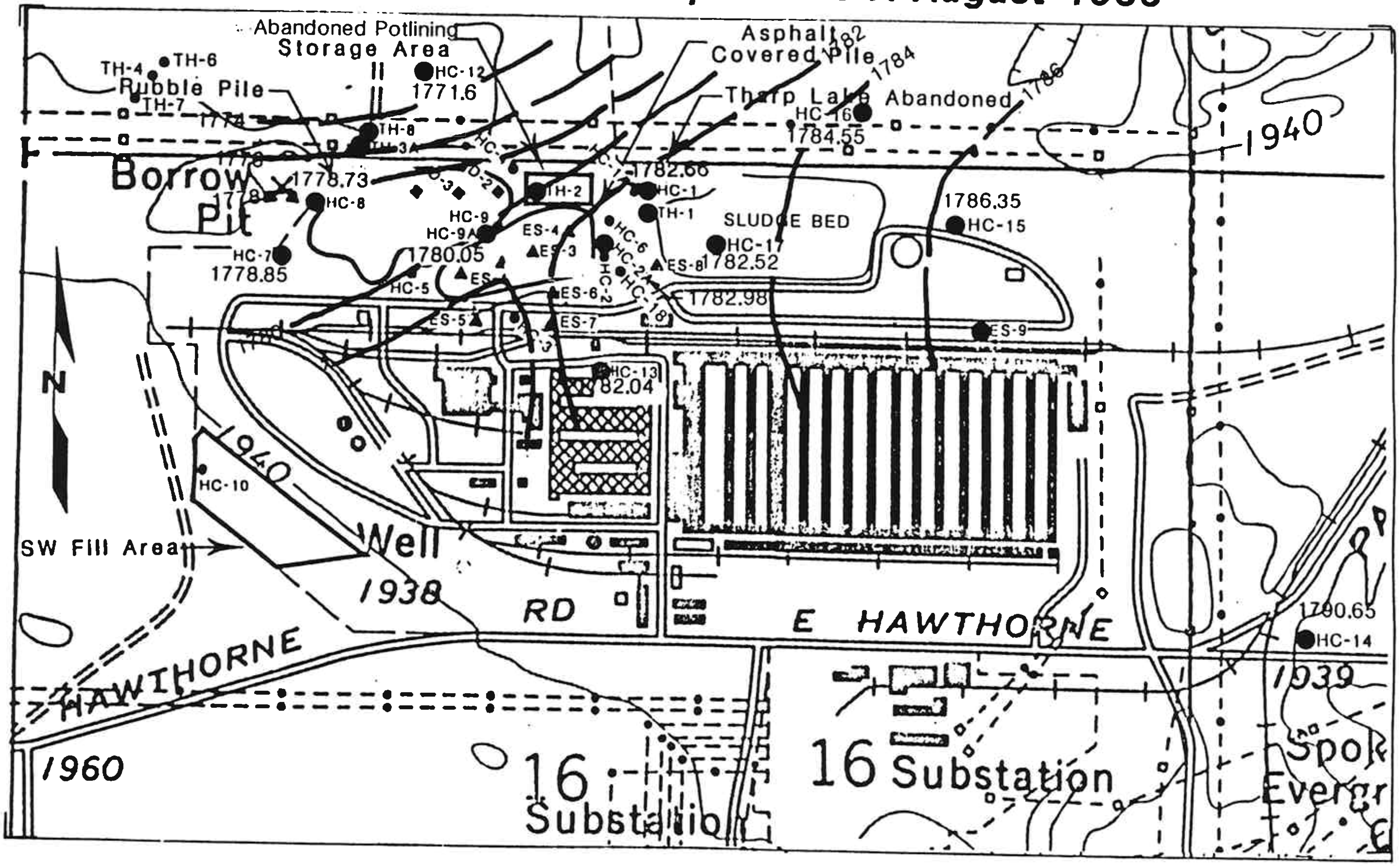
Figure 12

Gı ndwater Elevation Contour Ma - Zone A August 1988



Dartford and Mead Quadrangles

Scale 1"-624'

● HC-8 Observation Well Location and Number Finished in A-Zone

1786.35 Spot Water Level Elevation in Feet

1786 Groundwater Elevation Contour in Feet

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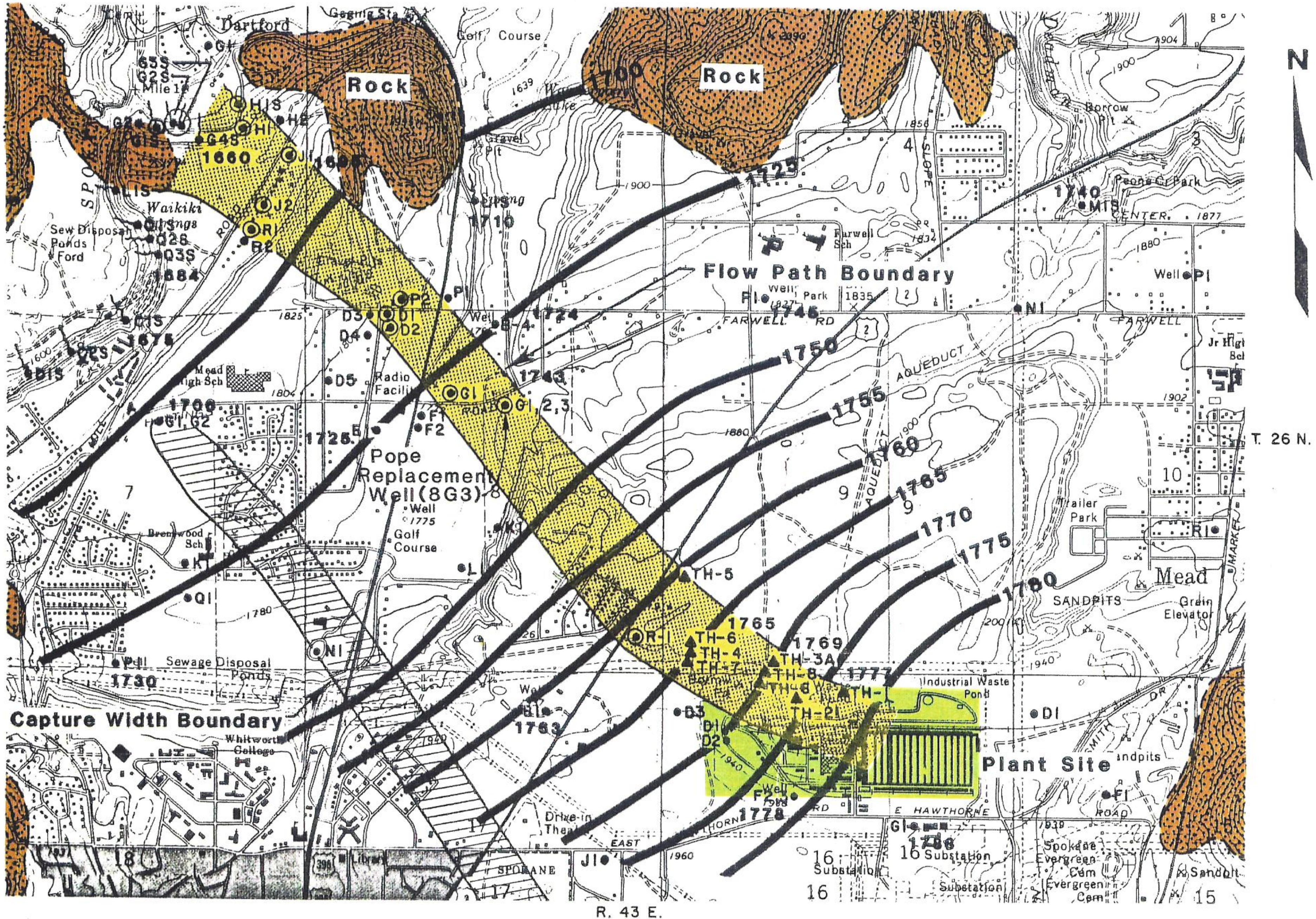
Figure 13

W er Table in Vicinity of Mead Plant Sh g Estimated Cyanide Flow Boundary d Capture Width Boundar, r Whitworth Well 7G2



- Spring
- ● Well
- ▲ Test Hole

◉ Selected Well or Spring Showing Cyanide >100ppb

● 1725 Water Level Elevation in Feet used in Construction of Water Table Map

0 .25 .5 MILE

Water Table Elevation

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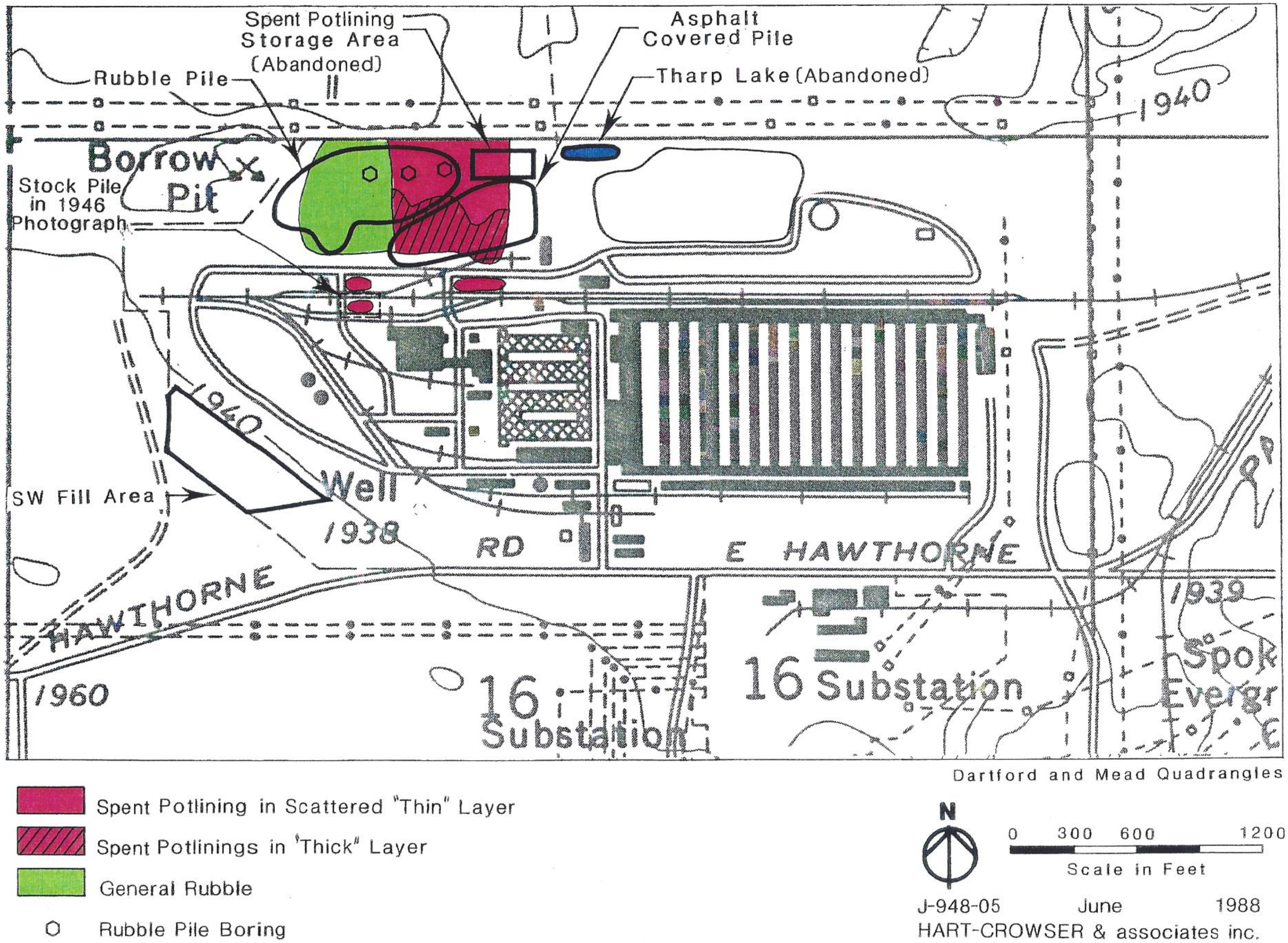
Figure 14

Extent of Spent Potlining Disposal Operations 1946 - 1959



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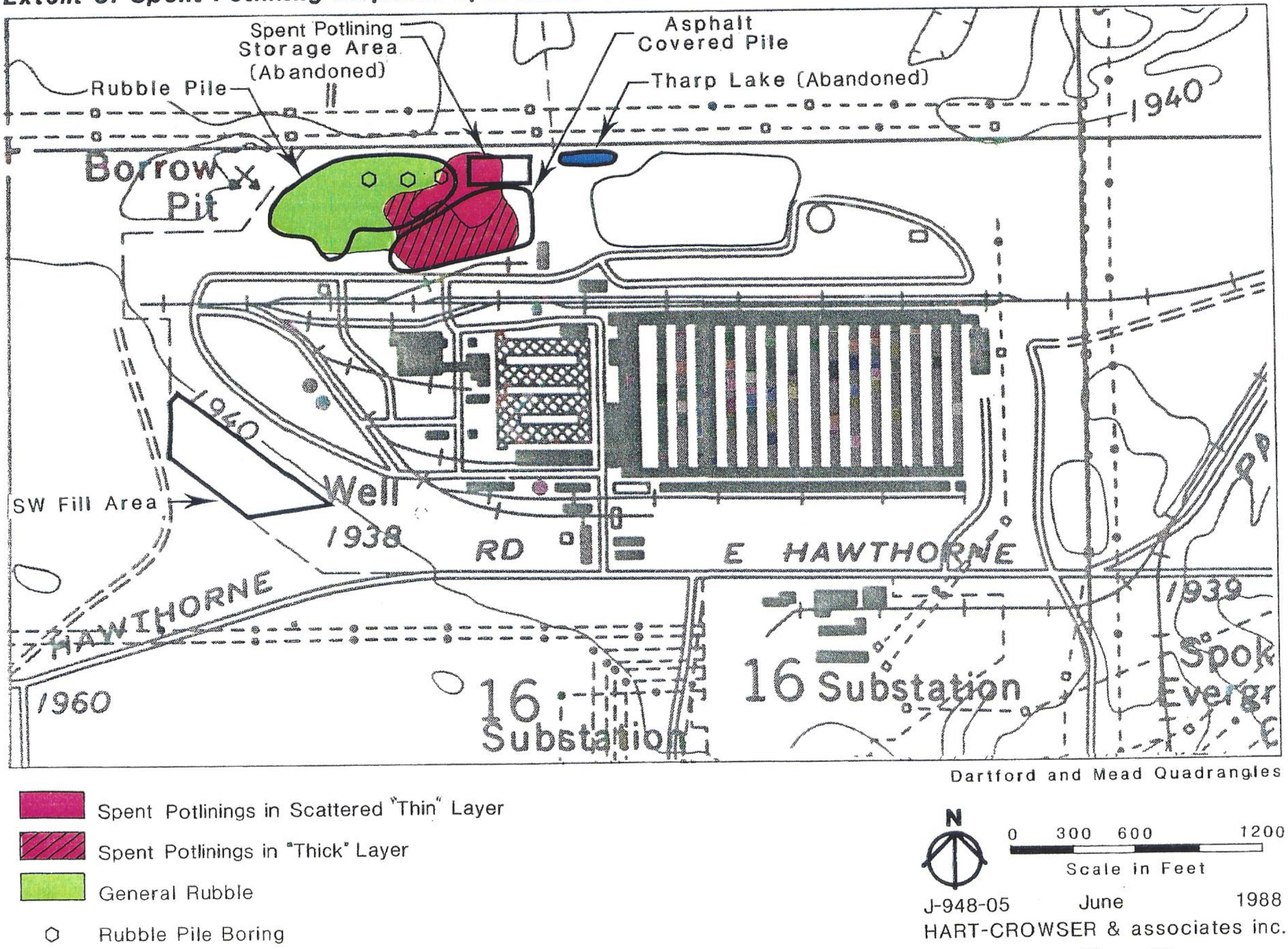
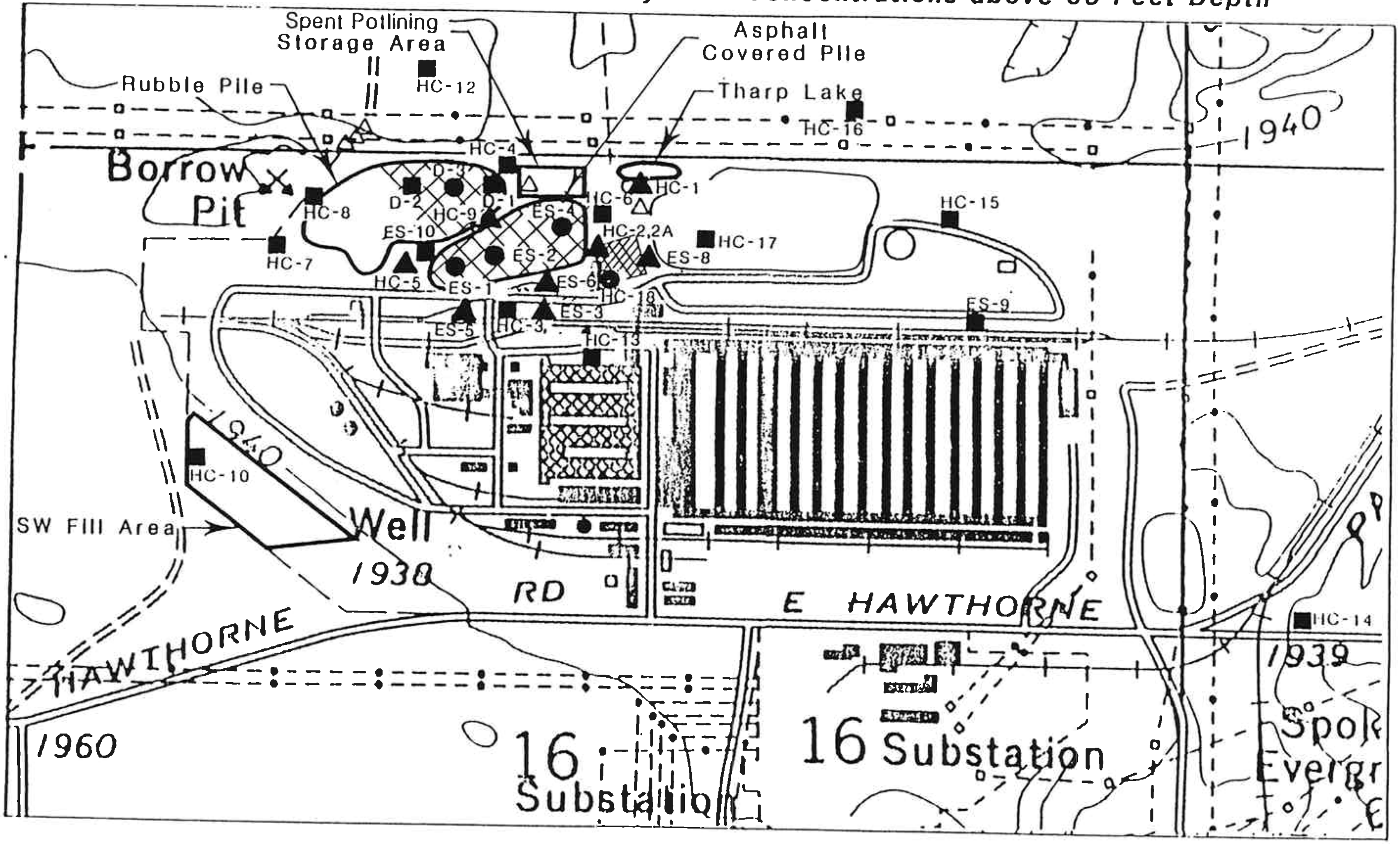
Extent of Spent Potlining Disposal Operations 1962 - 1972



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 16

Extent of Spent Potlining Material and Soil Cyanide Concentrations above 50 Feet Depth



Dartford and Mead Quadrangles

▨ Spent Potlining Material

● + 100 ug/g

▲ 10 to 100 ug/g

■ > 10 ug/g

Note: At least two samples had to display concentrations within the indicated range to be included in that range.

0 300 600 1200

Scale In Feet

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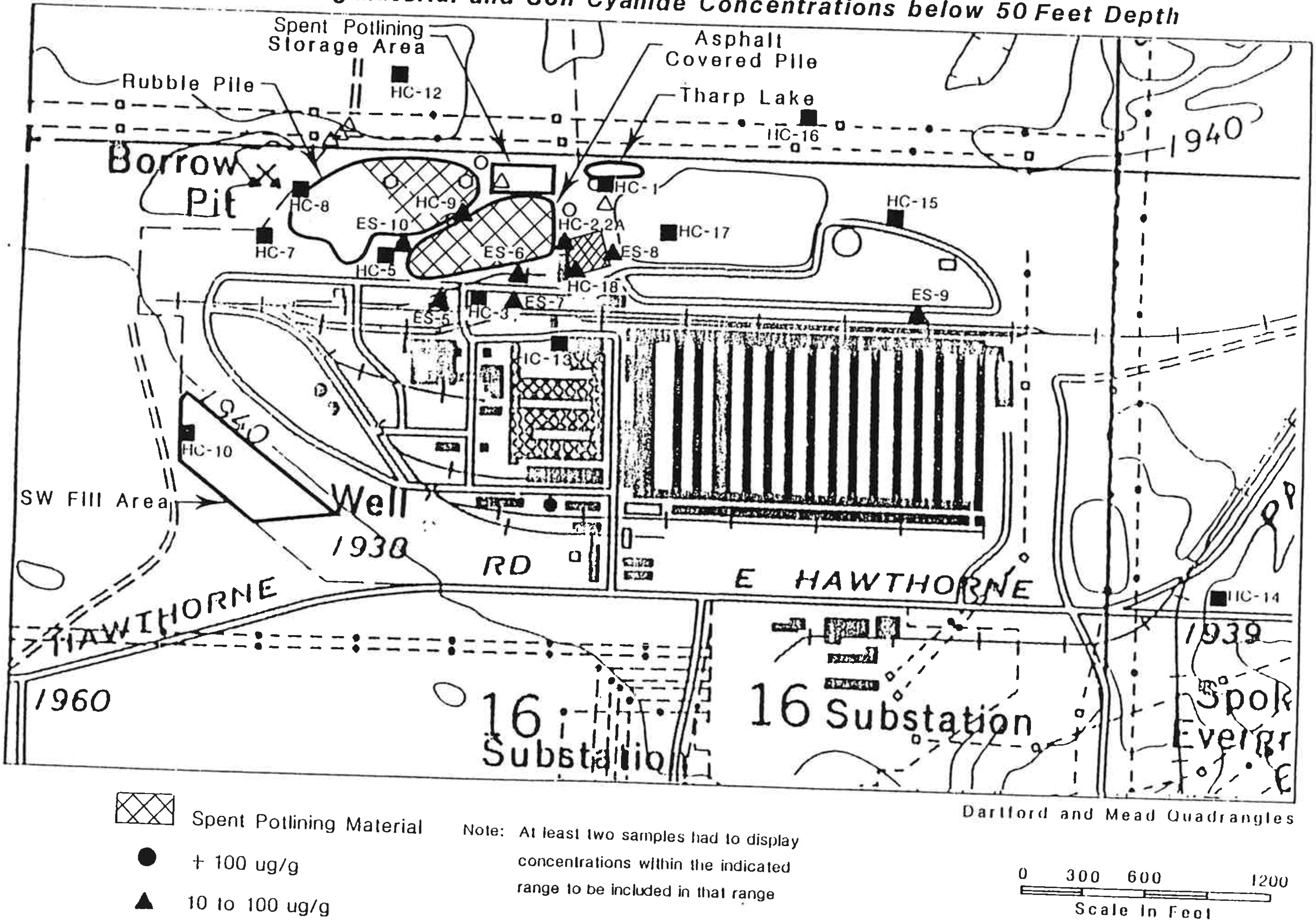
Figure 17

Extent of Spent Potlining Material and Soil Cyanide Concentrations below 50 Feet Depth



▨ Spent Potlining Material

● + 100 ug/g

▲ 10 to 100 ug/g

■ > 10 ug/g

Note: At least two samples had to display concentrations within the indicated range to be included in that range

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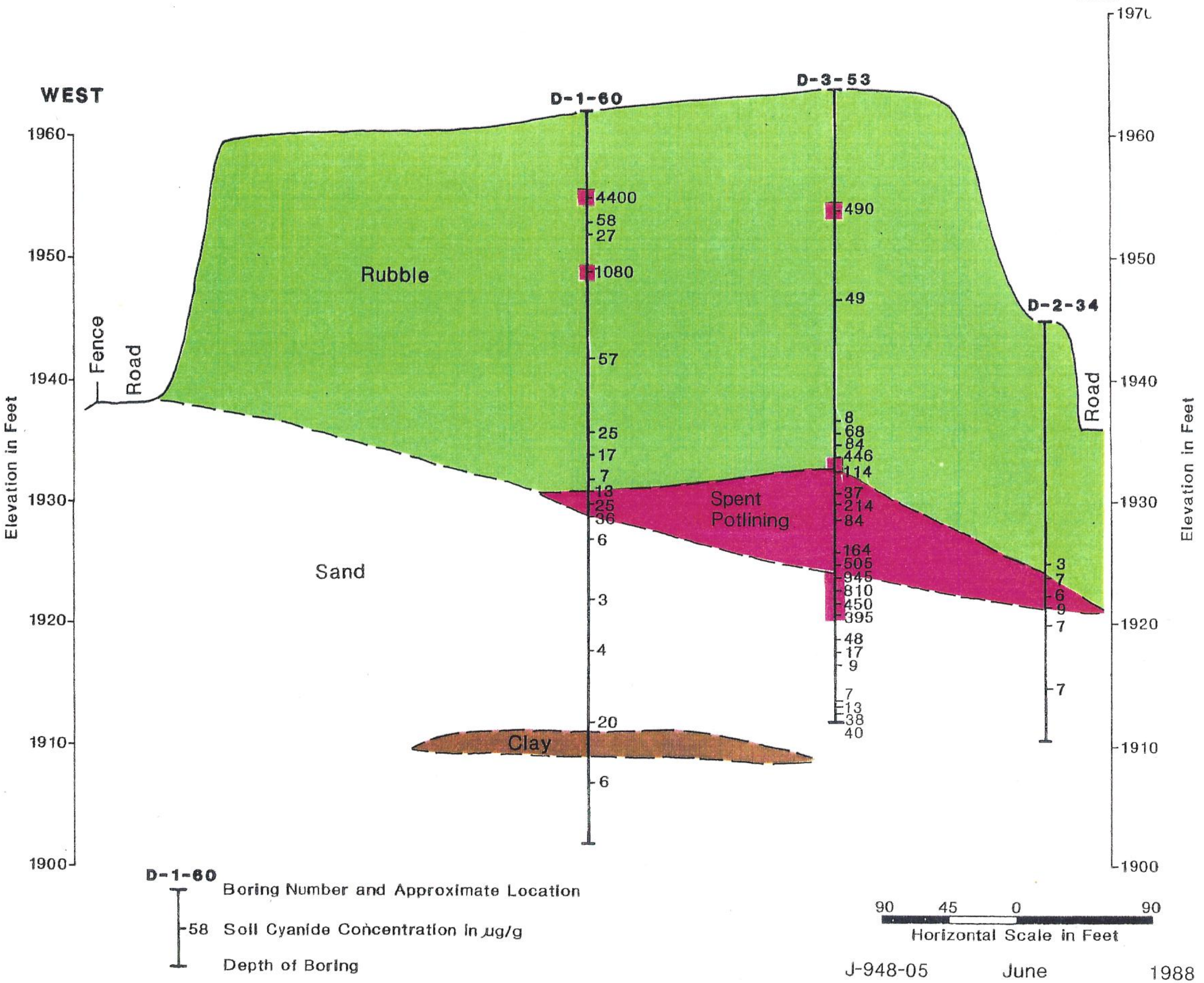
Schematic Geologic Cross Section - Ru Pile



J-948-05 June 1988

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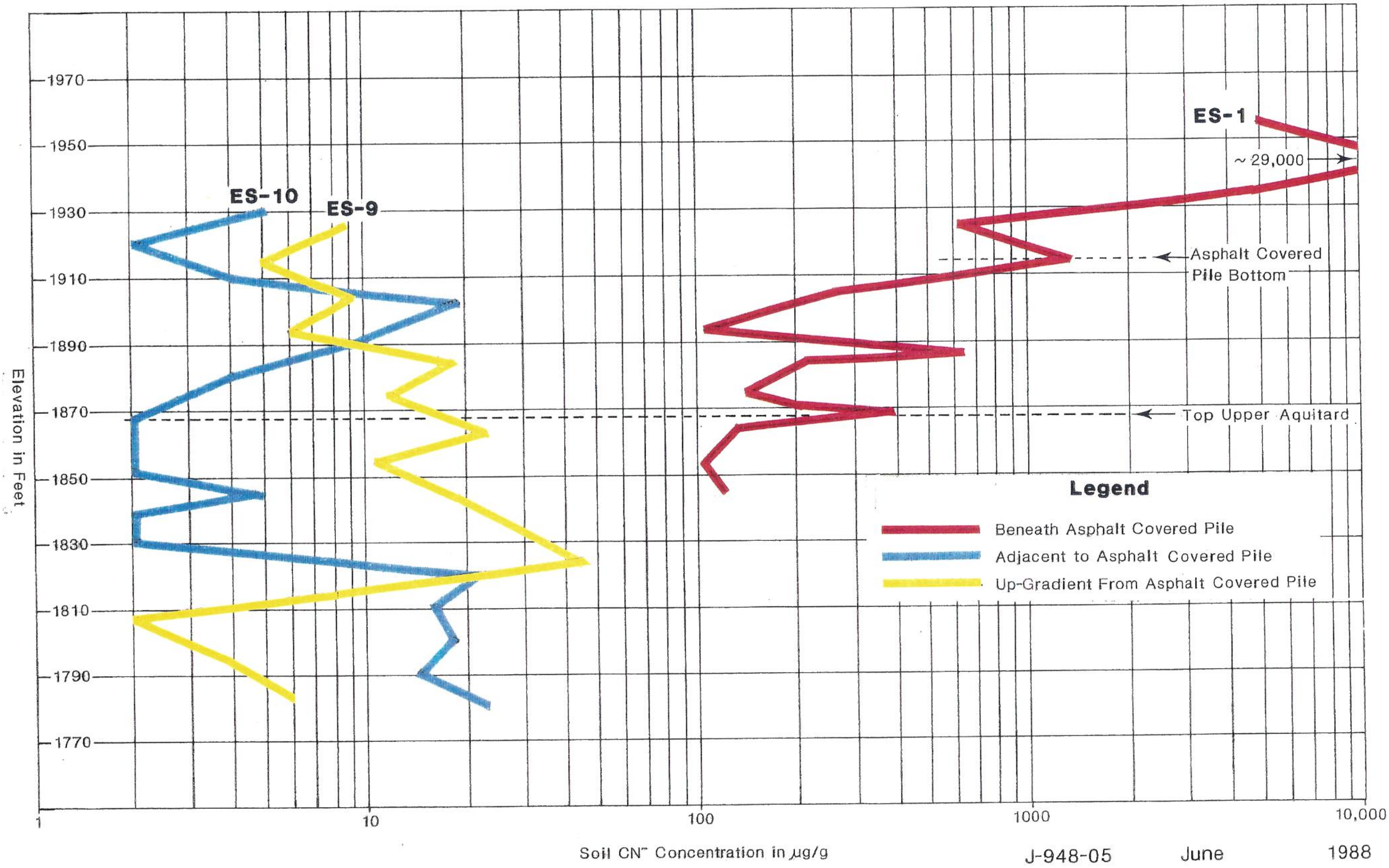
Soil Cyanide Concentrations Beneath Mead Plant



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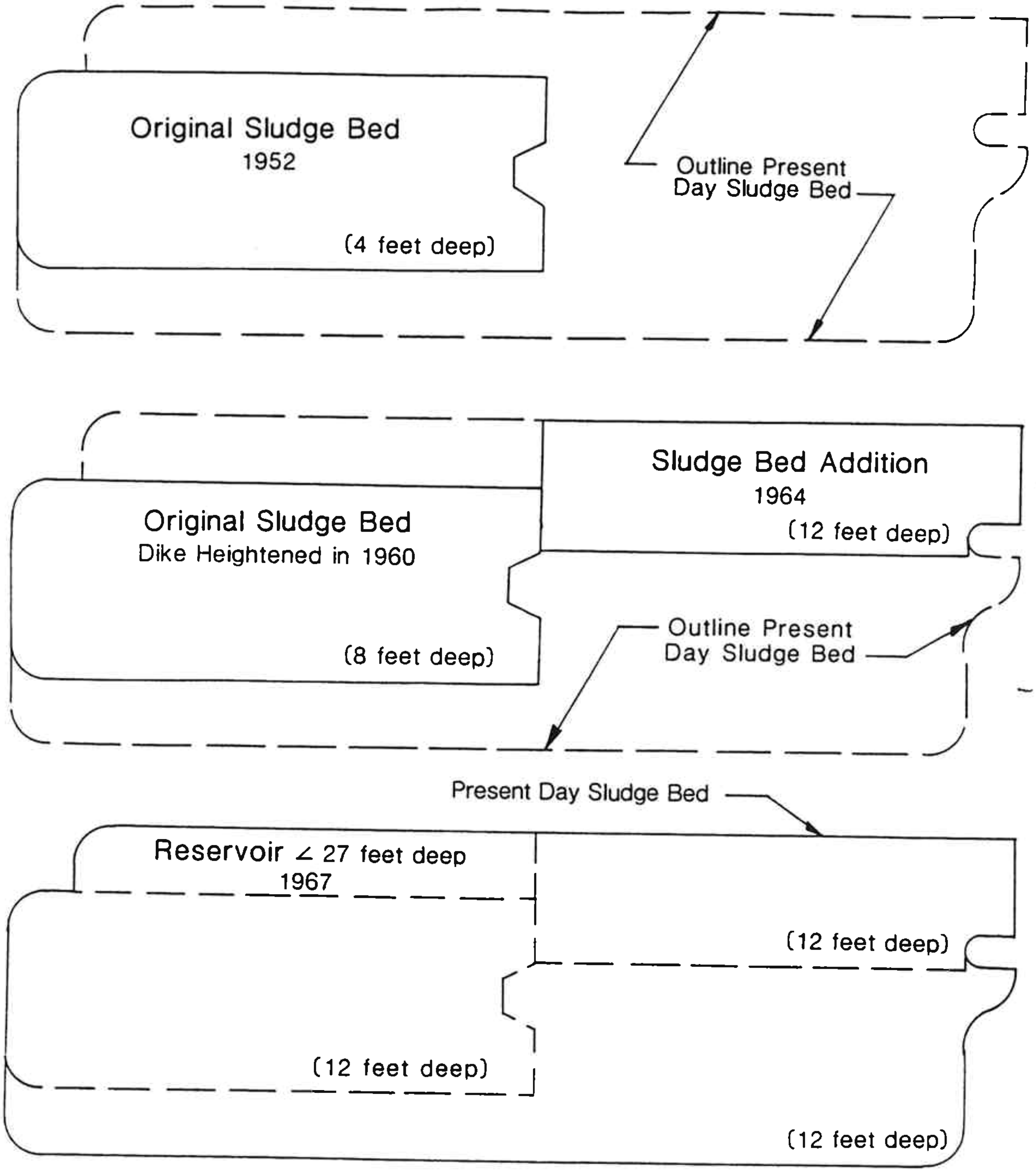
Sludge Bed Construction Sequence



NOT TO SCALE

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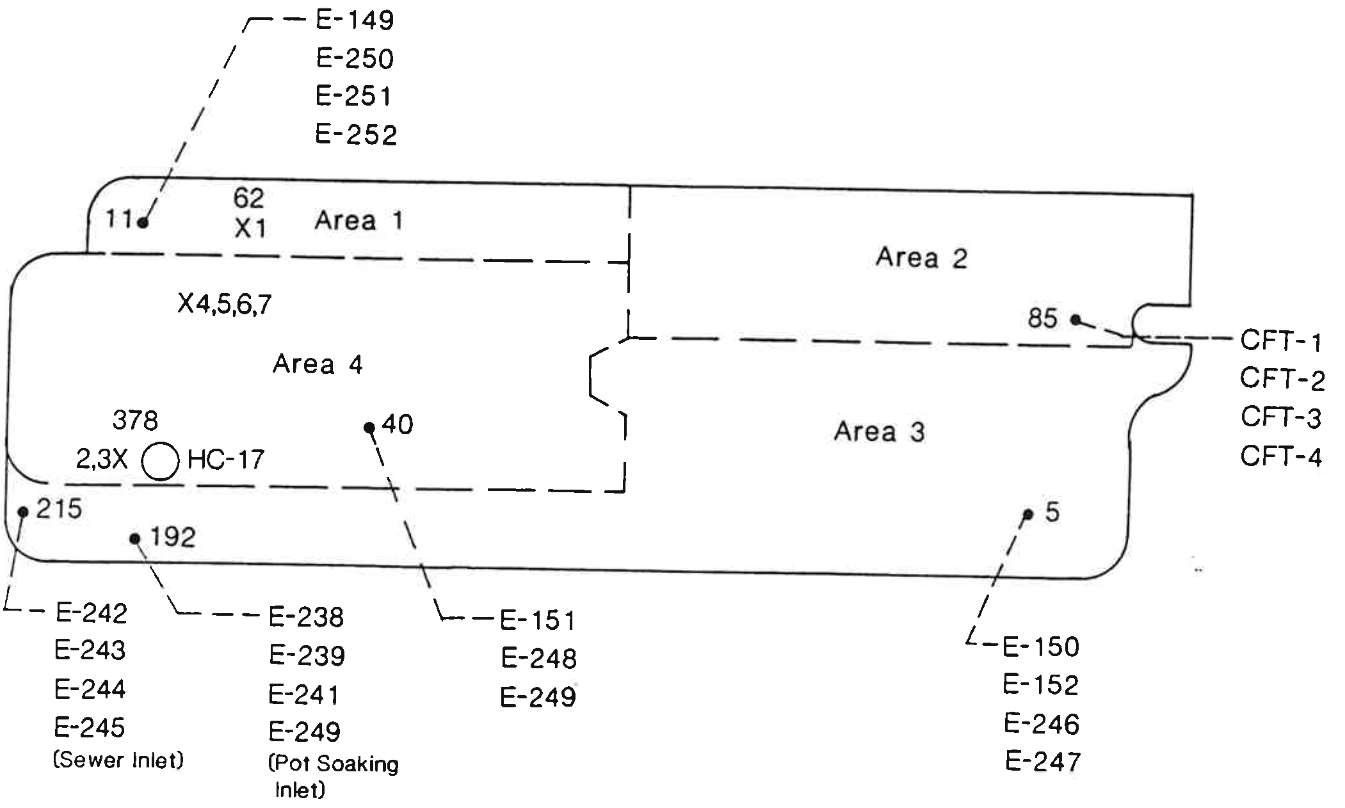
Figure 21

Sludge Bed Sampling Location Plan



Note: See Table 2 for analytical results and other data.

○
X
●
Approximate Sampling Location

192 Average Total Cyanide Concentration in Soil in ppm

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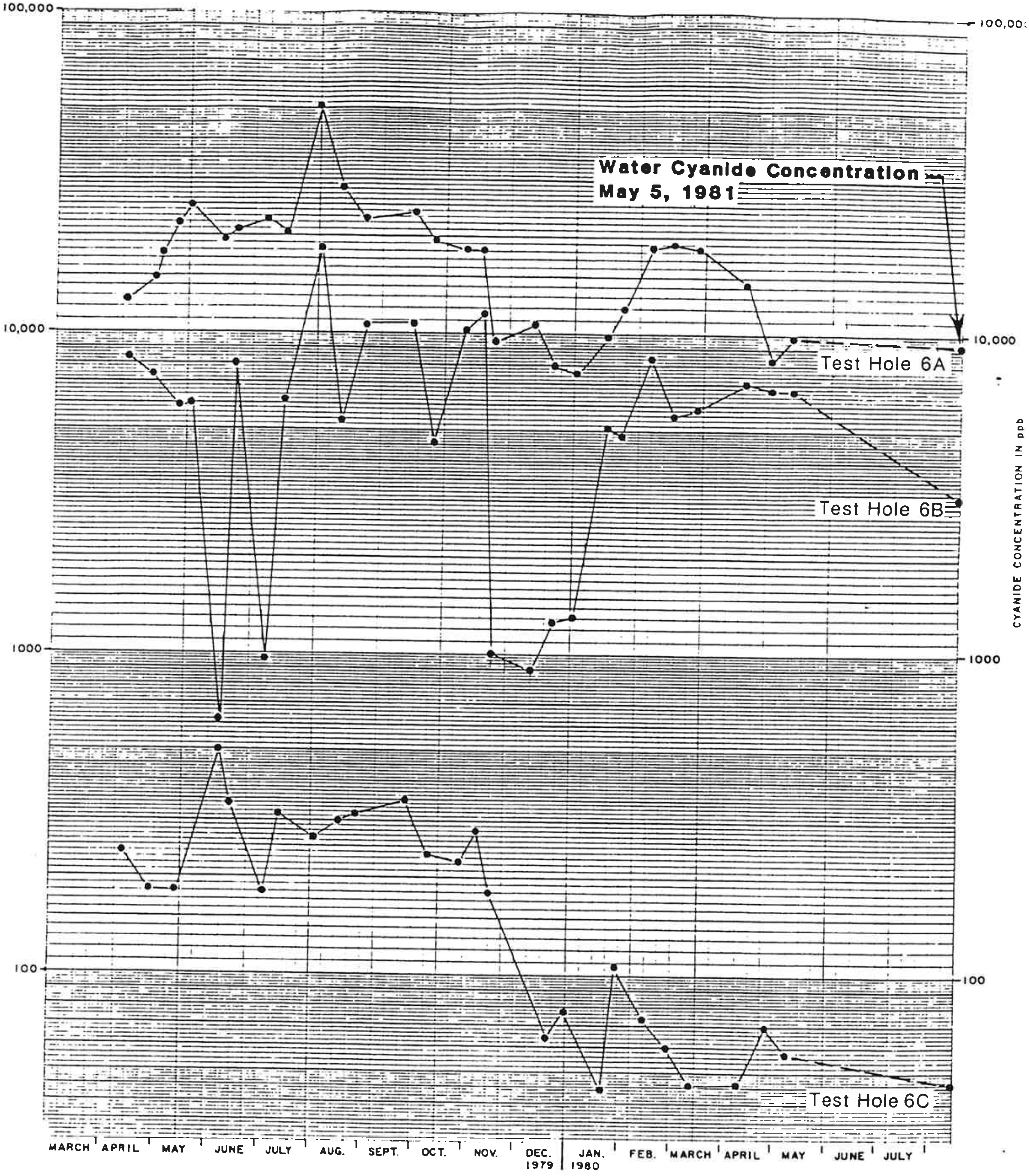
Figure 22

Cyanide Concentration in Zones A, B and C for Test Hole 6



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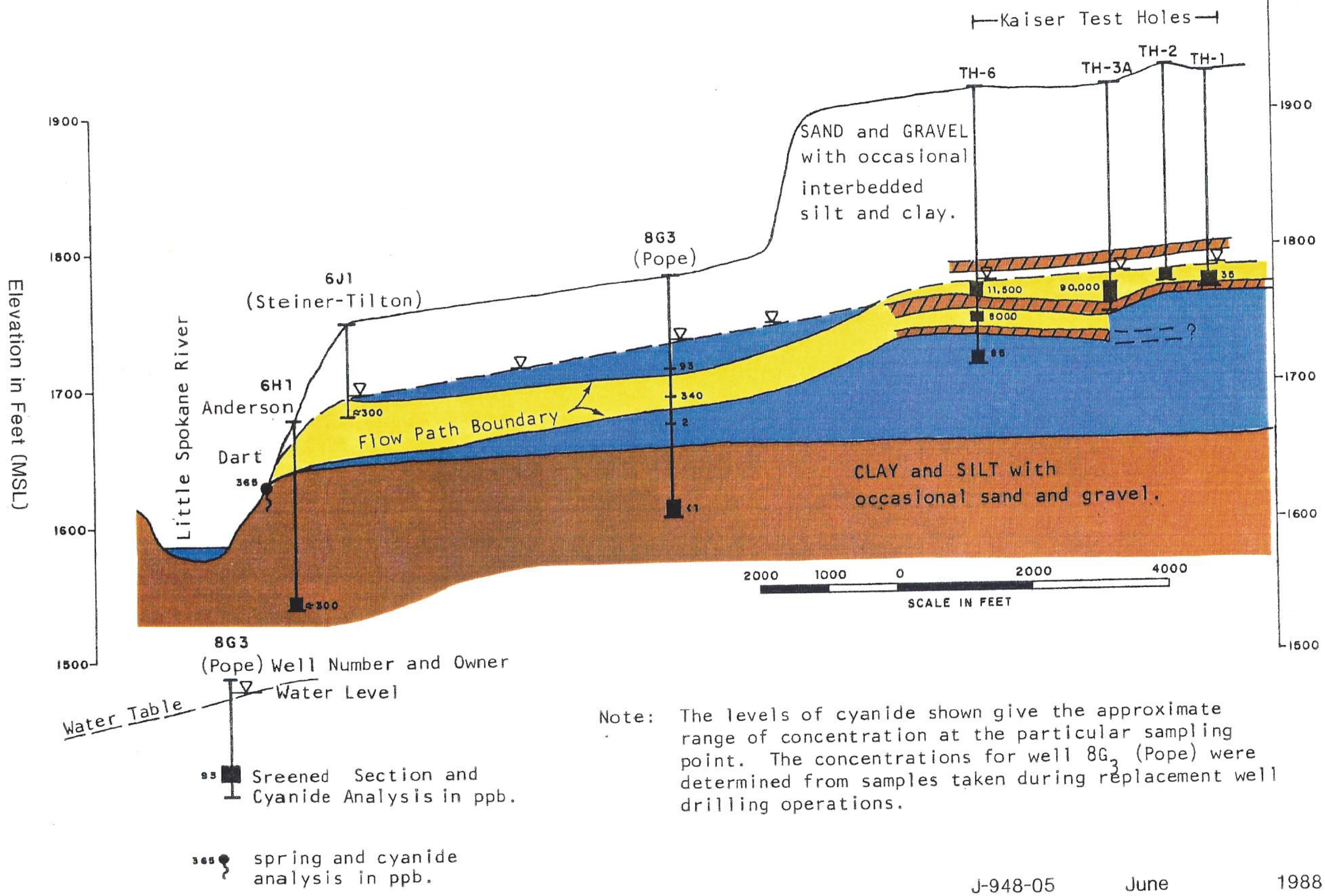
HART-CROWSER & associates inc.
Figure 23

Cyanide Flow - Path Profile Downgradient of Plant Site Sources



Note: The levels of cyanide shown give the approximate range of concentration at the particular sampling point. The concentrations for well $8G_3$ (Pope) were determined from samples taken during replacement well drilling operations.

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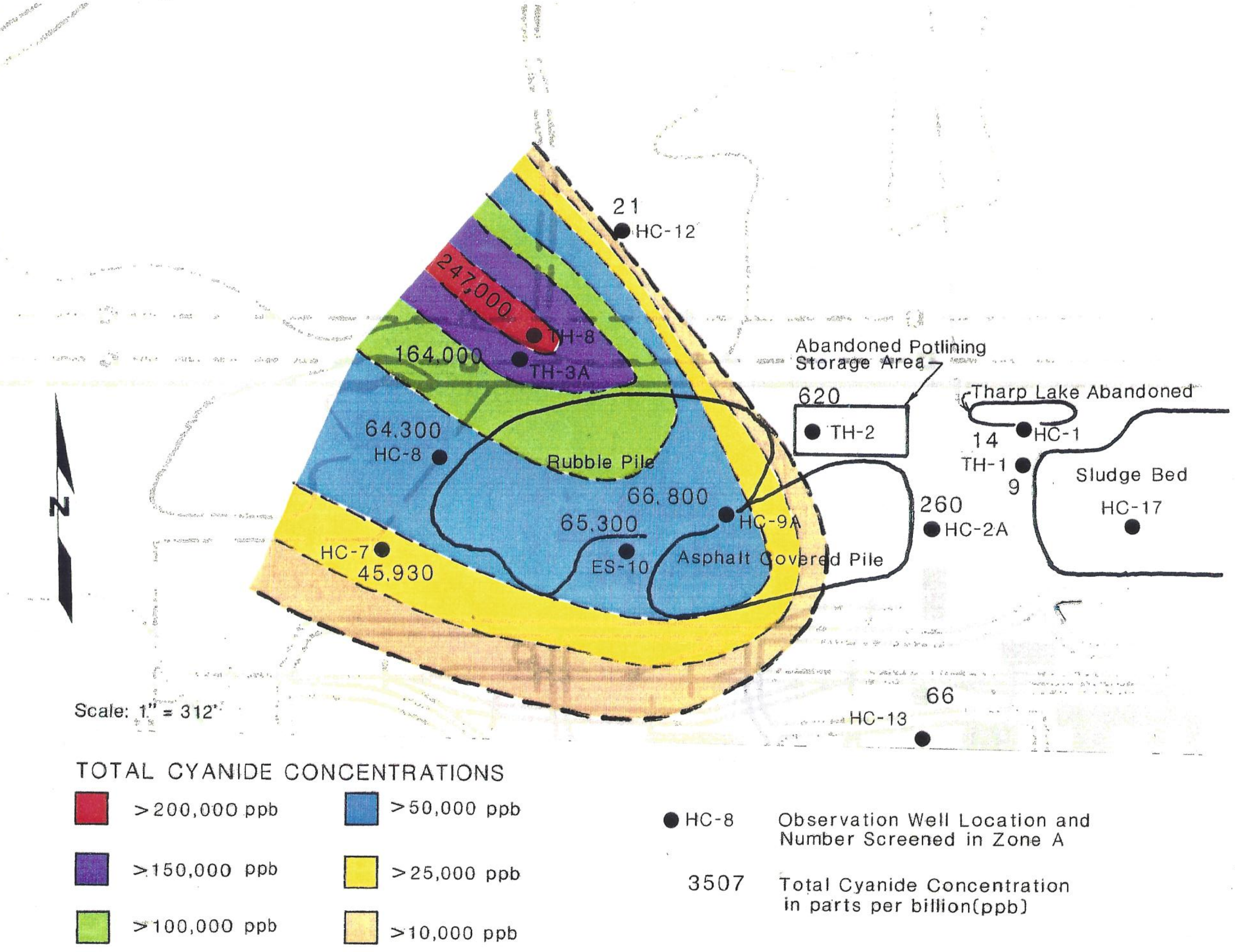
Figure 24

Zone Cyanide Concentrations October 1981



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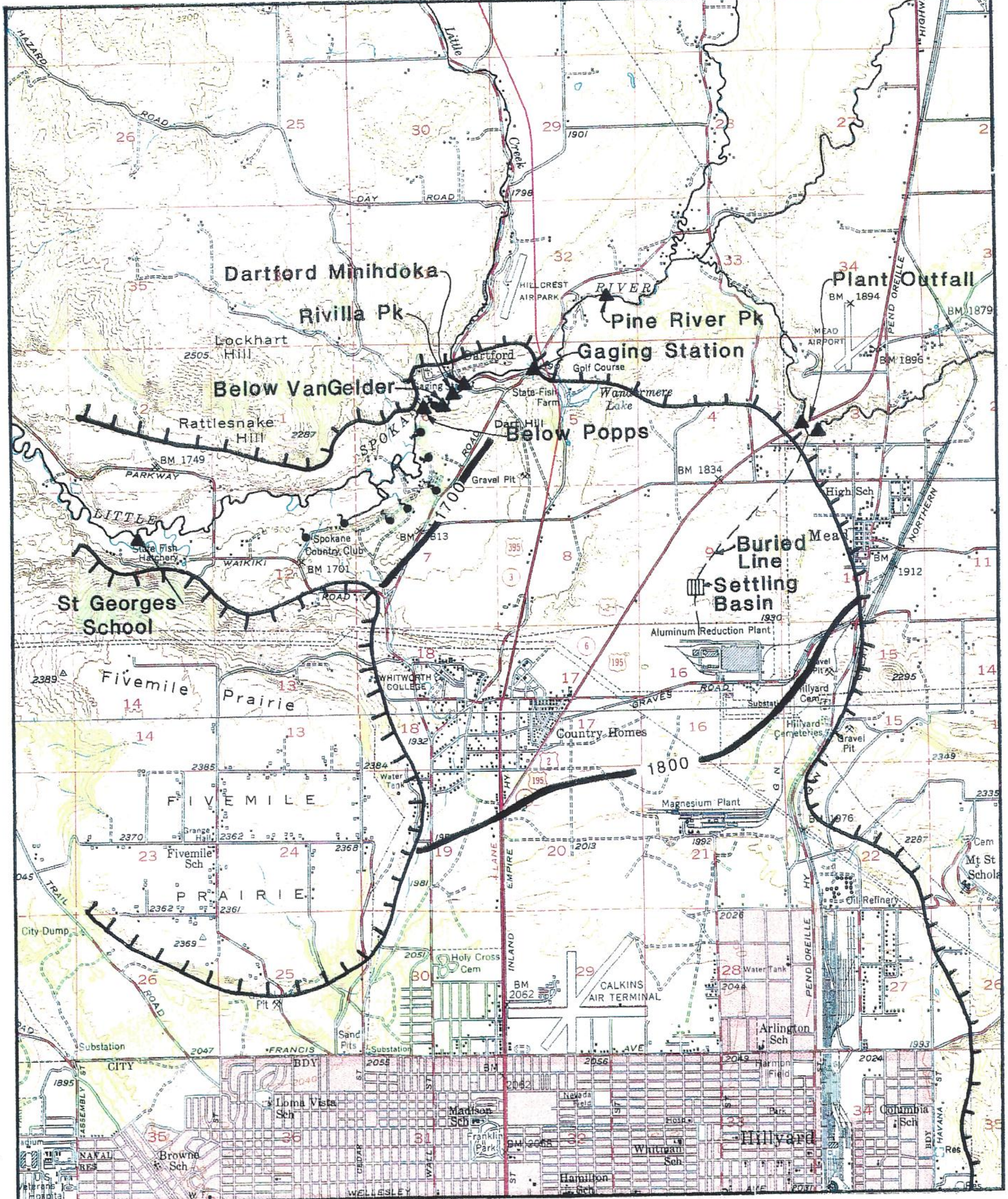
HART-CROWSER & associates inc.
Figure 25

Surface Water Sampling Location Map



Base map prepared from USGS 15-minute quadrangles of Deer Park and Spokane, Washington, dated 1949/1950.

▲ Surface Water Sampling Locations

Springs

Aquifer Boundary

1700 Water Table Contour

Scale in Miles: 0 1 2

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Figure 26

Comparison of River Flows and Cyanide Concentrations in the Little Spokane River

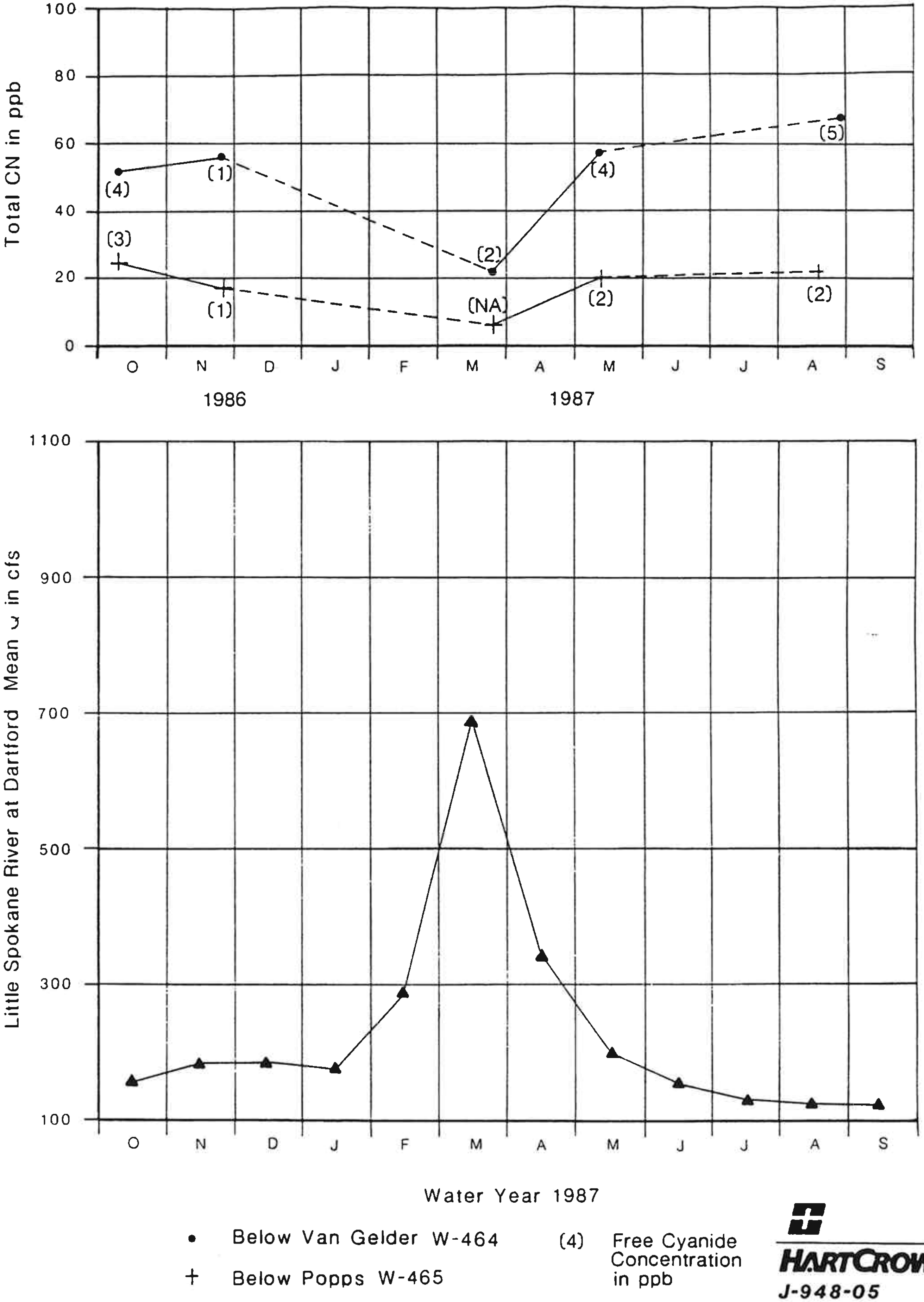

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Figure 27

Plot **Cyanide Decline in Test Hole 1**

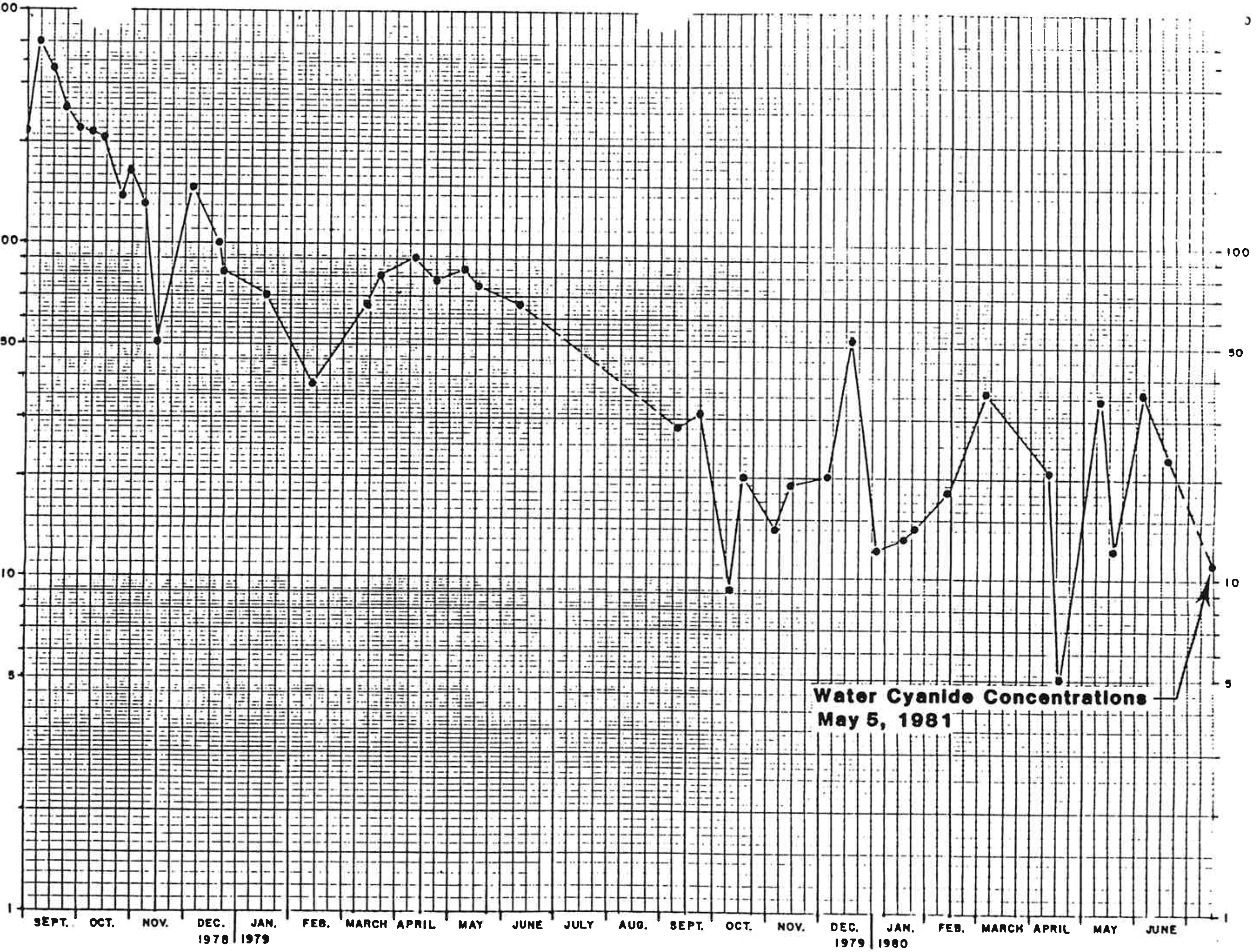

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Figure 28

Schematic Cyanide Flow Paths Beneat ead Plant

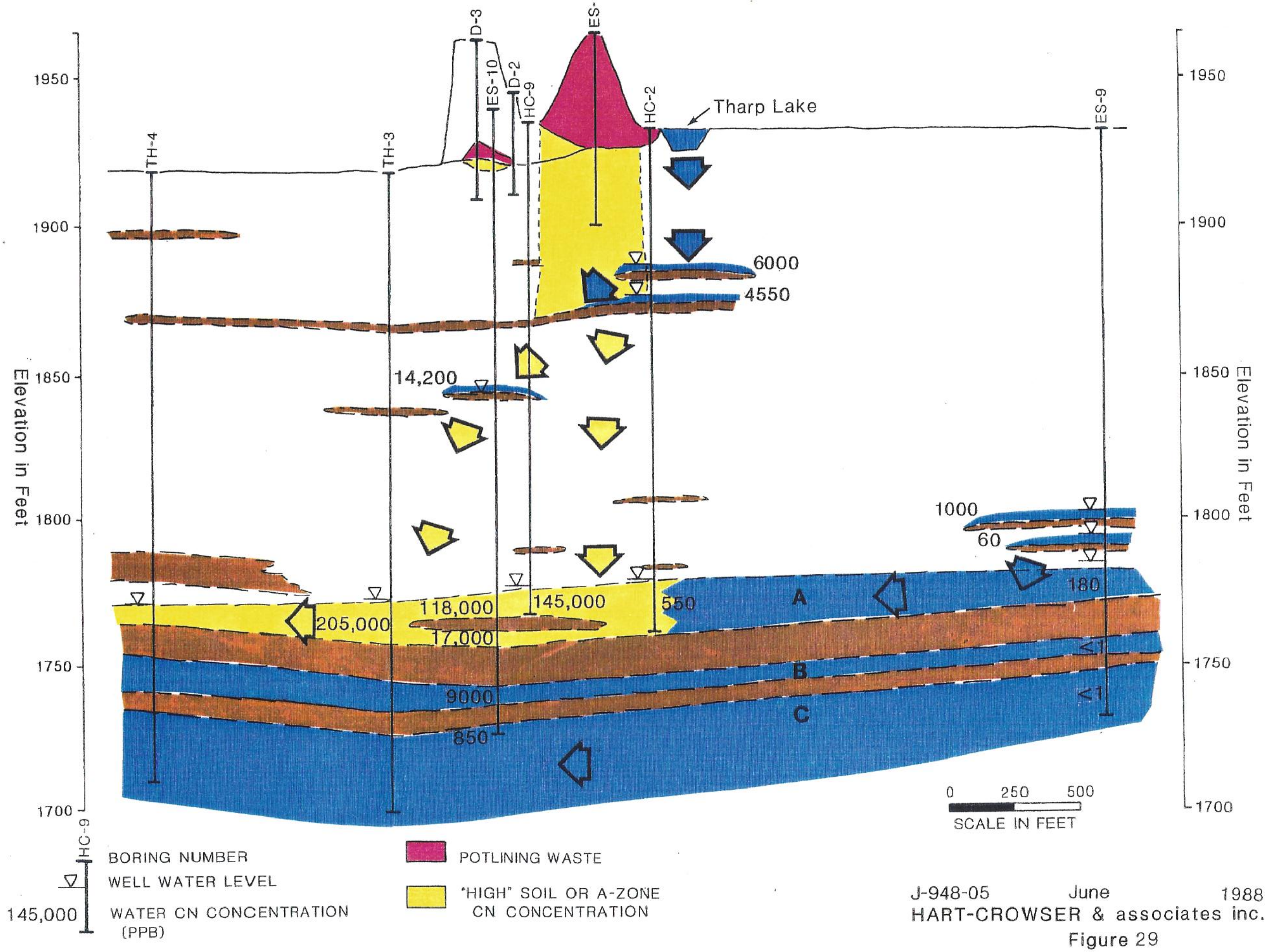

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Figure 29

Co[illegible]ur Map - Top of Upper Aquitard

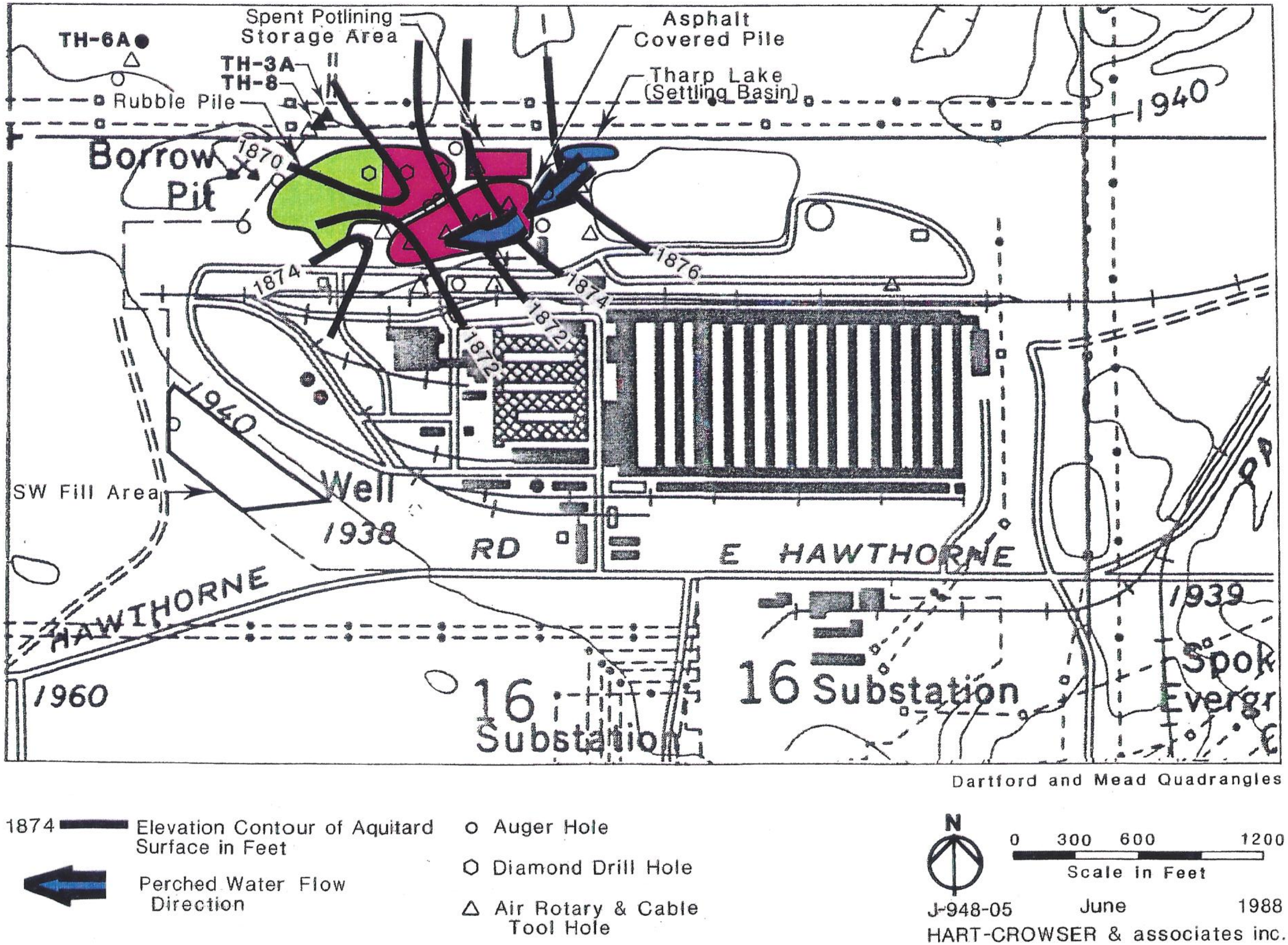

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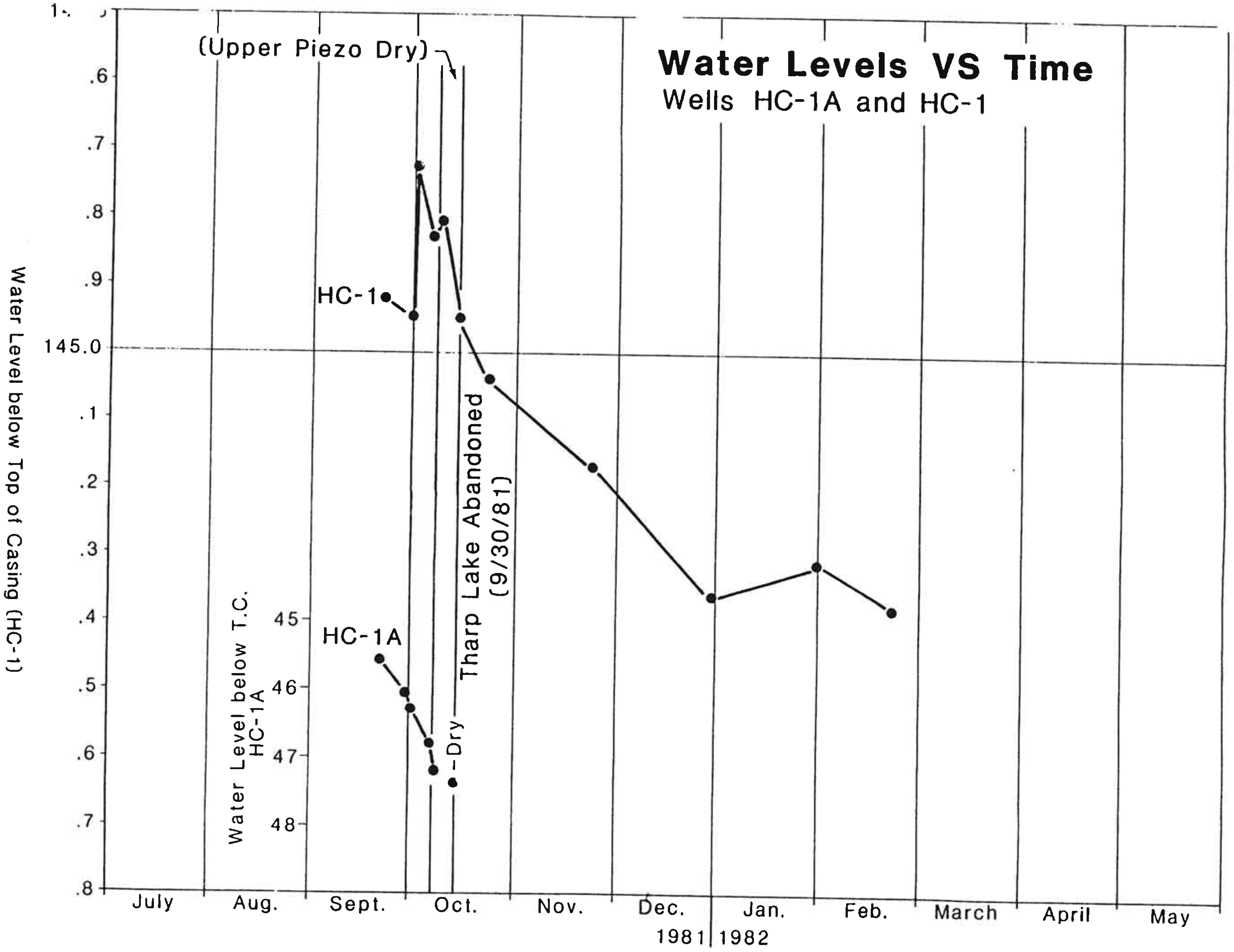
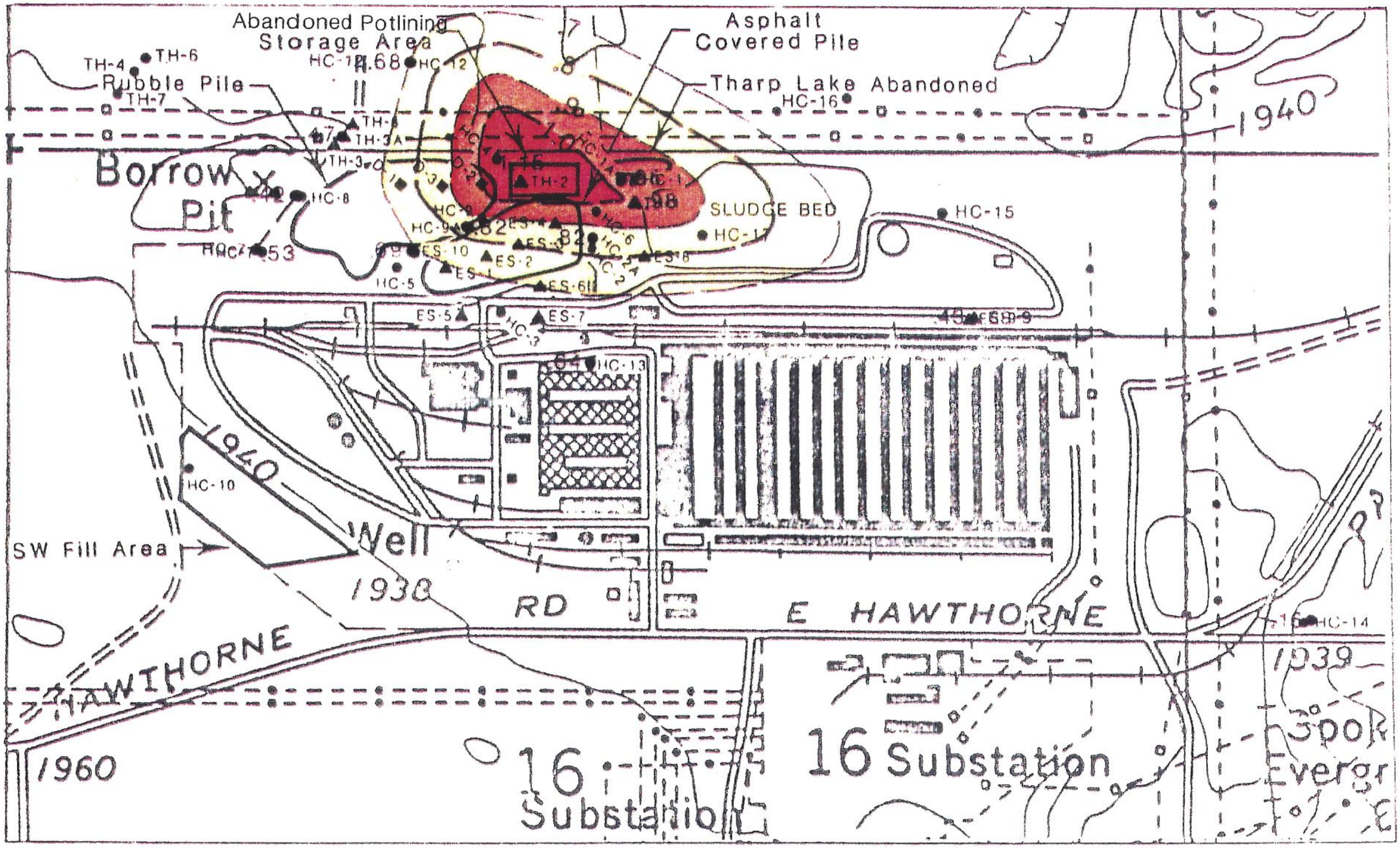
Figure 30



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 31

Well and Boring Location Map



Decline in A-Zone Water Table

July, 1981 to September, 1982

N

Scale 1"-624'

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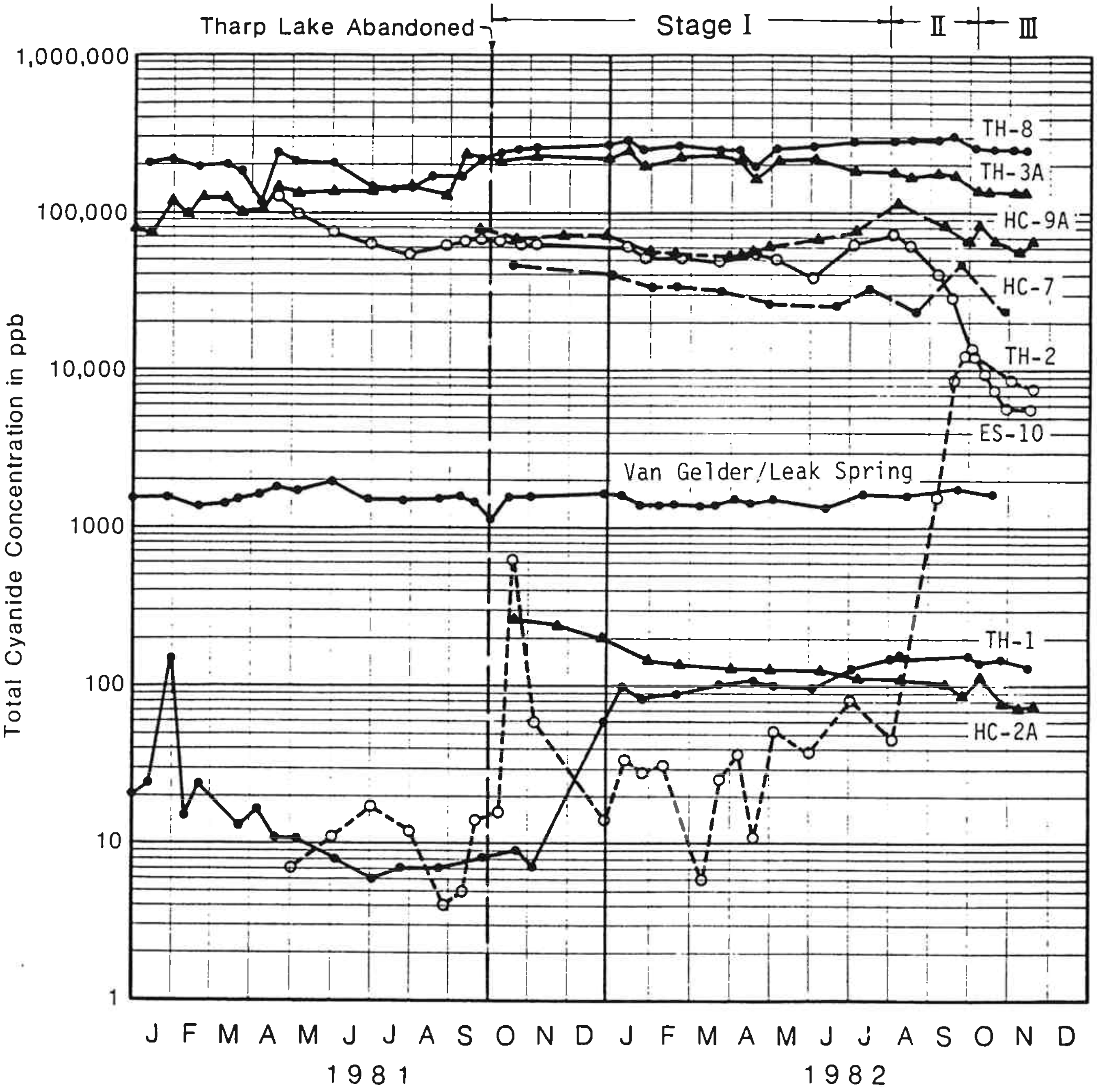
Total Cyanide Concentration at Selected Sampling Locations



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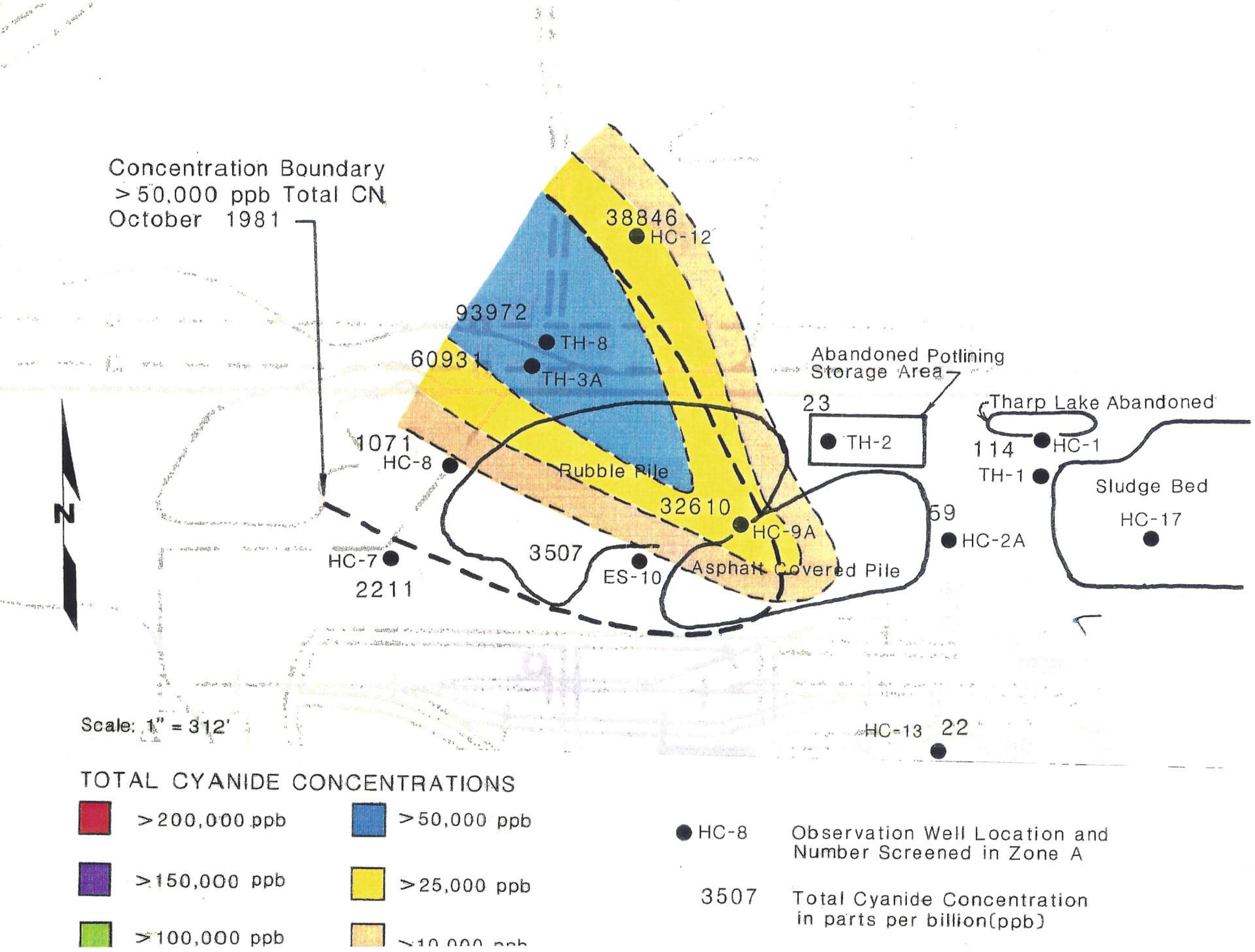
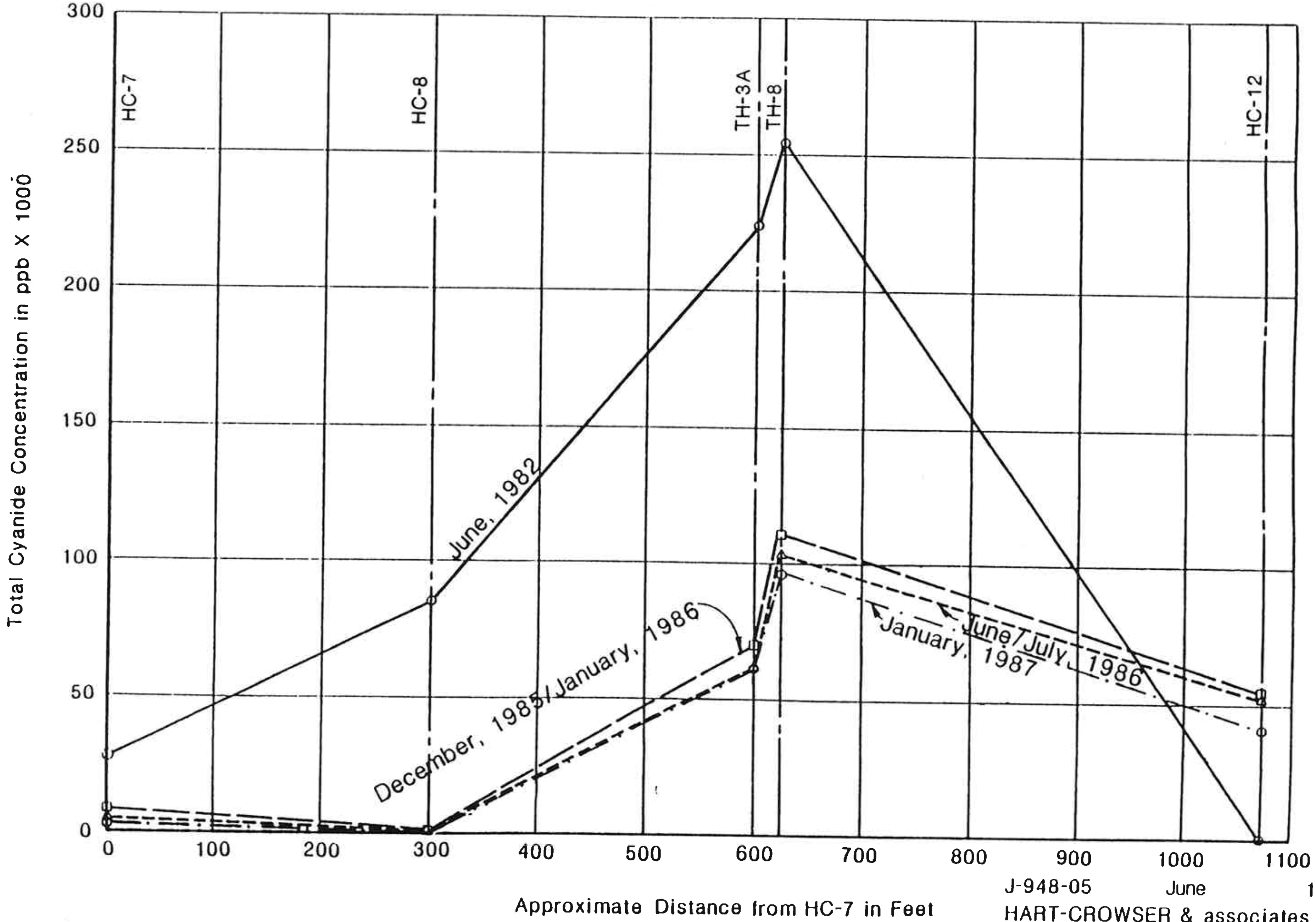
HART-CROWSER & associates inc.
Figure 33

Zone Cyanide Concentrations January 1987



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 34

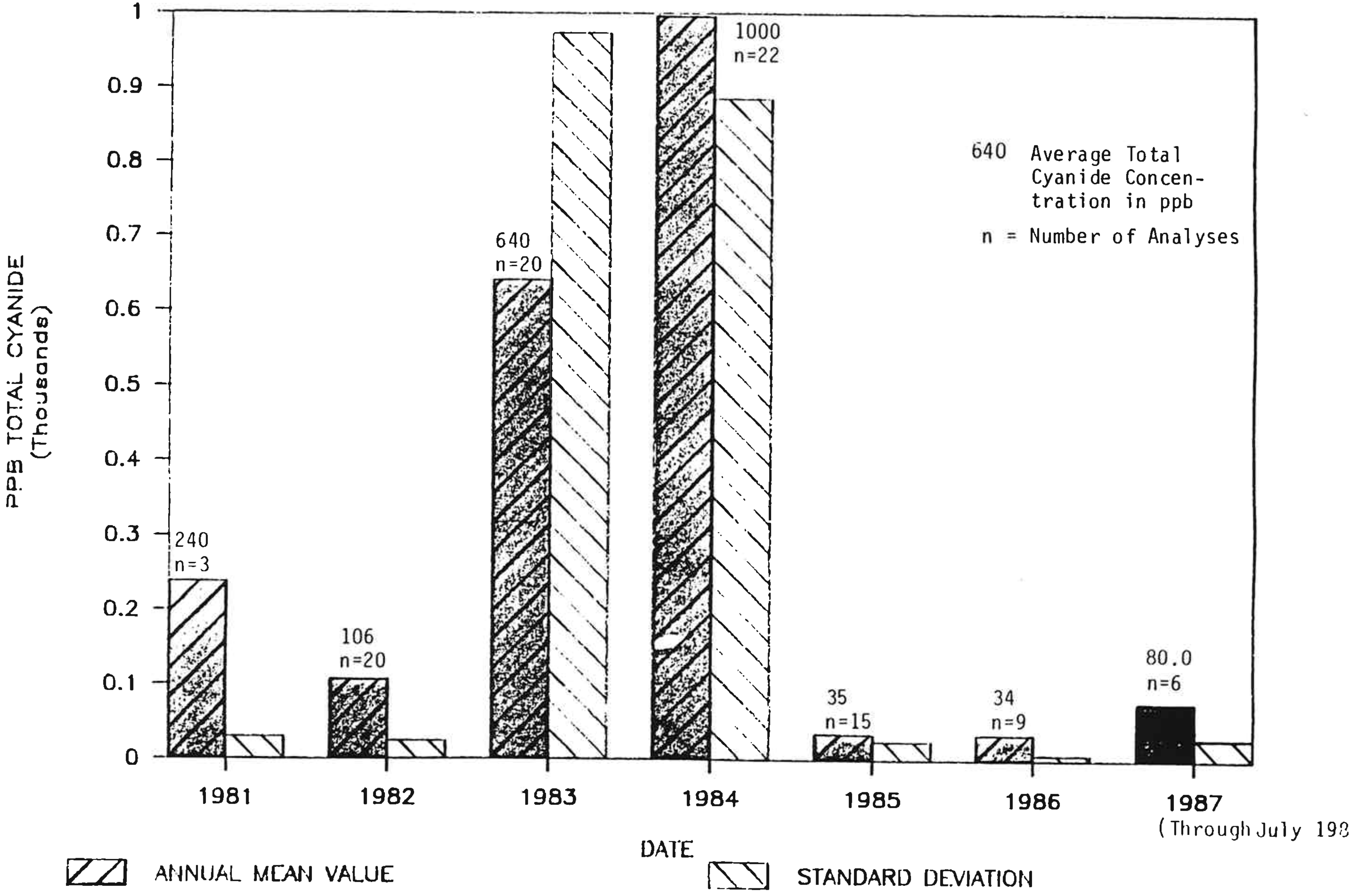
Cyanide Concentration Profile across Plume



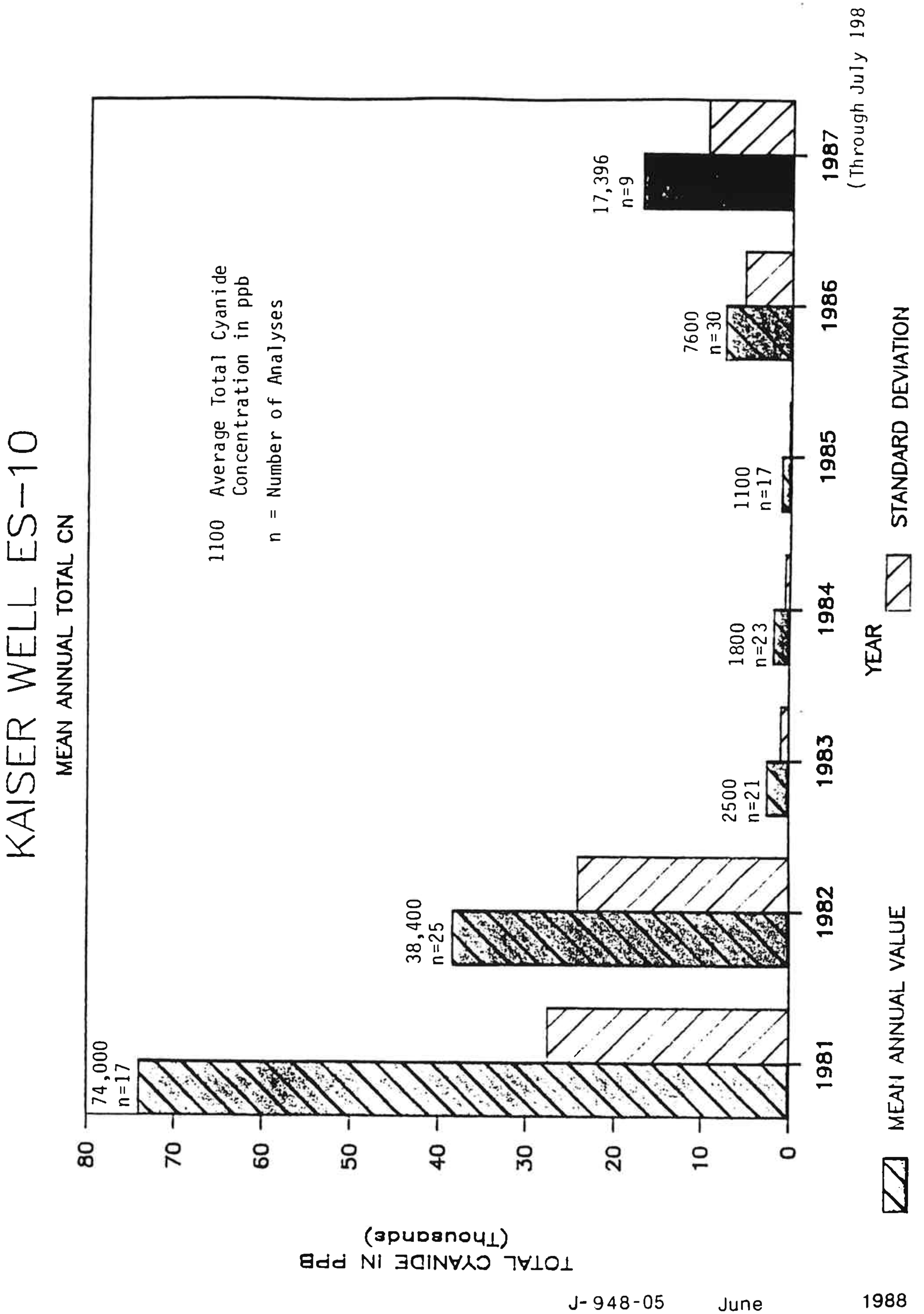
J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 35

KAISER WELL HC-2A

MEAN ANNUAL TOTAL CN



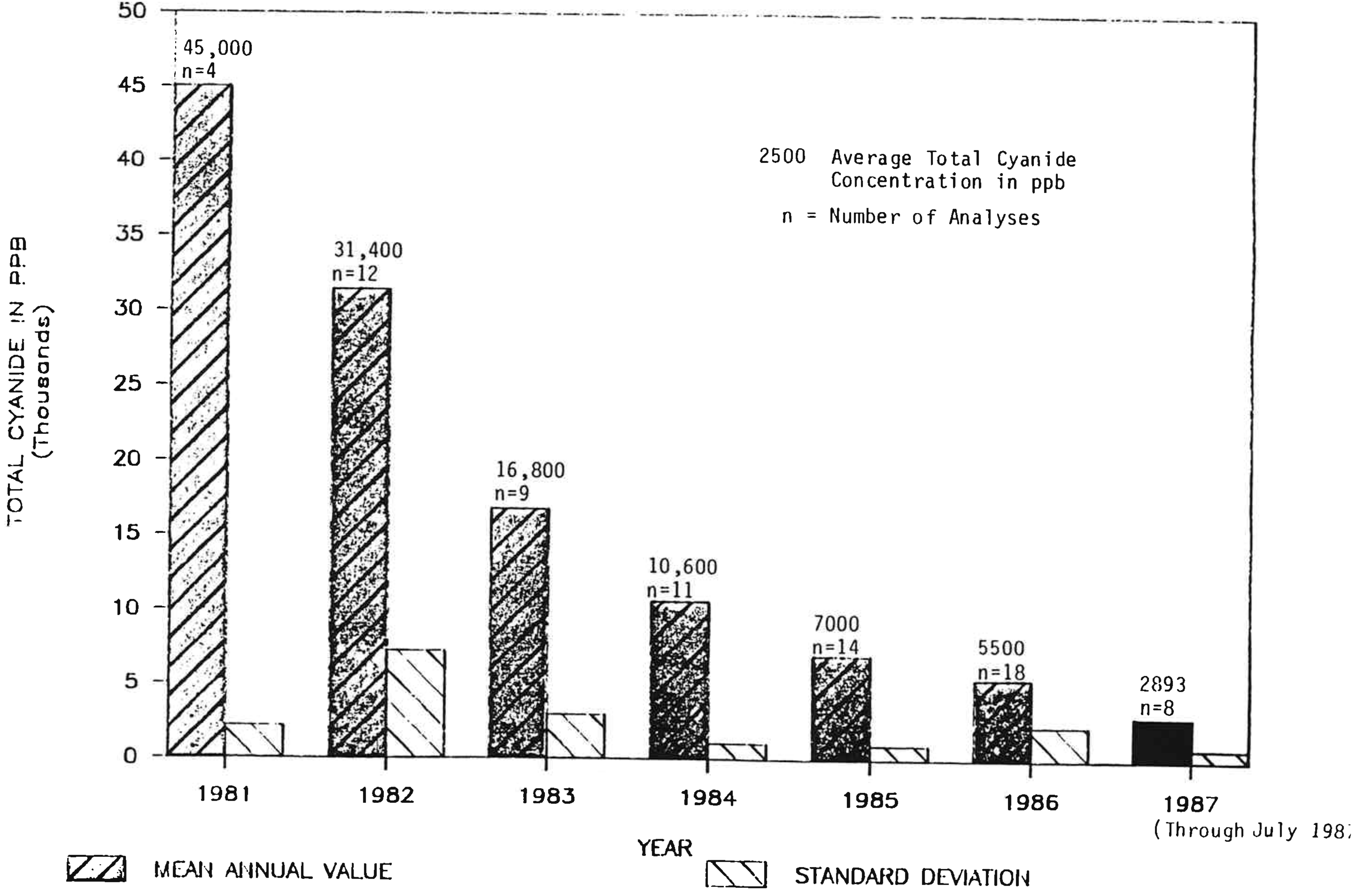
J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 36



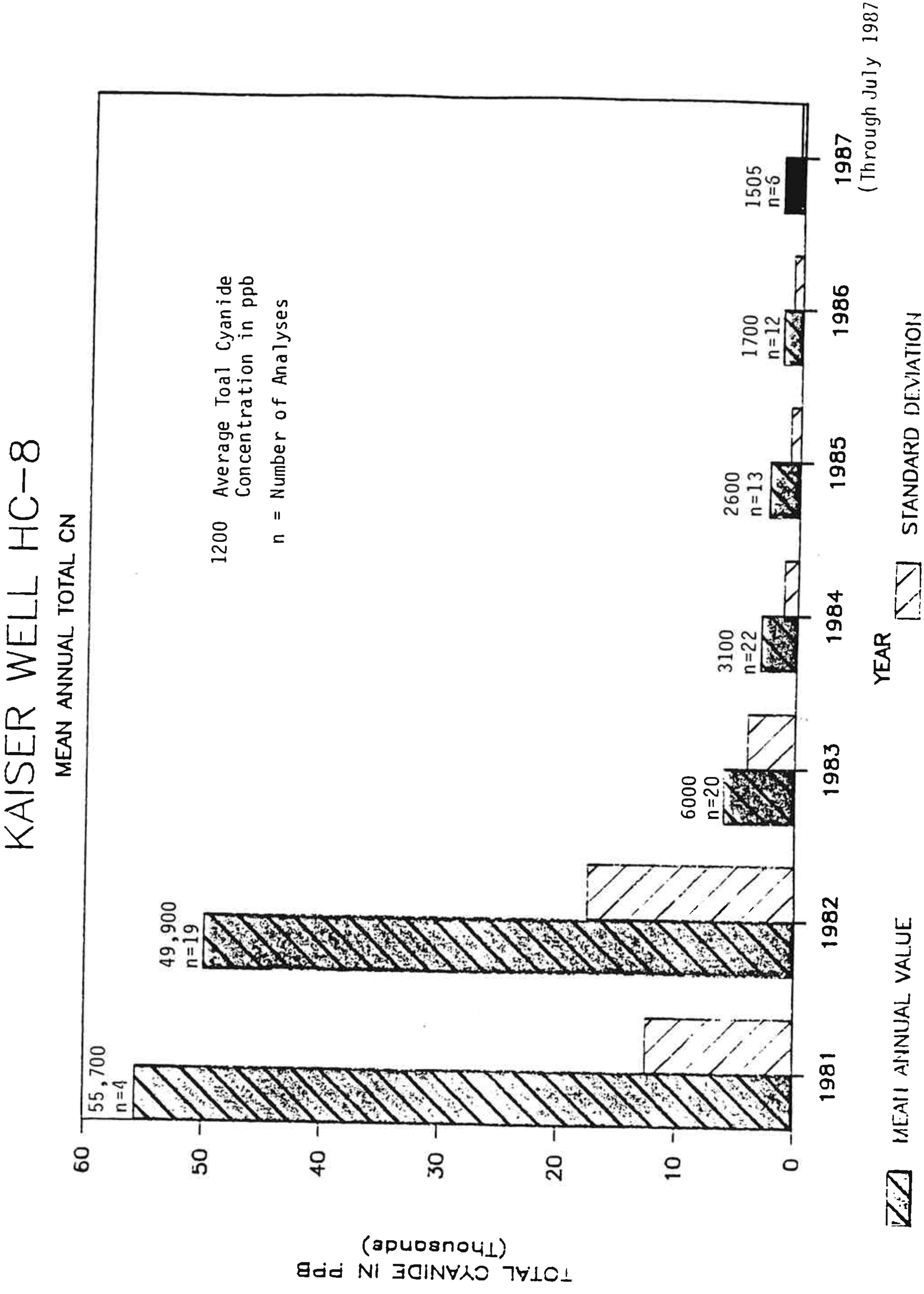
J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 37

KAISER WELL HC-7

MEAN ANNUAL TOTAL CN



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 38



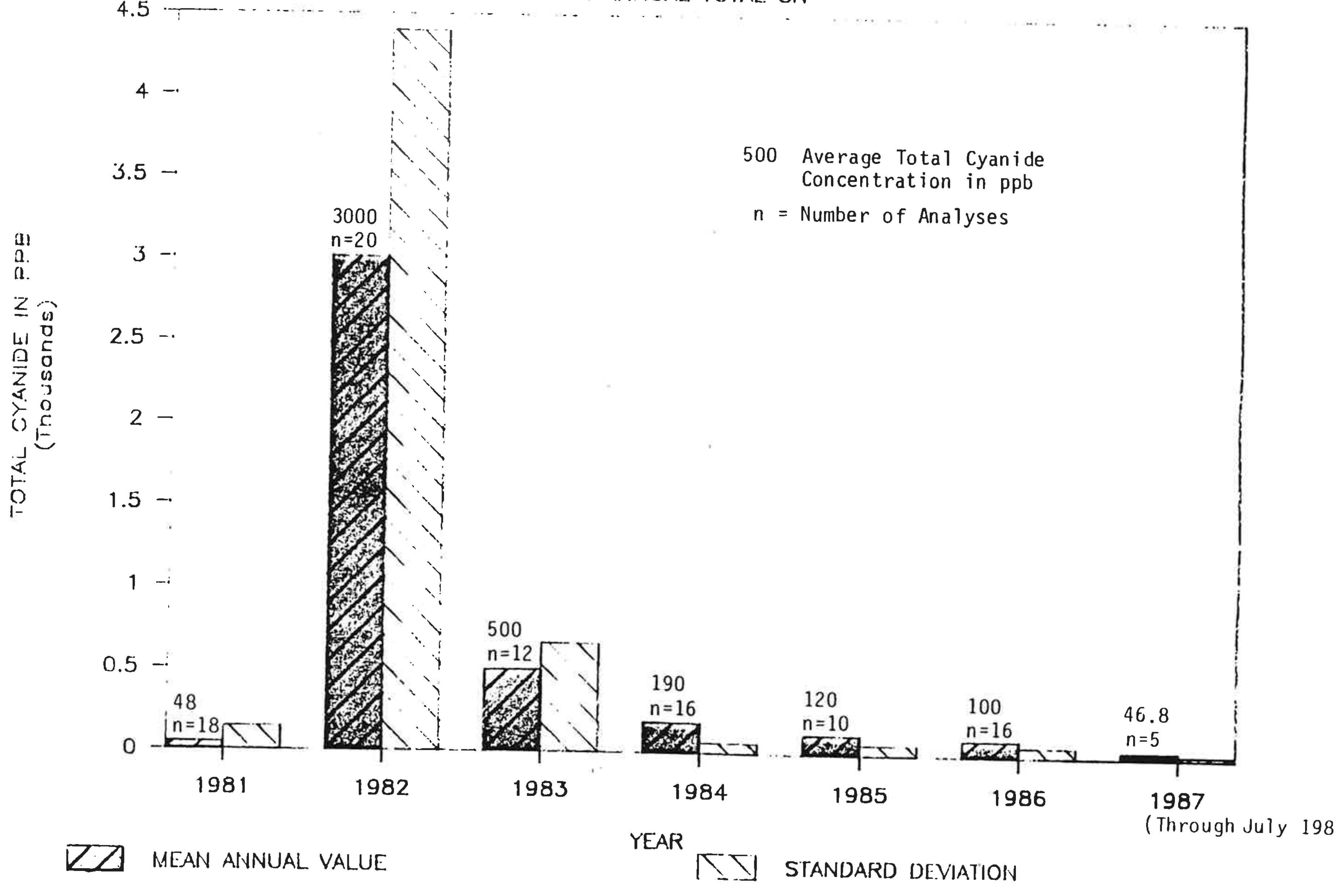
J-948-05 June 1988

HART-CROWSER & associates inc.

Figure 39

KAISER WELL TH-2

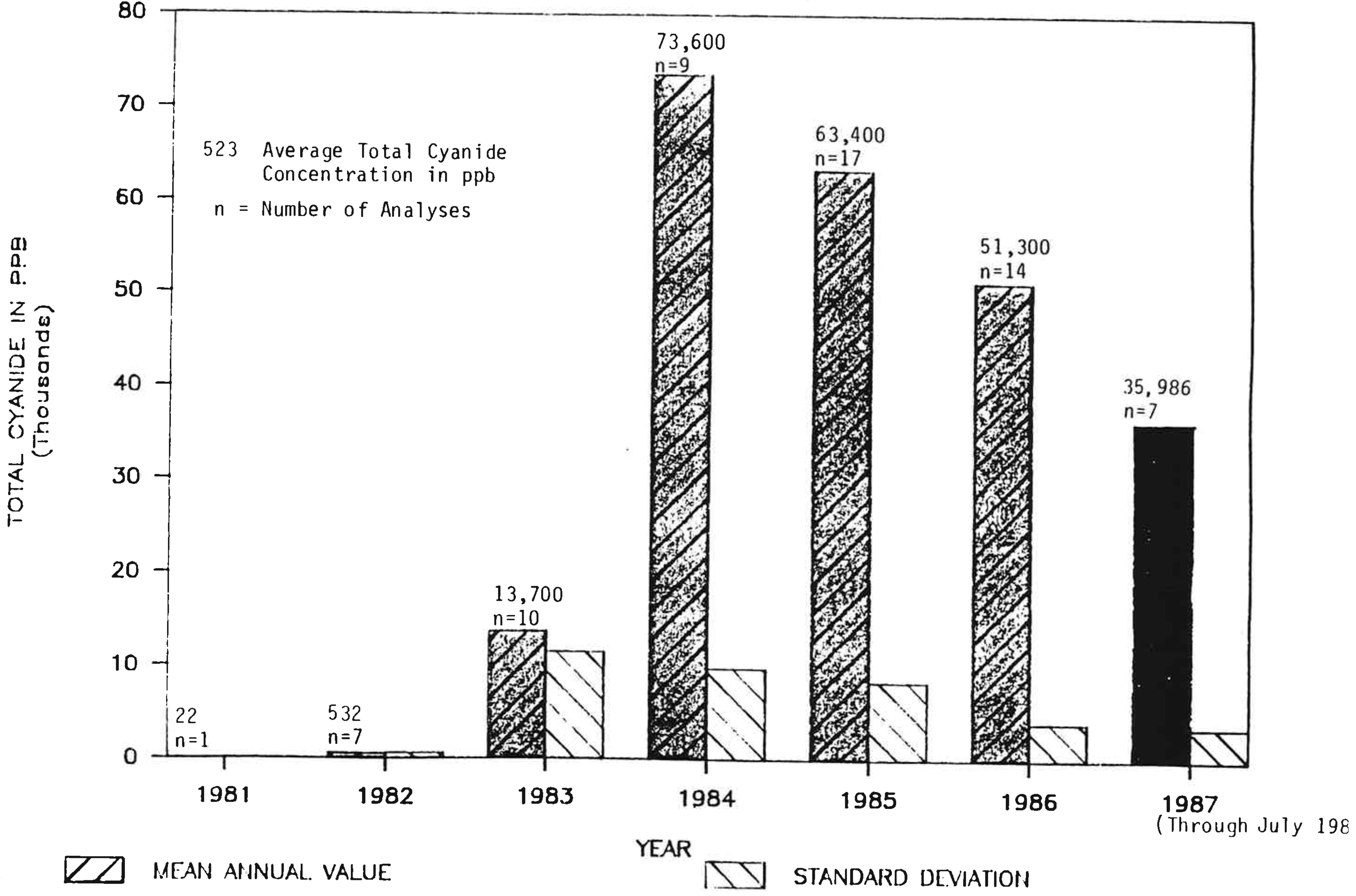
MEAN ANNUAL TOTAL CN



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 40

KAISER WELL HC-12

MEAN ANNUAL TOTAL CN



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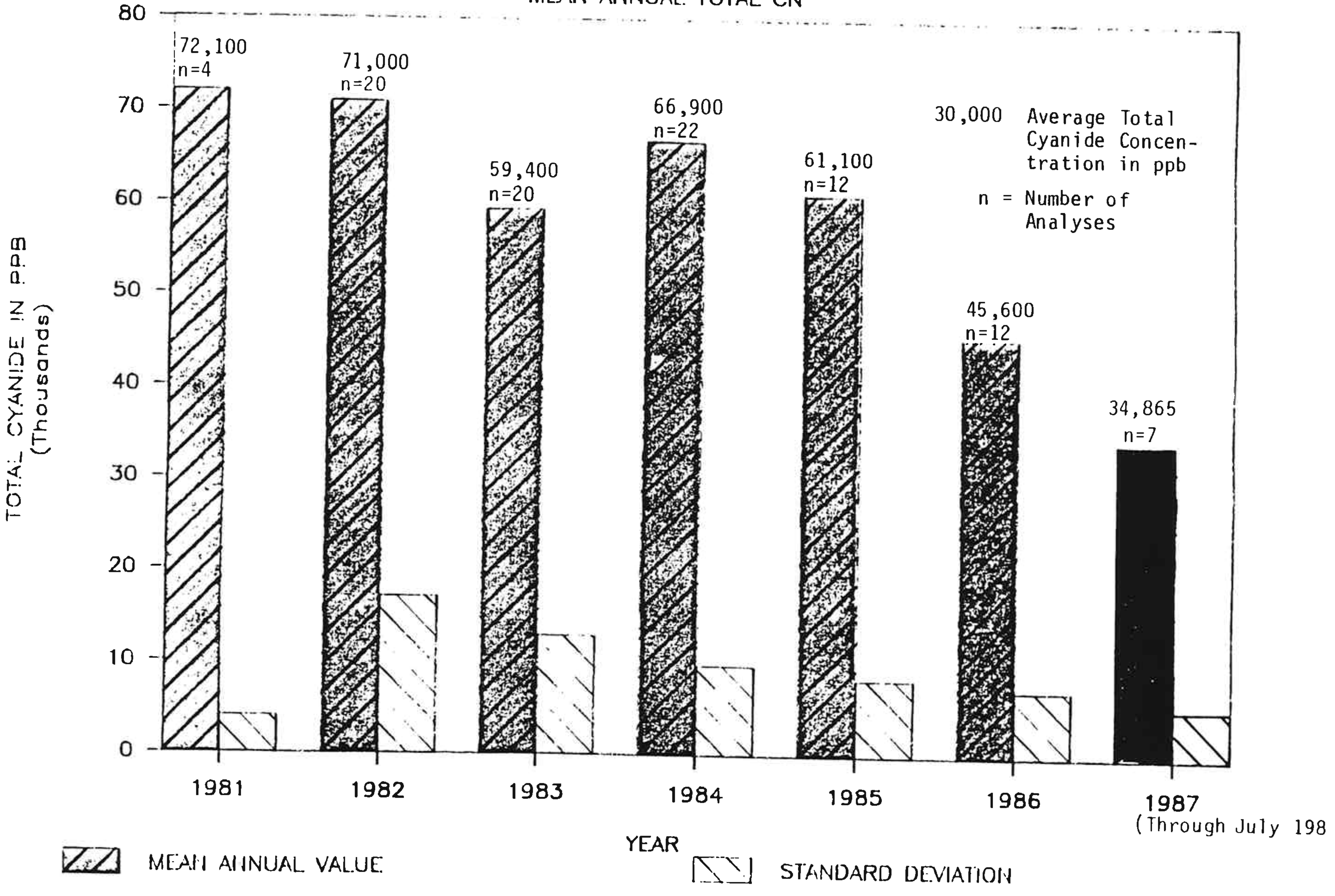
HART-CROWSER & associates inc.
Figure 41

KAISER WELL HC-9A

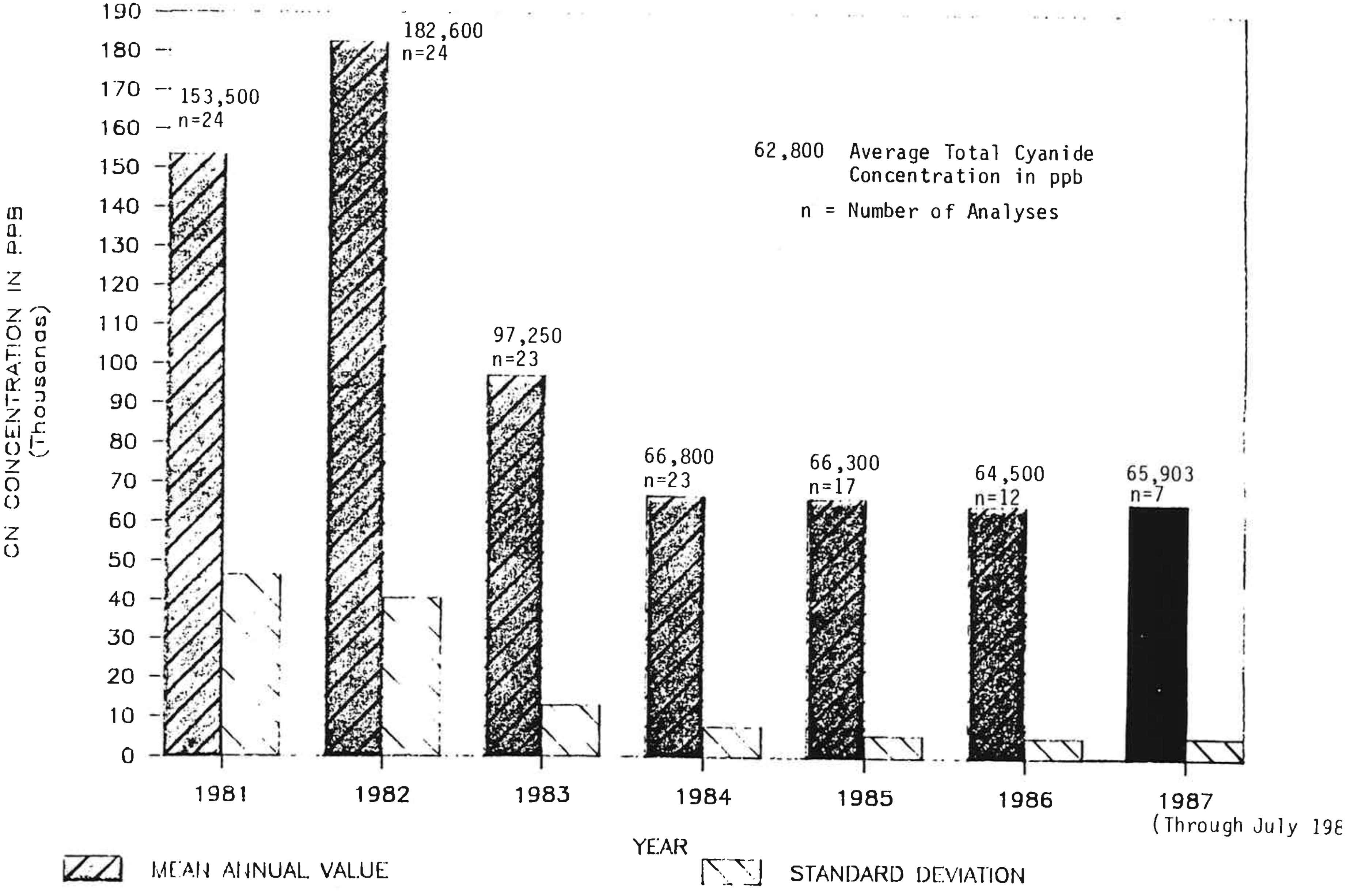
MEAN ANNUAL TOTAL CN



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 42

KAISER WELL TH-3A

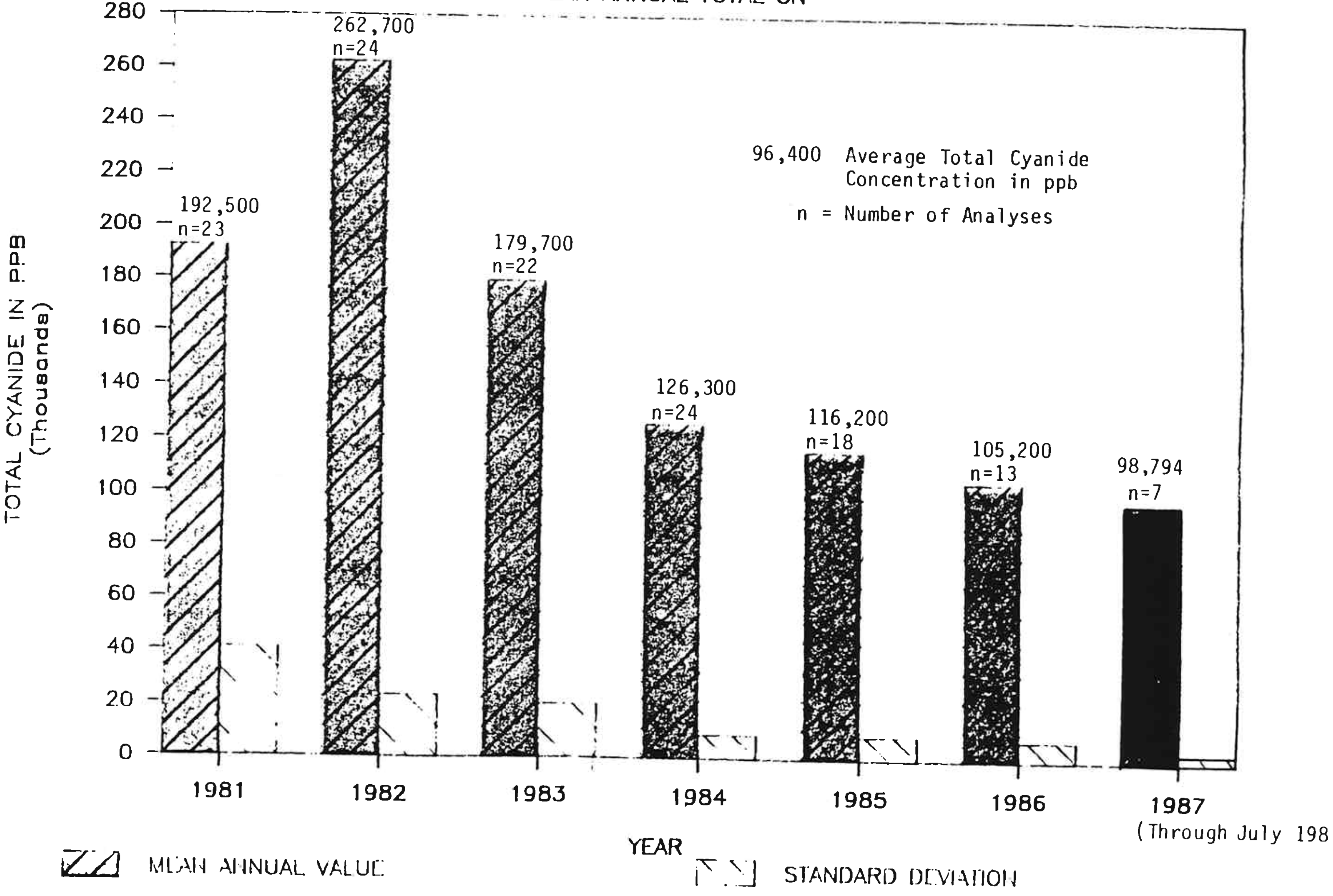
MEAN ANNUAL TOTAL CN



J- 948-05 June 1988
HART-CROWSER & associates inc.
Figure 43

KAISER WELL TH-8

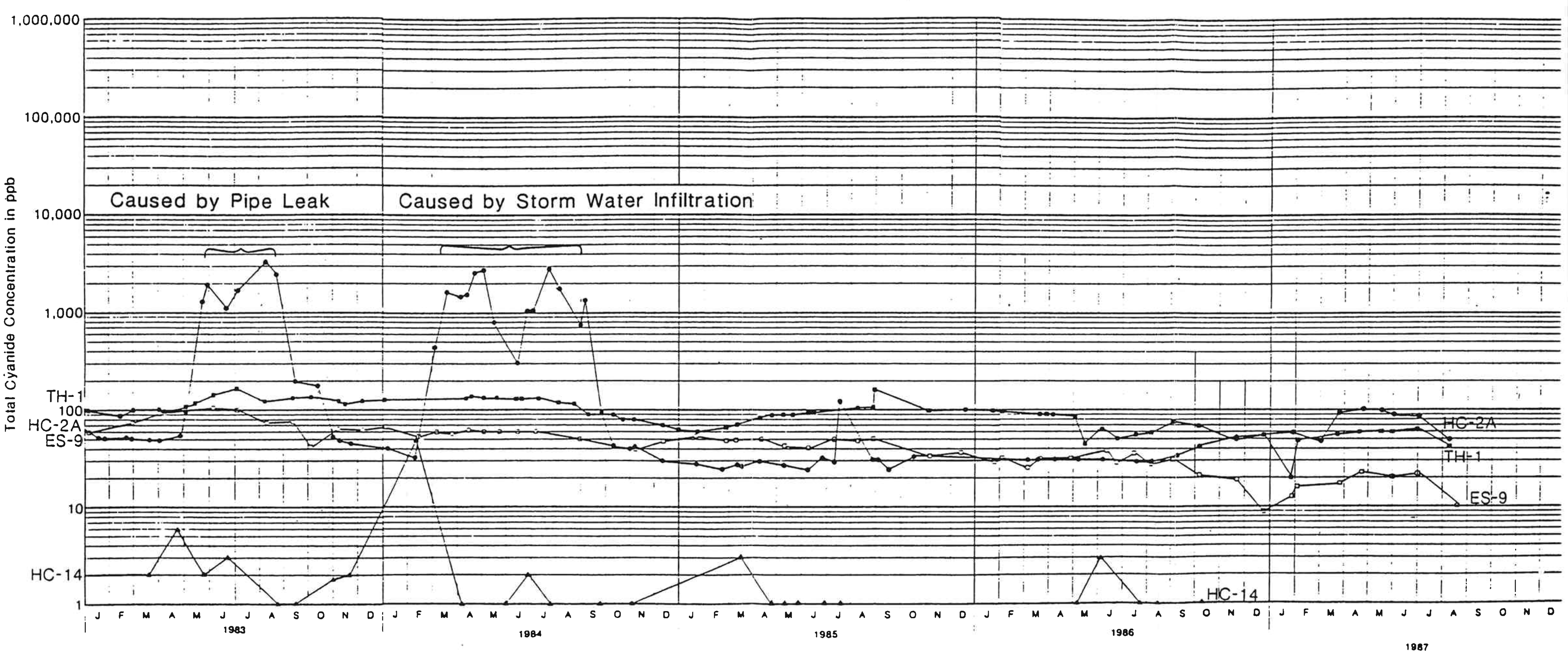
MEAN ANNUAL TOTAL CN



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 44

Total Cyanide Concentration in Selected Wells

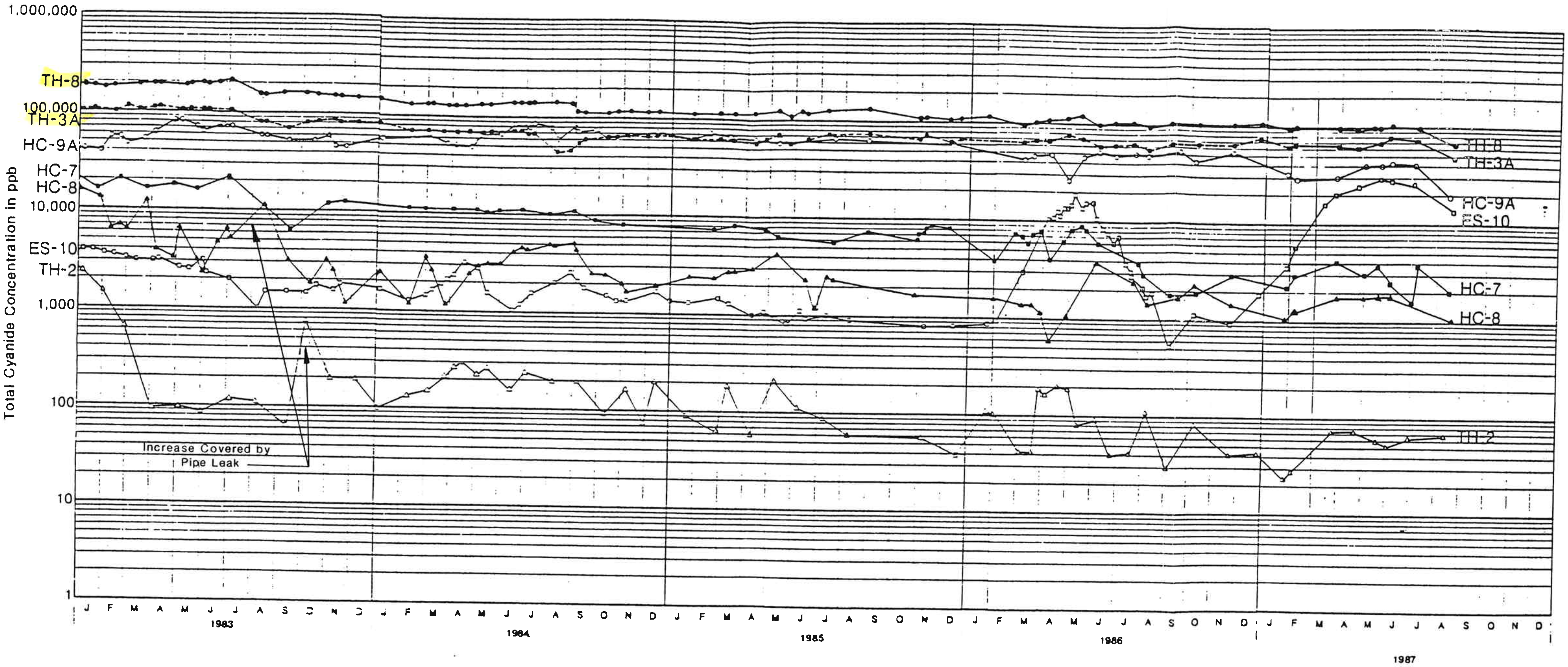
'Ipgradient of Potlining Pile



J-948-05 June 1988
HART-CROWSER & associates inc
Figure 45

Total Cyanide Concentration in Selected Wells

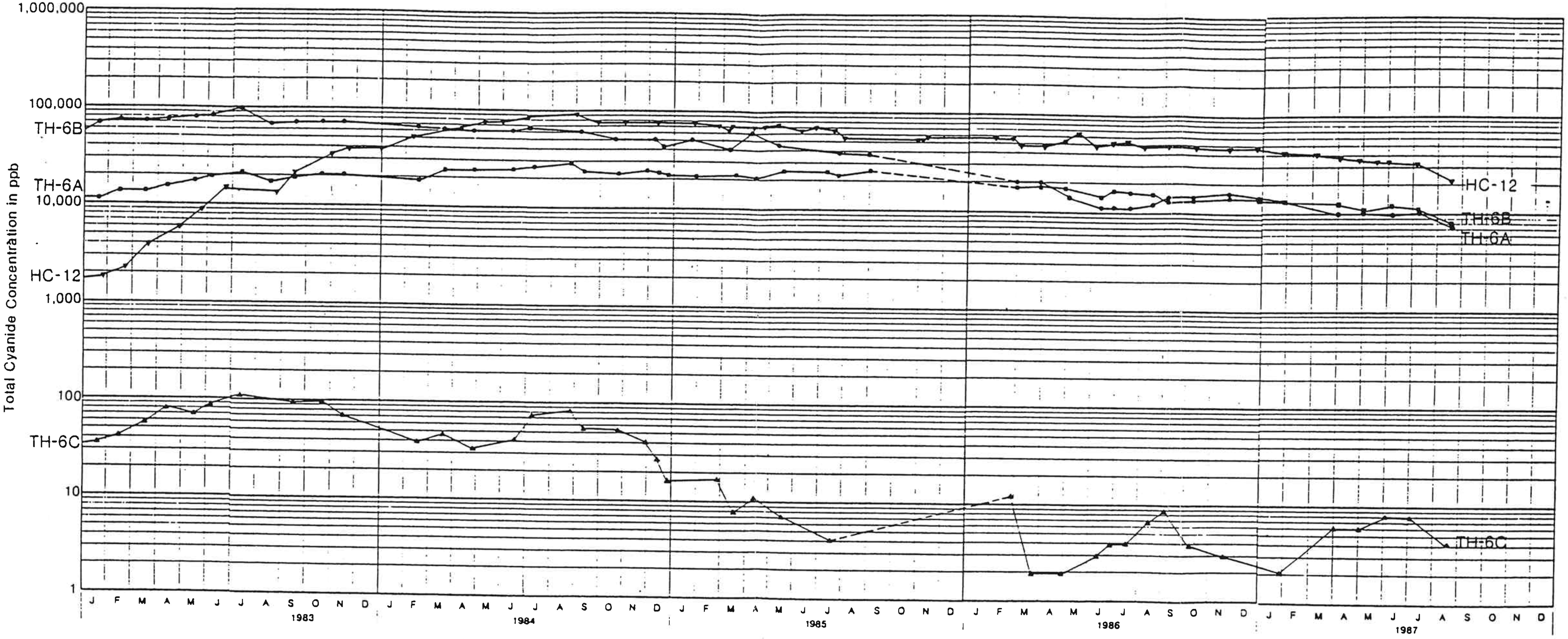
Downgradient of Potlining Pile



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 46

Total Cyanide Concentration in Selected Wells

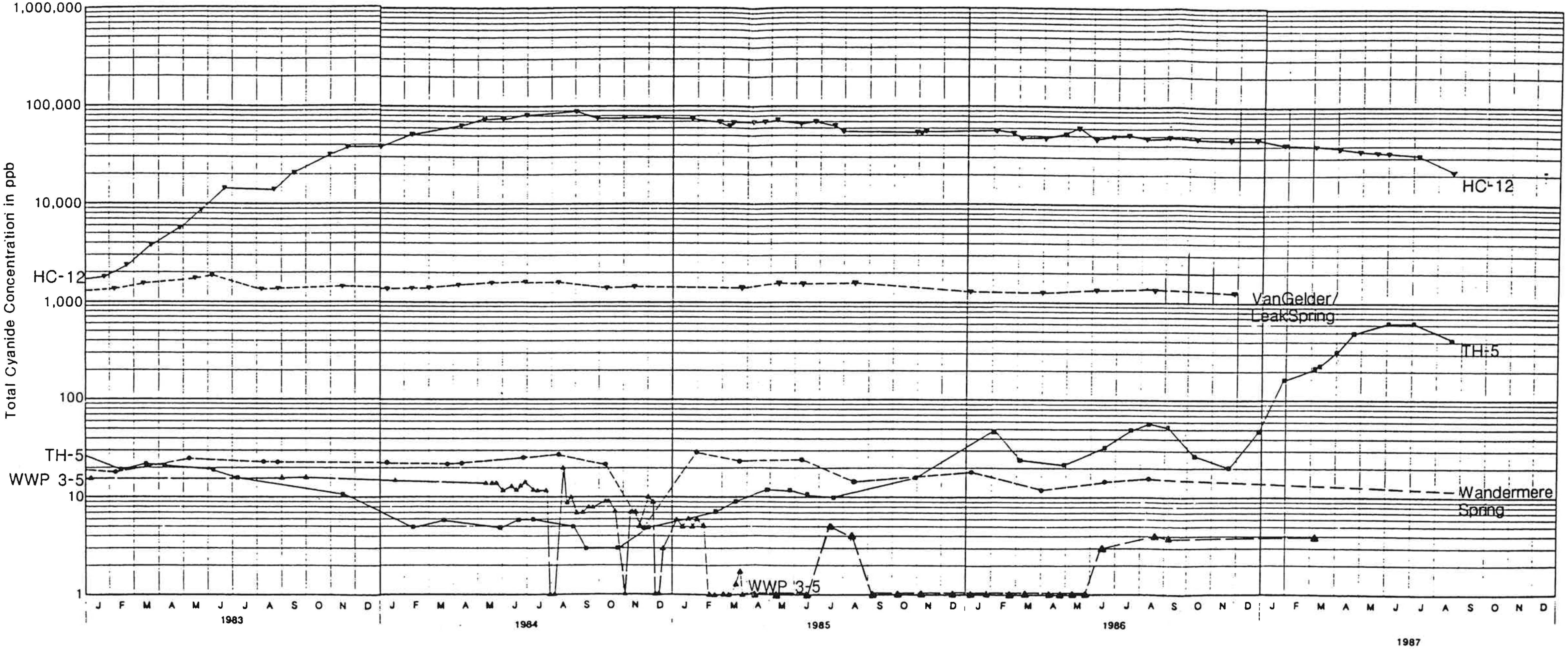
Downgradient of Potlining Pile



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 47

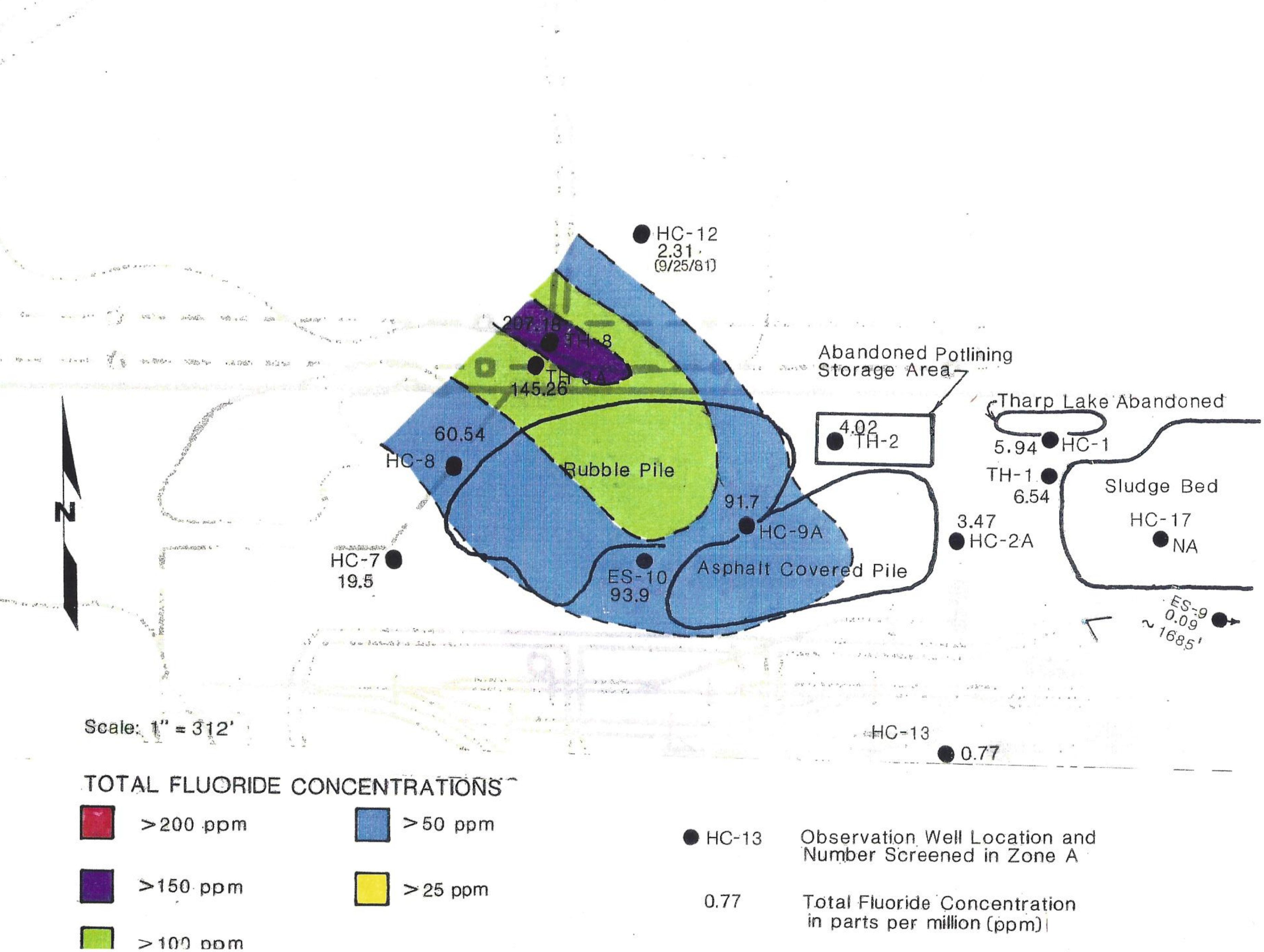
Total Cyanide Concentration in Selected Wells and Springs

Down-Gradient of Potlining Pile



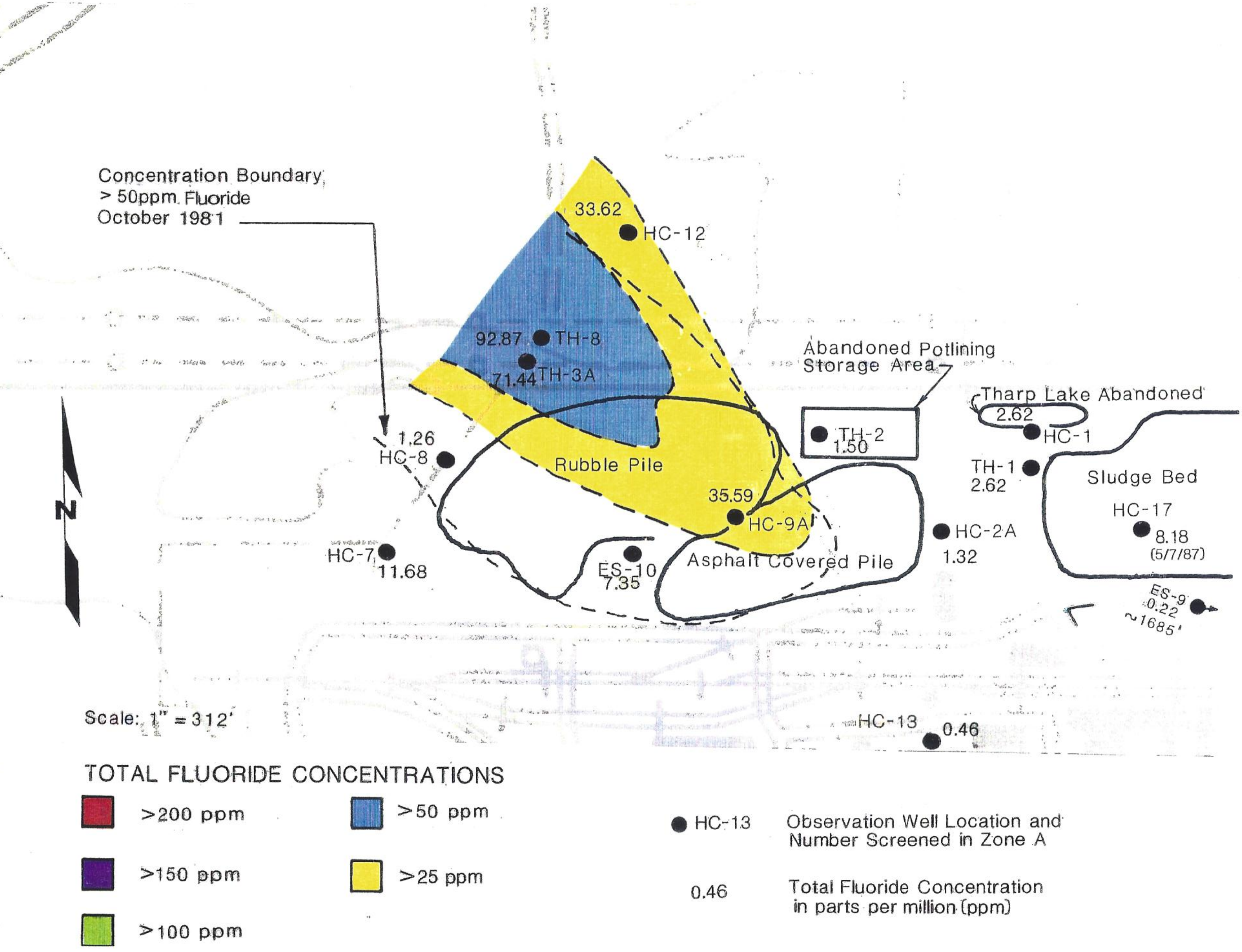
J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 48

A Zone Fluoride Concentrations - October 1981



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 49

Zone Fluoride Concentrations anuary 1987



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 50

Fluoride Concentration Profile across Plume

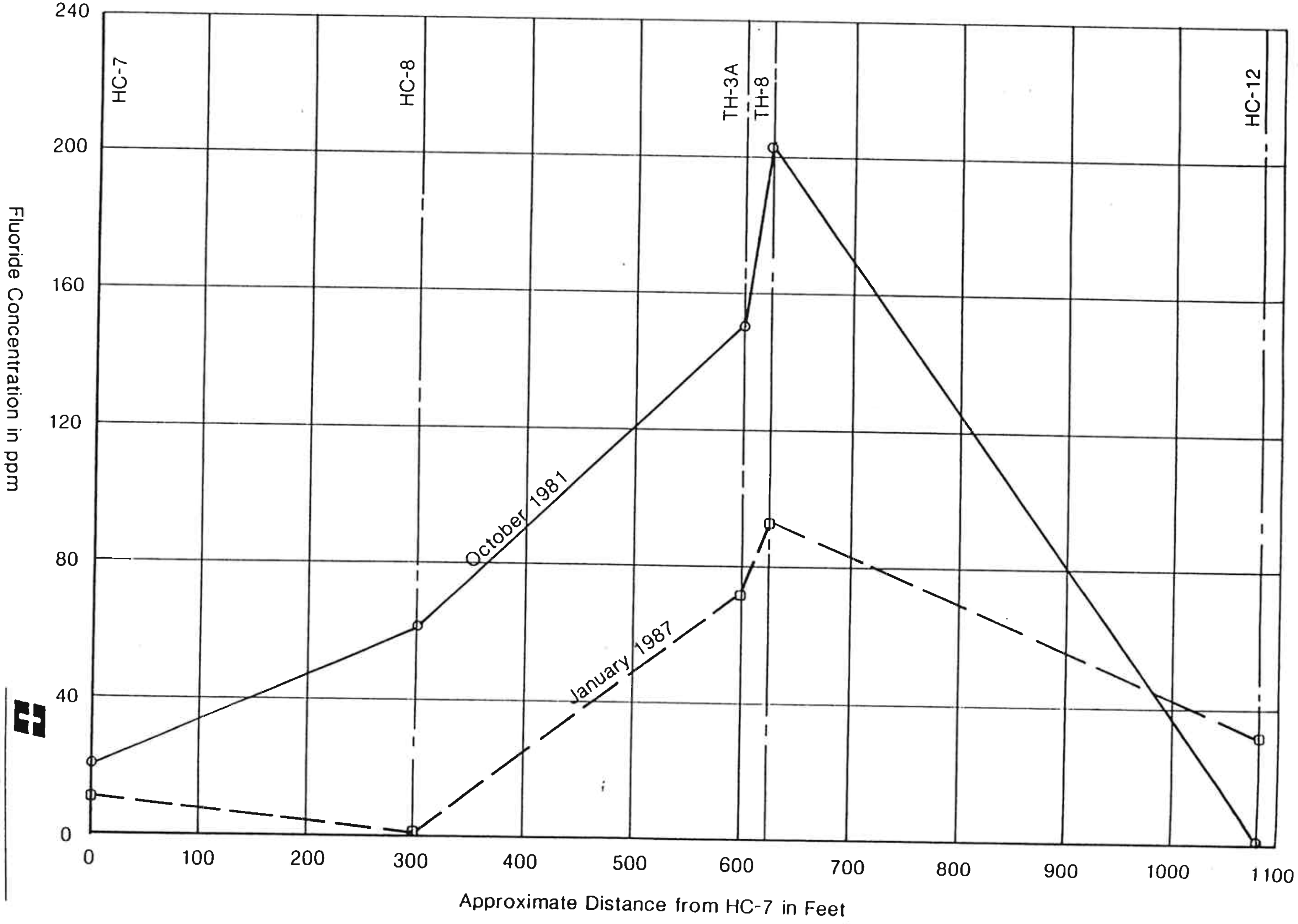


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Figure 51

Total Fluoride Concentration in Selected Wells, 1983 - 1987

Upgradient of Potlining Pile

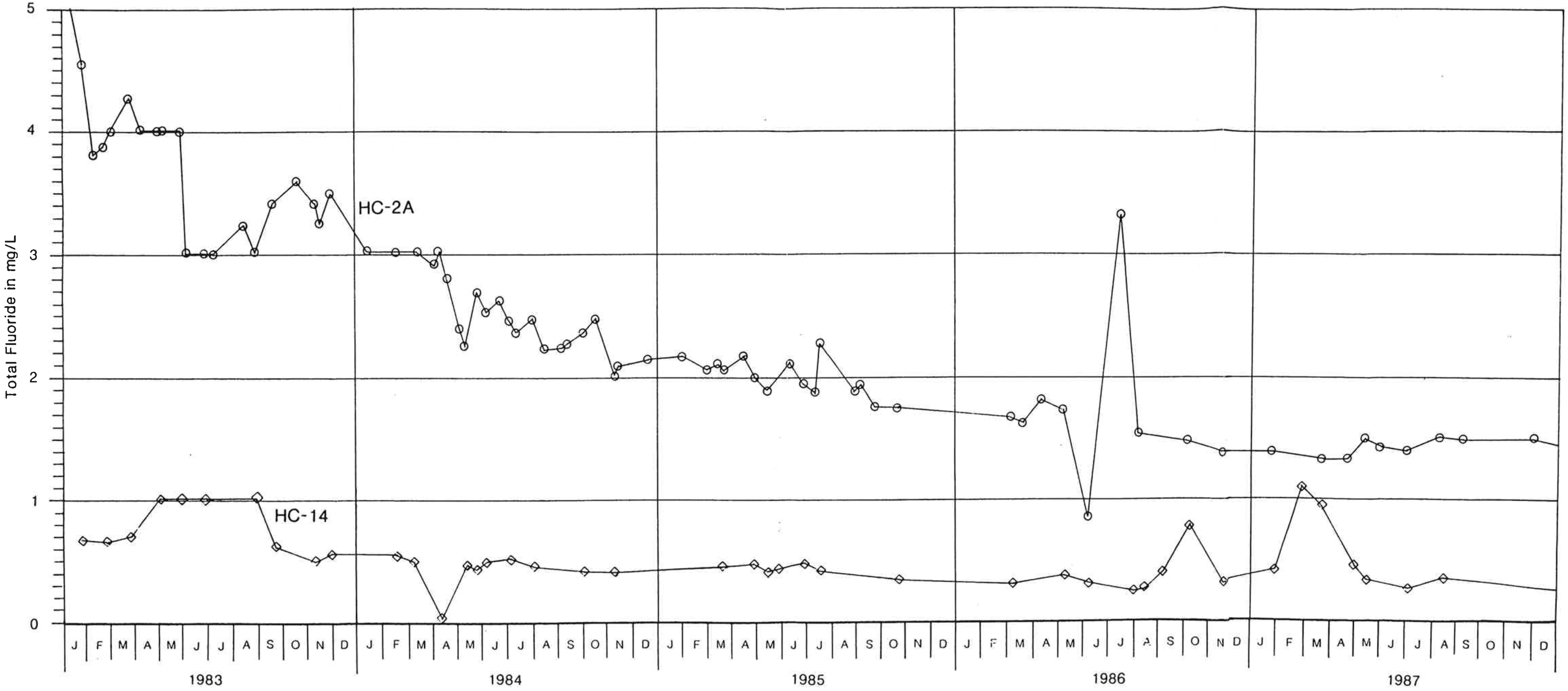

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Figure 52

Total Fluoride Concentration in Selected Wells and Springs, 1983 - 1987

Downgradient of Potlining Pile

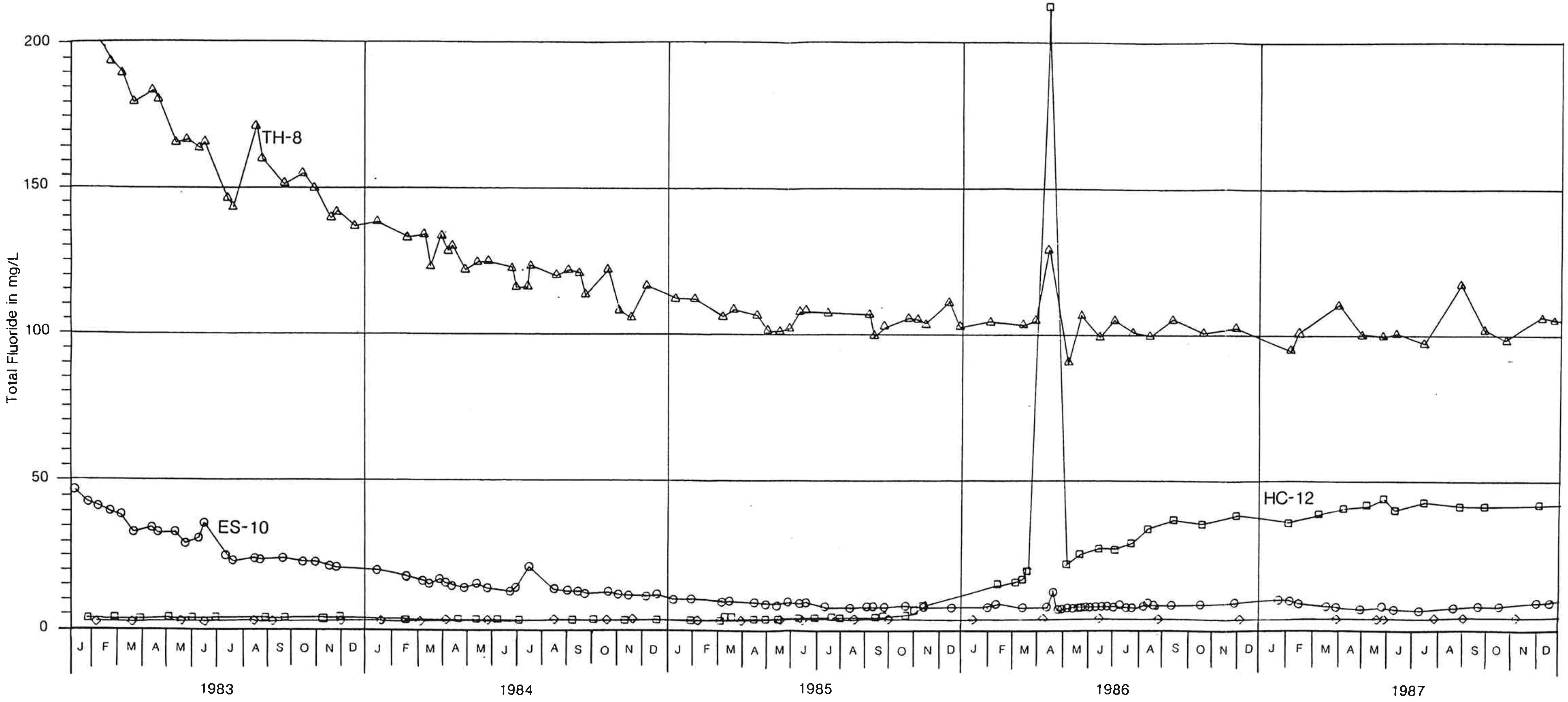

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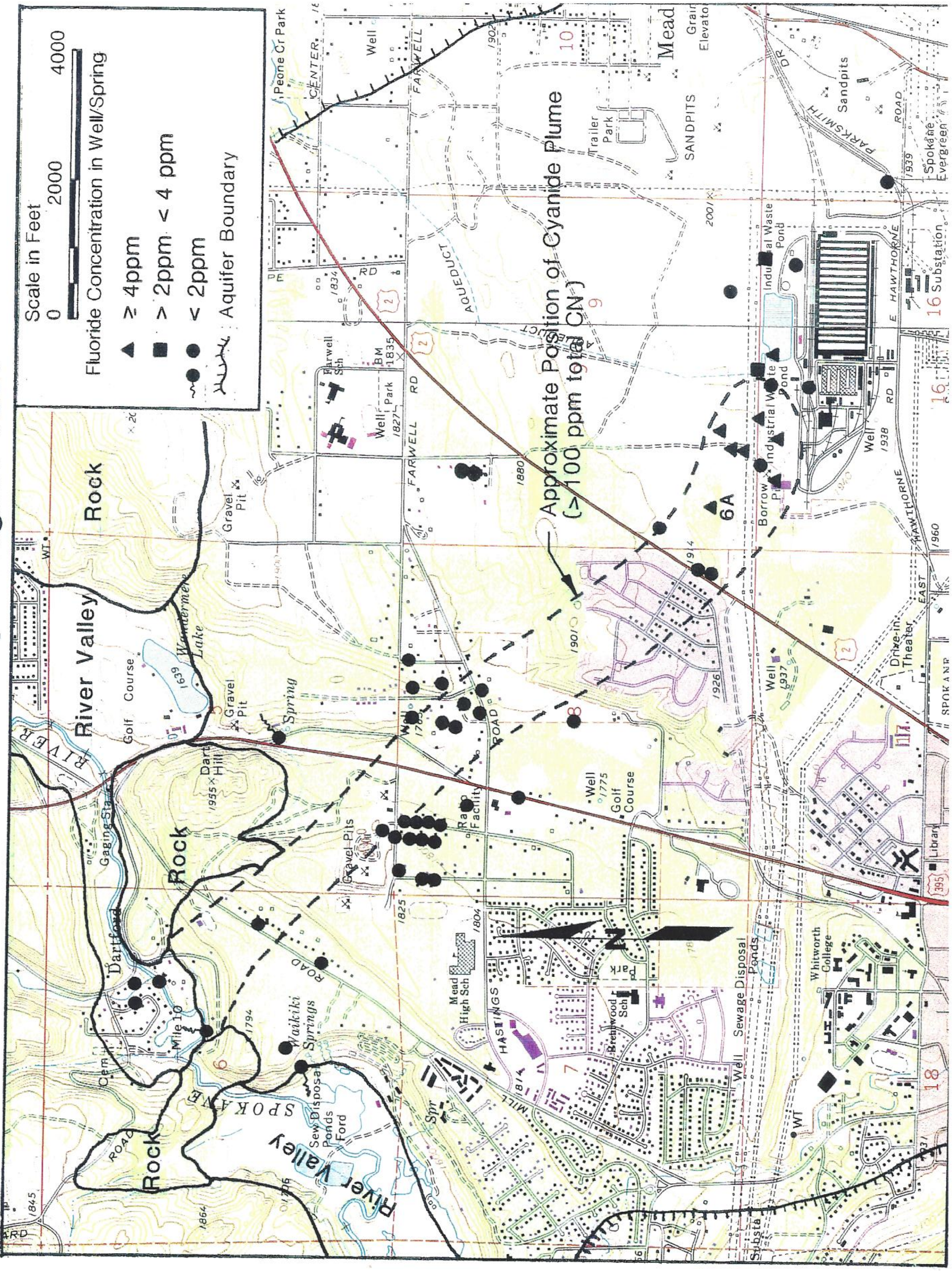
Figure 53

Regional Fluoride Concentration Map - August 1987



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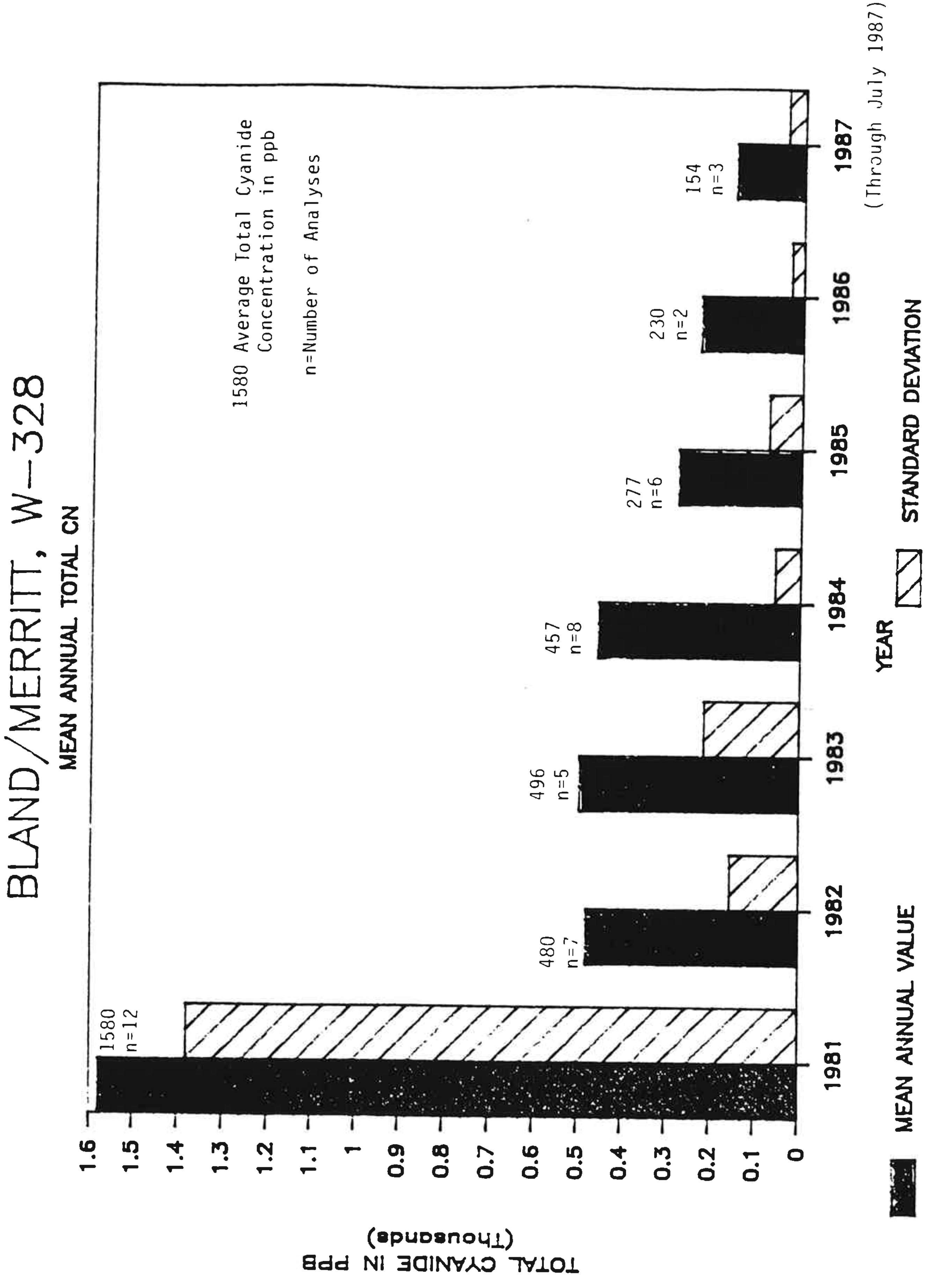
J-948-02 7/88

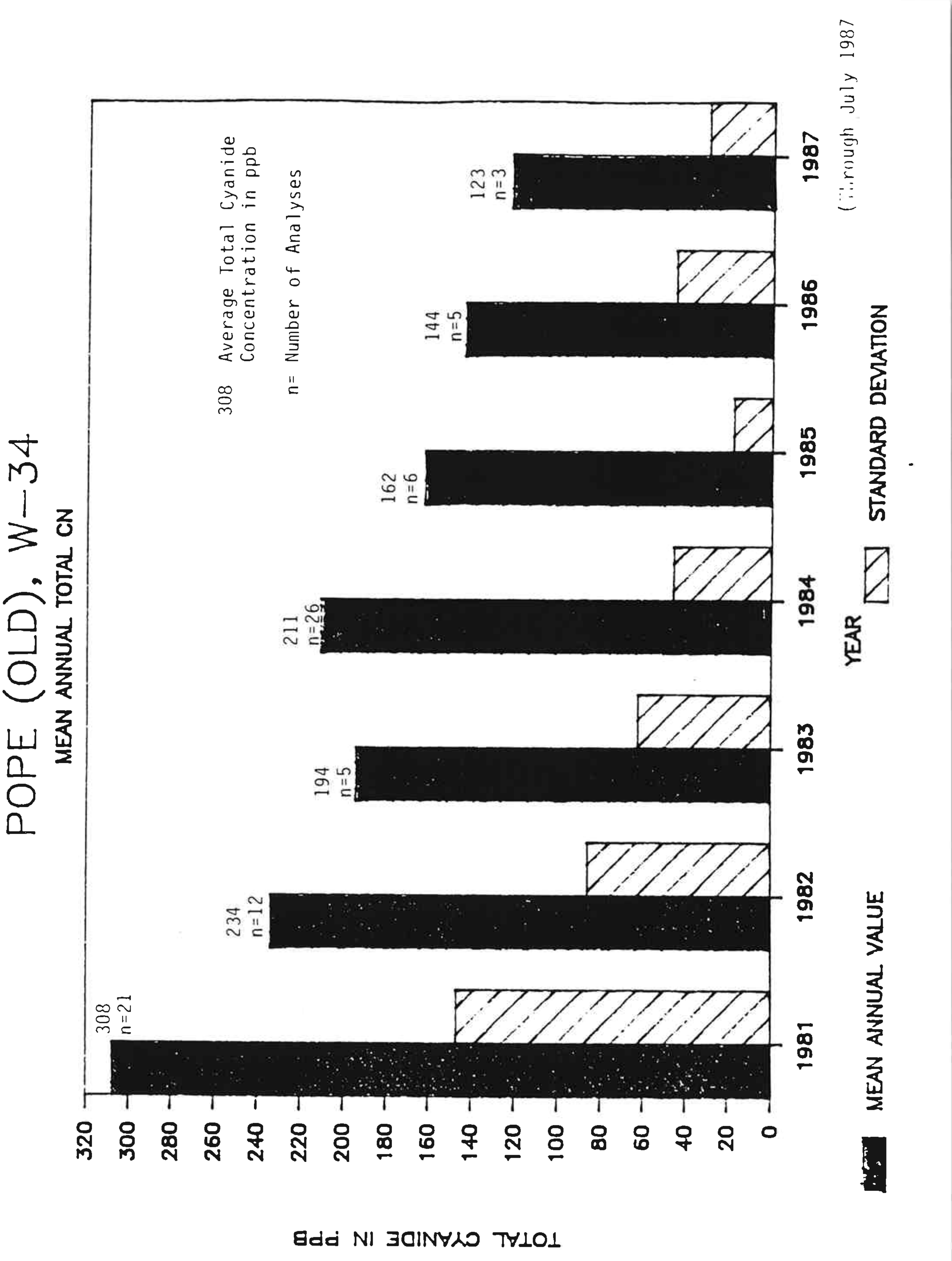
Figure 54



BLAND/MERRITT, W—328

MEAN ANNUAL TOTAL CN

J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 55



POPE (OLD), W—34

MEAN ANNUAL TOTAL CN

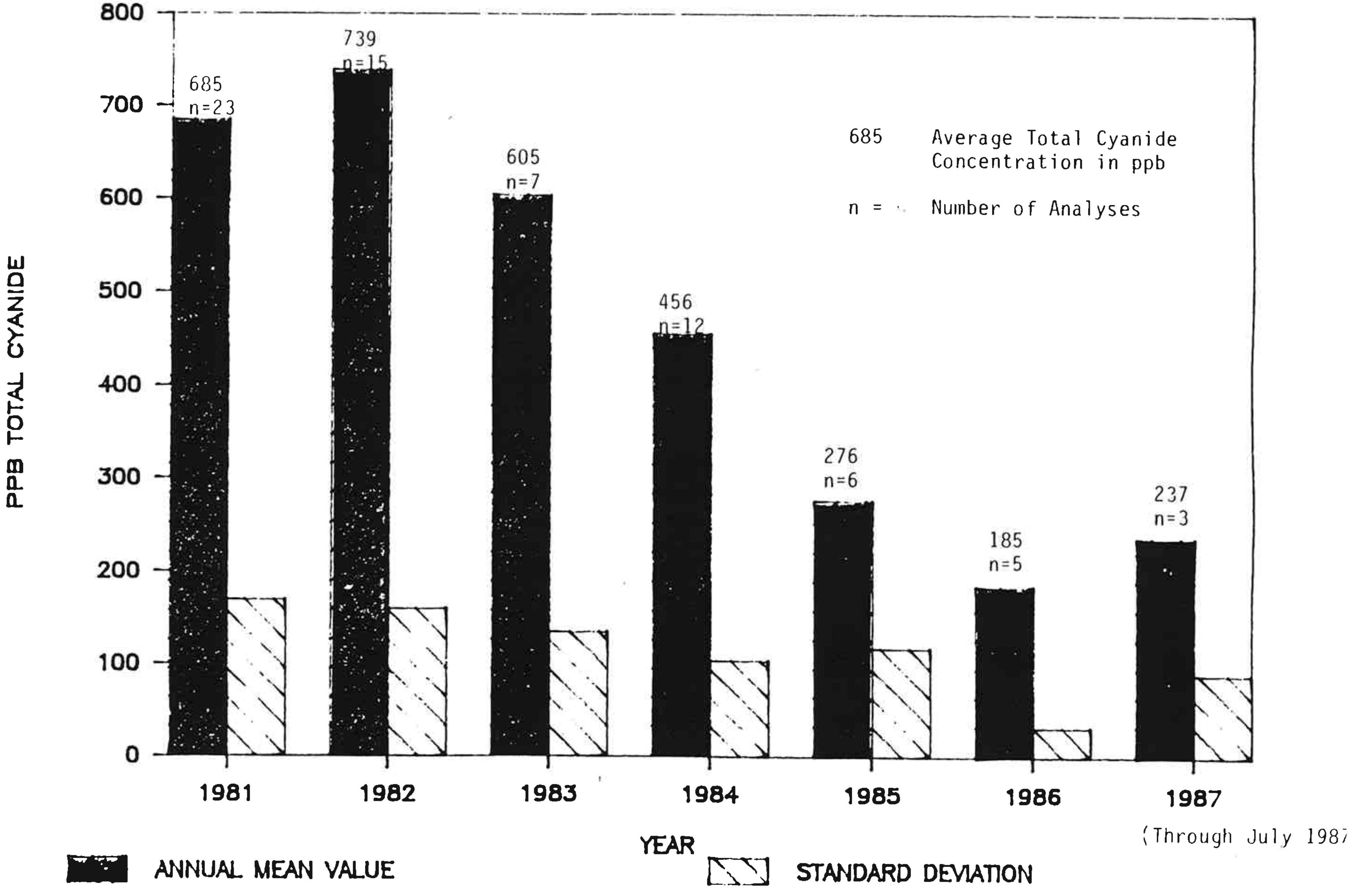
J-948-05 June 1988

HART-CROWSER & associates inc.

Figure 56

SPOKANE COUNTY SHOP #A, W-5

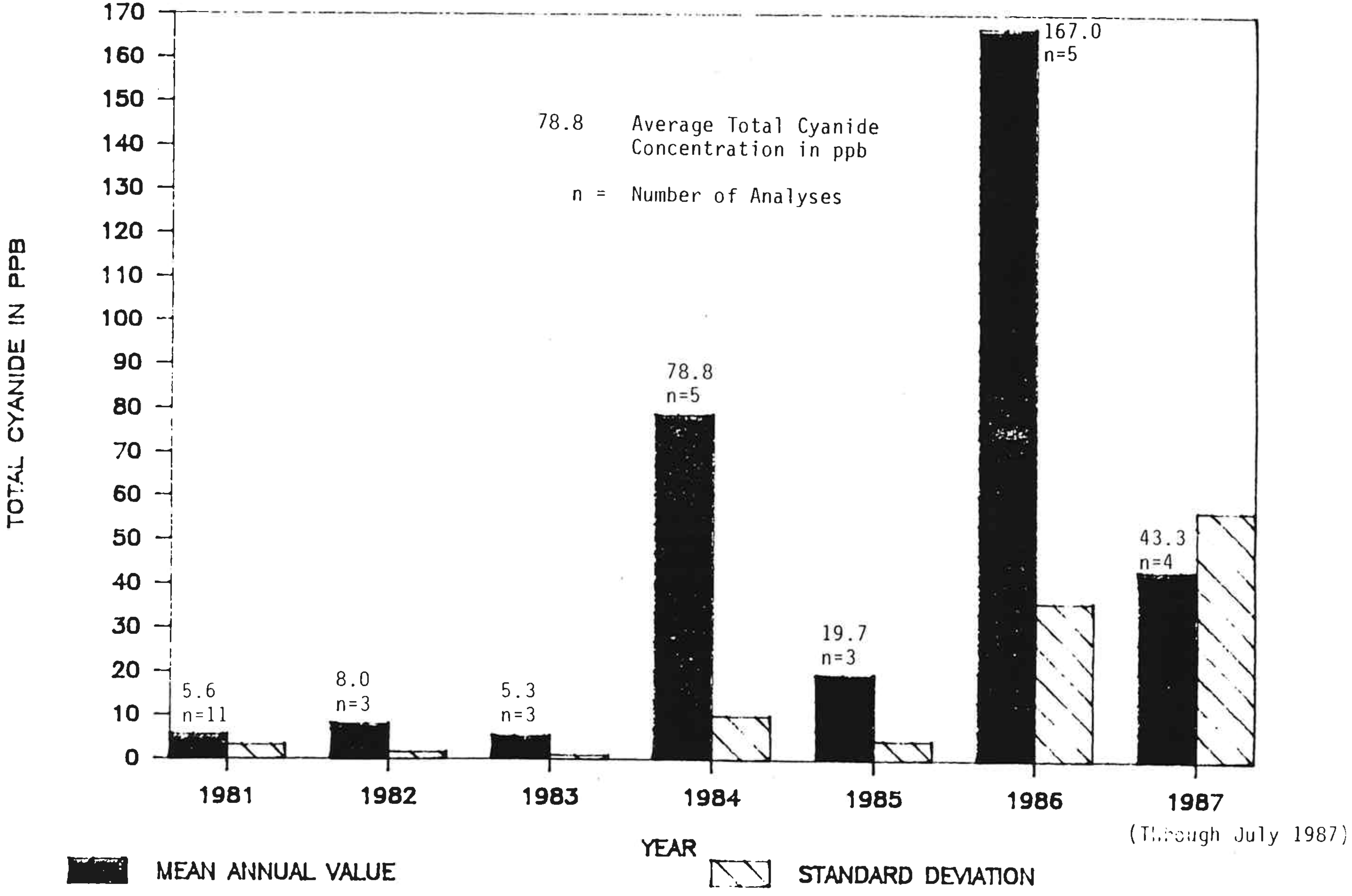
MEAN ANNUAL TOTAL CN



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 57

COLBORN, W—6

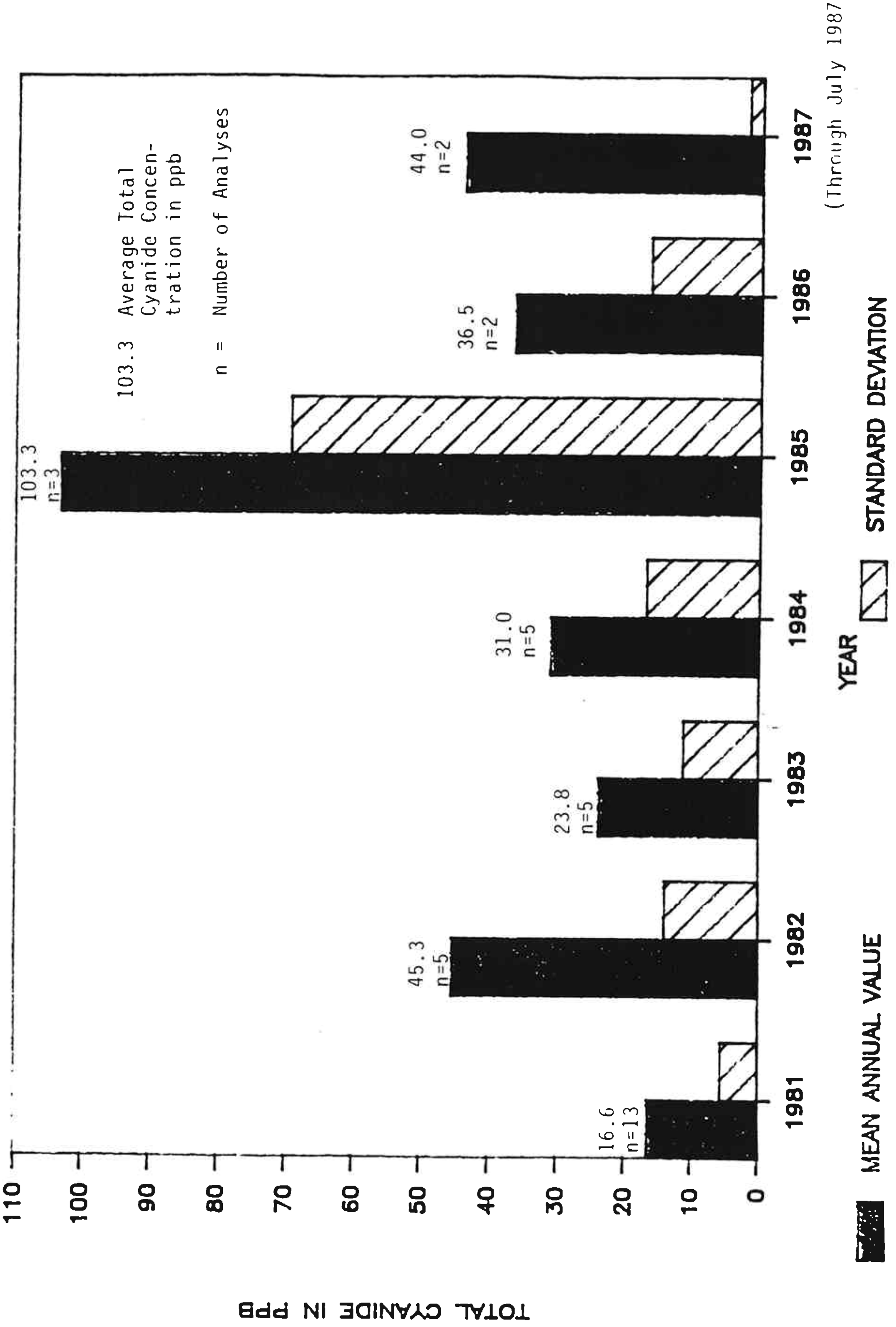
MEAN ANNUAL TOTAL CN



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 58

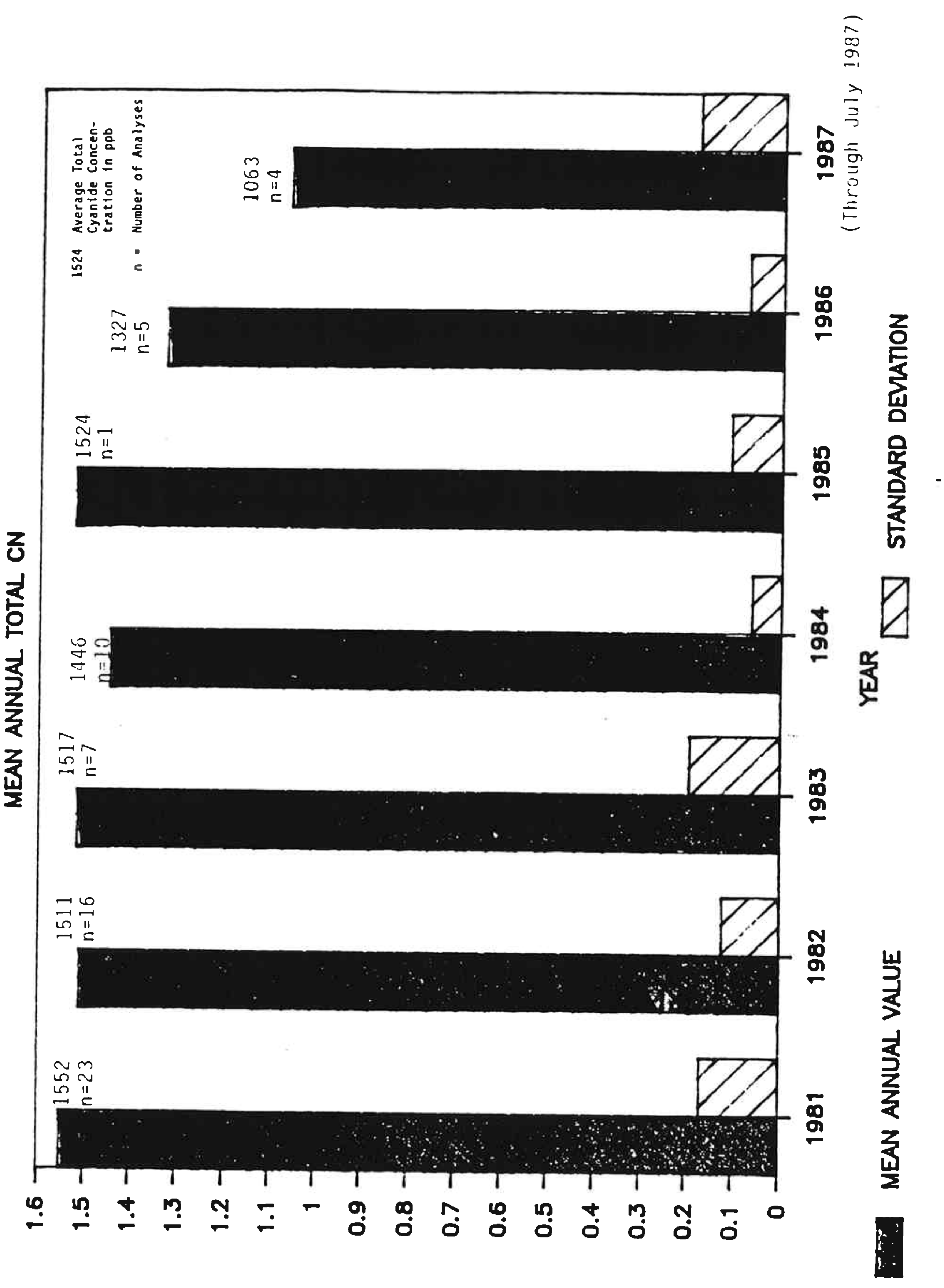
PRUMER/DAVIS, W—114

MEAN ANNUAL TOTAL CN



J-948-05 June 1988
HART-CROWSER & associates inc.
Figure 59

VAN GELDER / LEAK, W—195 (SPRING)



J-948-02 June 1988
HART-CROWSER & associates inc.
Figure 60

J-948-05

APPENDIX A
WELL AND BORING DATA

Table A-1 - Well Construction Data Summary within KACC-Mead Plant

Geologic Logs and Well Construction Features
- TH-1 through TH-8 and TH-3A
- HC-1 through HC-18 and HC-1A, HC-2A, HC-9A
- ES-1 through ES-10
- D-1 through D-3

TABLE A-1 - WELL CONSTRUCTION DATA SUMMARY WELLS WITHIN KACC-MEAD PLANT

	WELL NUMBER	WELL DEPTH	BORING DEPTH	GRNDSURF. ELEVATION	TOP CASING ELEVATION	SCREENING DEPTH	SCREEN TOP ELEVATION	INSTALLED BY DATE	DRILLING METHOD
	TH-1	157	158	1926.00	1929.29	153-157	1773	R & B 3/78	NA
	TH-2	157	163	1933.00	1935.49	153-157	1780	R & B 3/78	NA
	TH-3	210	214	1919.00	1921.04	140-210	1779	R & B 3/78	NA
	TH-3A	161	163	1919.70	1921.64	145-161	1774.7	R & B 3/78	NA
	TH-4	205	205	1919.00	1921.03	145-205	1774	R & B 3/78	NA
	TH-5	186	214	1904.70	1906.67	135-186	1769.7	R & B 3/78	NA
	TH-6A	150	200	1918.10	1919.10	147-150	1771.1	R & B 3/79	NA
	TH-6B	172	200	1918.10	1919.10	167-172	1751.1	R & B 3/79	NA
	TH-6C	200	200	1918.10	1919.10	195-200	1751.1	R & B 3/78	NA
	TH-7A	151	199	1919.60	1921.66	146-151	1773.6	R & B 3/78	NA
	TH-7B	168	199	1919.60	1921.66	163-168	1756.6	R & B 3/78	NA
	TH-7C	199	199	1919.60	1921.66	194-199	1725.6	R & B 3/78	NA
	TH-8	159	163	*1919.00	*1921.00	154-159	*1765	R & B 7/79	NA
6" steel casing/no info on riser	ES-1	NA	125	1965.50	1965.50	NA	NA	Eng. Sci. 8/82	AR
"	ES-2	NA	80	1966.00	1966.00	NA	NA	Eng. Sci. 8/82	AR
	ES-3	NA	30	1965.50	1965.50	NA	NA	Eng. Sci. 8/82	AR
	ES-4	NA	64	1964.20	1964.20	NA	NA	Eng. sci. 8/82	AR
	ES-5	NA	170	1937.40	1938.20	NA	NA	Eng. sci. 8/82	AR
	ES-6	NA	68	1938.20	1938.80	NA	NA	Eng. Sci. 8/82	AR
	ES-7	NA	165	1937.70	1938.50	NA	NA	Eng. Sci. 8/82	AR
	ES-8	NA	160	1925.60	1927.10	NA	NA	Eng. Sci. 8/82	AR
4" singl/~~[illegible]~~ 4" screen	ES-9	159	197.5	1933.60	1934.60	154	1773.99	H.C. 12/5/80	CT
4" steel casing + screen	ES-10	170	209	1939.70	1941.50	165	1774.7	H.C. 1/16/81	CT
	HC-1A	47	48.2	1925.99	1926.69	43	1882.99	H.C. 4/20/81	HSA
1½" PVC riser	HC-1	156	157	1925.26	1928.16	151	1774.26	H.C. 4/15/81	HSA
1½" PVC riser	HC-2A	167	168.5	1934.48	1937.48	162	1772.48	H.C. 4/10/81	HSA
1½" PVC riser	HC-2	60.5	65.5	1935.14	1935.14	55.5	1879.6	H.C. 3/17/81	HSA
1½"	HC-3	68.5	70	1937.75	1937.75	63.5	1874.2	H.C. 3/25/81	HSA
1½"	HC-4	52.5	53.5	1923.35	1925.35	47.5	1875.8	H.C. 3/23/81	HSA
1½"	HC-5	68	72	1941.72	1943.72	63	1878.7	H.C. 3/20/81	HSA
1½"	HC-6	50	51	1926.30	1929.30	47.8	1879.0	H.C. 2/22/81	HSA
1½"	HC-7	169	170	1936.55	1937.85	159	1777.5	H.C. 4/29/81	HSA
1½"	HC-8	162.5	164.5	1932.13	1933.98	157.5	1774.6	H.C. 5/8/81	HSA
1½"	HC-9A	162	164.5	1937.75	1939.05	157	1780.75	H.C. 4/1/81	HSA
1½"	HC-9	67	68.5	1935.40	1938.90	67	1867.9	H.C. 3/27/81	HSA
1½"	HC-10	181	184	1942.00	1942.00	176	1766.0	H.C. 5/15/81	HSA
1½"	HC-11	165	165	1906.30	1908.40	157	1749.3	H.C. 6/26/81	HSA
1½"	HC-12	148	150	1913.50	1915.60	145	1768.5	H.C. 7/8/81	HSA
1½"	HC-13	162	162	1937.04	1937.04	157	1780.04	H.C. 7/17/81	HSA
1½"	HC-14	160	162.5	1941.93	1943.73	156	1785.9	H.C.7/23/81	HSA
1½"	HC-15	145.5	156	1928.51	1932.01	140.5	1788.[illegible]	H.C. 7/8/82	HSA
1½"	HC-16	141.5	149	1921.55	1924.55	136.5	1785.05	H.C. 7/12/82	HSA
	HC-17	158.5	163	1938.00	1941.10	153.5	1784.5	H.C. 7/21/82	HSA

NOTES:

1. NA indicates data not available
2. * indicates only approximately
3. R & B means Robinson and Noble Inc., Eng. Sci. means Engineering Science Inc., and H.C. means Hart Crowser Inc.
4. AR means air rotary drilling, CT means cable tool drilling, and HSA means hollow stem auger drilling

J-948-05

TABLE A-1 - WELL CONSTRUCTION DATA SUMMARY WELLS WITHIN KACC-MEAD PLANT

WELL NUMBER	WELL DEPTH	BORING DEPTH	GRNDSURF. ELEVATION	TOP CASING ELEVATION	SCREENING DEPTH	SCREEN TOP ELEVATION	INSTALLED BY DATE	DRILLING METHOD
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TH-2	157	163	1933.00	1935.49	153-157	1780	R & B 3/78	NA
TH-3	210	214	1919.00	1921.04	140-210	1779	R & B 3/78	NA
TH-3A	161	163	1919.70	1921.64	145-161	1774.7	R & B 3/78	NA
TH-4	205	205	1919.00	1921.03	145-205	1774	R & B 3/78	NA
TH-5	186	214	1904.70	1906.67	135-186	1769.7	R & B 3/78	NA
TH-6A	150	200	1918.10	1919.10	147-150	1771.1	R & B 3/78	NA
TH-6B	172	200	1918.10	1919.10	167-172	1751.1	R & B 3/78	NA
TH-6C	200	200	1918.10	1919.10	195-200	1751.1	R & B 3/78	NA
TH-7A	151	199	1919.60	1921.66	146-151	1773.6	R & B 3/78	NA
TH-7B	168	199	1919.60	1921.66	163-168	1756.6	R & B 3/78	NA
TH-7C	199	199	1919.60	1921.66	194-199	1725.6	R & B 3/78	NA
TH-8	159	163	*1919.00	*1921.00	154-159	*1765	R & B 7/79	NA
ES-1	NA	125	1965.50	1965.50	NA	NA	Eng. Sci. 9/82	AR
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ES-4	NA	64	1964.20	1964.20	NA	NA	Eng. sci. 8/82	AR
ES-5	NA	170	1937.40	1938.20	NA	NA	Eng. sci. 8/82	AR
ES-6	NA	68	1938.20	1938.80	NA	NA	Eng. Sci. 8/82	AR
ES-7	NA	165	1937.70	1938.50	NA	NA	Eng. Sci. 8/82	AR
ES-8	NA	160	1925.60	1927.10	NA	NA	Eng. Sci. 8/82	AR
ES-9	159	197.5	1933.60	1934.60	154	1773.99	H.C. 12/5/80	CT
ES-10	170	209	1939.70	1941.50	165	1774.7	H.C. 1/16/81	CT
HC-1A	47	48.2	1925.99	1926.69	43	1882.99	H.C. 4/20/81	HSA
HC-1	156	157	1925.26	1928.16	151	1774.26	H.C. 4/15/81	HSA
HC-2A	167	168.5	1934.48	1937.48	162	1772.48	H.C. 4/10/81	HSA
HC-2	60.5	65.5	1935.14	1935.14	55.5	1879.6	H.C. 3/17/81	HSA
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HC-4	52.5	53.5	1923.35	1925.35	47.5	1875.8	H.C. 3/23/81	HSA
HC-5	68	72	1941.72	1943.72	63	1878.7	H.C. 3/20/81	HSA
HC-6	50	51	1926.80	1928.80	47.3	1879.5	H.C. 3/22/81	HSA
HC-7	169	170	1936.55	1937.85	159	1777.5	H.C. 4/29/81	HSA
HC-8	162.5	164.5	1932.13	1933.98	157.5	1774.6	H.C. 5/8/81	HSA
HC-9A	162	164.5	1937.75	1939.05	157	1780.75	H.C. 4/1/81	HSA
HC-9	67	68.5	1935.40	1938.90	67	1867.9	H.C. 3/27/81	HSA
HC-10	181	184	1942.00	1942.00	176	1766.0	H.C. 5/15/81	HSA
HC-11	165	165	1906.00	1908.40	157	1749.0	H.C. 6/26/81	HSA
HC-12	148	150	1910.50	1915.50	145	1765.5	H.C. 7/8/81	HSA
HC-13	162	162	1937.04	1937.04	157	1780.04	H.C. 7/17/81	HSA
HC-14	160	162.5	1941.90	1943.70	156	1785.9	H.C.7/23/81	HSA
HC-15	145.5	156	1928.51	1932.01	140.5	1788.0	H.C. 7/13/82	HSA
HC-16	141.5	149	1921.55	1924.55	136.5	1785.05	H.C. 7/12/82	HSA
HC-17	158.5	163	1938.00	1941.10	153.5	1784.5	H.C. 7/21/82	HSA

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1. NA indicates data not available
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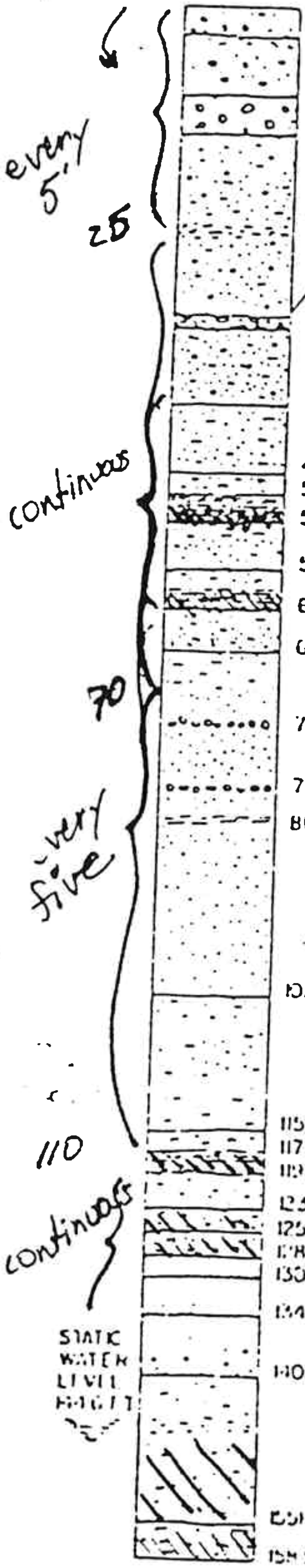
4. AR means air rotary drilling, CT means cable tool drilling, and HSA means hollow stem auger drilling

sample for HC-1 in red

TEST Hole TH-1

FIGURE 1

DESCRIPTIVE LOG (Robinson & Noble 1978)



0 GROUND SURFACE (1926 feet)
3 FT SILT, SAND AND GRAVEL GRAY WITH ORGANIC MATTER
9 FT SAND AND GRAVEL, SILTY TO 3 FEET - BROWN 3 FEET TO 9 FEET
13 FT COARSE SAND AND GRAVEL
28'
32 FT SAND, SILT AND FINE GRAVEL LIGHT BROWN (VERY SILTY AT 22.5 FEET TO 23 FEET
33 FT COBBLES AND SILT
41 FT SAND, GRAVEL AND SILT
48 FT FINE TO MEDIUM SAND AND SILT
50 FT MEDIUM TO COARSE SAND AND SILT - CEMENTED
53 FT CLAY (PLASTIC) AND SAND BROWN
58 FT FINE TO MEDIUM SAND AND SILT
62 FT SILT, CLAY AND SAND, YELLOW BROWN DARKER WITH DEPTH
66 FT FINE TO COARSE SAND AND SILT
70 FT
78 FT
80 FT
101 FT FINE TO MEDIUM SAND, SILT TAN (CLEANER AND DIRTIER STREAKS AS SHOWN)
115 FT FINE TO COARSE SAND AND SILT, LIGHT BROWN
117 FT FINE TO MEDIUM SAND AND SILT, BROWN CEMENTED
119 FT CLAY AND SILT, BROWN (PLASTIC)
123 FT MEDIUM SAND AND SILT, CLEANER AT 123 FEET
125 FT FINE TO COARSE SAND AND SILT, CEMENTED
128 FT SILT, FINE TO MEDIUM SAND, CEMENTED
130 FT MEDIUM TO COARSE SAND - CLEAN
134 FT FINE TO COARSE SAND AND SILT
140 FT FINE TO COARSE SAND AND SOME FINE GRAVEL
155 FT MEDIUM TO COARSE SAND AND SILT, WITH FINE GRAVEL (CLEANER AND SILTY ZONES AS SHOWN)
158.5 FT FINE TO MEDIUM SAND, AND SILT [illegible]
TOTAL DEPTH 159.5 FEET

KAISER MEAD PROJECT NO. 177-4
TEST HOLE 1

ROBINSON AND NOBLE

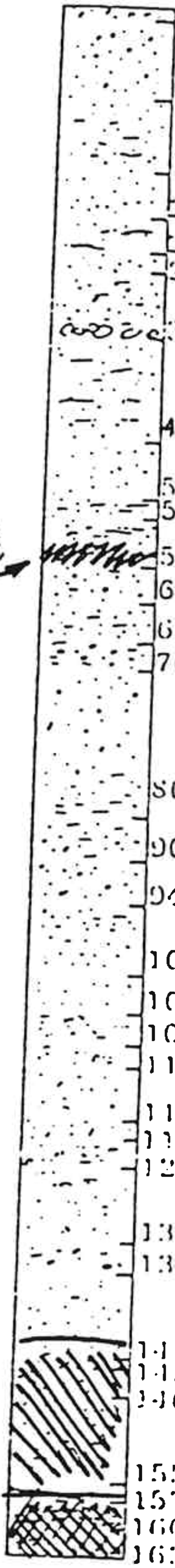
4 '13 78

Figure A-1

TEST HOLE #2

(Robinson & Noble 1978)

Ground Surface



57
1/48

CLAY?

1.5 ft. Silt, sand and fine gravel

10 Coarse sand and fine gravel - black-brown

17.5 Silt, medium to coarse sand - tan

22 Medium to coarse sand - black-tan

26 Medium sand with streaks of clay

28 Medium to coarse sand, and granules - clean

Silt, fine sand, and small pebbles
(cobbles at 35 feet)

35

46 Fine to medium sand and silt - gray-tan

52 Fine to medium sand, gray-tan - clean

54 Silt, sand cemented, light brown

59 Silt, sand, clay cemented

63 Medium to coarse sand, silt and fine gravel

67 Silt, fine to coarse sand & fine gravel - gray

70 Silt and gravel (pebbles) tan

Fine to coarse sand, fine gravel
silt increasing toward 86 feet

86

90 Silt, fine to coarse sand and gravel - gray

94.5 Medium to coarse sand and pebbles - gray

102 Silt, fine to medium sand, cemented - tan

106 Medium to coarse sand - gray

109.5 Silt and sand, fine to medium - tan-gray

111.5 Fine to medium sand, silt & clay, tan-gray, cemented

117 Fine to medium sand and silt - tan-gray

119 Silt, fine to medium sand

122 Silt, fine to medium sand w/clay & pebbles, cemented

130 Medium sand and silt cemented - light brown

133 Silt, fine to medium sand and fine gravel

141 Medium sand and silt - gray-brown

143 Silt, medium to coarse sand - dark gray

146 Medium to coarse sand, green, clean, water-bearing

Medium to coarse sand and silt, water-bearing fluid
(some cemented layers)

155

157 Clay, silt gray-blue - plastic

160 Clay, silt, with sand

163 ft. Clay, gray - plastic

Kaiser Mead

Project No. 177-4

ROBINSON & NOBLE, INCORPORATED

Figure A-2

.R GEOLOGISTS
;HINGTON

:AD WORKS
.ST HOLE NO. 3

LOGGED BY: IG DOW
ANDLER ELLIS

DATE: 1/3/78

TH-3 TEST Hole TH-3

T26N R43E C16 (Robinson and Kolle 1979)

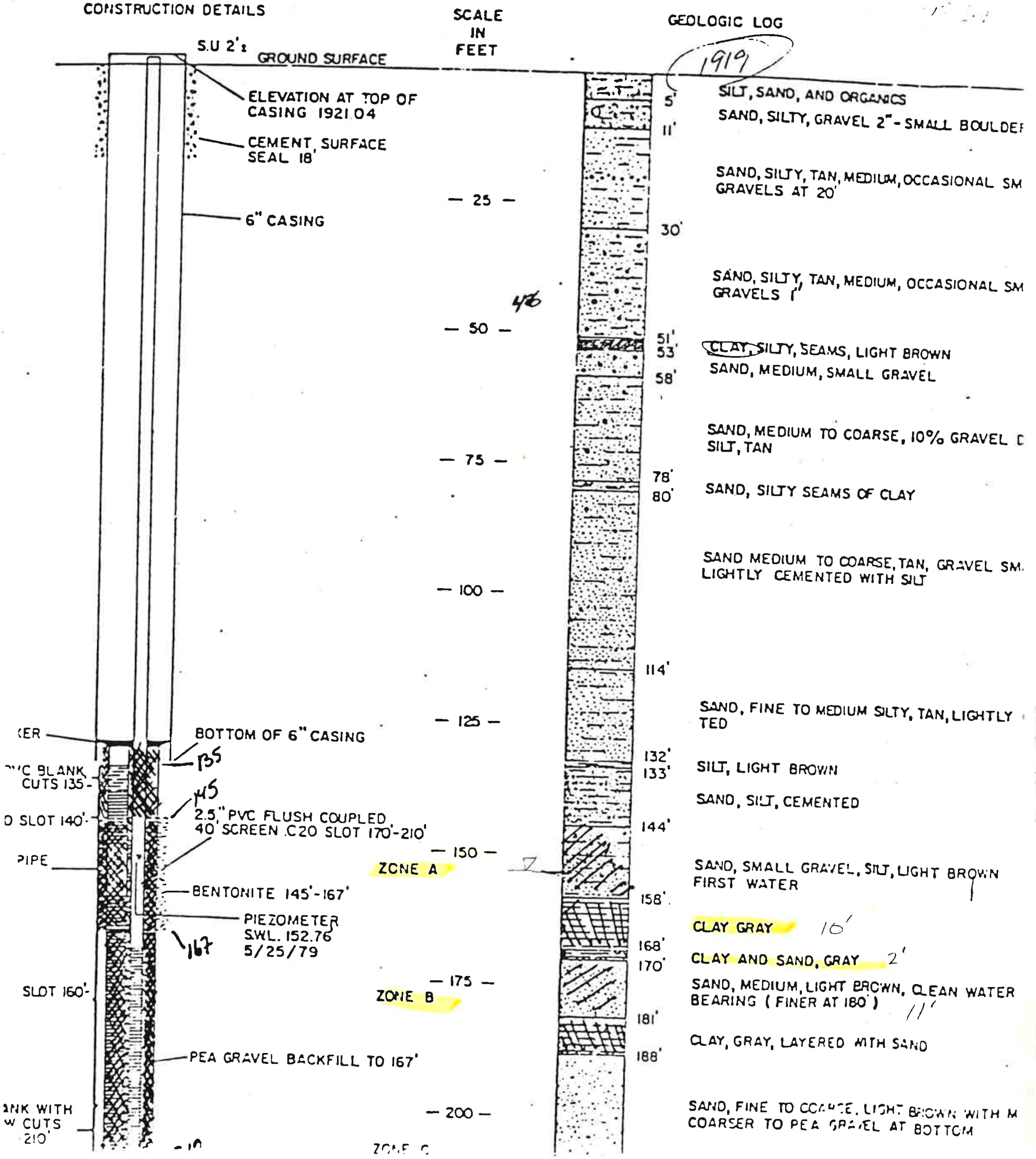


Figure A-3

WASHINGTON EST HOLE 3A CHANDLER ELLIS

TH-3A

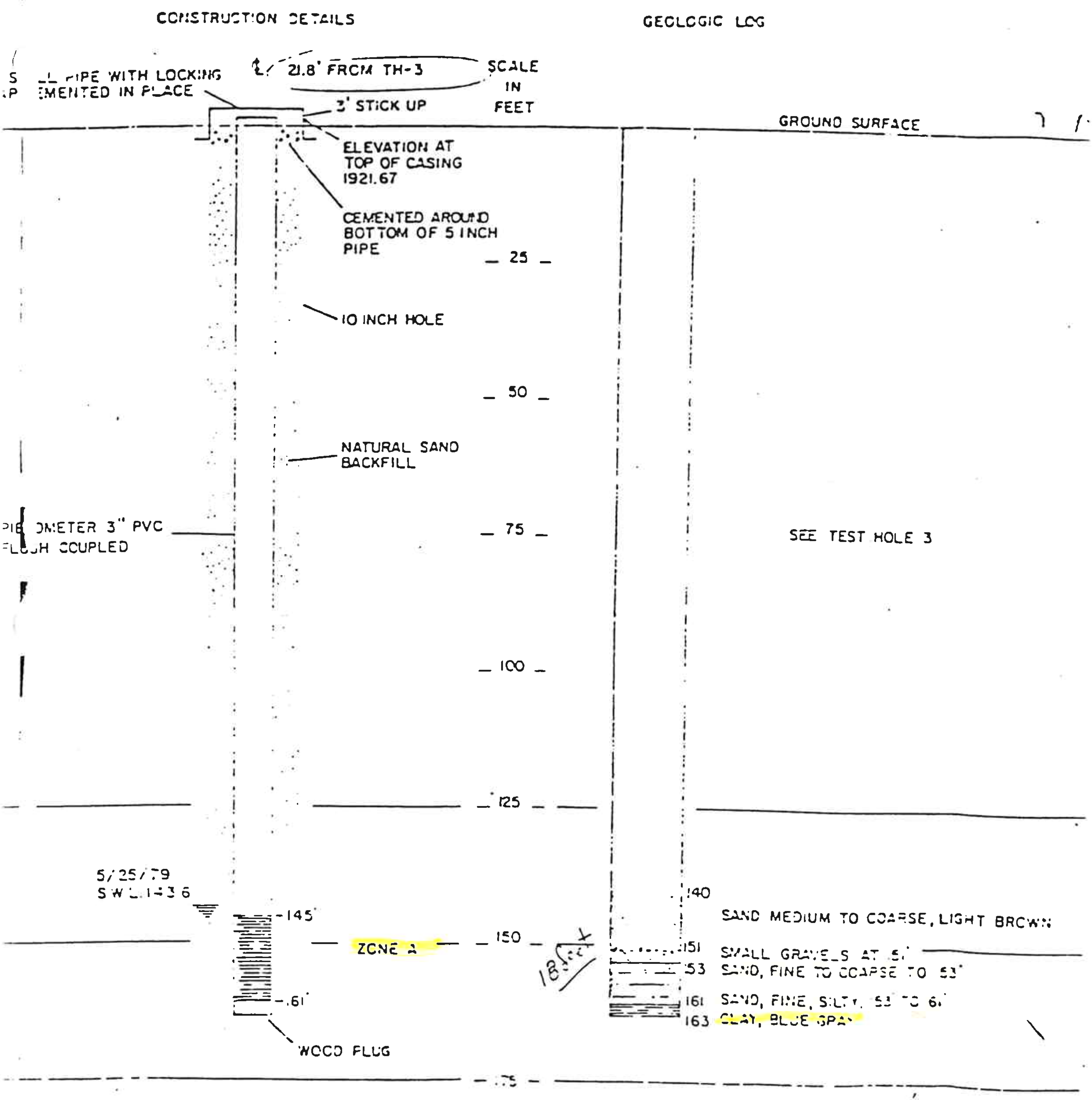


Figure A-4

TH-4 TEST Hole TH-4

T26N R43E S9 R/W 1979

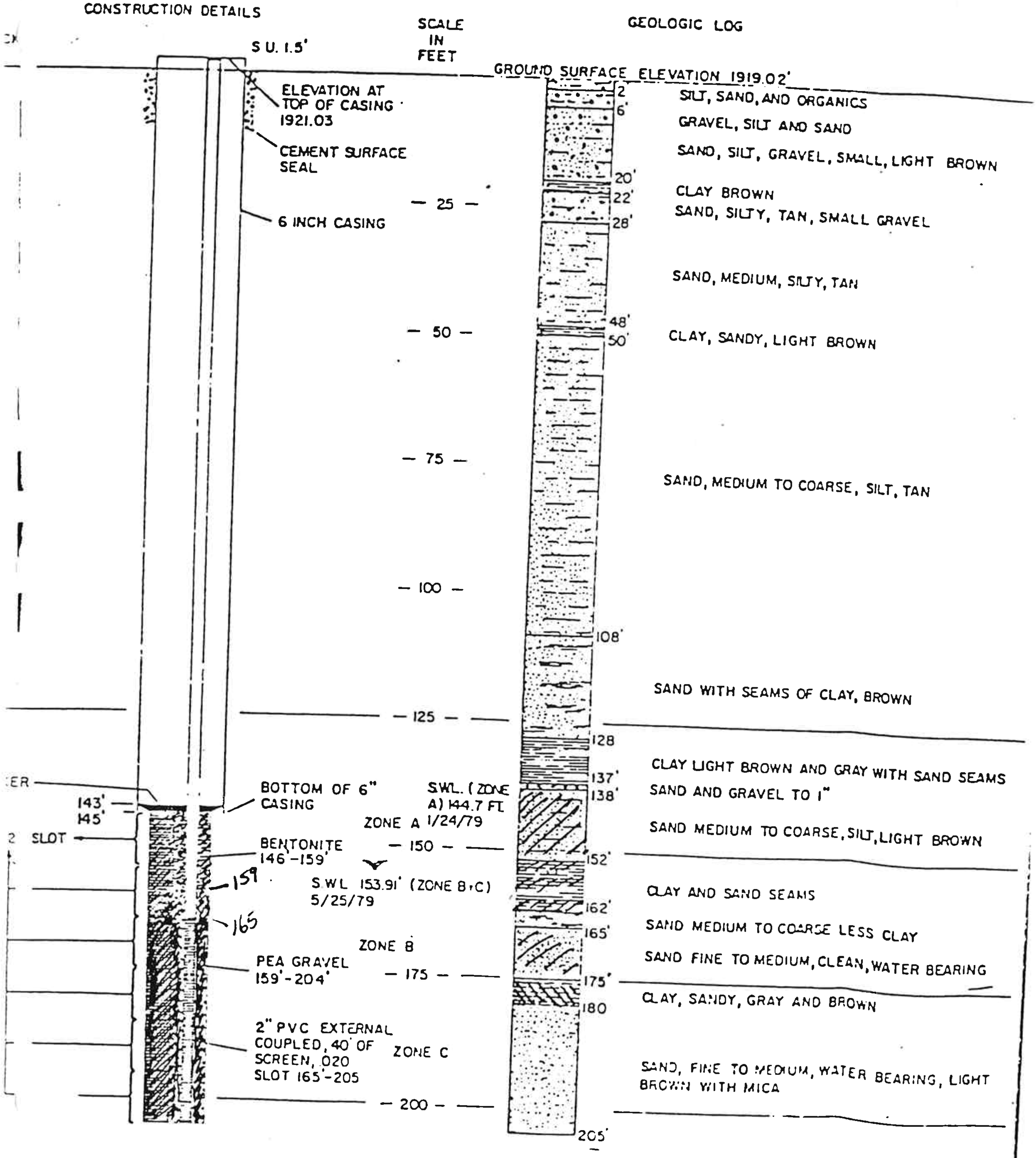
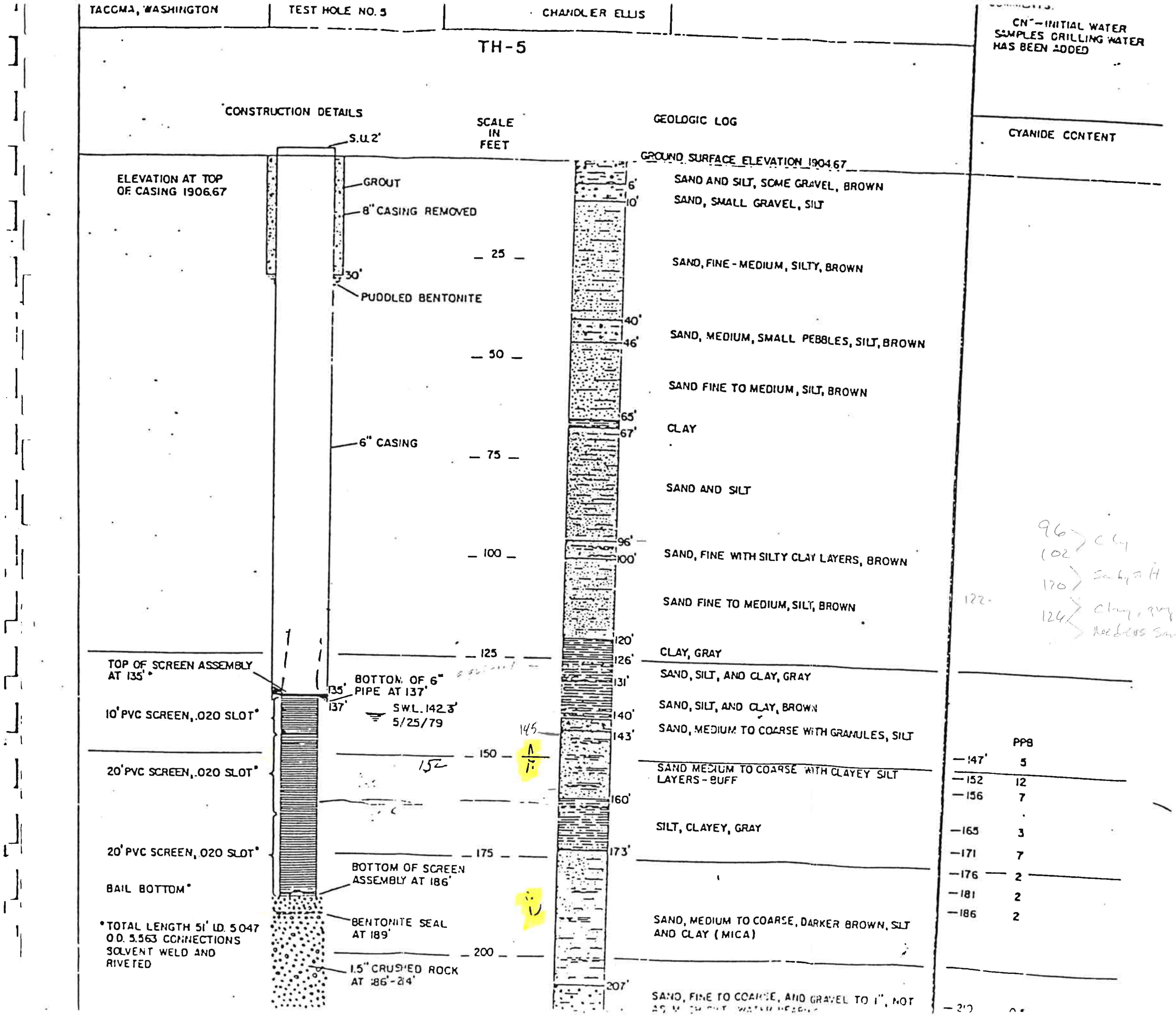


Figure A-5



	PPB
147'	5
152	12
156	7
165	3
171	7
176	2
181	2
186	2
2[illegible]	[illegible]

Figure A-6

1, WASHINGTON | TEST HOLE 6 | CHANDLER ELLIS

TH-6

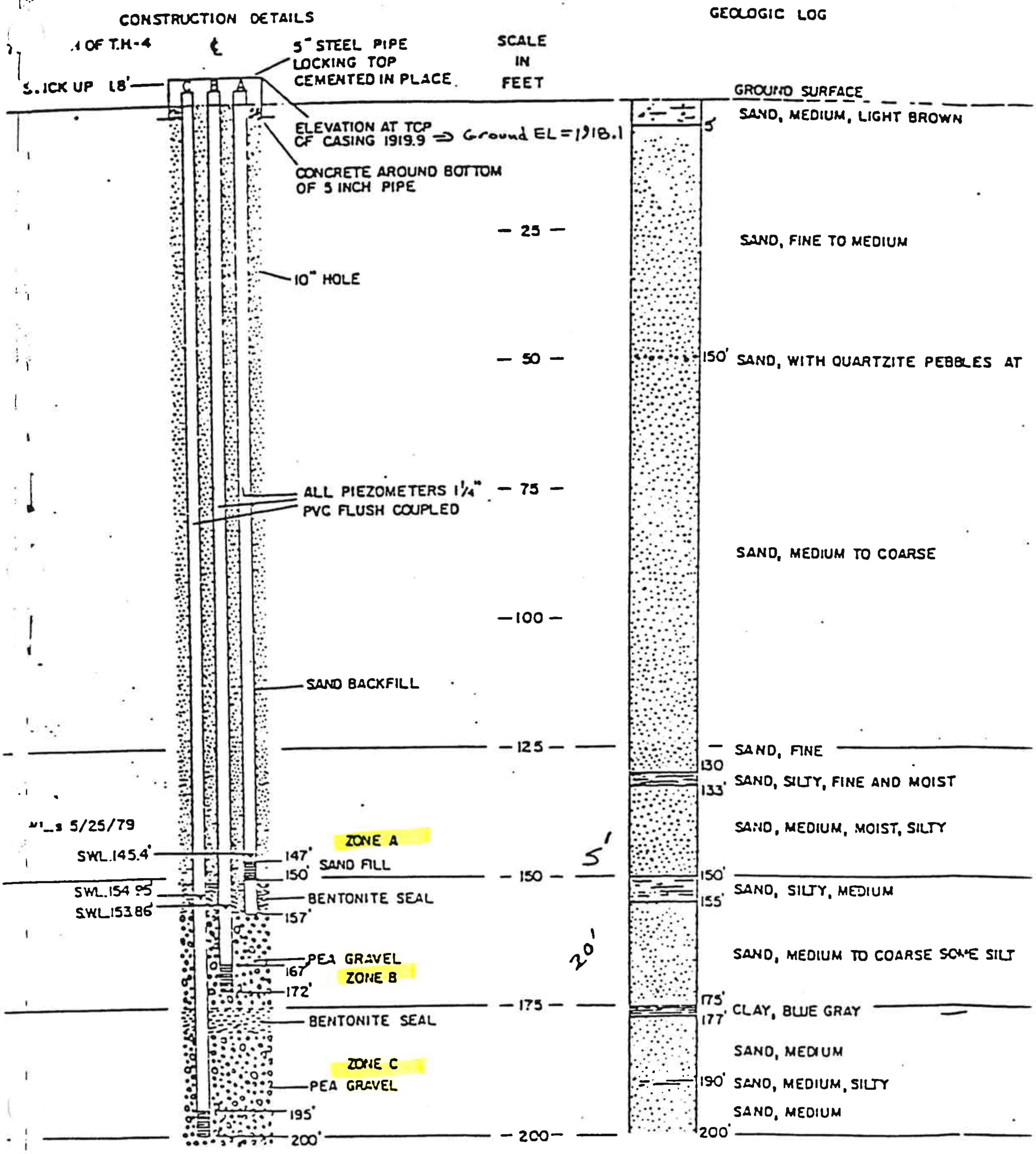


Figure A-7

R..BINSON AND NOBLE INC.
GROUND WATER GEOLOGISTS
T..OMA, WASHINGTON

KAISER ALUMIUM CO.
MEAD WORKS
TEST HOLE 7

JOB NO. 77-4C
LOGGED BY. DOUG DO
CHANDLE

TH-7

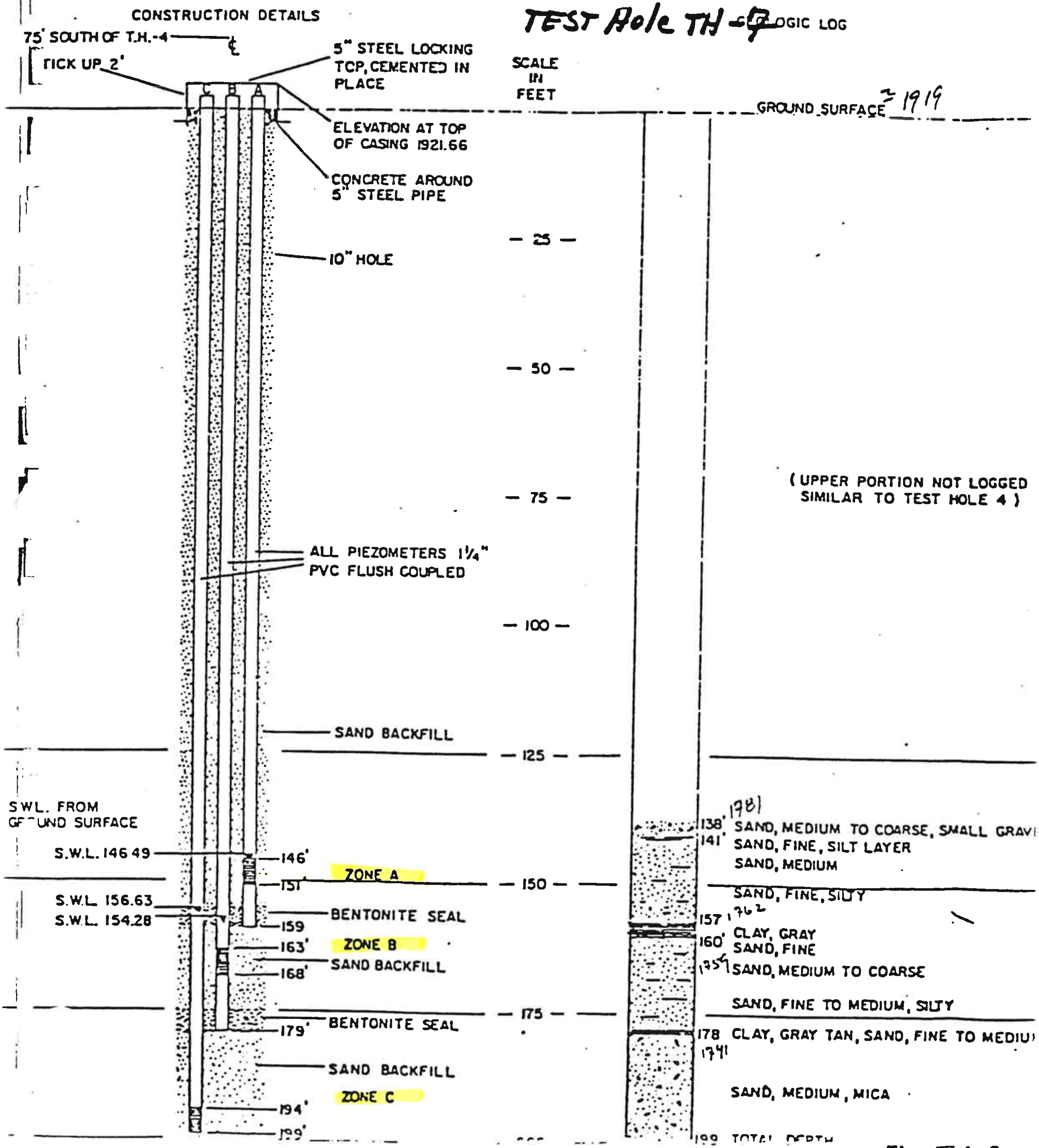


Figure A-8

BINSON AND NOBLE INC.
ROUND WATER GEOLOGISTS
TACOMA, WASHINGTON

KAISER ALUMINUM CO.
MEAD WORKS
TEST HOLE 8

JOB NO. 77-4 C
LOGGED BY: DOUG DOW

NOTES: 112' NE FROM TH-3A, JULY 1979. TEST PUMP, AUGUST 1, 1979 TEMP. 19°C DURING PUMP TEST

TEST Hole TH-8
(Robinson & Noble 1979)

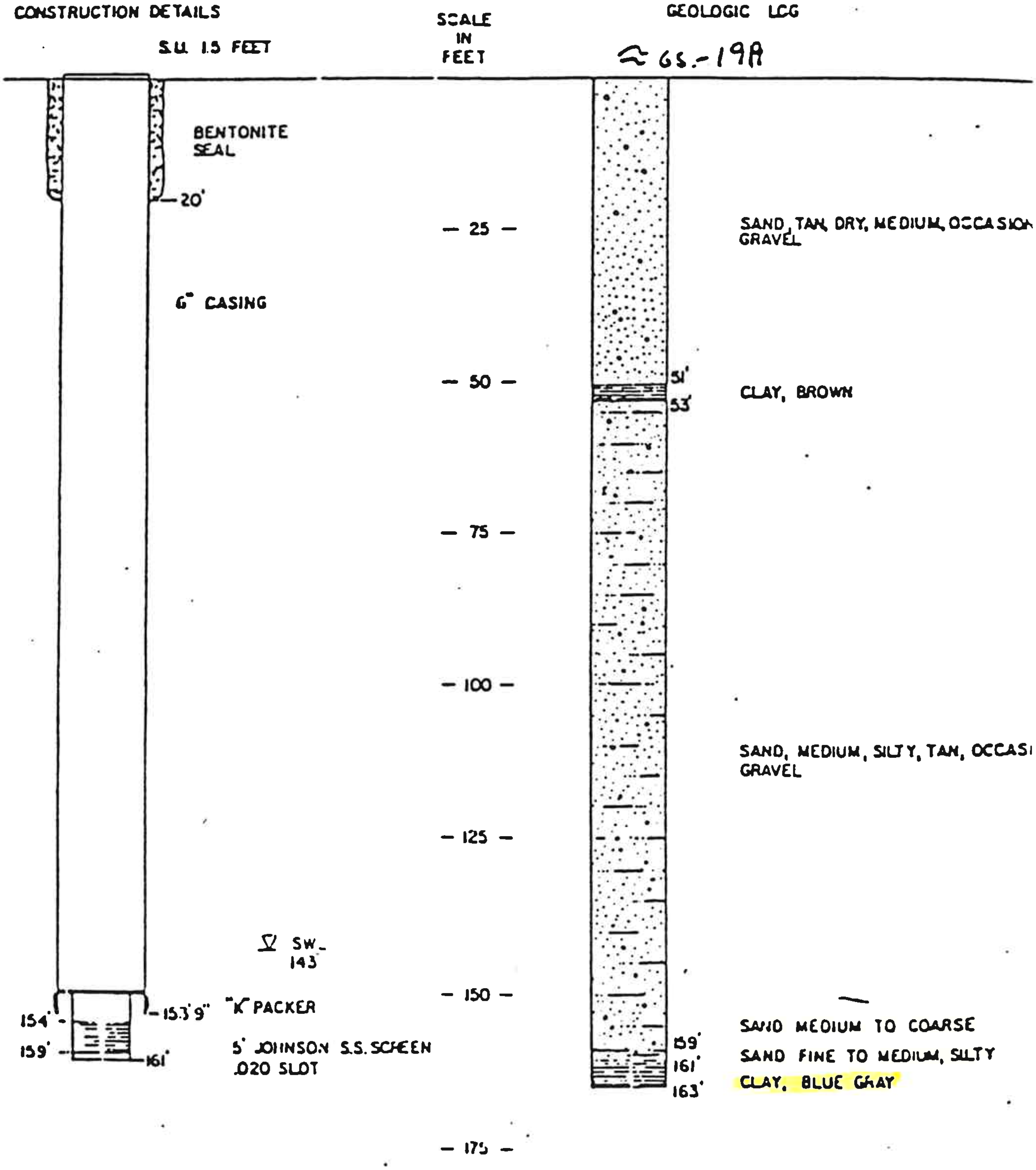


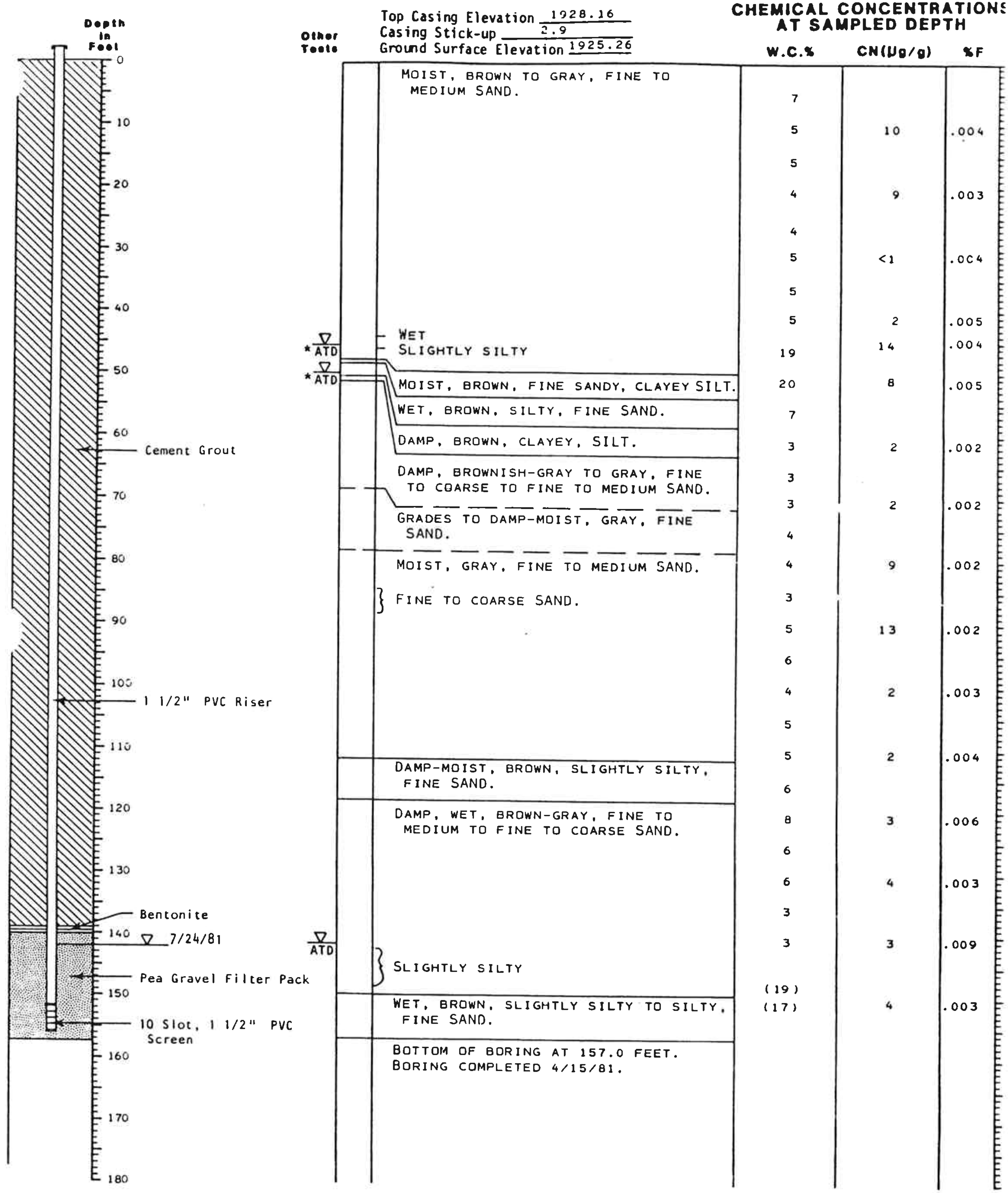
Figure A-9

WELL DESIGN

GEOLOGIC LOG HC-1

Top Casing Elevation 1928.16
Casing Stick-up 2.9
Ground Surface Elevation 1925.26

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH



MOIST, BROWN TO GRAY, FINE TO MEDIUM SAND.

WET

SLIGHTLY SILTY

MOIST, BROWN, FINE SANDY, CLAYEY SILT.

WET, BROWN, SILTY, FINE SAND.

DAMP, BROWN, CLAYEY, SILT.

DAMP, BROWNISH-GRAY TO GRAY, FINE TO COARSE TO FINE TO MEDIUM SAND.

GRADES TO DAMP-MOIST, GRAY, FINE SAND.

MOIST, GRAY, FINE TO MEDIUM SAND.

FINE TO COARSE SAND.

DAMP-MOIST, BROWN, SLIGHTLY SILTY, FINE SAND.

DAMP, WET, BROWN-GRAY, FINE TO MEDIUM TO FINE TO COARSE SAND.

SLIGHTLY SILTY

WET, BROWN, SLIGHTLY SILTY TO SILTY, FINE SAND.

BOTTOM OF BORING AT 157.0 FEET.
BORING COMPLETED 4/15/81.

W.C.%	CN(µg/g)	%F
7		
5	10	.004
5		
4	9	.003
4		
5	<1	.004
5		
5	2	.005
19	14	.004
20	8	.005
7		
3	2	.002
3		
3	2	.002
4		
4	9	.002
3		
5	13	.002
6		
4	2	.003
5		
5	2	.004
6		
8	3	.006
6		
6	4	.003
3		
3	3	.009
(19)		
(17)	4	.003

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Sample

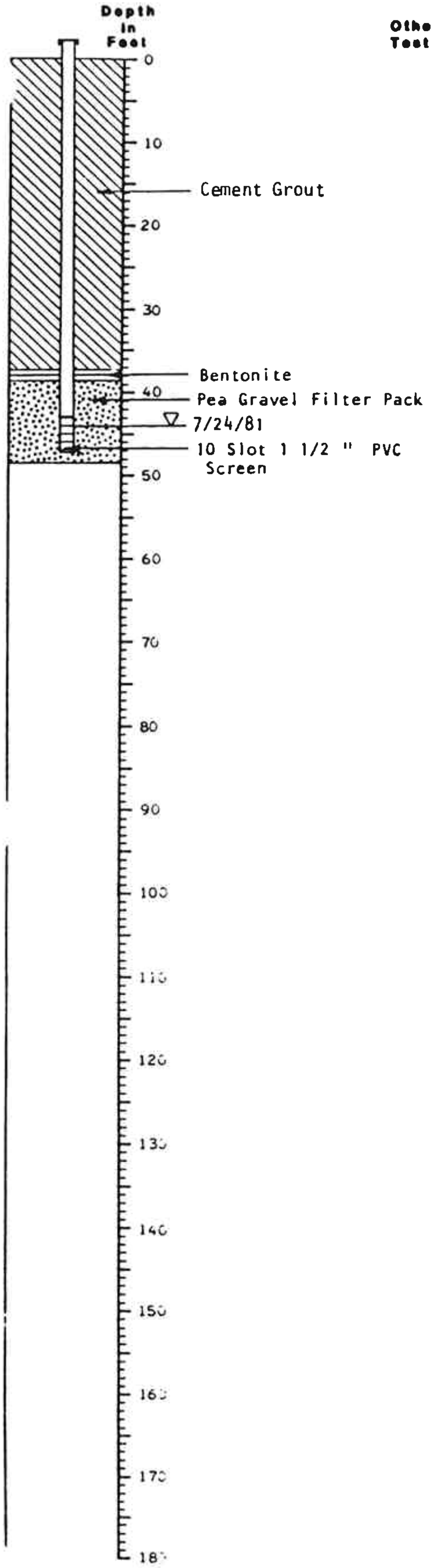
W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982

HART-CROWSER & associates Inc.

Figure A-10

WELL DESIGN



GEOLOGIC LOG HC-1A

Top Casing Elevation 192638
Casing Stick-up 1.7
Ground Surface Elevation 1924.68

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

Other Tests		W.C.%	CN(µg/g)	%F
	MONITORING WELL HC-1A INSTALLED IN SEPARATE AUGERED BORING. SEE HC-1 FOR GEOLOGIC LOG, AND SOIL CHEMICAL QUALITY DATA			
	BOTTOM OF BORING AT 48.2 FEET. BORING COMPLETED 4/20/81.			

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Sample

W.C.%	= Weight Basis
*	Perched Water
▽	Water Level
4000	Water CN Concentration in ppb

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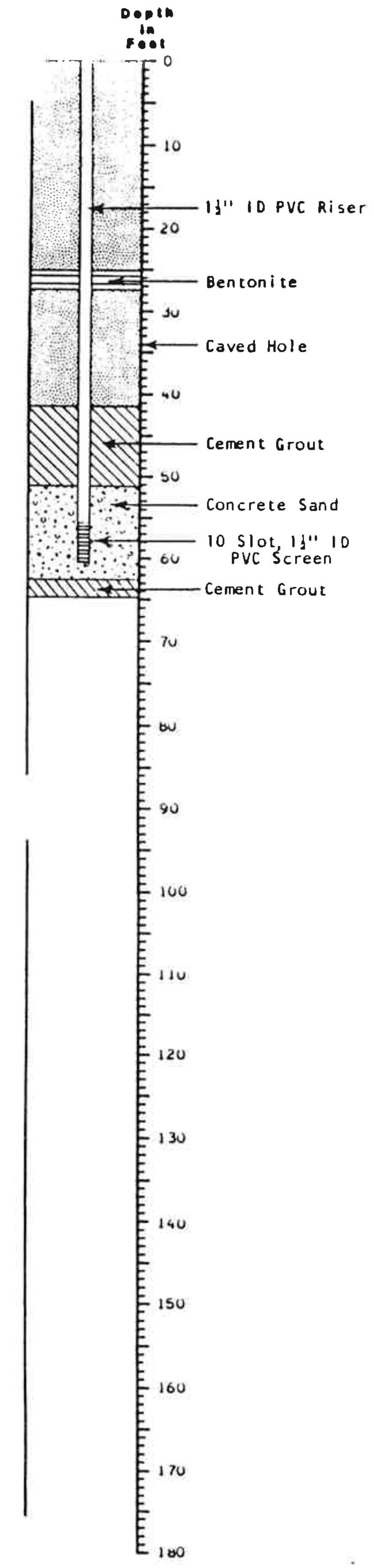
HART-CROWSER & associates Inc.
Figure A-11

WELL BORING AND CONSTRUCTION INFORMATION

WELL DESIGN



GEOLOGIC LOG HC-2

Top Casing Elevation 1935.1
Casing Stick-up 0
Ground Surface Elevation 1935.1

Other Tests

ATD ▽ 6,000

ATD ▽

DAMP, BROWN, SILTY, FINE SAND, WITH BLACK-WHITE CEMENTED LAYERS, WITH GRAVEL FROM 4 TO 7 FEET (FILL)

DAMP, BROWN, SLIGHTLY SILTY, FINE TO MEDIUM SAND, WITH SOME COARSE SAND AND FEW GRAVEL.

— SILTY CLAY (3 INCHES THICK.)

— GRADES SILTIER

— WET TO SATURATED BELOW 46 FEET.

WET, BROWN, SILTY CLAY TO CLAYEY SILT INTERBEDDED WITH SANDY SILT TO SILTY SAND LAYERS

DAMP TO SATURATED, BROWN, CLEAN TO SILTY, FINE TO MEDIUM SAND.

— DAMP, BROWN, LAMINATED, SILTY CLAY, (4.7 INCHES THICK.)

DEPTH OF BORING 65.5 FEET.
COMPLETED 3/17/81.

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
17	36	3.3
6	10	0.11
6	10	0.06
6		
5	13	0.07
5		
10	24	0.07
(32)	6	0.12
	2	0.65
9	4	0.06
(32)	12	0.5
7		

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Samples

W.C.% = Weight Basis

*	Perched Water
▽	Water Level
4000	Water CN Concentration in ppb

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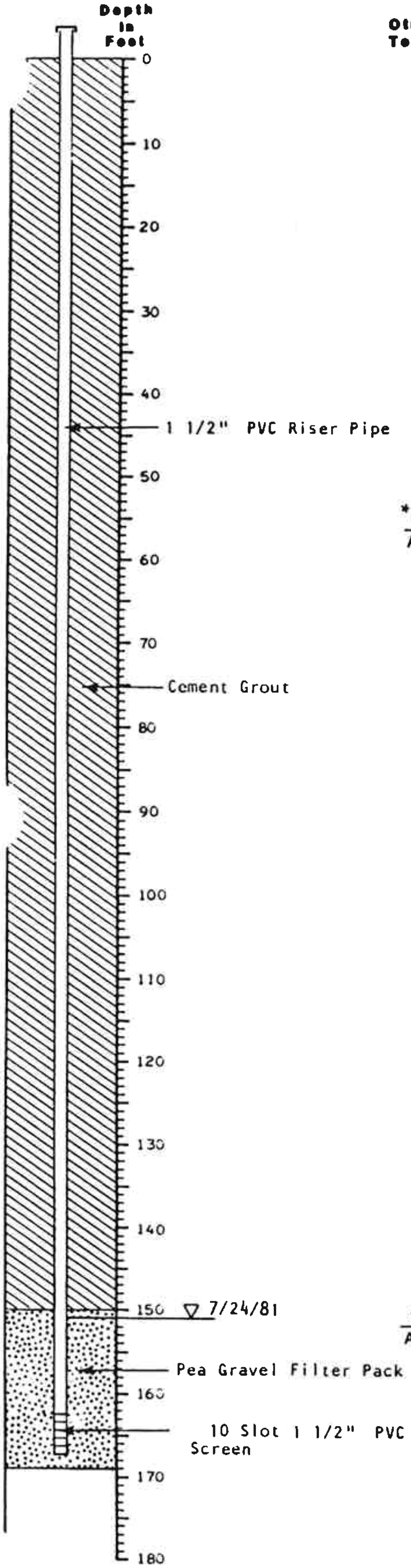
HART-CROWSER & associates inc.

Figure A-12

WELL DESIGN



GEOLOGIC LOG HC-2A

Top Casing Elevation 1937.48
Casing Stick-up 3.0
Ground Surface Elevation 1934.48

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH

Other Tests		W.C.%	CN(µg/g)	%F
	NOT SAMPLED FIRST 50 FEET. SEE LOG FOR HC-2.			
	DAMP TO WET, BROWN, FINE TO MEDIUM SAND.	6.0	3	.007
* ▽ ATD		6.0		
		(46.0)	60	.014
	INTERBEDDED, DAMP, BROWN, SILTY CLAY AND MOIST TO WET, BROWN, SILTY, FINE SAND.	17.0		
		3.0		
		5.0		
	SLIGHTLY SILTY, FINE TO MEDIUM SAND.	2.0	5	.006
	DAMP, GRAY, SLIGHTLY SILTY TO CLEAN, FINE TO COARSE SAND.	3.0		
	DAMP, GRAYISH-BROWN TO GRAY, FINE TO MEDIUM SAND.	3.0	30	.010
		4.0		
		4.0	19	.008
		4.0		
		10.0	20	.015
		3.0		
		4.0		
		4.0	18	.004
	DAMP, GRAY, SILTY FINE SAND TO FINE SANDY SILT (1.0 FEET THICK).	5.0	18	.011
	MOIST, BROWN, SILTY CLAY.	7.0	15	.002
	DAMP, BROWN, SLIGHTLY SILTY, FINE SAND.	3.0		
		3.0		
	DAMP, BROWNISH-GRAY TO BROWN, CLEAN TO SILTY, FINE TO COARSE SAND.	4.0	8	.002
	FINE TO MEDIUM SAND.	7.0	<1	.006
		21.0		
	MOIST TO WET, BROWN, VERY SILTY, FINE SAND WITH DAMP, GREEN-GRAY, CLAY (0.1 FEET THICK).	2.0	2	0
▽ ATD		11.0		
	DAMP TO WET, GRAY TO BROWNISH-GRAY, SLIGHTLY SILTY TO CLEAN, FINE TO MEDIUM AND FINE TO COARSE SAND.	(16.0)		
		(15.0)		
		(14)		
		(16)		
	BOTTOM OF BORING AT 168.5 FEET. BORING COMPLETED 4/10/81.			

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

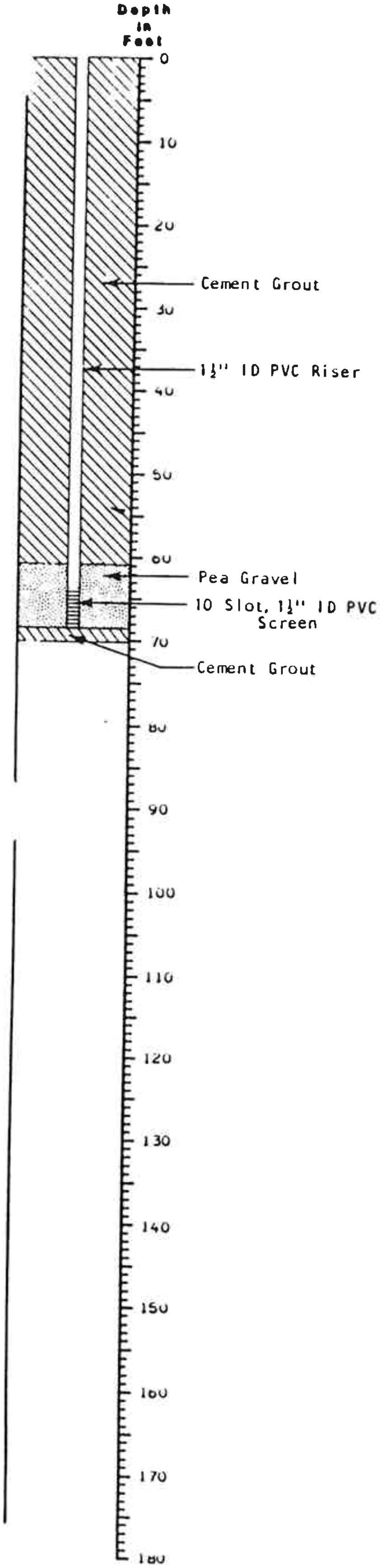
J-948-02 June 1982

HART-CROWSER & associates Inc.

Figure A-13

WELL BORING AND CONSTRUCTION INFORMATION

WELL DESIGN



GEOLOGIC LOG HC-3

Other Tests

Top Casing Elevation 1937.7
Casing Stick-up 0
Ground Surface Elevation 1937.7

WET, BROWN, SILTY, FINE TO MEDIUM SAND (FILL)

MOIST TO DAMP, BROWN TO GRAY-BROWN, FINE TO MEDIUM SAND.
SILTY LAYER

DAMP, BROWN TO GRAY-BROWN, FINE TO COARSE SAND, WITH FEW FINE GRAVEL.

MOIST TO DAMP, BROWN TO GRAY-BROWN, FINE TO MEDIUM SAND.

DAMP, TAN, FINE TO COARSE SAND, WITH FEW FINE GRAVEL, SLIGHTLY CEMENTED.

DAMP, MOTTLED, SILTY CLAY/CLAYEY SILT

DAMP, GRAY-BROWN, FINE TO COARSE SAND, WITH FEW GRAVEL.

DAMP TO MOIST, GRAY-BROWN, FINE TO MEDIUM SAND.

MOIST, BROWN, FINE SANDY SILT

LAMINATED, GRADES TO WET, BROWN, SILTY, FINE TO MEDIUM SAND WITH SILTY CLAY LAMINAE.

MOIST, GRAY-BROWN, FINE TO MEDIUM SAND.

BOTTOM OF BORING 70 FEET.
COMPLETED 3/25/81.

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
10		
19	4	.075
17		
4		
3	2	.030
3		
5	2	.035
2		
3	2	.023
5		
4	4	.020
5		
8	4	.010
21	18	.012
5		

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

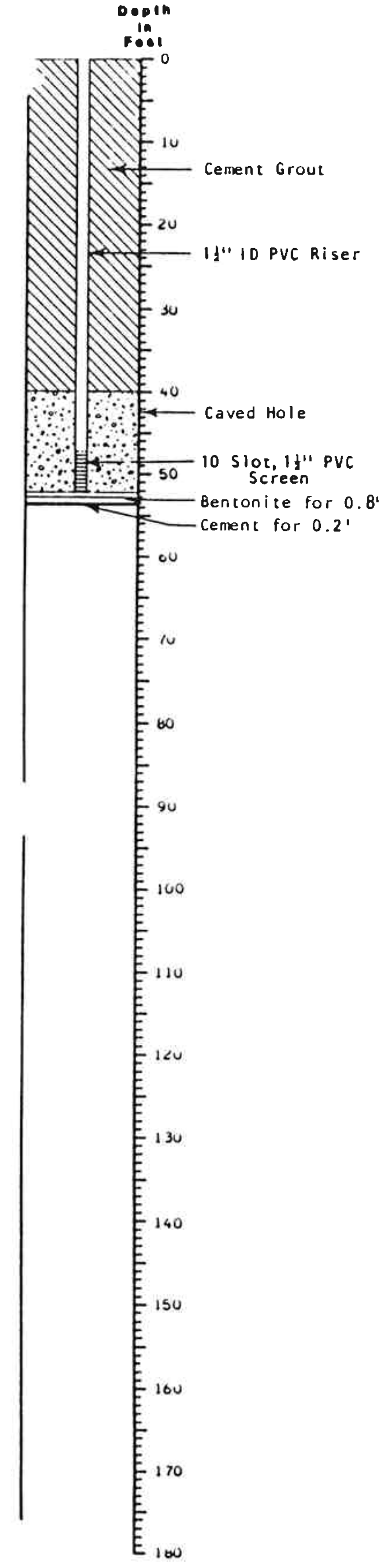
J-948-02 June 1982

HART-CROWSER & associates Inc.

Figure A-14

WELL BORING AND CONSTRUCTION INFORMATION

WELL DESIGN



GEOLOGIC LOG HC-4

Top Casing Elevation 1925.3
Casing Stick-up 2.0
Ground Surface Elevation 1923.3

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

Other Tests		W.C.%	CN(µg/g)	%F
	DAMP TO WET, BROWN, SILTY TO VERY SILTY, FINE TO COARSE SAND.	9		
	MOIST, BROWN, FINE TO COARSE SAND, WITH FEW FINE GRAVEL.	6	2	0.30
	— GRADES FINER	5		
		12		
			1	.011
	DAMP, GRAY-BROWN, FINE TO MEDIUM TO FINE TO COARSE SAND WITH FEW FINE GRAVEL.	2		
	SANDY, SILTY CLAY 2'' THICK	2	2	.010
	— DAMP, TAN, SILTY CLAY, 3'' THICK.			.018
	— — — — — — — — — — —	2	2	
	GRADES TO DAMP, GRAY-BROWN, FINE TO MEDIUM SAND.	2	2	.007
		3		
	— MOIST	17		
	WET TO SATURATED, BROWN, FINE SANDY, SILT TO SILTY, FINE SAND WITH LAYERS OF DAMP TAN, SILTY, CLAY TO CLAYEY, SILT.	14	<1	.014
	GRADES TO MOIST, GRAY-BROWN, SILTY, FINE TO MEDIUM SAND.			
	BOTTOM OF BORING AT 53.5 FEET. COMPLETED 3/23/81.			

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Samples

W.C.% = Weight Basis

*	Perched Water
$\underline{\nabla}$	Water Level
4000	Water CN Concentration in ppb

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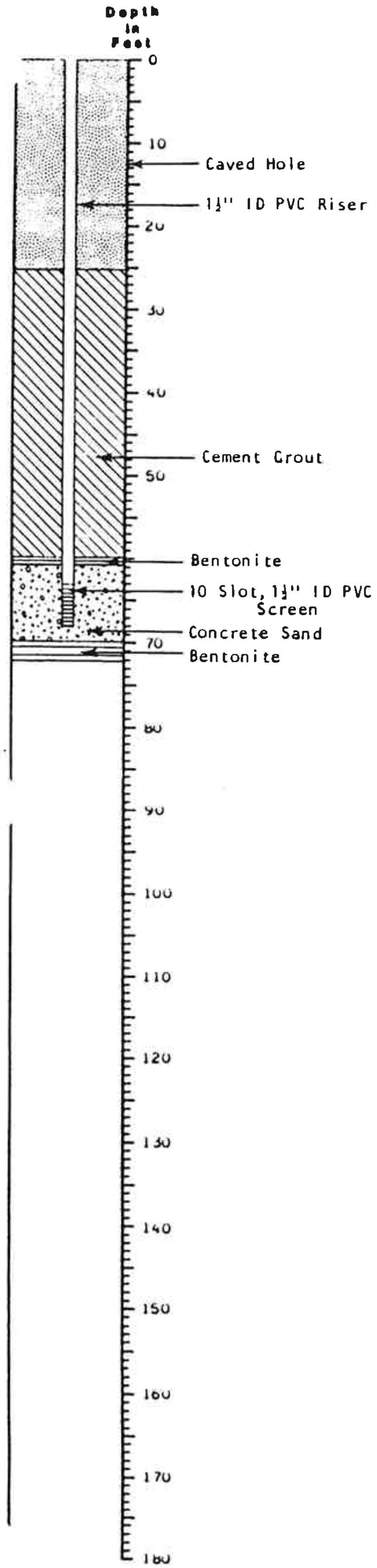
HART-CROWSER & associates Inc.
Figure A-15

WELL BORING AND CONSTRUCTION INFORMATION

WELL DESIGN



GEOLOGIC LOG HC-5

Other Tests

Top Casing Elevation 1943.7
Casing Stick-up 2.0
Ground Surface Elevation 1941.7

MOIST TO WET, BLACK-BROWN, SLIGHTLY SILTY TO SILTY, FINE TO COARSE SAND. (FILL)

DAMP, BROWN, SLIGHTLY SILTY, FINE TO MEDIUM SAND, WITH FEW GRAVEL.
- CLAYEY, SILT (1 INCH THICK.)
- CEMENTED SAND (12 INCHES THICK.)
- SLIGHTLY SILTY.

GRADES TO DAMP, BROWN, FINE SAND TO FINE TO MEDIUM SAND.
- WET, CLAYEY, SILT (1 - 2 INCHES THICK).
- WET, SILTY, CLAY 6'' THICK
- BROWN, WET, SILTY, FINE SAND (12 INCHES THICK.)
- MOIST TO WET, BROWN, SILTY, FINE SAND.

WET, BROWN, SILTY, FINE SAND TO FINE SANDY, SILT.

DAMP, MOTTLED-BROWN, FINE TO MEDIUM SAND. - WHITE PRECIPITATE AT 71 FT.

DEPTH BORING 72 FEET.
COMPLETED 3/20/81.

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

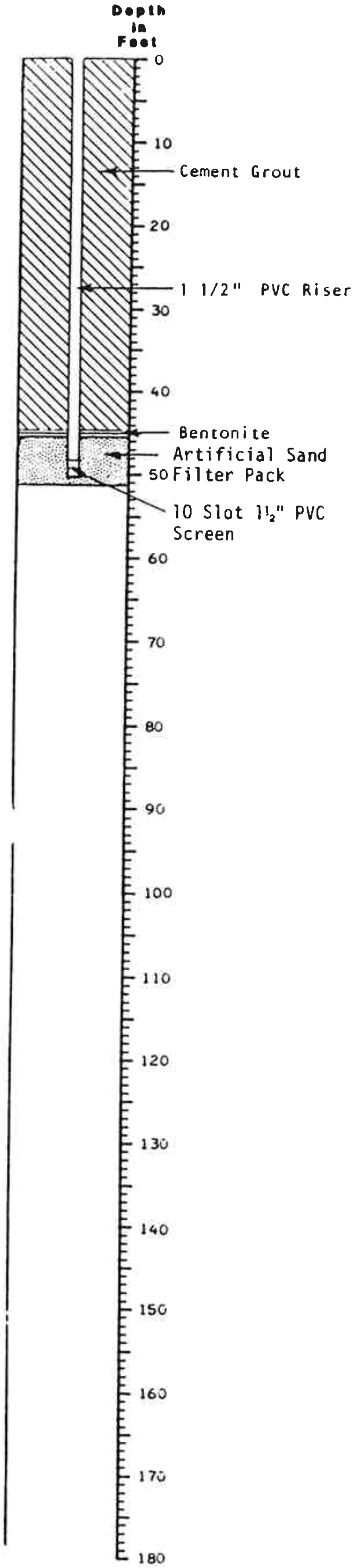
W.C.%	CN(μg/g)	%F
8		
9	5	5.2
10	2	0.7
8	3	0.5
4		
3		
	6	0.7
4		
28	23	0.7
7	24	0.2
23	12	0.6
3		
4	4	.003
5		
	6	.004
4	5	.006

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates Inc.
Figure A-16

WELL DESIGN



GEOLOGIC LOG HC-6

Top Casing Elevation 1928.3
Casing Stick-up 1.5
Ground Surface Elevation 1926.8

QUALITATIVE CHEMICAL CONCENTRATIO
AT SAMPLED DEPTH

Other Tests		W.C.%	CN(µg/g)	%F
	BORING WAS NOT SAMPLED THE INITIAL 24 FEET.			
	SAMPLING STARTED AT 24 FEET. DAMP, BROWNISH-GRAY, FINE TO COARSE SAND.	3		
	DAMP TO WET, BROWN TO GRAYISH-BROWN, SLIGHTLY SILTY TO CLEAN, FINE SAND.	7		
*▽ ATD			<1	.002
			<1	.002
	DAMP, BROWN, SILTY, CLAY (.3 FEET THICK).	26	<1	.007
		5		
			1	.002
*▽ ATD		4		
	MOIST, TAN, SILTY CLAY.	(29)	4	.004
	BOTTOM OF BORING AT 51.0 FEET. BORING COMPLETED 2/22/81.			

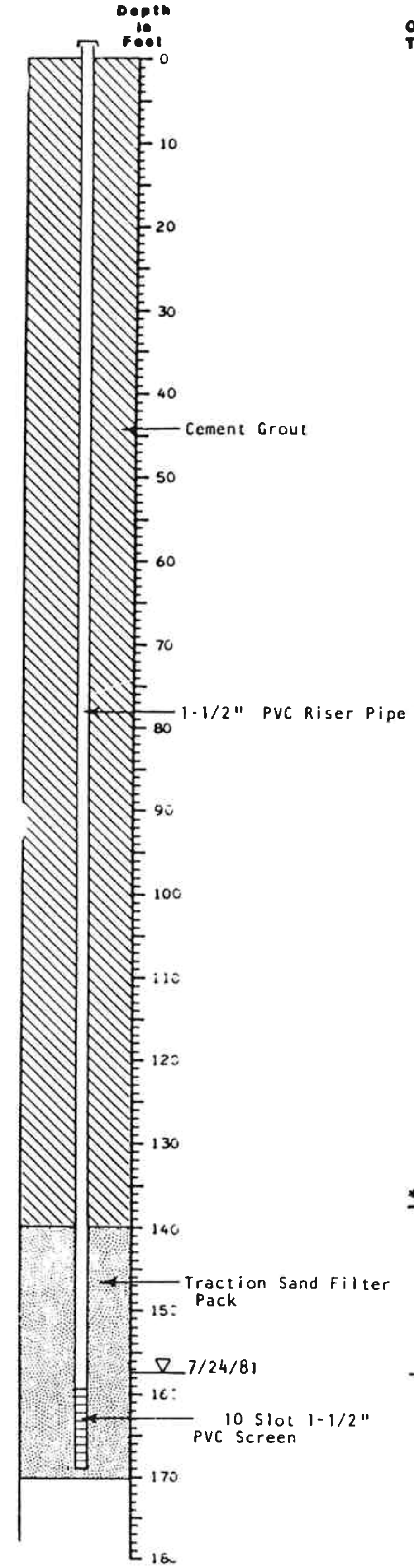
NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982

HART-CROWSER & associates inc.
Figure A-17

WELL DESIGN



GEOLOGIC LOG HC-7

Top Casing Elevation 1937.85
Casing Stick-up 1.3
Ground Surface Elevation 1936.5

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

Other Tests		W.C.%	CN(μg/g)	%F
	MOIST, BROWN, SLIGHTLY SILTY, FINE SAND TO SILTY, FINE TO COARSE SAND.	6		
	DAMP TO MOIST, GRAYISH-BROWN, FINE TO MEDIUM AND FINE TO COARSE SAND, WITH OCCASIONAL GRAVELS.	4		
		5	<1	.001
		4		
		3	<1	.001
		4		
		3		
			4	.002
	DAMP, GRAY-RUST (MOTTLED), CLAYEY, SILT (.2 FEET THICK).	12		
	FINE SAND.	5	4	.003
			3	.010
	WET, BROWN, SILTY FINE SAND TO FINE SANDY SILT.	5		
	MOIST, GRAY, FINE TO MEDIUM SAND.	5	4	.004
		5		
	MOIST, GRAY, FINE TO COARSE SAND.	3	4	.003
		4		
		3		
			2	.002
		3		
		3		
			2	.005
		4		
	DAMP, GRAY TO GRAYISH-BROWN, FINE TO MEDIUM SAND.	4		
			2	.008
		4		
		4		
			2	.006
		3		
		3		
			2	.005
		4		
		4		
			2	.007
		4		
		4		
			3	.008
		4		
*▽ ATD			3	.010
	SILTY CLAY.	(36)	3	.006
	DAMP TO WET, BROWN, SILTY, FINE SAND WITH SOME SLIGHTLY SILTY, FINE TO MEDIUM SAND.	4	3	.006
		11		
	DAMP TO WET, GRAY-BROWN, SLIGHTLY SILTY, FINE TO MEDIUM SAND.	3		
			3	.008
		7		
▽ ATD		(14)		
	WET, BROWN, SLIGHTLY SILTY TO SILTY, FINE SAND.		9	.010
		(21) (23) (23) (25) (30)		
	WET, BROWN, CLAYEY, FINE SANDY SILT.		28	.011
	BOTTOM OF BORING AT 170.0 FEET. BORING COMPLETED 4/29/81.			

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

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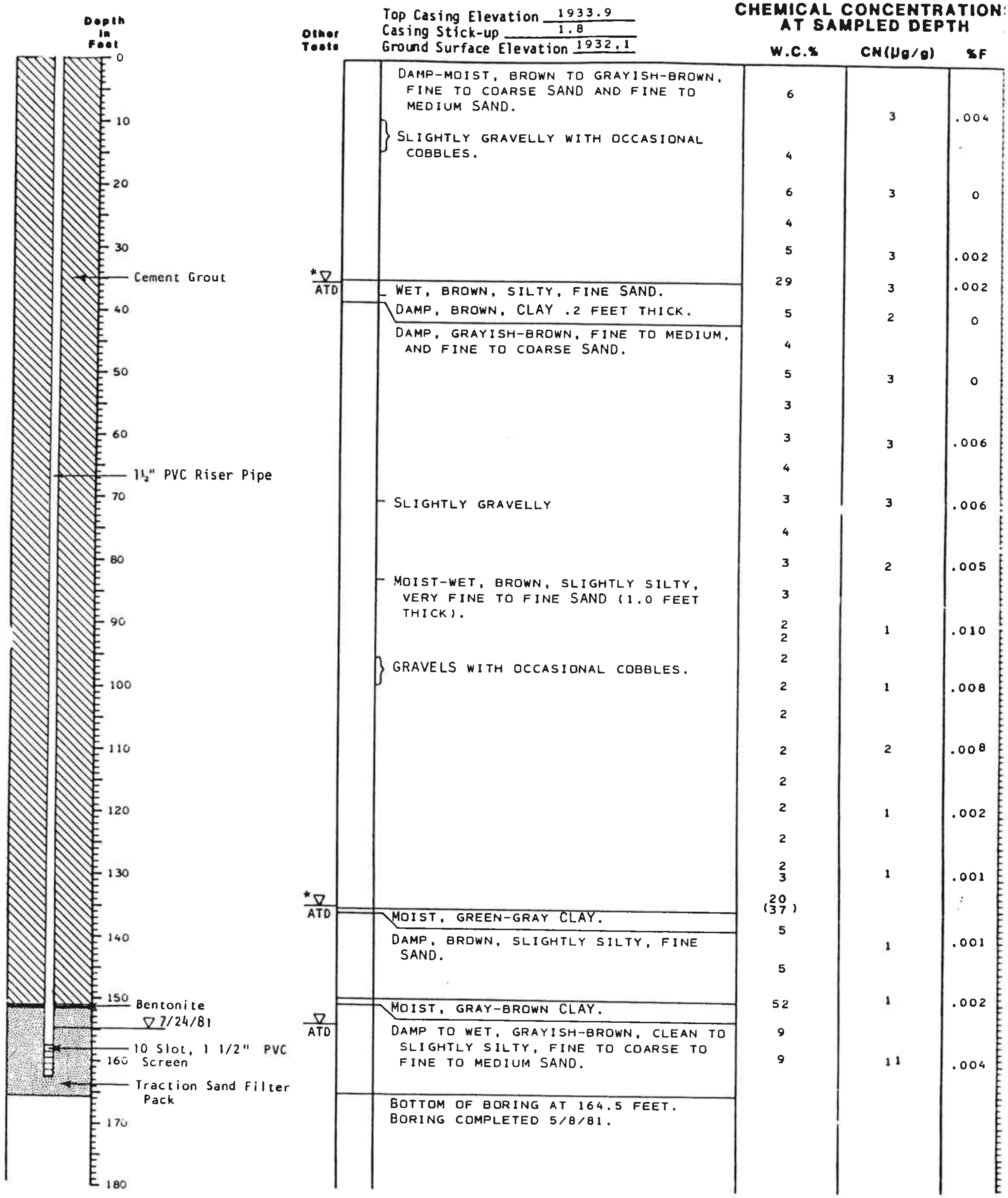
Figure A-18

WELL DESIGN

GEOLOGIC LOG HC-8

Top Casing Elevation 1933.9
Casing Stick-up 1.8
Ground Surface Elevation 1932.1

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH



W.C.%	CN(µg/g)	%F
6		
	3	.004
4		
6	3	0
4		
5	3	.002
29	3	.002
5	2	0
4		
5	3	0
3		
3	3	.006
4		
3	3	.006
4		
3	2	.005
3		
2	1	.010
2		
2		
2	1	.008
2		
2	2	.008
2		
2	1	.002
2		
2		
3	1	.001
20 (37)		
5		
	1	.001
5		
52	1	.002
9		
9	11	.004

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

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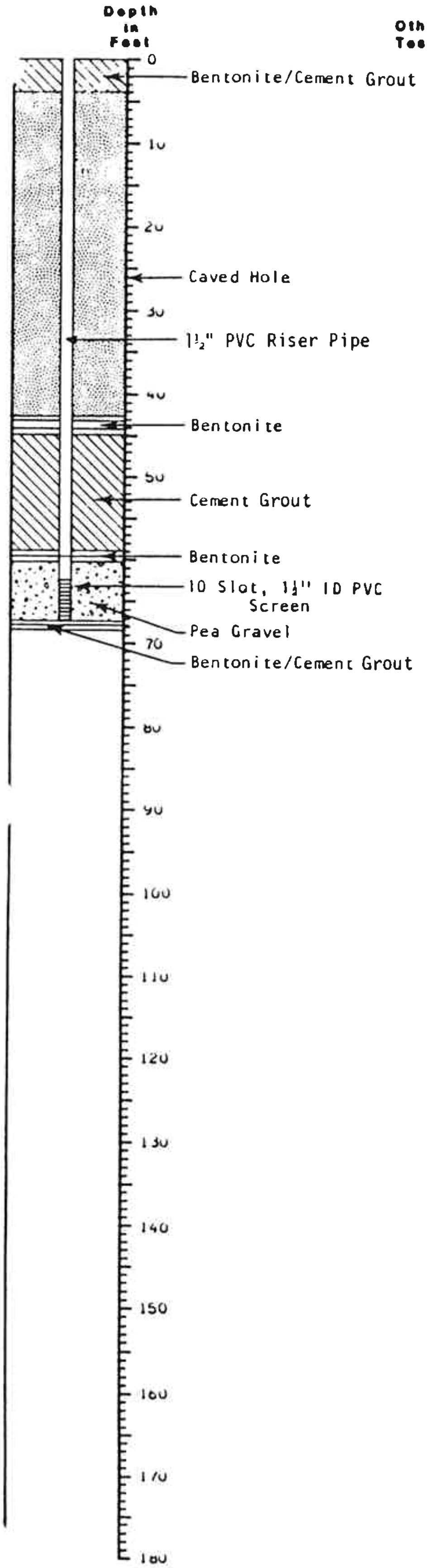
HART-CROWSER & associates inc.

Figure A-19

WELL BORING AND CONSTRUCTION INFORMATION

WELL DESIGN



GEOLOGIC LOG HC-9

Other Tests

Top Casing Elevation 1940.25
Casing Stick-up 3.5
Ground Surface Elevation 1937.3

DAMP TO MOIST, BROWN TO GRAY, SLIGHTLY SILTY TO SILTY, FINE TO MEDIUM SAND. (FILL)

DAMP, BLACK, SAND AND GRAVEL WITH BRICKS AND WOOD CHIPS (FILL)

DAMP, BROWN, SLIGHTLY SILTY TO SILTY, FINE TO COARSE SAND, ODOR OF NH_3

TRACE SILT AND FINE GRAVEL

GRADES TO DAMP TO MOIST, GRAY-BROWN, FINE TO MEDIUM SAND, TRACE SILTY, ODOR OF NH_3

MOTTLED, LAMINATED, SILTY, CLAY (4 INCHES THICK.)

SAND IS FINER

WET, BROWN, SLIGHTLY SILTY TO SILTY FINE SAND

DAMP, BROWN, CLAYEY, SILT LAYER, (2½" THICK)

BOTTOM OF BORING AT 68.5 FEET.
COMPLETED 3/27/81.

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
8		
12		
	72	9.5
11	47	4.15
	95	0.25
5		
	14	0.59
5		
	53	0.16
5		
5		
5		
	50	0.09
6		
5		
5		
6		
6	63	0.12
	14	.012
26	19	.012

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% - Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982

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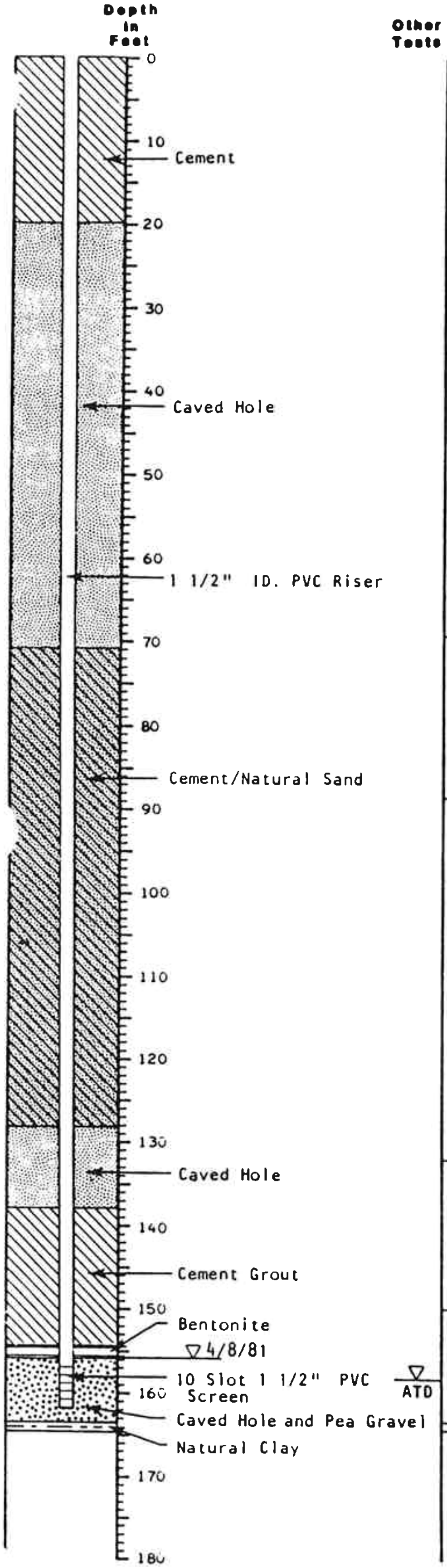
Figure A-20

WELL DESIGN



GEOLOGIC LOG HC-9A

Top Casing Elevation 1939.05
Casing Stick-up 1.30
Ground Surface Elevation 1937.75

Other Tests

NO SAMPLING TO 67.0 FEET. SEE LOG HC-9 FOR GEOLOGIC LOG AND OTHER DATA.

WET, BROWN, SILTY, FINE SAND TO DAMP, BROWN, SILTY CLAY.

DAMP, GRAY, CLEAN TO SLIGHTLY SILTY, FINE TO COARSE SAND.

DAMP, RUSTY, CLAYEY, SILT (0.1 FEET THICK).

DAMP, GRAYISH-BROWN TO BROWN, CLEAN TO SLIGHTLY SILTY, FINE TO MEDIUM SAND.

SILTY CLAY (½ INCH THICK).

SILTY CLAY SEAM (0.1 FEET THICK).

DAMP, GRAYISH-BROWN TO BROWN, CLEAN TO SLIGHTLY SILTY, FINE SAND WITH OCCASIONAL FINE TO MEDIUM AND FINE TO COARSE SAND.

DAMP TO WET, BROWN, CLEAN TO SLIGHTLY SILTY, FINE TO MEDIUM SAND.

INTERBEDDED, DAMP, BROWN, CLAY AND SILTY TO SLIGHTLY SILTY, FINE SAND.

BOTTOM OF BORING AT 164.5 FEET.
BORING COMPLETED 4/1/81.

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH

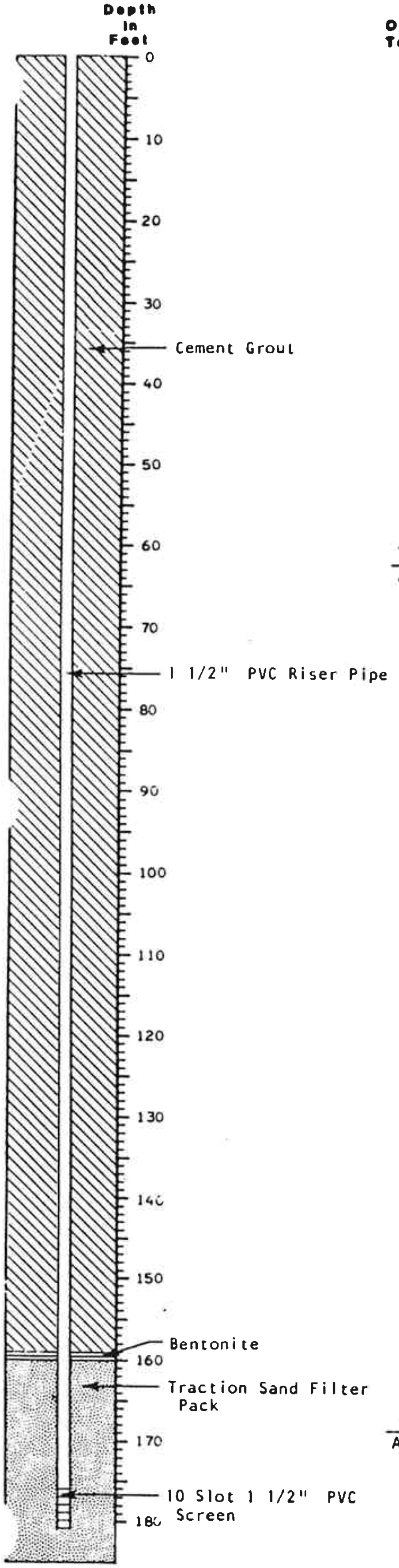
W.C.%	CN(µg/g)	%F
30		
4	3	.024
3		
4	15	.007
5		
6	22	.007
6		
5	9	.010
6		
6	28	.011
5		
5	75	.013
5		
5	29	.010
8		
15	30	.014
	112	.022
7		
4	15	.008
14		
(17)	17	.008
(20)		

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates inc.
Figure A-21

WELL DESIGN



GEOLOGIC LOG HC-10

Top Casing Elevation 1942.0
Casing Stick-up 0.0
Ground Surface Elevation 1942.0

Other Tests

MOIST TO DAMP, BROWN, FINE TO COARSE TO FINE TO MEDIUM SAND.

SLIGHTLY SILTY ZONE.

GRADES TO DAMP, BROWN, FINE SAND.

* ▽ ATD

WET, BROWN, VERY SILTY, FINE SAND.

MOIST, BROWN, CLAY (Ω 3 FEET THICK).

MOIST TO DAMP, BROWNISH-GRAY, FINE TO COARSE SAND.

MOIST TO DAMP, GRAYISH-BROWN, FINE TO MEDIUM SAND.

SLIGHTLY FINE GRAVELLY

DAMP, BROWN-GRAY (MOTTLED), CLAY (Ω 15 FEET THICK).

DAMP TO WET, BROWNISH-GRAY, FINE TO COARSE SAND.

▽ ATD

WET

WET, BROWNISH-GRAY, SLIGHTLY SILTY, FINE TO COARSE SAND.

BOTTOM OF BORING AT 184.0 FEET.
BORING COMPLETED 5/15/81.

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
5		
4	<1	.005
3		
4	1	.004
5		
4	1	.006
4		
5	1	.003
5		
4		
4	1	.004
6		
8		
3	2	.006
4	<1	.002
3		
4	2	.029
5		
4	2	.002
4		
4	2	.011
4		
4	2	.002
5		
5	2	.002
3		
3	2	.004
3		
3	1	.017
4		
3	1	.006
3		
3	1	.007
3		
7	1	.003
9		
9	2	.010

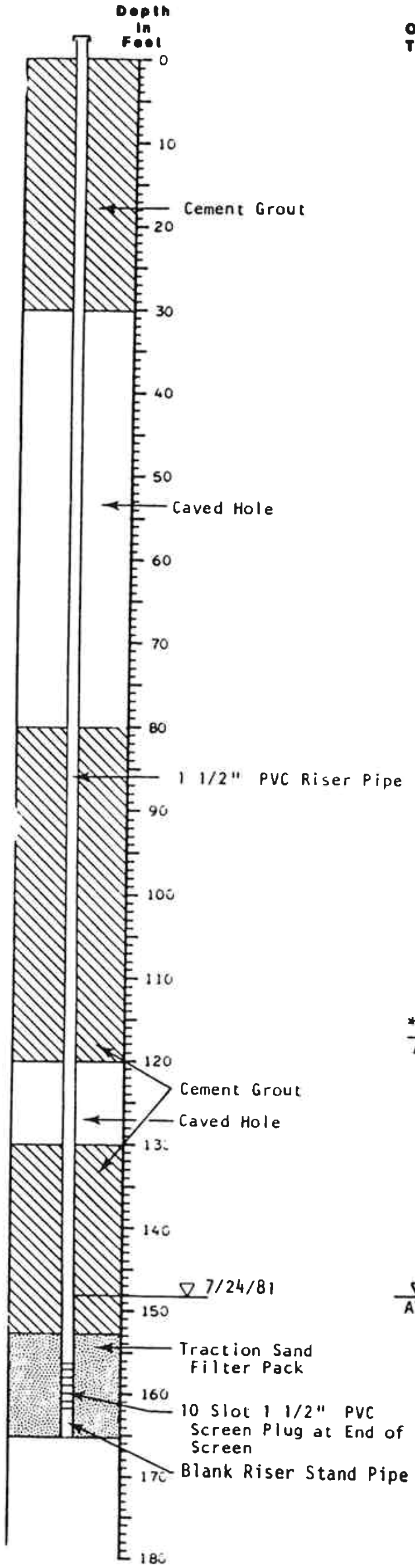
NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982

HART-CROWSER & associates Inc.
Figure A-22

WELL DESIGN



GEOLOGIC LOG HC-11

Top Casing Elevation 1908.4
Casing Stick-up 2.1
Ground Surface Elevation 1906.3

Other Tests

INTERBEDDED, MOIST TO DAMP, GRAY TO BROWN, FINE TO FINE TO COARSE SAND WITH OCCASIONAL THIN SILTY CLAY LENSES.

DAMP, BROWN TO GRAYISH-BROWN, FINE TO COARSE AND FINE TO MEDIUM SAND.

} FINE SAND.

DAMP TO WET, SILTY, VERY FINE SAND TO CLEAN FINE SAND.

- DAMP, BROWN, SILTY, CLAY (0.3 FEET THICK).
_ WET

DAMP, BROWN, SLIGHTLY FINE SANDY TO SILTY, CLAY.

DAMP TO WET, SLIGHTLY SILTY, FINE SAND.

*▽ ATD

MOIST, BROWN, SLIGHTLY FINE SANDY, SILT TO MOIST, GREEN-GRAY CLAY.

DAMP, GRAY, FINE SAND.

DAMP TO WET, GRAYISH-BROWN TO BROWN, FINE TO MEDIUM AND FINE TO COARSE SAND.

▽ ATD

} SLIGHTLY SILTY

BOTTOM OF BORING AT 165.0 FEET.
BORING COMPLETED 6/26/81.

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
17		
3		
	1	.010
4		
3		
	3	.010
3		
4	3	.010
4		
4	4	.010
3		
3	4	.010
4		
4	7	.012
3		
3	3	.006
3		
3	3	.002
5		
3		
	3	.002
3		
23		
	2	.001
7		
6		
	3	.003
13		
	3	.003
4		
3	2	.007
3		
3	3	.002
6		
10	4	.002
15		
17	4	.002
11	5	.002

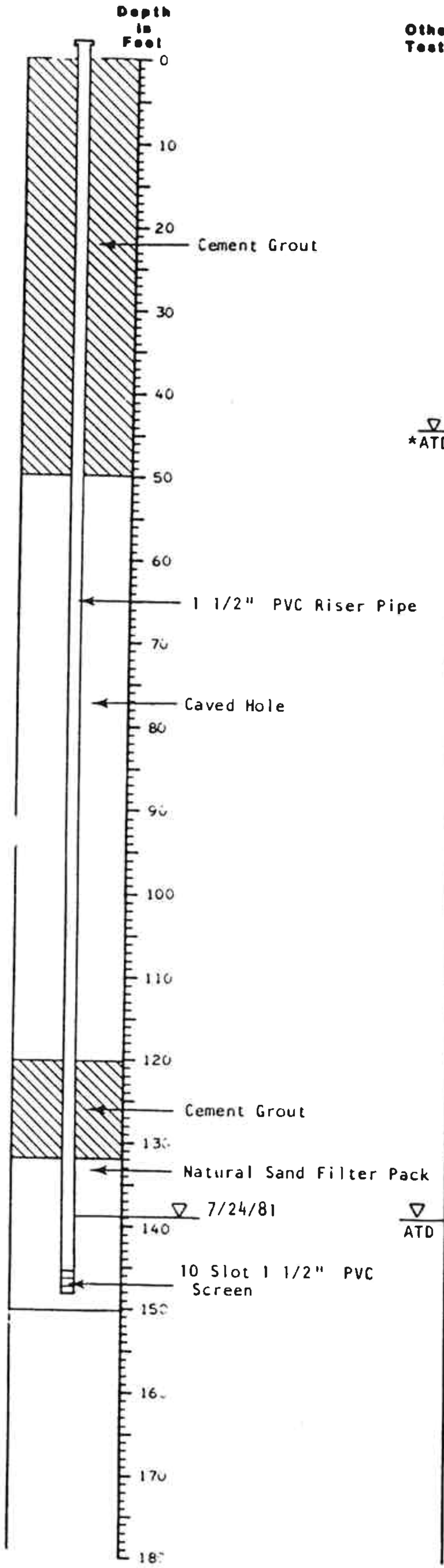
NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982

HART-CROWSER & associates inc.
Figure A-23

WELL DESIGN



GEOLOGIC LOG HC-12

Top Casing Elevation 1915.6
Casing Stick-up 2.1
Ground Surface Elevation 1913.5

Other Tests

▽ *ATD

▽ ATD

DAMP, BROWN, FINE TO MEDIUM SAND. SLIGHTLY SILTY TO SILTY.

FINE SAND.

MOIST, BROWN, CLAYEY, SILT TO SILTY, CLAY.

SLIGHTLY GRAVELLY

DAMP, GRAYISH-BROWN TO GRAY, FINE TO MEDIUM SAND WITH OCCASIONAL COARSE SANDY ZONES.

SILT (.05 FEET THICK)

INTERBEDDED

DAMP, BROWN, SLIGHTLY SILTY, FINE SAND AND DAMP, GRAYISH-BROWN, FINE TO MEDIUM SAND.

DAMP, GREENISH-GRAY, CLAY.

DAMP TO WET, GRAY, FINE TO COARSE SAND.

WET, BROWN, SLIGHTLY SILTY, FINE SAND (GETS CLEANER AND COARSER WITH DEPTH).

FINE TO COARSE SAND.

BOTTOM OF BORING AT 150 FEET.
BORING COMPLETED 7/8/81.

QUALITATIVE CHEMICAL CONCENTRATIO AT SAMPLED DEPTH

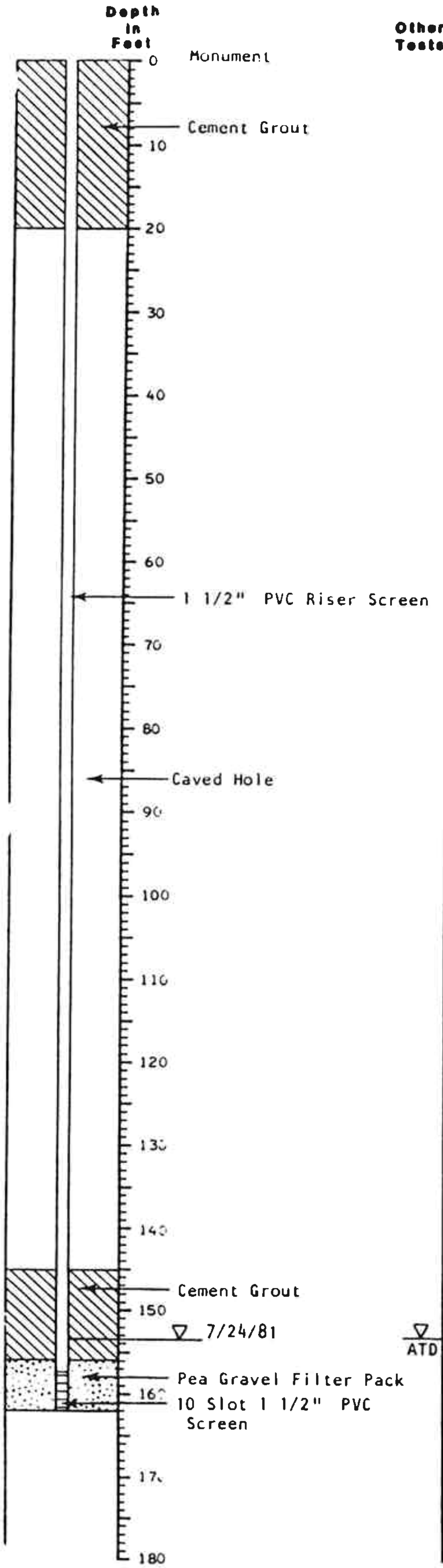
W.C.%	CN(μg/g)	%F
11 7		
3	<1	.016
5		
5	1	.014
4		
4	1	.017
3		
3	2	.016
3	2	.025
5	1	.018
2		
2	2	.024
3		
3	<1	.008
3		
4	1	.007
5		
4	2	.005
4		
4	1	.004
4		
4	2	.008
11 3		
3	2	.003
10		
4	1	.006
2		
8	<1	.006
(20)		
(22)	1	.008
10		

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates Inc.
Figure A-24

WELL DESIGN



GEOLOGIC LOG HC-13

Top Casing Elevation 1934.04
Casing Stick-up NONE (MONUMENT)
Ground Surface Elevation 1934.04

DAMP, BROWN, SLIGHTLY SILTY TO SILTY, FINE TO MEDIUM SAND.
MOTTLED

MOIST TO DAMP, BROWN TO GRAY, FINE TO MEDIUM SAND AND FINE TO COARSE SAND.
GRAVELLY

DAMP, BROWN, SLIGHTLY SILTY TO SILTY, FINE TO MEDIUM TO FINE TO COARSE SAND.
WET

DAMP, GRAY, FINE TO COARSE SAND.

DAMP, BROWN TO GRAYISH-BROWN, FINE TO MEDIUM SAND.

DAMP, BROWN TO GRAYISH-BROWN, SLIGHTLY SILTY TO SILTY, FINE SAND WITH SOME SILT SEAMS.

DAMP TO WET, GRAYISH-BROWN TO BROWN, FINE TO COARSE TO FINE TO MEDIUM SAND.

DAMP, GREENISH-GRAY CLAY(0.3 FEET THICK).

BOTTOM OF BORING AT 162.0 FEET.
BORING COMPLETED 7/17/81.

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
6		
6	1	.002
6		
6	1	.002
4		
4	1	.000
1		
3	2	.001
5		
7	2	.001
5		
5	2 2	.001 .010
5		
3	5	.002
3		
4	<1	.003
4		
6	<1	.002
5		
5	<1	.002
4		
4	<1	<.001
4		
4	1	<.001
3		
18		
15	2	.004
7		
6		
8	<1	.006
6		
8		
5	1	.006
(16)		
11	1	.006

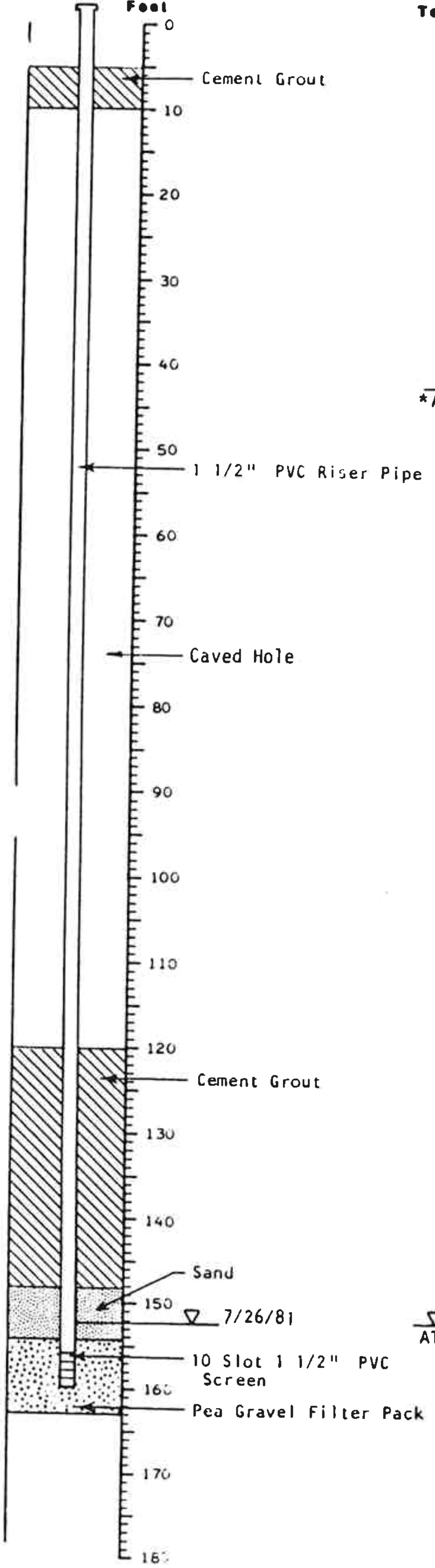
NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982

HART-CROWSER & associates inc.
Figure A-25

WELL DESIGN



GEOLOGIC LOG HC-14

Top Casing Elevation 1943.7
Casing Stick-up 1.8
Ground Surface Elevation 1941.9

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH

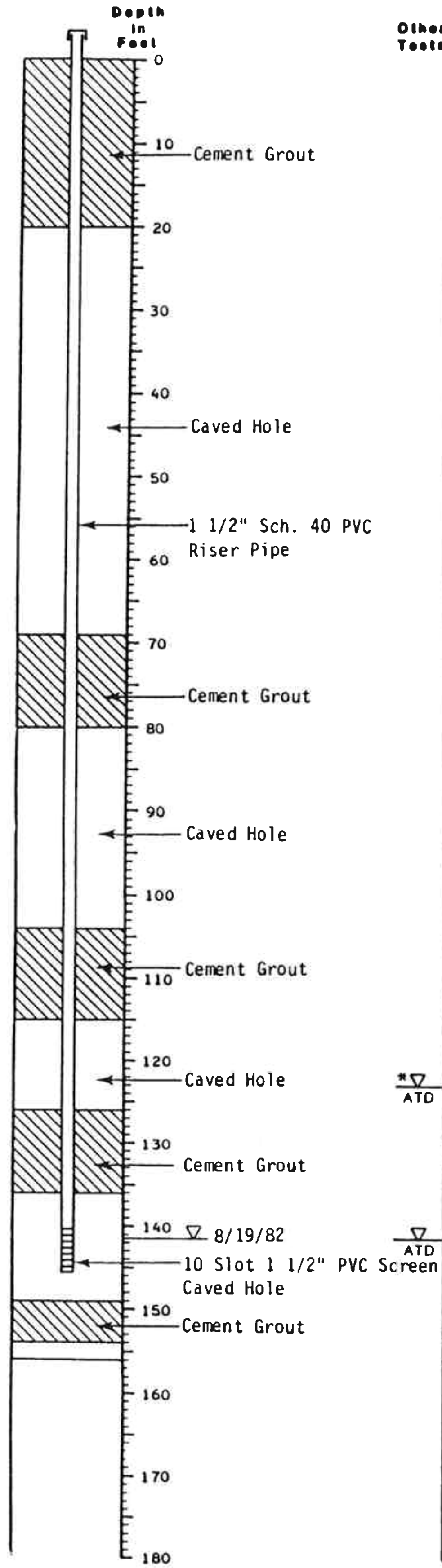
Other Tests		W.C.%	CN(μg/g)	%F
	DAMP, BROWN, FINE SAND.			
		4		
		2	<1	.002
		2		
	DAMP, GRAYISH-BROWN TO GRAY, SLIGHTLY SILTY TO CLEAN, FINE TO COARSE SAND.	2	<1	.001
	SLIGHTLY FINE GRAVELLY.	3		
			<1	.002
	DAMP, BROWN, SLIGHTLY SANDY SILT.	3		
	DAMP TO WET, BROWN, CLEAN TO SILTY FINE SAND.	5	<1	.004
*ATD	WET, BROWN, CLAY (0.1 FEET THICK).	5		
	DAMP, GRAY, FINE TO COARSE SAND.	3		
		3	<1	.002
	SLIGHTLY FINE GRAVELLY.	1	<1	.004
		2		
		2	<1	.002
		2		
	SLIGHTLY GRAVELLY.	2	<1	.002
		2		
		2	<1	.002
		2		
		2	<1	.002
		2		
		2	<1	.002
		2		
		2	<1	.002
		2		
	INTERBEDDED, DAMP TO WET, CLEAN TO WET SILTY, FINE TO FINE TO COARSE SAND.	23	2	<.001
	SILT AND CLAY SEAMS.	6	2	<.032
	MOIST, BROWN, SILTY, FINE SAND TO FINE SANDY SILT.	22	2	.002
	DAMP, BROWN, CLAY.	2	2	<.001
ATD	DAMP TO WET, GRAYISH-BROWN TO BROWN, CLEAN, FINE TO COARSE SAND TO SLIGHTLY SILTY, FINE TO MEDIUM SAND.	3		
		20	1	.001
		18	1	.002
	MOIST, GREEN-GRAY TO BLUE-GRAY, CLAY.			
	WET, BLUE-GRAY, SILTY, CLAYEY, FINE SAND.			
	BOTTOM OF BORING AT 162.5 FEET BORING COMPLETED 7/23/81.			

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Sample

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates Inc.
Figure A-26

WELL DESIGN



GEOLOGIC LOG HC-15

Top Casing Elevation 1932.01
Casing Stick-up 3.45
Ground Surface Elevation 1928.6

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

Other Tests		W.C.%	CN(µg/g)	%F
	DAMP TO MOIST, BROWN, SLIGHTLY SILTY AND CLEAN, FINE TO MEDIUM AND FINE TO COURSE SAND.	5	<1	.008
	WET, BROWN, FINE SANDY SILT TO SILTY FINE SAND.	6	1	.004
	MOIST, BROWN, FINE TO MEDIUM SAND.	5	<1	.003
	MOIST, BROWN, FINE SAND.	8	1	.002
	WET, BROWN, SILTY FINE SAND.			
	}MOIST TO WET.	4	1	.002
	MOIST, BROWN, FINE TO COURSE AND FINE TO MEDIUM SAND WITH OCCASIONAL GRAVELS.	4	<1	.002
		4	<1	<.001
		5	<1	<.001
		5	<1	<.001
		6	<1	<.001
		7	<1	.001
*▽ ATD	MOIST TO WET AND SLIGHTLY SILTY TO SILTY	6	1	<.001
		13	<1	<.001
	DAMP, GRAY, FINE SANDY SILT.			
	WET, BROWN, SLIGHTLY SILTY TO SILTY FINE SAND.	22	<1	<.001
	DAMP, BROWNISH-GRAY, FINE SANDY SILT.			
▽ ATD	MOIST TO WET, BROWN, CLEAN TO SLIGHTLY SILTY, FINE TO COARSE, AND FINE TO MEDIUM SAND.	3	<1	<.001
	FINE SAND.			
	DAMP, GRAY, SILTY CLAY TO CLAYEY SILT.	17	1	<.001
	WET, GRAY, SILTY FINE SAND.	14	<1	<.001
	BOTTOM OF HOLE AT 156.0 FEET. COMPLETED 7/8/82.			

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 May 1988

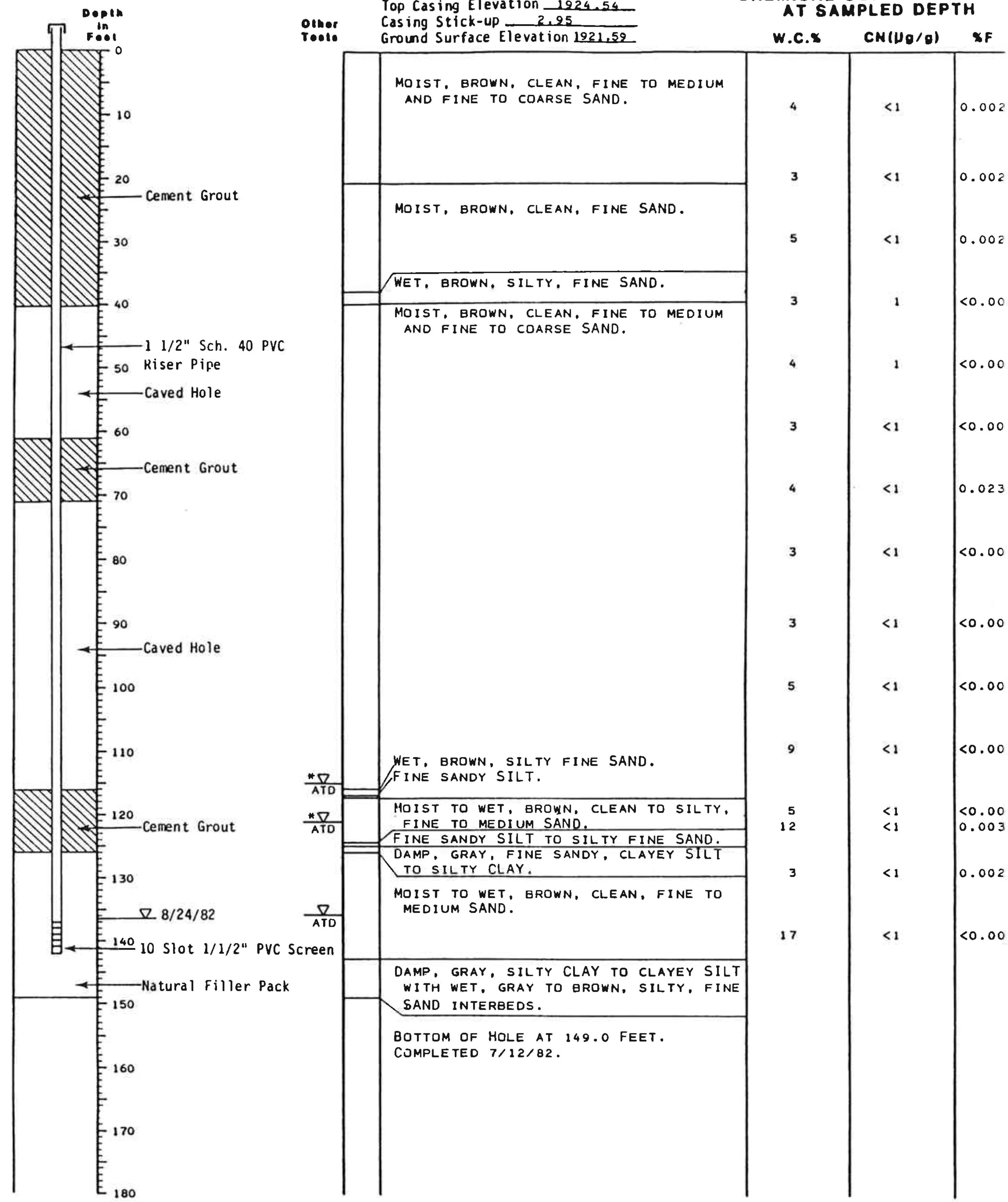
HART-CROWSER & associates Inc.
Figure A-27

WELL DESIGN

GEOLOGIC LOG HC-16

Top Casing Elevation 1924.54
Casing Stick-up 2.95
Ground Surface Elevation 1921.59

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH



MOIST, BROWN, CLEAN, FINE TO MEDIUM AND FINE TO COARSE SAND.

MOIST, BROWN, CLEAN, FINE SAND.

WET, BROWN, SILTY, FINE SAND.

MOIST, BROWN, CLEAN, FINE TO MEDIUM AND FINE TO COARSE SAND.

WET, BROWN, SILTY FINE SAND.
FINE SANDY SILT.

MOIST TO WET, BROWN, CLEAN TO SILTY, FINE TO MEDIUM SAND.

FINE SANDY SILT TO SILTY FINE SAND.

DAMP, GRAY, FINE SANDY, CLAYEY SILT TO SILTY CLAY.

MOIST TO WET, BROWN, CLEAN, FINE TO MEDIUM SAND.

DAMP, GRAY, SILTY CLAY TO CLAYEY SILT WITH WET, GRAY TO BROWN, SILTY, FINE SAND INTERBEDS.

BOTTOM OF HOLE AT 149.0 FEET.
COMPLETED 7/12/82.

W.C.%	CN(μg/g)	%F
4	<1	0.002
3	<1	0.002
5	<1	0.002
3	1	<0.00
4	1	<0.00
3	<1	<0.00
4	<1	0.023
3	<1	<0.00
3	<1	<0.00
5	<1	<0.00
9	<1	<0.00
5	<1	<0.00
12	<1	0.003
3	<1	0.002
17	<1	<0.00

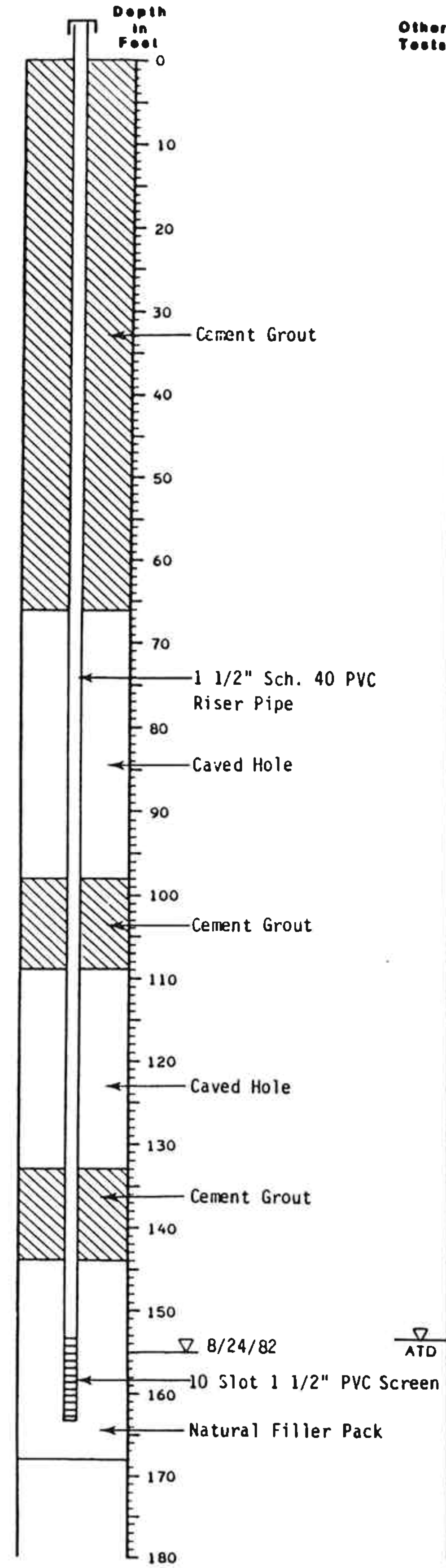
NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 May 1988

HART-CROWSER & associates inc.
Figure A-28

WELL DESIGN



GEOLOGIC LOG HC-17

Top Casing Elevation 1941.10
Casing Stick-up 3.10
Ground Surface Elevation 1938.0

QUALITATIVE CHEMICAL CONCENTRATIO AT SAMPLED DEPTH

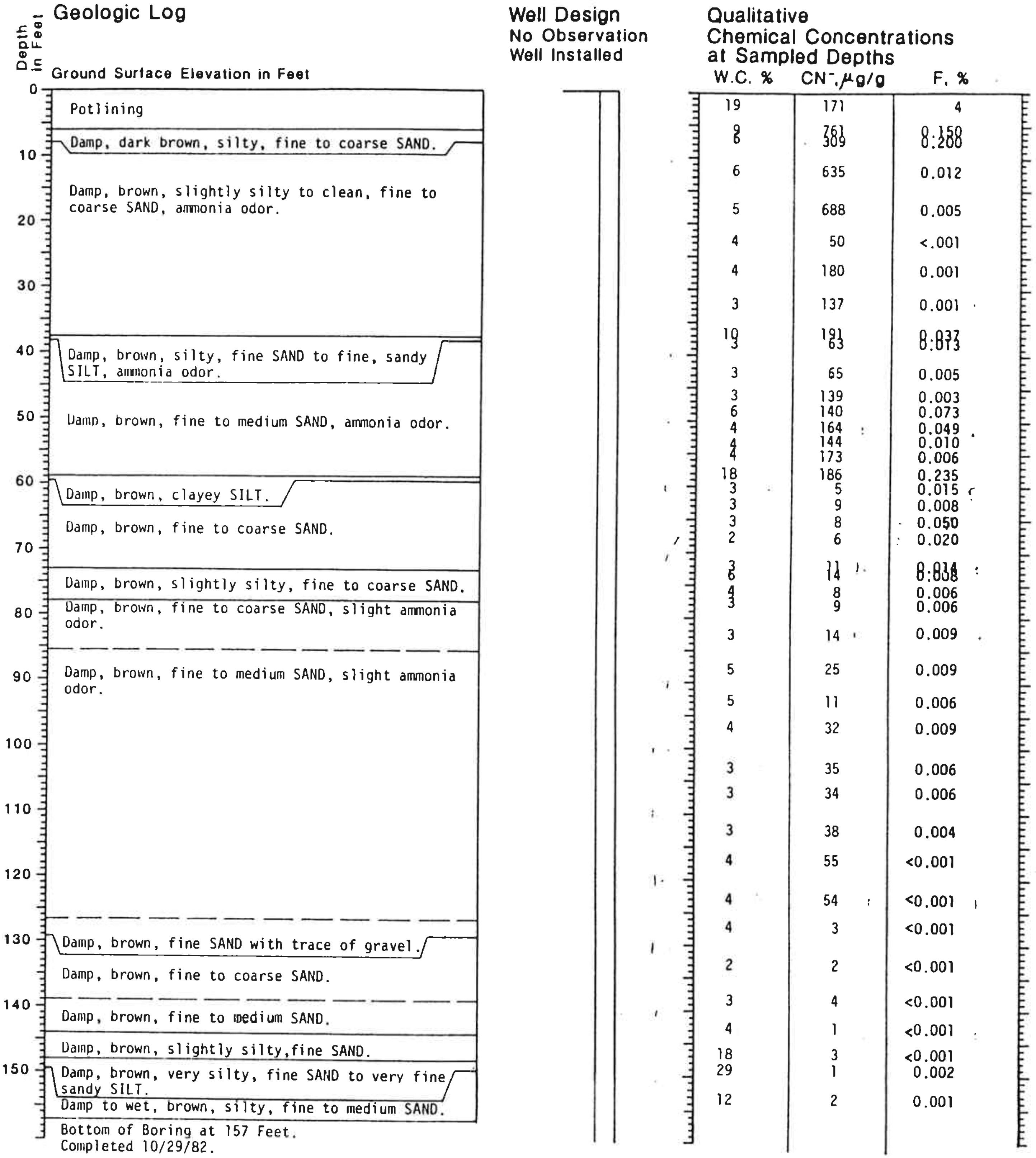
Other Tests		W.C.%	CN(µg/g)	%F
	WET, BLACK, FINE SANDY SILT (SLUDGE).			
	MOIST, BROWN, CLEAN TO SLIGHTLY FINE TO FINE TO COARSE SAND.	5	<1	0.05
		7	<1	0.01
		2	<1	0.02
	WET, BROWN, VERY SILTY, FINE SAND.			
	MOIST, BROWN, CLEAN, FINE TO MEDIUM AND FINE TO COARSE SAND WITH OCCASIONAL SCATTERED GRAVEL.	2	<1	0.02
		2	<1	0.01
		2	<1	0.01
		2	<1	0.00
		7	<1	0.00
		3	<1	0.00
		1	<1	0.00
		3	<1	0.01
		3	<1	0.00
	MOIST TO WET, BROWN, CLEAN TO SILTY FINE SAND WITH FINE SANDY SILT INTERBEDS.	7	<1	<0.0
	WET, GRAYISH-BROWN, FINE SANDY SILT TO SILTY FINE SAND.	7	<1	0.00
	- SILTY MOIST TO WET, FINE TO MEDIUM AND FINE TO COARSE SAND WITH SILTY LENSES.	1	<1	<0.0
▽ ATD	- SILTY			
		12	<1	0.03
	DAMP, GRAY, SLIGHTLY CLAYEY, FINE SANDY, SILT.			
	BOTTOM OF HOLE @ 168.0 FEET. COMPLETED 7/21/82.			

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 May 1988
HART-CROWSER & associates Inc.
Figure A-29

Boring Log and Construction Data for Well HC-18



Geologic Log

Ground Surface Elevation in Feet

Potlining

Damp, dark brown, silty, fine to coarse SAND.

Damp, brown, slightly silty to clean, fine to coarse SAND, ammonia odor.

Damp, brown, silty, fine SAND to fine, sandy SILT, ammonia odor.

Damp, brown, fine to medium SAND, ammonia odor.

Damp, brown, clayey SILT.

Damp, brown, fine to coarse SAND.

Damp, brown, slightly silty, fine to coarse SAND.

Damp, brown, fine to coarse SAND, slight ammonia odor.

Damp, brown, fine to medium SAND, slight ammonia odor.

Damp, brown, fine SAND with trace of gravel.

Damp, brown, fine to coarse SAND.

Damp, brown, fine to medium SAND.

Damp, brown, slightly silty,fine SAND.

Damp, brown, very silty, fine SAND to very fine sandy SILT.

Damp to wet, brown, silty, fine to medium SAND.

Bottom of Boring at 157 Feet.
Completed 10/29/82.

Well Design

No Observation
Well Installed

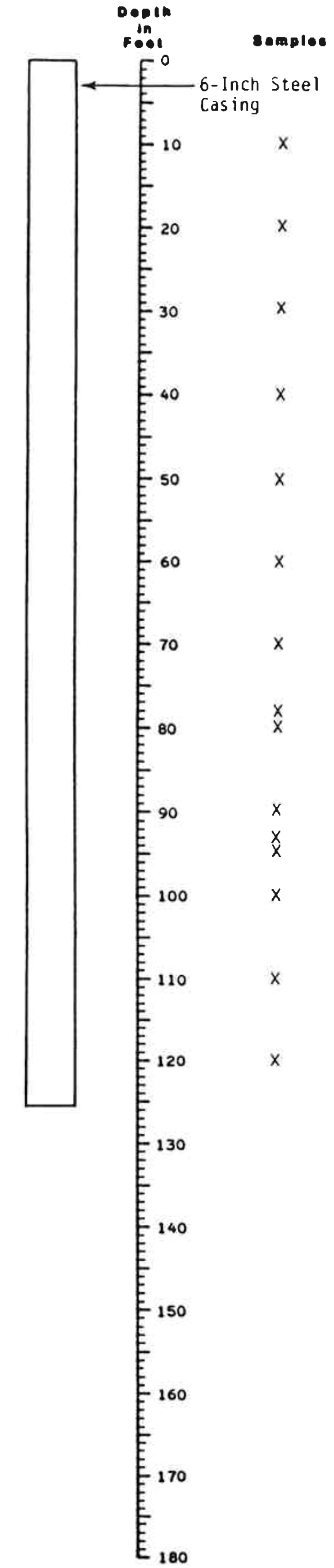
Qualitative Chemical Concentrations at Sampled Depths

W.C. %	CN⁻, µg/g	F, %
19	171	4
9	761	0.150
6	309	0.200
6	635	0.012
5	688	0.005
4	50	<.001
4	180	0.001
3	137	0.001
10	191	0.037
3	63	0.013
3	65	0.005
3	139	0.003
6	140	0.073
4	164	0.049
4	144	0.010
4	173	0.006
18	186	0.235
3	5	0.015
3	9	0.008
3	8	0.050
2	6	0.020
3	11	0.014
6	14	0.008
4	8	0.006
3	9	0.006
3	14	0.009
5	25	0.009
5	11	0.006
4	32	0.009
3	35	0.006
3	34	0.006
3	38	0.004
4	55	<0.001
4	54	<0.001
4	3	<0.001
2	2	<0.001
3	4	<0.001
4	1	<0.001
18	3	<0.001
29	1	0.002
12	2	0.001

NOTES: 1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year.
ATD:At Time of Drilling

J-948-02 March 1983
HART-CROWSER & associates, inc.
Figure A-30

WELL DESIGN



GEOLOGIC LOG

Other Tests

Top Casing Elevation 1965.5
Casing Stick-up 0
Ground Surface Elevation 1965.5

POT-LINING WASTE MATERIAL, AMMONIA ODOR.

DAMP, BROWN, SLIGHTLY GRAVELLY SLIGHTLY SILTY, FINE SAND.

DRY, TAN, SLIGHTLY SANDY SILT.

DAMP, BROWN, CLEAN FINE SAND.

DRY, LIGHT TAN CLAY.

DRY, BROWN, SLIGHTLY SANDY, FINE TO COARSE GRAVEL.

DRY, BROWN SAND.

BOTTOM OF BORING 125 FEET

NOTE: BORING ES-1 THROUGH ES-8 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. THE GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

QUALITATIVE CHEMICAL CONCENTRATIO AT SAMPLED DEPTH

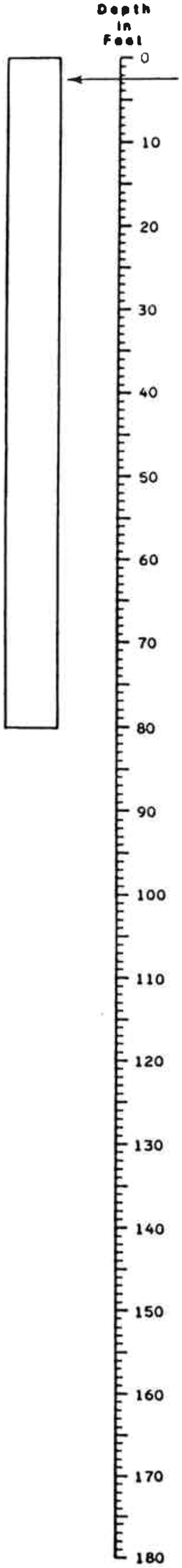
W.C.%	CN(μg/g)	%F
5	4960	13.3
<1	29250	8.1
6	4640	9.9
7	600	0.1
3	1320	2.2
4	260	0.04
4	104	0.05
1	612	0.23
4	214	0.03
5	140	0.04
2	207	0.05
6	394	0.07
1	130	0.09
4	104	0.02
4	60	0.02

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 August 1982
HART-CROWSER & associates Inc.
Figure A-31

WELL DESIGN



GEOLOGIC LOG

Top Casing Elevation 1966.0
Casing Stick-up 0
Ground Surface Elevation 1966.0

QUALITATIVE CHEMICAL CONCENTRATIO AT SAMPLED DEPTH

Samples	Other Tests	Geologic Log	W.C.%	CN(µg/g)	%F
X		POT-LINING WASTE MATERIAL.	3	5420	12.6
X			<1	1320	10.0
X			21	10140	3.76
X		WET, DARK GRAY, SILT WITH WHITE MATERIAL AT POT-LINING WASTE CONTACT.	9	660	7.30
X		DRY, BROWN, SILTY, FINE TO MEDIUM SAND WITH SOME GRAVELS.	2	335	0.03
X			3	725	0.39
X		DRY, GRAY, FINE GRAVELLY, FINE TO COARSE SAND.	<1	240	0.03

BOTTOM OF BORING 80 FEET

NOTE: BORING ES-1 THROUGH ES-8 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. THE GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Samples

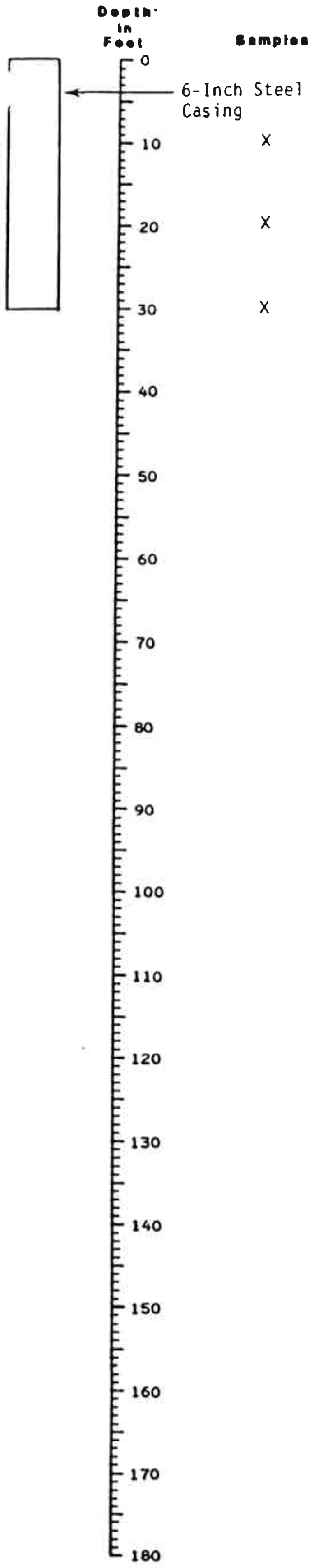
W.C.% = Weight Basis

*	Perched Water
▽	Water Level
4000	Water CN Concentration in ppb

J-948-02 August 1982

HART-CROWSER & associates Inc.
Figure A-32

WELL DESIGN



GEOLOGIC LOG

Top Casing Elevation 1965.5
Casing Stick-up 0
Ground Surface Elevation 1965.5

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

Other Tests		W.C.%	CN(µg/g)	%F
	POT-LINING WASTE MATERIAL, STRONG AMMONIA ODOR	7	4260	6.80
		5	4240	9.93
	BOTTOM OF BORING 30 FEET	2	5880	7.65

NOTE: BORING ES-1 THOUGH ES-2 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. THE GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

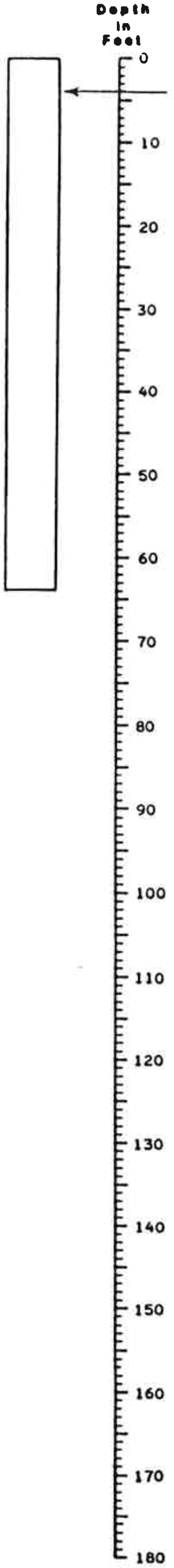
W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 August 1982
HART-CROWSER & associates inc.
Figure A-33

WELL DESIGN

GEOLOGIC LOG

Top Casing Elevation 1964.2
Casing Stick-up 0
Ground Surface Elevation 1964.2



Other Tests

POT-LINING WASTE MATERIAL.

DRY, TAN, SILTY, FINE TO COARSE SAND.

BOTTOM OF BORING 64.0 FEET

NOTE: BORING ES-1 THROUGH ES-2 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. THE GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

QUALITATIVE CHEMICAL CONCENTRATIO AT SAMPLED DEPTH

Depth in Feet	Samples	W.C.%	CN(µg/g)	%F
10	X	11	4760	11.1
20	X	14	2660	7.25
30	X	15	2200	11.8
40	X	7	1080	3.90
50	X	3	540	1.35

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
∇ Water Level
4000 Water CN Concentration in ppb

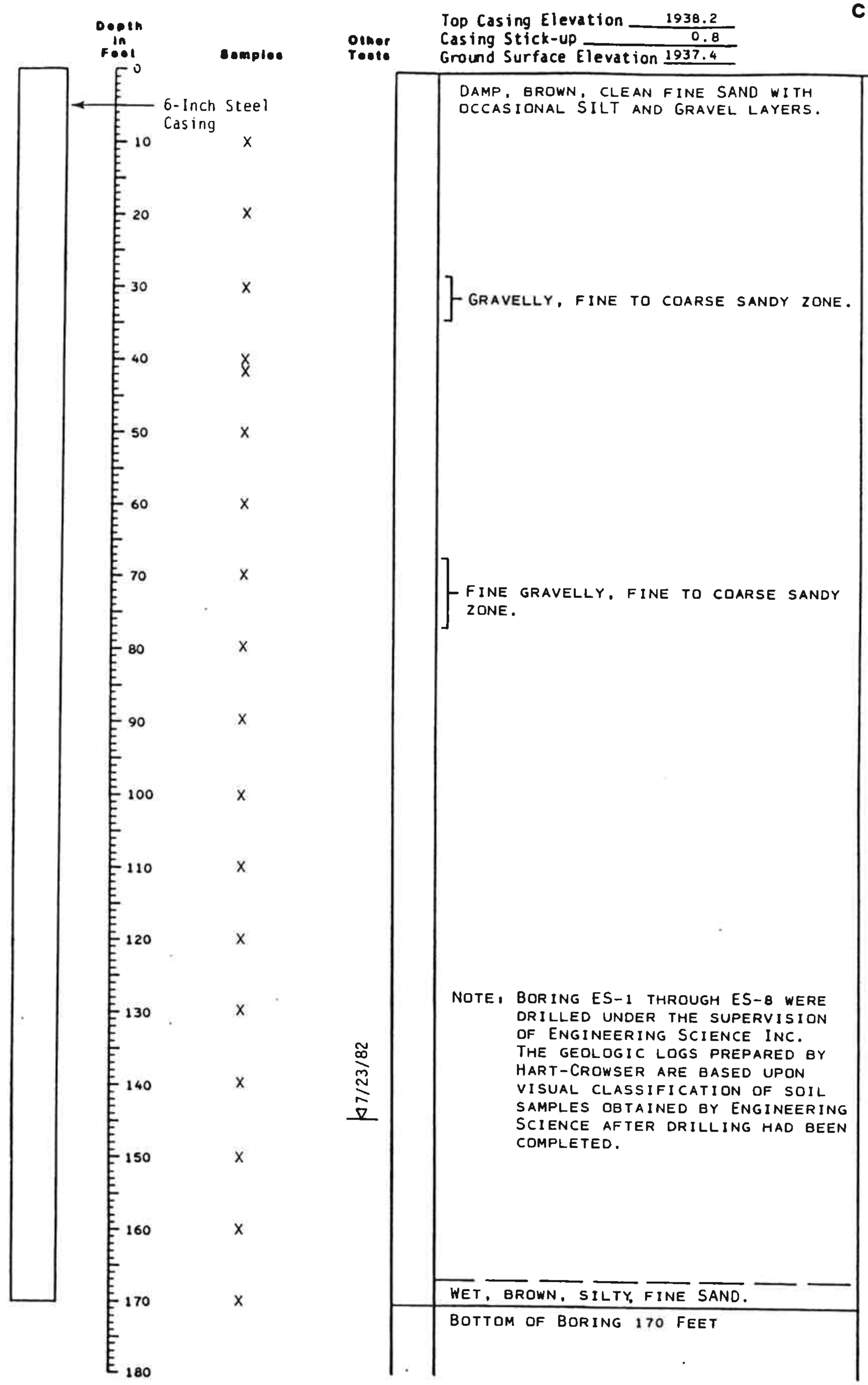
J-948-02 August 1982
HART-CROWSER & associates inc.
Figure A-34

WELL DESIGN

GEOLOGIC LOG

Top Casing Elevation 1938.2
Casing Stick-up 0.8
Ground Surface Elevation 1937.4

QUALITATIVE CHEMICAL CONCENTRATIO AT SAMPLED DEPTH



DAMP, BROWN, CLEAN FINE SAND WITH OCCASIONAL SILT AND GRAVEL LAYERS.

GRAVELLY, FINE TO COARSE SANDY ZONE.

FINE GRAVELLY, FINE TO COARSE SANDY ZONE.

NOTE: BORING ES-1 THROUGH ES-8 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. THE GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

WET, BROWN, SILTY, FINE SAND.

BOTTOM OF BORING 170 FEET

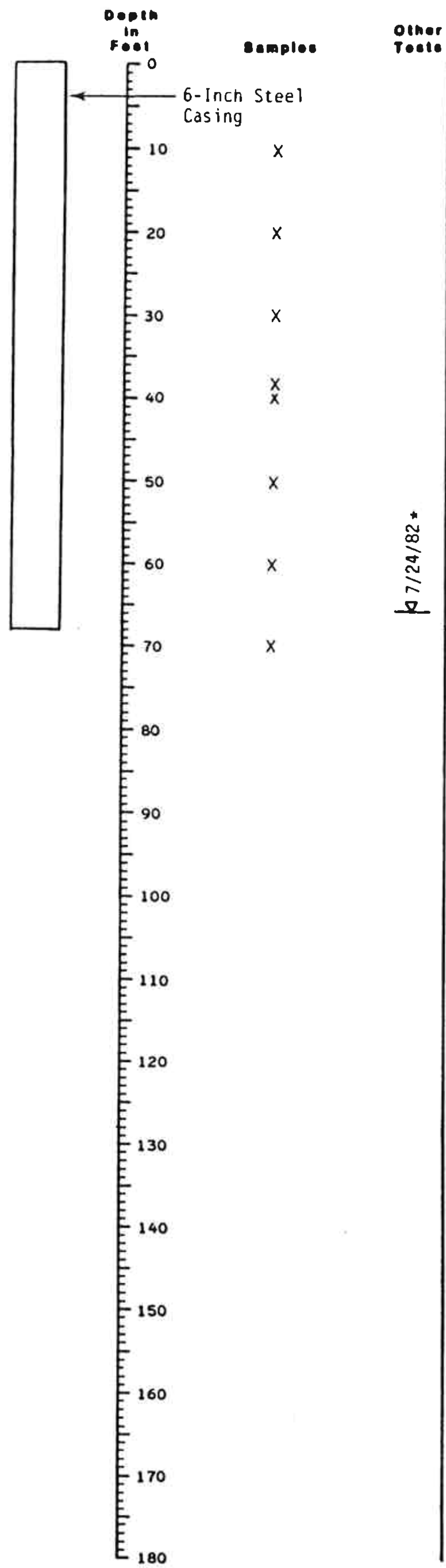
Depth in Feet	Samples	W.C.%	CN(µg/g)	%F
10	X	6	26	0.3
20	X	5	9	0.0
30	X	3	53	0.2
40	X X	4 NA	3 8	0.01 0.01
50	X	4	12	0.01
60	X	4	9	0.00
70	X	2	2	0.00
80	X	2	6	0.00
90	X	3	12	0.00
100	X	4	3	0.01
110	X	3	5	0.00
120	X	4	2	0.01
130	X	4	4	0.01
140	X	5	9	0.00
150	X	3	5	0.01
160	X	4	8	0.01
170	X	20	32	0.01

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 August 1982
HART-CROWSER & associates Inc.
Figure A-35

WELL DESIGN



GEOLOGIC LOG

Top Casing Elevation 1938.8
Casing Stick-up 0.6
Ground Surface Elevation 1938.2

MOIST TO WET, BROWN, SLIGHTLY SILTY, FINE SAND.

DAMP TO MOIST, BROWN, CLEAN FINE SAND WITH SOME FINE TO MEDIUM AND FINE TO COARSE SANDY ZONES.

FINE TO MEDIUM ZONE.

DAMP TO MOIST, BROWN, FINE SANDY SILT/CLAY.

FINE TO COARSE SANDY ZONE.

WET, BROWN, SLIGHTLY SILTY, FINE SAND

BOTTOM OF BORING 68.0 FEET

NOTE: BORING ES-1 THROUGH ES-8 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. THE GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

QUALITATIVE
CHEMICAL CONCENTRATIO
AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
7	211	1.93
9	96	1.03
4	55	0.04
4	55	0.04
22	138	0.10
3	38	0.01
2	54	0.02
3	10	0.01
27		

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Samples

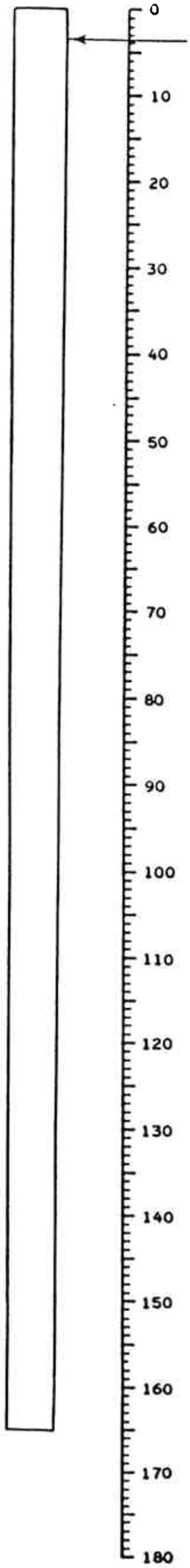
W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 August 1982

HART-CROWSER & associates Inc.

Figure A-36

WELL DESIGN



GEOLOGIC LOG

Top Casing Elevation 1938.5
Casing Stick-up 1.2
Ground Surface Elevation 1937.7

QUALITATIVE CHEMICAL CONCENTRATIO AT SAMPLED DEPTH

DAMP, BROWN, FINE TO MEDIUM SAND, WITH ZONES OF FINE GRAVEL.

NOTE: BORINGS ES-1 THROUGH ES-8 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. THE GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

– CLAYEY ZONE.

DAMP, BROWN, CLEAN FINE SAND.

– SLIGHTLY SILTY.

DAMP, BROWN, FINE TO MEDIUM SAND WITH SOME FINE GRAVELLY ZONES.

BOTTOM OF BORING 165.0 FEET

Other Tests: ∇ 7/23/82

Depth in Feet	Samples	W.C.%	CN(µg/g)	%F
10	X	5	985	.01
		6	304	0.02
20	X	3	76	0.01
30	X	3	8	0.01
40	X	5	12	0.00
	X	NA	60	0.02
50	X	7	42	0.01
60	X	2	32	0.00
	X	22	16	0.12
70	X	6	21	0.01
80	X	1	18	0.00
90	X	5	15	0.01
100	X	4	20	0.01
110	X	3	17	0.01
120	X	4	17	0.00
130	X	5	25	0.007
140	X	4	13	0.00
150	X	4	9	0.00
160	X	3	15	0.01
	X	13	26	0.01

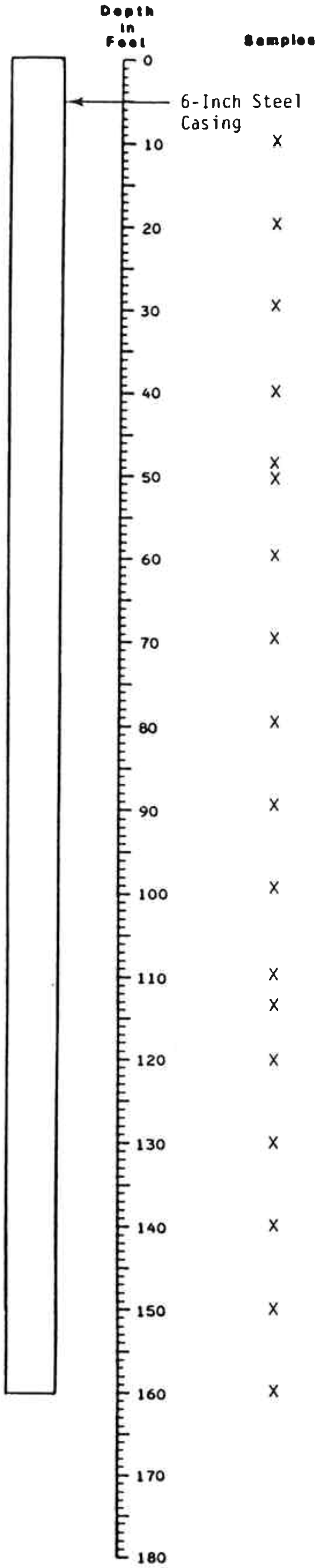
NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
∇ Water Level
4000 Water CN Concentration in ppb

J-948-02 August 1982

HART-CROWSER & associates inc.
Figure A-37

WELL DESIGN



GEOLOGIC LOG

Top Casing Elevation 1927.1
Casing Stick-up 1.5
Ground Surface Elevation 1925.6

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

Samples	Other Tests	Geologic Log	W.C.%	CN(µg/g)	%F
		DAMP, BROWN, FINE TO MEDIUM SAND.	20	45	2.48
X			3	9	0.046
X			5	16	0.014
X			4	15	0.012
		— MEDIUM GRAVELLY ZONE.			
X			2	8	0.005
X			14	4	0.024
X		WET, BROWN, FINE SANDY SILT/CLAY.	3	14	0.006
		DAMP, BROWN, SLIGHTLY SILTY, FINE TO MEDIUM SAND.			
X			4	15	0.008
X		DAMP, BROWN, SLIGHTLY SILTY CLAY.	3	23	0.007
		DAMP, BROWN, CLEAN FINE SAND.			
X			4	12	0.012
X			5	24	0.008
X			3	14	0.006
X			5	15	0.013
X		DAMP TO MOIST, FINE SANDY SILT TO SILTY FINE SAND.	NA	12	0.026
X		DAMP, BROWN, CLEAN FINE TO MEDIUM SAND.	2.8	17	0.012
X			3	15	0.014
X			4	32	0.016
X			5	24	0.014
X			14	14	0.016
		BOTTOM OF BORING 160 FEET			

NOTE: BORINGS ES-1 THROUGH ES-8 WERE DRILLED UNDER THE SUPERVISION OF ENGINEERING SCIENCE INC. GEOLOGIC LOGS PREPARED BY HART-CROWSER ARE BASED UPON VISUAL CLASSIFICATION OF SOIL SAMPLES OBTAINED BY ENGINEERING SCIENCE AFTER DRILLING HAD BEEN COMPLETED.

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

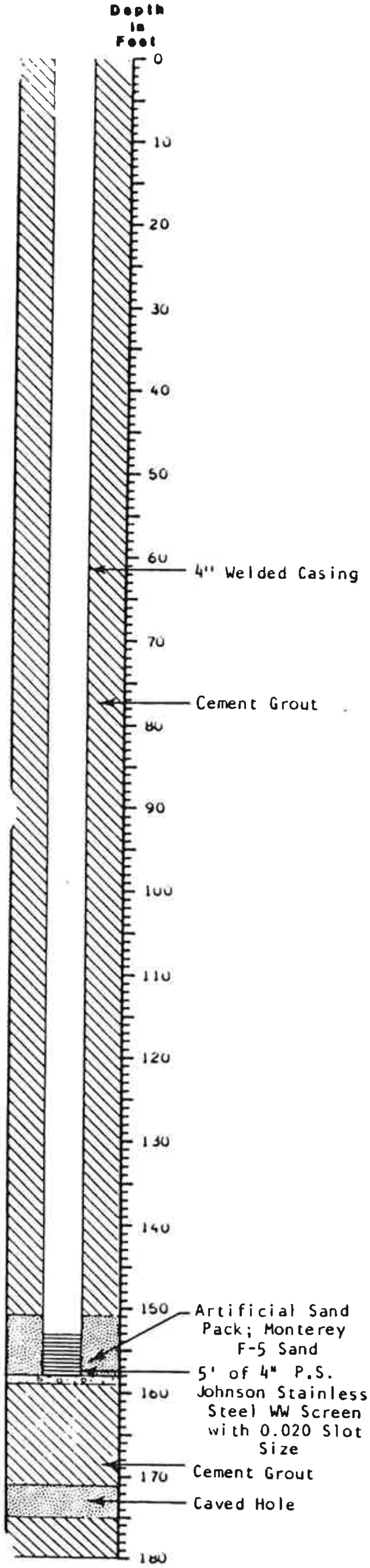
W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 August 1982

HART-CROWSER & associates inc.
Figure A-38

WELL BORING AND CONSTRUCTION INFORMATION

WELL DESIGN



GEOLOGIC LOG ES-9

Top Casing Elevation 1934.6
Casing Stick-up 1.0
Ground Surface Elevation 1933.6

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

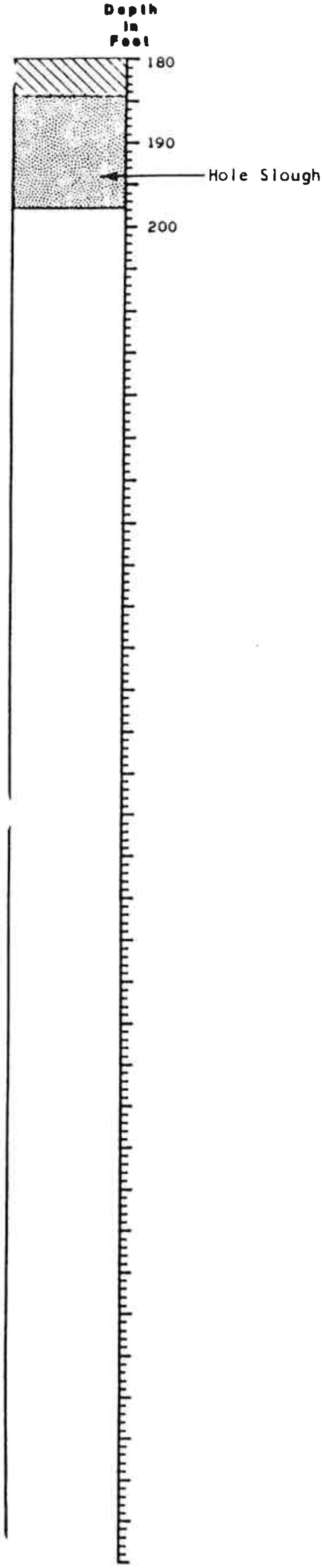
Other Tests			W.C.%	CN(μg/g)	%F
		DAMP, BROWN TO GRAY, CLEAN TO SILTY, FINE TO MEDIUM SAND, WITH INTERMITTENT CLAYEY SILT LAYERS.	8 6 5 3 4 5 11 8 42 4 7	8 5 9 6 18	.011 .011 .010 .013 .023
		DAMP, GRAY, SLIGHTLY SILTY, GRAVELLY, FINE TO MEDIUM SAND.	2 3	12	.021
		DAMP, BROWN TO GRAY, CLEAN TO SILTY, FINE TO MEDIUM SAND.	4 4 7 4 3 4 4 4 4	23 11 19 15	.016 .016 .032 .026
		GRADES FINER	4	45	.016
ATD ▽* 1,000		DAMP TO SATURATED, GRAY, FINE SAND WITH SILT LAYERS	7 6 5 22	8 2	.016 .008
		DAMP, MOIST, BROWN, CLAY.			
ATD ▽* 60		GRAY TO GRAY BROWN, SLIGHTLY SILTY TO SILTY, FINE SAND.	23 24	4	.008
		DAMP, GRAY-BROWN, CLAY.			
ATD ▽ 7 8 3	A	DAMP TO SATURATED, GRAY, FINE TO COARSE SAND, WITH SCATTERED GRAVEL, OCCASIONAL SILTY ZONES.	2 (9) (9)	(6)	(.012)
		DAMP, BLUE-GRAY, CLAYEY, SILT WITH SILTY FINE SAND ZONES.	(40) (18) (41)	(10) (8)	(.013) (.015)
<1	B	GRAY, SLIGHTLY SILTY, FINE SAND.	(28)		
		DAMP, GREEN-BROWN, SILTY CLAY.	(16)	(3)	(.011)

NA	Not Available
ATD	At Time of Drilling
(25)	Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates Inc.
Sheet 1 of 2 Figure A-39

WELL DESIGN



GEOLOGIC LOG ES-9 (Cont.)

Other Tests			QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH		
			W.C.%	CN(μg/g)	%F
<1	C	CLEAN, FINE TO MEDIUM SAND, SOME GRAVEL AND COBBLES.	(11.5) (17.1) (6.4)	(8) (14)	(.017 (.013
		BOTTOM OF HOLE 197.5 FEET. COMPLETED 12/5/80.			

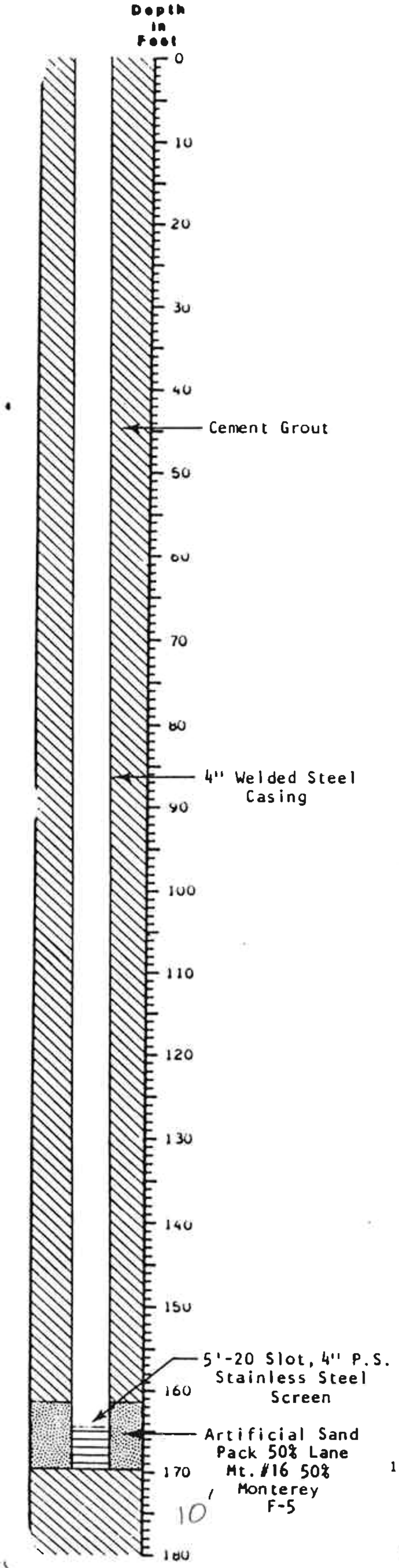
NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates Inc.
Sheet 2 of 2 Figure A-39

WELL BORING AND CONSTRUCTION INFORMATION

WELL DESIGN



GEOLOGIC LOG ES-10

Top Casing Elevation 1941.5
Casing Stick-up 1.8
Ground Surface Elevation 1939.7

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH

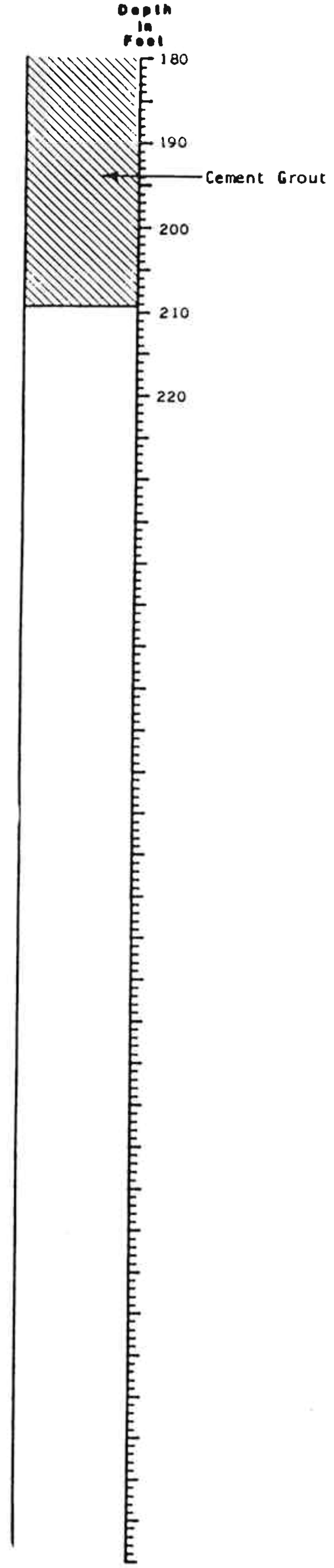
Other Tests		W.C.%	CN(µg/g)	%F
	DAMP TO MOIST, GRAY, SILTY, FINE TO COARSE SAND, WITH OCCASIONAL BRICK AND FILL DEBRIS.	8	5	:225
	MOIST, BROWN, CLEAN TO SLIGHTLY SILTY, FINE TO MEDIUM SAND.	5	2	.074
	MOIST, BROWN, FINE TO COARSE SAND, WITH FEW GRAVEL AND COBBLES.	4	2	.011
	MOIST, GRAY-BROWN, FINE TO COARSE SAND, WITH INTERBEDDED SILTY, FINE TO MEDIUM SAND LAYERS.	20	8	.064
	MOIST, BROWN, SLIGHTLY GRAVELLY, FINE TO COARSE SAND.	4	9	.015
	MOIST, BROWN, FINE TO COARSE SAND, WITH INTERBEDDED SILTY, FINE TO MEDIUM SAND LAYERS.			
	MOIST, BROWN, FINE TO MEDIUM SAND.	5	4	.014
	- SILTY SAND			
	MOIST TO DAMP, GRAY, CLEAN, FINE TO COARSE SAND, WITH FEW GRAVELS AND COBBLES.	3	2	.005
	GRADES TO	3		
	MOIST, BROWN-GRAY, CLEAN, FINE SAND.	4	2	.006
ATD ∇ * 14,200	- SATURATED	(17)	(5)	(.006)
	DAMP, BROWN-GRAY, CLAY.			
	DAMP, GRAY, FINE TO MEDIUM SAND, WITH FEW GRAVEL AND COBBLES.	3	2	.006
		3	2	.006
	-SLIGHTY SILTY	3	21	.008
	MOIST, GRAY, CLEAN, FINE SAND.	3	16	.008
	GRADES FINER	3	18	.008
	MOIST, BROWN, SILTY, FINE SAND.			
ATD ∇	MOIST TO SATURATED, CLEAN, FINE TO MEDIUM SAND.	11	14	
A		(11)	(23)	(.008)
118,000	GRADES FINER			
	BROWN, CLAYEY/SILTY, FINE SAND.	(12)	(23)	(.008)
17,000	GRAY, FINE SAND.			

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
∇ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates inc.
Sheet 1 of 2 Figure A-40

WELL DESIGN



GEOLOGIC LOG ES-10 (Cont.)

QUALITATIVE CHEMICAL CONCENTRATION AT SAMPLED DEPTH

Other Tests			W.C.%	CN(µg/g)	%F
9,000	B	MOIST, GREEN-GRAY TO GRAY, SILTY, CLAY TO CLAYEY SILT.	(21) (26.5)	(2) (16)	(.012) (.010)
		BROWN, CLEAN, FINE SAND.			
850		DAMP, GREEN-GRAY, SILTY, CLAY TO CLAYEY SILT.			
	C	BROWN, SLIGHTLY SILTY, FINE SAND TO FINE TO MEDIUM SAND.	(20)	(19)	(.010)
		BOTTOM OF HOLE AT 209 FEET. COMPLETED 1/16/81.			

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982

HART-CROWSER & associates inc.

Sheet 2 of 2 Figure A-40

WELL DESIGN

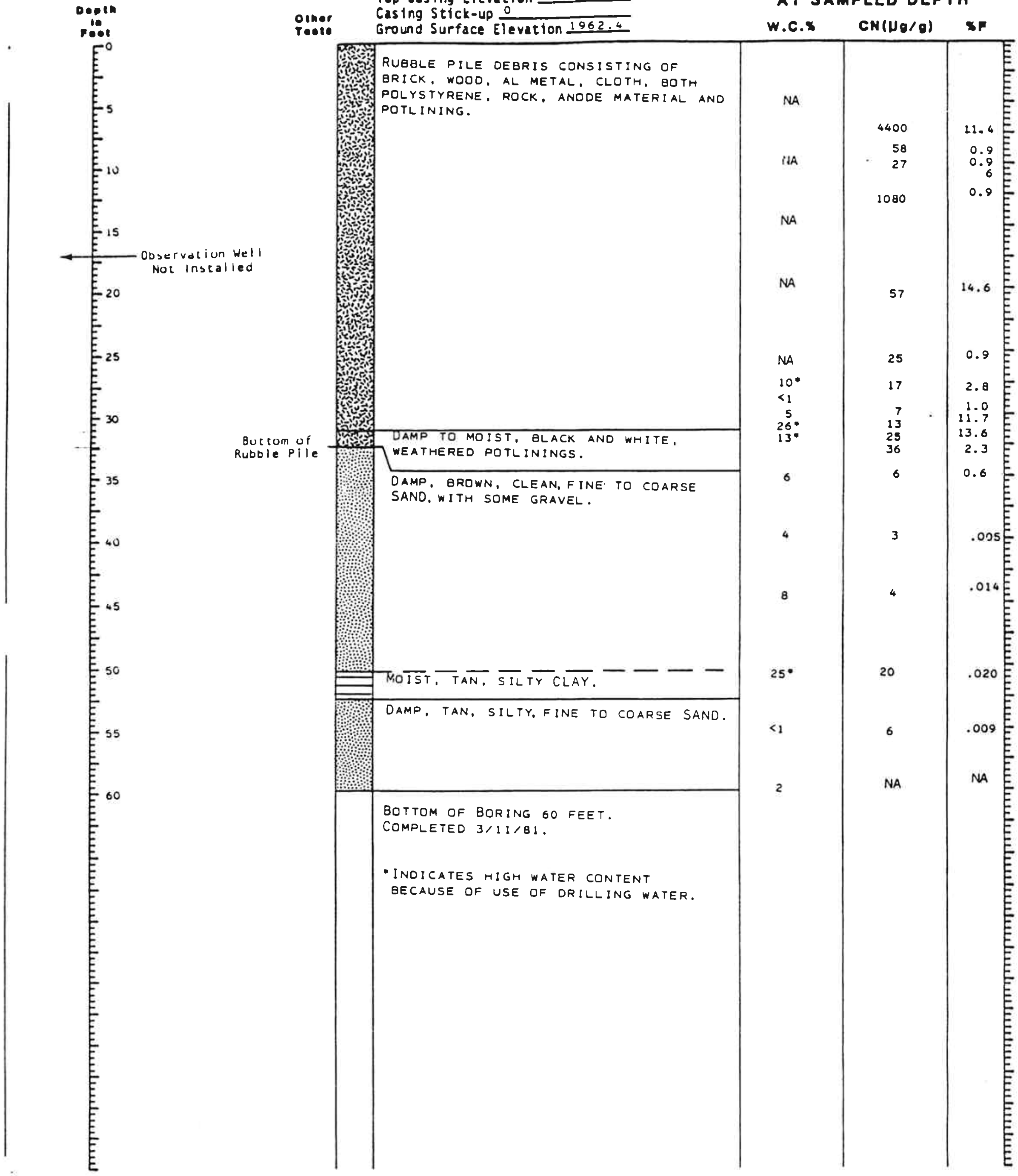
GEOLOGIC LOG D-1

Top Casing Elevation NONE

Casing Stick-up 0

Ground Surface Elevation 1962.4

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH



RUBBLE PILE DEBRIS CONSISTING OF BRICK, WOOD, AL METAL, CLOTH, BOTH POLYSTYRENE, ROCK, ANODE MATERIAL AND POTLINING.

DAMP TO MOIST, BLACK AND WHITE, WEATHERED POTLININGS.

DAMP, BROWN, CLEAN, FINE TO COARSE SAND, WITH SOME GRAVEL.

MOIST, TAN, SILTY CLAY.

DAMP, TAN, SILTY, FINE TO COARSE SAND.

BOTTOM OF BORING 60 FEET.
COMPLETED 3/11/81.

*INDICATES HIGH WATER CONTENT BECAUSE OF USE OF DRILLING WATER.

W.C.%	CN(µg/g)	%F
NA		
	4400	11.4
	58	0.9
NA	27	0.9
		6
	1080	0.9
NA		
NA	57	14.6
NA	25	0.9
10*	17	2.8
<1		
5	7	1.0
26*	13	11.7
13*	25	13.6
	36	2.3
6	6	0.6
4	3	.005
8	4	.014
25*	20	.020
<1	6	.009
2	NA	NA

NA Not Available

ATD At Time of Drilling

(25) Parenthesis Denote Saturated Samples

W.C.% - Weight Basis

* Perched Water

▽ Water Level

4000 Water CN Concentration in ppb

J-948-02 June 1982

HART-CROWSER & associates inc.

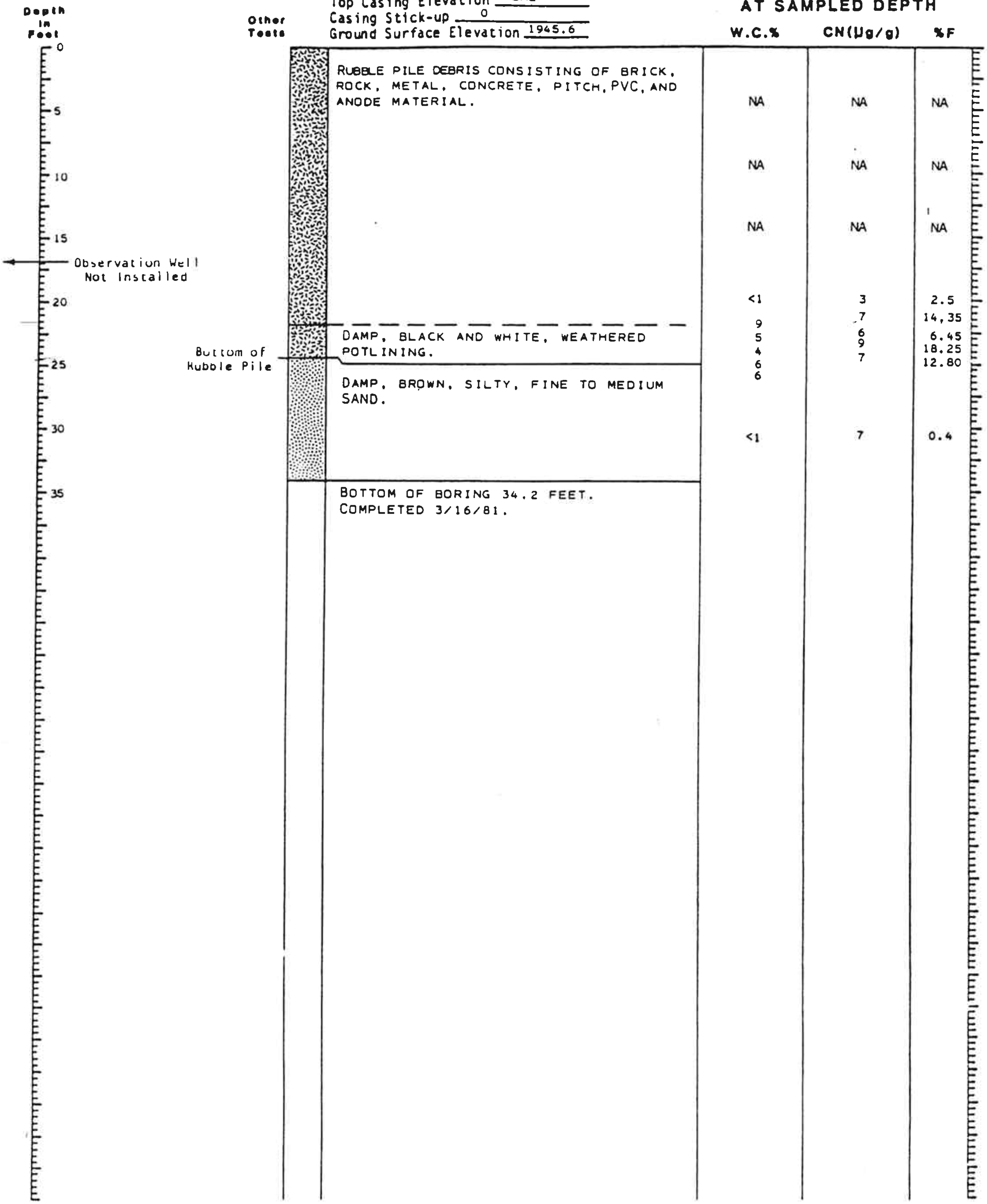
Figure A-41

WELL DESIGN

GEOLOGIC LOG D-2

Top Casing Elevation NONE
Casing Stick-up 0
Ground Surface Elevation 1945.6

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH



RUBBLE PILE DEBRIS CONSISTING OF BRICK, ROCK, METAL, CONCRETE, PITCH, PVC, AND ANODE MATERIAL.

DAMP, BLACK AND WHITE, WEATHERED POTLINING.

DAMP, BROWN, SILTY, FINE TO MEDIUM SAND.

BOTTOM OF BORING 34.2 FEET.
COMPLETED 3/16/81.

W.C.%	CN(μg/g)	%F
NA	NA	NA
NA	NA	NA
NA	NA	NA
<1	3	2.5
9 5 4 6 6	7 6 9 7	14,35 6.45 18.25 12.80
<1	7	0.4

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
• Perched Water
∇ Water Level
4000 Water CN Consentration in ppb

J-948-02 June 1982

HART-CROWSER & associates Inc.

Figure A-42

WELL DESIGN

GEOLOGIC LOG D-3

Top Casing Elevation NONE
Casing Stick-up 0
Ground Surface Elevation 1963.9

Depth in Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

Other Tests

Observation Well Not Installed

Bottom of Rubble Pile

RUBBLE DEBRIS CONTAINING BRICKS, CONCRETE, WOOD, ANODE MATERIAL, POTLINING.

DAMP, BLACK AND WHITE, WEATHERED POTLINING (STRONG NH3 ODOR).

DAMP, BROWN, CLEAN TO SILTY, FINE TO MEDIUM SAND (CEMENTED FROM ~ 38 TO 40 FEET).

BOTTOM OF BORING 53 FEET.
COMPLETED 3/20/81.

QUALITATIVE CHEMICAL CONCENTRATIONS AT SAMPLED DEPTH

W.C.%	CN(µg/g)	%F
3	490	1.36
6	49	1.59
	8	2.69
<1	68	5.00
11	84	8.54
20	446	2.56
15	114	5.30
25	36	3.05
15	214	3.15
	84	3.60
12	164	13.70
6	515	9.80
7	945	0.6
10	810	0.9
9	450	0.39
9	395	0.41
<1	48	0.41
4	17	0.42
3	9	0.03
8	7	0.01
5	13	0.01
2	38	0.02
3	40	0.02

NA Not Available
ATD At Time of Drilling
(25) Parenthesis Denote Saturated Samples

W.C.% = Weight Basis
* Perched Water
▽ Water Level
4000 Water CN Concentration in ppb

J-948-02 June 1982
HART-CROWSER & associates Inc.
Figure A-43

APPENDIX B
WELL DATA SUMMARY (1986)

Table B-1 - Status of Wells and springs in Kaiser/Mead Sampling Area as of November 1986 (Alphabetical Order)

Table B-2 - Status of Wells and Springs in Kaiser/Mead Sampling Area as of November 1986 (Ascending Order - by number)

Table B-1

STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1986
(WELL AND SPRING NAMES IN ALPHABETICAL ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Airth, W. E.	12606 Mayfair	44	W-44	NA	NA	
Anderson, Gary	13614, Minihdoka	160/6H1	--	140	135-140	
Apitz	12520 Ruby	74	--	93	NA	
Bach	12515 Mayfair	205	--	180	NA	
Barrett, James	13902 Karen	99	W-99	25	NA	
Biglow	13819 Minihdoka	161	--	--	--	Spring
Bilbrey, Vickie	12723, Mayfair	37/8D3	W-37	104	NA	
Billberg	12102 Division	554	W-554	43	NA	
Billberg, Milfred	12110 Division	209	W-209	43	NA	Kitchen Sink
Blumer	408 Koda	1080	--	--	--	Spring
Bonneville Power	--	1661	--	556	NA	
Boston	817 Hastings	138	W-138	85	NA	
Bouten, Frank	13117 Mill Road	5677	W-5677	120	NA	
Brinson/Troglia	622 Carolina	8	W-8	51	NA	
Burris	13224 Mill Road	116A	--	70	NA	
Burroughs, Ted	13318 Mill Road	120C	W-120	368	NA	
Cast	1618 Farwell	16	--	90	NA	
Cherry & Farwell	Suburban Water	--	SS3-7	--	--	
Chevillet, M.	13210, Mill road	117B/6J2	--	70	NA	
Colborn, G.	12515, Dakota	6	W-6	51	NA	Irrigation Well
Cork, R.	307 Koda	139	W-139	45	NA	
Custom Camper	12303 Division	94	W-94	50	NA	
Daily, Shirley	525 Hastings	36	W-36	47	NA	
Dakota & Hastings	Spokane Sub. Water	--	SS3-5	--	--	Well?
Davis/Prumer	13106, Mill Road	114/6R2	W-114	75	NA	
Dept. Transpotation	--	5P1	--	79	49-79	
Deshler	513, Hastings	5	--	48	NA	
Downey, William	12720 Ruby	77	W-77	106	NA	Kitchen Sink
Fox Milling	POB # 279, Mead	15D1	--	353	OPEN BOTTOM	
Freya & Farwell	Suburban Water	--	SS3-6	--	--	
Fulsaas, B.	12605, Ruby	75/8D5	W-75	120	110-120	
Goss	12621, Hamilton	10	--	47	NA	
Henkle	13810 Minihdoka	168	W-168	--	--	Spring
Hollingsworth, H.	13004 Mill Road	92F	W-7246	86	NA	Kitchen Sink
Holz, Trudy/Janet	12707 Hamilton	202	W-202	46	NA	
Howell	12706, Mayfair	46/8D1	W-46	NA	NA	
Jarvis, R.	617 Hastings	--	W-7625	--	--	
Jeffries/Wehnes	11424 Newport	327	W-327	200	NA	Kitchen Sink
Jens, V.	--	8F1	--	93	NA	
Jordan, A. L.	12705, Mayfair	38/8D4	W-38	95	NA	
Kaiser Settle Basin	Outfall to Peone Ck.	--	W-25	--	--	Outfall
Kaiser Well	Kaiser Plant	16D1	--	297	NA	
Kaiser Well#1	Kaiser Plant	16D2	--	285	208-278	
Kaiser Well#4	Kaiser Plant	16D3	--	286	236-286	
Kaiser Well#5	Kaiser Plant	16F2	--	268	238-268	
Kaiser Well#6	Kaiser Plant	16F3	--	284	242-283	

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STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1986
(WELL AND SPRING NAMES IN ALPHABETICAL ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Kaiser Well#ES1	Kaiser Plant	ES1	ES1	125	OPEN BOTTOM?	
Kaiser Well#ES10	Kaiser Plant	ES10	ES10	169	164-169	
Kaiser Well#ES2	Kaiser Plant	ES2	ES2	80	OPEN BOTTOM?	
Kaiser Well#ES3	Kaiser Plant	ES3	ES3	30	OPEN BOTTOM?	
Kaiser Well#ES4	Kaiser Plant	ES4	ES4	64	OPEN BOTTOM?	
Kaiser Well#ES5	Kaiser Plant	ES5	ES5	170	OPEN BOTTOM?	
Kaiser Well#ES6	Kaiser Plant	ES6	ES6	68	OPEN BOTTOM?	
Kaiser Well#ES7	Kaiser Plant	ES7	ES7	165	OPEN BOTTOM?	
Kaiser Well#ES8	Kaiser Plant	ES8	ES8	160	OPEN BOTTOM?	
Kaiser Well#ES9	Kaiser Plant	ES9	ES9	159	153-158	
Kaiser Well#HC1	Kaiser Plant	HC1	HC1	157	151-156	
Kaiser Well#HC10	Kaiser Plant	HC10	HC10	185	176-181	
Kaiser Well#HC11	Kaiser Plant	HC11	HC11	165	156-161	
Kaiser Well#HC12	Kaiser Plant	HC12	HC12	150	145-148	
Kaiser Well#HC13	Kaiser Plant	HC13	HC13	162	157-162	
Kaiser Well#HC14	Kaiser Plant	HC14	HC14	162	155-160	
Kaiser Well#HC15	Kaiser Plant	HC15	HC15	149	140-145	
Kaiser Well#HC16	Kaiser Plant	HC16	HC16	149	136-141	
Kaiser Well#HC17	Kaiser Plant	HC17	HC17	168	153-163	
Kaiser Well#HC1A	Kaiser Plant	HC1A	HC1A	48	42-47	
Kaiser Well#HC2	Kaiser Plant	HC2	HC2	62	55-60	
Kaiser Well#HC2A	Kaiser Plant	HC2A	HC2A	169	162-167	
Kaiser Well#HC3	Kaiser Plant	HC3	HC3	69	63-68	
Kaiser Well#HC4	Kaiser Plant	HC4	HC4	52	47-52	
Kaiser Well#HC5	Kaiser Plant	HC5	HC5	70	63-68	
Kaiser Well#HC6	Kaiser Plant	HC6	HC6	50	48-50	
Kaiser Well#HC7	Kaiser Plant	HC7	HC7	170	159-169	
Kaiser Well#HC8	Kaiser Plant	HC8	HC8	164	156-161	
Kaiser Well#HC9	Kaiser Plant	HC9	HC9	67	62-67	
Kaiser Well#HC9A	Kaiser Plant	HC9A	HC9A	163	157-162	
Kaiser Well#TH1	Kaiser Plant	TH1	1	158	153-157	
Kaiser Well#TH2	Kaiser Plant	TH2	2	163	153-157	
Kaiser Well#TH3	Kaiser Plant	TH3	3	214	140-210	
Kaiser Well#TH3A	Kaiser Plant	TH3A	3A	163	145-161	
Kaiser Well#TH4	Kaiser Plant	TH4	4	205	145-205	
Kaiser Well#TH5	Kaiser Plant	TH5	5	214	135-186	
Kaiser Well#TH6A	Kaiser Plant	TH6A	6A	200	147-150	
Kaiser Well#TH6B	Kaiser Plant	TH6B	6B	200	167-172	
Kaiser Well#TH6C	Kaiser Plant	TH6C	6C	200	195-200	
Kaiser Well#TH7A	Kaiser Plant	TH7A	7A	199	146-151	
Kaiser Well#TH7B	Kaiser Plant	TH7B	7B	199	163-168	
Kaiser Well#TH7C	Kaiser Plant	TH7C	7C	199	194-199	
Kaiser Well#TH8	Kaiser Plant	TH8	8	163	154-159	
Kelsey	12706 Hamilton	7170	--	NA	NA	
Kostecka	Box 101, Mead	71	W-71	48	NA	
Kostecka, M.	12105 Ruby Road	--	W-7387	80	--	

STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1986
(WELL AND SPRING NAMES IN ALPHABETICAL ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Lessig, L. W.	605 1/2 Hastings	4	W-4	48	NA	
Linberg	--	8N1	--	89	NA	
Little Spokane Riv.	Dartford & Minihdoka	--	W-24	--	--	River
Little Spokane Riv.	Below Van Gel.Spring	--	W-464	--	--	River
Little Spokane Riv.	Above WS at Park Br.	--	W-149	--	--	River
Little Spokane Riv.	Below WS at Gage	--	W-19	--	--	River
Little Spokane Riv.	Rivilla Park	--	W-438	--	--	River
Little Spokane Riv.	50 Yds. d/s Popp Pt.	--	W-463	--	--	River
Little Spokane Riv.	St. George School	--	W-6970	--	--	River
Ludesher/Dart	13717 Minihdoka	163/6H1S	W-163	--	--	Spring
MacLean	13111 Mill Road	141	--	--	--	Spring
Market & Gay	Suburban Water	--	SS3-13	--	--	
Marr, CE	--	7Q1	--	88	NA	
Martin	12709, Dakota	2	--	40	NA	
McLean, John	13003 Mill Road	--	W-5661	--	--	
Mead School Dist.	Dist. 354	4P1	--	146	126-146	
Merritt, C. J.	330 Koda Court	165	W-165	10	NA	
Merritt/Bland	11226, Newport Hwy	328/8R1	W-328	185	NA	Kitchen Sink
Miller, R.	13818 Keran	98	W-98	17	NA	
Moen	608 Koda	194	--	30	NA	
Moore/Exley	13812 Karen	222	--	5	NA	Well?
Myron/Cork	408 Koda	--	W-2326	--	--	Spring/Creek
Nelson, Bud	537, Regina	52/8K1	--	27	OPEN BOTTOM	
Nelson, D. L.	--	17B1	--	224	199-220	
Nordby	12405 Dakota	69	--	69	NA	
North, F.A.	--	8F2	--	75	NA	
Northgate Church	311 Hastings	203	W-203	78	NA	Outside Tap
Northview Bible Ch.	13621, Mill Road	142/6H2	W-142	205	OPEN BOTTOM	
NW Pipeline Co.	--	17J1	--	248	NA	
Paulson	724 Hastings	4423	--	NA	NA	
Pecchia, E.	13402 Mill Road	118	W-118	50	NA	
Peone Creek	Below Kaiser Outfall	--	W-145	--	--	Creek
Peone Creek	Above Kaiser Outfall	--	W-28	--	--	Creek
Pine Acres	--	8L1	--	60	NA	
Pioneer Reality	12310, Division	9/8C1	--	75	NA	
Platz/Signell	12701 Ruby	76	W-76	119	NA	Bathrm sink
Pope, S. H.(Irr.)	514, Hastings	35/8G2	W-35	84	74-84	
Pope, S. H.(New)	514, Hastings	8G3	W-2147	176	162-167	
Pope, S. H.(Old)	514, Hastings	34/8G1	W-34	47	NA	
Popp, Dr.	13651 Minihdoka	218/6G1S	--	--	--	Spring(Irr.)
Popp, Dr.	13651, Minihdoka	167/6G2	--	127	NA	
Prema Mulch	RT#2, POB#38A, Mead	15F1	--	219	NA	
Procunier/Warren	12605 Mayfair	39	W-39	70	NA	
Prows, Leonard	12612 Hamilton	--	W-7588	--	--	Kitchen Sink
Reames, Dick	12324 Pittsburg	14	W-14	128	NA	
Ritchie	12524 Mayfair	43	W-43	75	NA	Kitchen Sink

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STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1986
(WELL AND SPRING NAMES IN ALPHABETICAL ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Rivilla Water Co.	14006 Karen Lane	96/661	--	30	21-29	
Rockser	12412 Mayfair	42	--	85	NA	
Schoesler	13019 Mill Road	7591	W-7591	120	NA	
Smitt/Van Gelder	13607 Minihdoka	195	W-195	--	--	Spring
Speaks	505 Hastings	93	W-93	80	NA	Mens Rm Sink
Spokane Coun.Shop #A	209 Farwell	51/5N1	W-51	106	NA	Well
Stedman, Mark	12221 Mayfair	8E1	--	80	73-78	
Stone, Walt	12523 Mayfair	40	W-40	86	NA	
Stone, Walt (Irr.)	12523 Mayfair	41	W-41	68	NA	Irrigation Well
Thain, Rich	12305 Pittsburg	15	W-15	380	NA	
Thompson, Peter	1919 Center Road	--	W-7585	--	--	
Thompson, R.	13114, Mill Road	115D/6R1	W-115D	20	NA	
Tilton Steiner	13418, Mill Road	1196/6J1	--	75	NA	
Unknown	--	7D1S	--	--	--	Spring
Van Gelder/Below SP	--	662S	--	--	--	Spring
Van Gelder/Deck	--	663S	--	--	--	Spring
Vanderlinde/Huguenin	326 Koda	159	W-159	5	NA	Well?
Vrem	509 Hastings	101	--	46	NA	
Waikiki Spring	--	6Q2S	--	--	--	Spring
Waikiki Spring	--	6Q1S	--	--	--	Spring
Waikiki Sys. No.1	--	7C2S	--	--	--	Spring
Waikiki Sys. No.2	--	7C1S	--	--	--	Spring
Waikiki Sys. No.3	--	6Q3S	--	--	--	Spring
Waikiki Sys. No.3A	--	6L1S	--	--	--	Spring
Wandermere Lake	#1 Tee	--	W-26	--	--	Lake
Wandermere Spring	Prior entering LSR	151/5L1S	W-151	--	--	Spring
Wandermere Spring	By Gravel Plant	--	W-33	--	--	Weir/Spring
Weisman	12622, Mayfair	45/8D2	W-45	NA	NA	
White, Dart J.	13906 Minihdoka	162	--	120	NA	
Whitworth College	--	1861	--	200	160-200	
Whitworth WD	#3A	7K1	--	164	NA	
Whitworth WD	Rigina	--	WH3A	--	--	
Whitworth WD	Farwell	--	WH3B	--	--	
Whitworth WD	Ivanhoe	--	WH2B	--	--	
Whitworth WD	#3	7P1	--	180	93-114	
Whitworth WD	#2	762	--	296	130-150	
Whitworth WD	Glendale	--	WH8A2	--	--	
Whitworth WD	Fairwood	761	--	135	NA	
Whitworth WD	Division & Holland	--	WH2A	--	--	
Wilkerson Add.Well	Unpurge Hold Tank	--	W-8	--	--	Tank
Winfree, B.	13020 Mill Road	91E	W-91E	80	NA	
WWP3-5	--	884	--	90	59-88	

Table B-2

STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1986
(WELL AND SPRING NUMBERS ARE IN ASCENDING ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Goss	12621, Hamilton	10	--	47	NA	
Vrem	509 Hastings	101	--	46	NA	
Blumer	408 Koda	1080	--	--	--	Spring
Davis/Prumer	13106, Mill Road	114/6R2	W-114	75	NA	
Thompson, R.	13114, Mill Road	115D/6R1	W-115D	20	NA	
Burris	13224 Mill Road	116A	--	70	NA	
Chevillet, M.	13210, Mill road	117B/6J2	--	70	NA	
Pecchia, E.	13402 Mill Road	118	W-118	50	NA	
Tilton Steiner	13418, Mill Road	1196/6J1	--	75	NA	
Burroughs, Ted	13318 Mill Road	120C	W-120	368	NA	
Boston	817 Hastings	138	W-138	85	NA	
Cork, R.	307 Koda	139	W-139	45	NA	
Reames, Dick	12324 Pittsburg	14	W-14	128	NA	
MacLean	13111 Mill Road	141	--	--	--	Spring
Northview Bible Ch.	13621, Mill Road	142/6H2	W-142	205	OPEN BOTTOM	
Thain, Rich	12305 Pittsburg	15	W-15	380	NA	
Wandermere Spring	Prior entering LSR	151/5L1S	W-151	--	--	Spring
Vanderlinde/Huguenin	326 Koda	159	W-159	5	NA	Well?
Fox Milling	POB # 279, Mead	15D1	--	353	OPEN BOTTOM	
Prema Mulch	RT#2, POB#38A, Mead	15F1	--	219	NA	
Cast	1618 Farwell	16	--	90	NA	
Anderson, Gary	13614, Minihdoka	160/6H1	--	140	135-140	
Biglow	13818 Minihdoka	161	--	--	--	Spring
White, Dart J.	13906 Minihdoka	162	--	120	NA	
Ludesher/Dart	13717 Minihdoka	163/6H1S	W-163	--	--	Spring
Merritt, C. J.	330 Koda Court	165	W-165	10	NA	
Popp, Dr.	13651, Minihdoka	167/6G2	—	127	NA	
Henkle	13810 Minihdoka	168	W-168	--	--	Spring
Kaiser Well	Kaiser Plant	16D1	--	297	NA	
Kaiser Well#1	Kaiser Plant	16D2	--	285	208-278	
Kaiser Well#4	Kaiser Plant	16D3	--	286	236-286	
Kaiser Well#5	Kaiser Plant	16F2	--	268	238-268	
Kaiser Well#6	Kaiser Plant	16F3	--	284	242-283	
Bonneville Power	--	16G1	--	556	NA	
Nelson, D. L.	--	17B1	--	224	199-220	
NW Pipeline Co.	--	17J1	--	248	NA	
Whitworth College	--	18G1	--	200	160-200	
Moen	608 Koda	194	--	30	NA	
Smitt/Van Gelder	13607 Minihdoka	195	W-195	--	--	Spring
Martin	12709, Dakota	2	--	40	NA	
Holz, Trudy/Janet	12707 Hamilton	202	W-202	46	NA	
Northgate Church	311 Hastings	203	W-203	78	NA	Outside Tap
Bach	12515 Mayfair	205	--	180	NA	
Billberg, Milfred	12110 Division	209	W-209	43	NA	Kitchen Sink
Popp, Dr.	13651 Minihdoka	218/6G1S	—	—	—	Spring(Irr.)
Moore/Exley	13812 Karen	222	--	5	NA	Well?

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STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1986
(WELL AND SPRING NUMBERS ARE IN ASCENDING ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Jeffries/Wehnes	11424 Newport	327	W-327	200	NA	Kitchen Sink
Merritt/Bland	11226, Newport Hwy	328/8R1	W-328	185	NA	Kitchen Sink
Pope, S. H.(Old)	514, Hastings	34/8B1	W-34	47	NA	
Pope, S. H.(Irr.)	514, Hastings	35/6B2	W-35	84	74-84	
Daily, Shirley	525 Hastings	36	W-36	47	NA	
Bilbrey, Vickie	12723, Mayfair	37/6D3	W-37	104	NA	
Jordan, A. L.	12705, Mayfair	38/6D4	W-38	95	NA	
Procunier/Warren	12605 Mayfair	39	W-39	70	NA	
Lessig, L. W.	605 1/2 Hastings	4	W-4	48	NA	
Stone, Walt	12523 Mayfair	40	W-40	86	NA	
Stone, Walt (Irr.)	12523 Mayfair	41	W-41	68	NA	Irrigation Well
Rockser	12412 Mayfair	42	--	85	NA	
Ritchie	12524 Mayfair	43	W-43	75	NA	Kitchen Sink
Airth, W. E.	12606 Mayfair	44	W-44	NA	NA	
Paulson	724 Hastings	4423	--	NA	NA	
Weisman	12622, Mayfair	45/8D2	W-45	NA	NA	
Howell	12706, Mayfair	46/8D1	W-46	NA	NA	
Mead School Dist.	Dist. 354	4P1	--	146	126-146	
Deshler	513, Hastings	5	--	48	NA	
Spokane Coun.Shop #A	209 Farwell	51/5N1	W-51	106	NA	Well
Nelson, Bud	537, Regina	52/8K1	--	27	OPEN BOTTOM	
Billberg	12102 Division	554	W-554	43	NA	
Bouten, Frank	13117 Mill Road	5677	W-5677	120	NA	
Dept. Transpotation	--	5P1	--	79	49-79	
Colborn, G.	12515, Dakota	6	W-6	51	NA	Irrigation Well
Nordby	12405 Dakota	69	--	69	NA	
Van Gelder/Below SP	--	6G2S	--	--	--	Spring
Van Gelder/Deck	--	6G3S	--	--	--	Spring
Waikiki Sys. No.3A	--	6L1S	--	--	--	Spring
Waikiki Spring	--	6Q1S	--	--	--	Spring
Waikiki Spring	--	6Q2S	--	--	--	Spring
Waikiki Sys. No.3	--	6Q3S	--	--	--	Spring
Kostecka	Box 101, Mead	71	W-71	48	NA	
Kelsey	12706 Hamilton	7170	--	NA	NA	
Apitz	12520 Ruby	74	--	93	NA	
Schoesler	13019 Mill Road	7591	W-7591	120	NA	
Fulsaas, B.	12605, Ruby	75/8D5	W-75	120	110-120	
Platz/Signell	12701 Ruby	76	W-76	119	NA	Bathrm sink
Downey, William	12720 Ruby	77	W-77	106	NA	Kitchen Sink
Waikiki Sys. No.2	--	7C1S	--	--	--	Spring
Waikiki Sys. No.1	--	7C2S	--	--	--	Spring
Unknown	--	7D1S	--	--	--	Spring
Whitworth WD	Fairwood	7G1	--	135	NA	
Whitworth WD	#2	7G2 ✓	--	296	130-150	
Whitworth WD	#3A	7K1	--	164	NA	
Whitworth WD	#3	7P1	--	180	93-114	

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STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1986
(WELL AND SPRING NUMBERS ARE IN ASCENDING ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Marr, CE	--	7Q1	--	88	NA	
Brinson/Troglia	622 Carolina	8	W-8	51	NA	
WWP3-5	--	8B4	--	90	59-88	
Stedman, Mark	12221 Mayfair	8E1	--	80	73-78	
Jens, V.	--	8F1	--	93	NA	
North, F.A.	--	8F2	--	75	NA	
Pope, S. H.(New)	514, Hastings	8G3	W-2147	176	162-167	
Pine Acres	--	8L1	--	60	NA	
Linberg	--	8N1	--	89	NA	
Winfree, B.	13020 Mill Road	91E	W-91E	80	NA	
Hollingsworth, H.	13004 Mill Road	92F	W-7246	86	NA	Kitchen Sink
Speaks	505 Hastings	93	W-93	80	NA	Mens Rm Sink
Custom Camper	12303 Division	94	W-94	50	NA	
Rivilla Water Co.	14006 Karen Lane	96/661	--	30	21-29	
Miller, R.	13818 Keran	98	W-98	17	NA	
Barrett, James	13902 Karen	99	W-99	25	NA	
Pioneer Reality	12310, Division	9/8C1	--	75	NA	
Kaiser Well#ES1	Kaiser Plant	ES1	ES1	125	OPEN BOTTOM?	
Kaiser Well#ES10	Kaiser Plant	ES10	ES10	169	164-169	
Kaiser Well#ES2	Kaiser Plant	ES2	ES2	80	OPEN BOTTOM?	
Kaiser Well#ES3	Kaiser Plant	ES3	ES3	30	OPEN BOTTOM?	
Kaiser Well#ES4	Kaiser Plant	ES4	ES4	64	OPEN BOTTOM?	
Kaiser Well#ES5	Kaiser Plant	ES5	ES5	170	OPEN BOTTOM?	
Kaiser Well#ES6	Kaiser Plant	ES6	ES6	68	OPEN BOTTOM?	
Kaiser Well#ES7	Kaiser Plant	ES7	ES7	165	OPEN BOTTOM?	
Kaiser Well#ES8	Kaiser Plant	ES8	ES8	160	OPEN BOTTOM?	
Kaiser Well#ES9	Kaiser Plant	ES9	ES9	159	153-158	
Kaiser Well#HC1	Kaiser Plant	HC1	HC1	157	151-156	
Kaiser Well#HC10	Kaiser Plant	HC10	HC10	185	176-181	
Kaiser Well#HC11	Kaiser Plant	HC11	HC11	165	156-161	
Kaiser Well#HC12	Kaiser Plant	HC12	HC12	150	145-148	
Kaiser Well#HC13	Kaiser Plant	HC13	HC13	162	157-162	
Kaiser Well#HC14	Kaiser Plant	HC14	HC14	162	155-160	
Kaiser Well#HC15	Kaiser Plant	HC15	HC15	149	140-145	
Kaiser Well#HC16	Kaiser Plant	HC16	HC16	149	136-141	
Kaiser Well#HC17	Kaiser Plant	HC17	HC17	168	153-163	
Kaiser Well#HC1A	Kaiser Plant	HC1A	HC1A	48	42-47	
Kaiser Well#HC2	Kaiser Plant	HC2	HC2	62	55-60	
Kaiser Well#HC2A	Kaiser Plant	HC2A	HC2A	169	162-167	
Kaiser Well#HC3	Kaiser Plant	HC3	HC3	69	63-68	
Kaiser Well#HC4	Kaiser Plant	HC4	HC4	52	47-52	
Kaiser Well#HC5	Kaiser Plant	HC5	HC5	70	63-68	
Kaiser Well#HC6	Kaiser Plant	HC6	HC6	50	48-50	
Kaiser Well#HC7	Kaiser Plant	HC7	HC7	170	159-169	
Kaiser Well#HC8	Kaiser Plant	HC8	HC8	164	156-161	
Kaiser Well#HC9	Kaiser Plant	HC9	HC9	67	62-67	

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STATUS OF WELLS AND SPRINGS IN KAISER/MEAD SAMPLING AREA
AS OF NOVEMBER 1996
(WELL AND SPRING NUMBERS ARE IN ASCENDING ORDER)

NAME	ADDRESS	WEL/SPR. NO.	COMPUT. NO.	WELL DEPTH	SCREEN DEP.	REMARKS
Kaiser Well#HC9A	Kaiser Plant	HC9A	HC9A	163	157-162	
Kaiser Well#TH1	Kaiser Plant	TH1	1	158	153-157	
Kaiser Well#TH2	Kaiser Plant	TH2	2	163	153-157	
Kaiser Well#TH3	Kaiser Plant	TH3	3	214	140-210	
Kaiser Well#TH3A	Kaiser Plant	TH3A	3A	163	145-161	
Kaiser Well#TH4	Kaiser Plant	TH4	4	205	145-205	
Kaiser Well#TH5	Kaiser Plant	TH5	5	214	135-186	
Kaiser Well#TH6A	Kaiser Plant	TH6A	6A	200	147-150	
Kaiser Well#TH6B	Kaiser Plant	TH6B	6B	200	167-172	
Kaiser Well#TH6C	Kaiser Plant	TH6C	6C	200	195-200	
Kaiser Well#TH7A	Kaiser Plant	TH7A	7A	199	146-151	
Kaiser Well#TH7B	Kaiser Plant	TH7B	7B	199	163-168	
Kaiser Well#TH7C	Kaiser Plant	TH7C	7C	199	194-199	
Kaiser Well#TH9	Kaiser Plant	TH8	8	163	154-159	
Thompson, Peter	1919 Center Road	--	W-7585	--	--	
Little Spokane Riv.	50 Yds. d/s Popp Pt.	--	W-463	--	--	River
Myron/Cork	408 Koda	--	W-2326	--	--	Spring/Creek
Market & Gay	Suburban Water	--	SS3-13	--	--	
Prows, Leonard	12612 Hamilton	--	W-7588	--	--	Kitchen Sink
Freya & Farwell	Suburban Water	--	SS3-6	--	--	
Whitworth WD	Rigina	--	WH3A	--	--	
Kaiser Settle Basin	Outfall to Peone Ck.	--	W-25	--	--	Outfall
Whitworth WD	Farwell	--	WH3B	--	--	
Dakota & Hastings	Spokane Sub. Water	--	SS3-5	--	--	Well?
Whitworth WD	Ivanhoe	--	WH2B	--	--	
Wandermere Lake	#1 Tee	--	W-26	--	--	Lake
Little Spokane Riv.	Above WS at Park Br.	--	W-149	--	--	River
Wandermere Spring	By Gravel Plant	--	W-33	--	--	Weir/Spring
Peone Creek	Above Kaiser Outfall	--	W-28	--	--	Creek
Jarvis, R.	617 Hastings	--	W-7625	--	--	
Whitworth WD	Glendale	--	WH8A2	--	--	
Little Spokane Riv.	Rivilla Park	--	W-438	--	--	River
Peone Creek	Below Kaiser Outfall	--	W-145	--	--	Creek
Little Spokane Riv.	Dartford & Minihdoka	--	W-24	--	--	River
Whitworth WD	Division & Holland	--	WH2A	--	--	
Little Spokane Riv.	Below Van Gel.Spring	--	W-464	--	--	River
Wilkerson Add.Well	Unpurge Hold Tank	--	W-8	--	--	Tank
McLean, John	13003 Mill Road	--	W-5661	--	--	
Kostecka, M.	12105 Ruby Road	--	W-7387	80	--	
Cherry & Farwell	Suburban Water	--	SS3-7	--	--	
Little Spokane Riv.	St. George School	--	W-6970	--	--	River
Little Spokane Riv.	Below WS at Gage	--	W-19	--	--	River

Notes :

1. Wells are grouped by ascending order. Wells with same initial digit are grouped together, and then are further grouped according to the second and third digits.

J-948-05

APPENDIX C
SELECTED HYDROLOGIC DATA

Table C-1 - Selected Water Level Data

Table C-2, C-3, C-4 - Water Budget Analyses

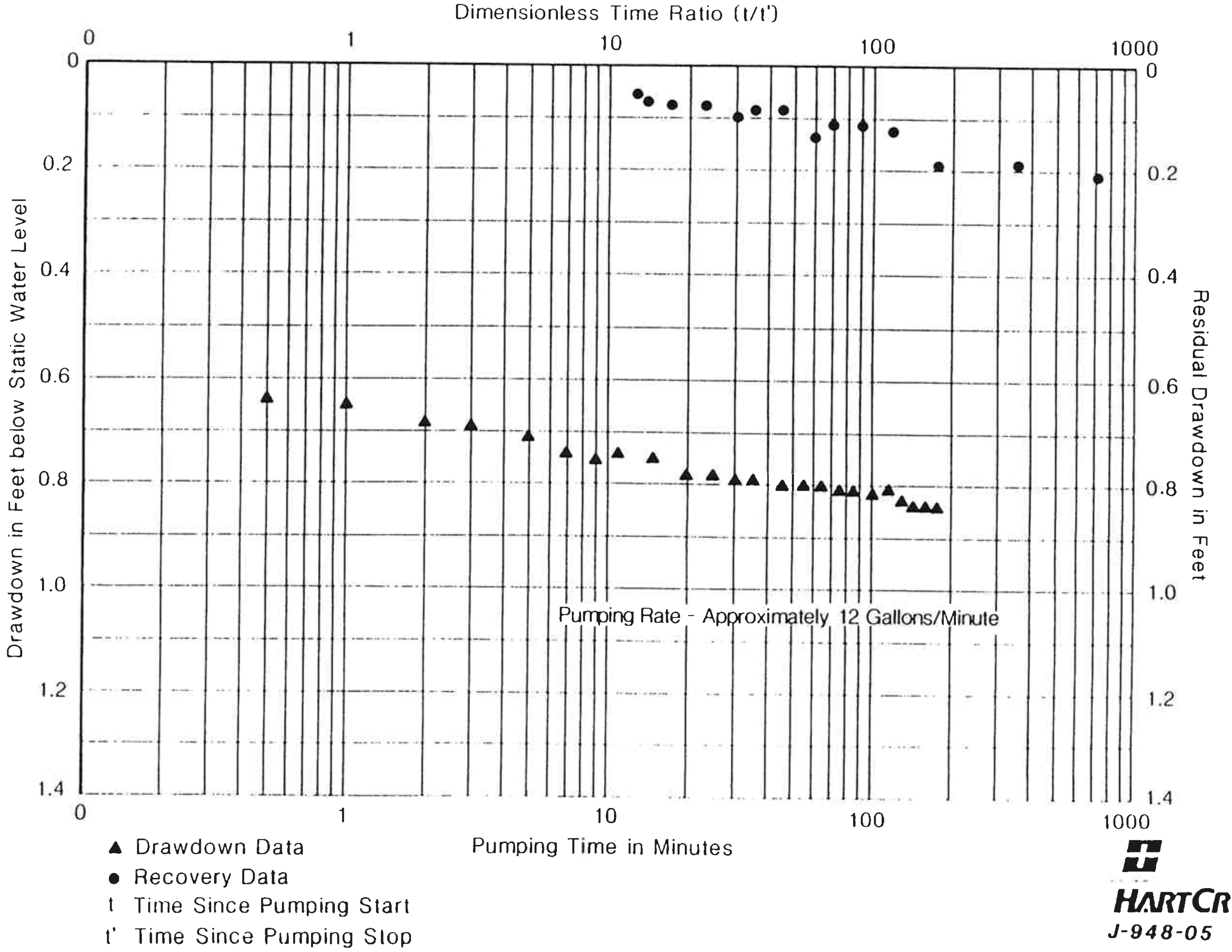
Figure C-1 - Pumping Test Data ES-9
Figure C-2 - Pumping Test Data ES-10
Figure C-3, C-4, C-5 - Water Budget Analyses
Figure C-6, C-7, C-8 - Grain Size Classifications

Table C-1 - Selected Water Level Data

	Elev.	Water Level			
		September 1981		August 1988	
	TOC	Depth	Elev.	Depth	Elev.
HC-1	1928.16	144.91	1783.25	145.5	1782.66
HC-2A	1937.48	154	1783.48	154.5	1782.98
HC-7	1937.85	158.54	1779.31	159	1778.85
HC-8	1933.98	155.15	1778.83	155.25	1778.73
HC-9A	1939.05	157	1782.05	159	1780.05
HC-12	1915.6	140.54	1775.06	144	1771.6
HC-13	1937.04	153.04	1784	155	1782.04
HC-14	1943.73	153.54	1790.19	153.08	1790.65
HC-15	1932.01	NA	NA	145.66	1786.35
HC-16	1924.55	NA	NA	140	1784.55
HC-17	1941.1	NA	NA	158.58	1782.52
TH-3A	1921.64	146.12	1775.52	NA	NA

All depths and elevations in feet
TOC Top of Casing
NA = Not Available

Pumping Test Data - ES-9



HARTCROWSER

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Figure C-1

Pumping Test Data - ES-10

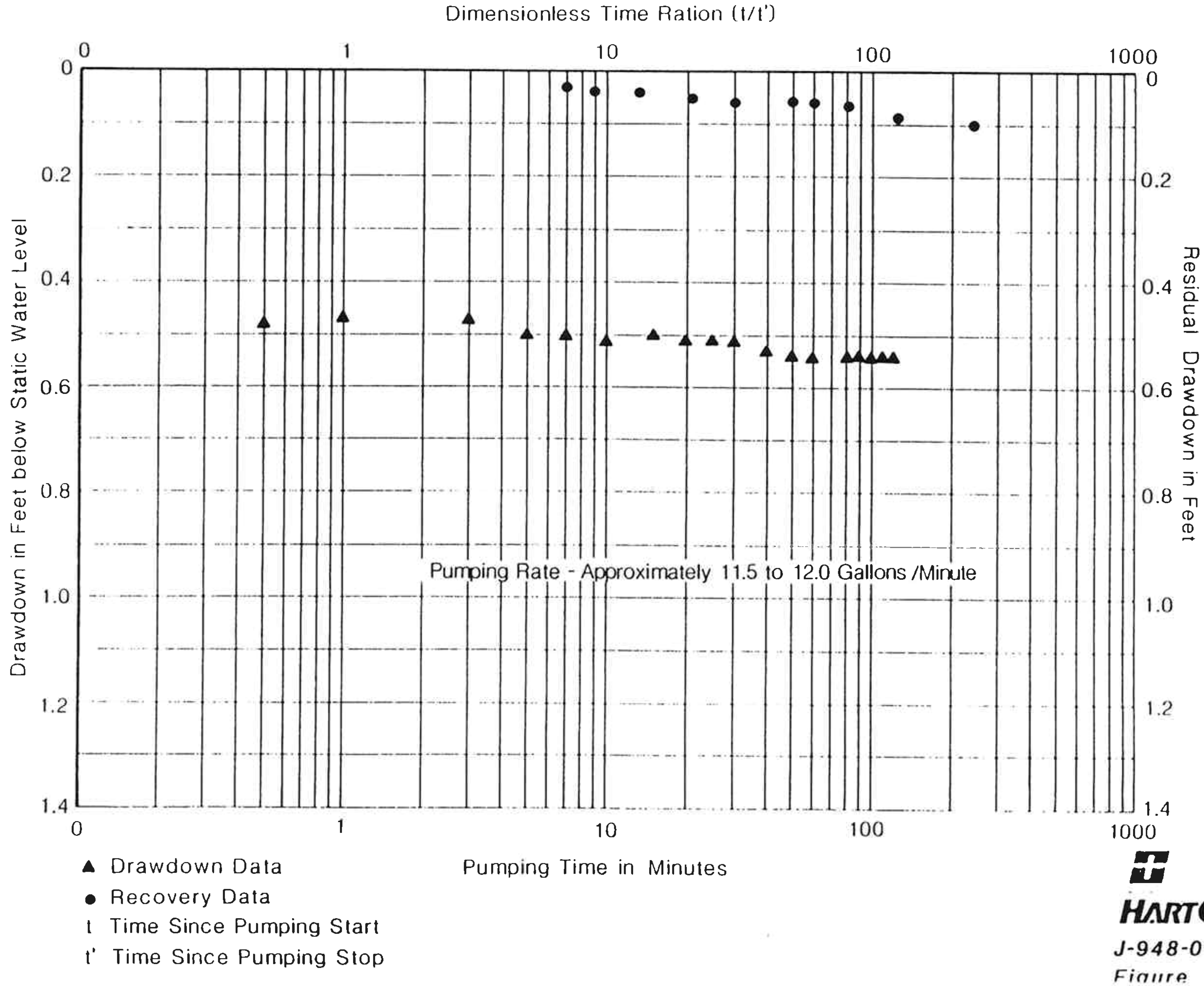

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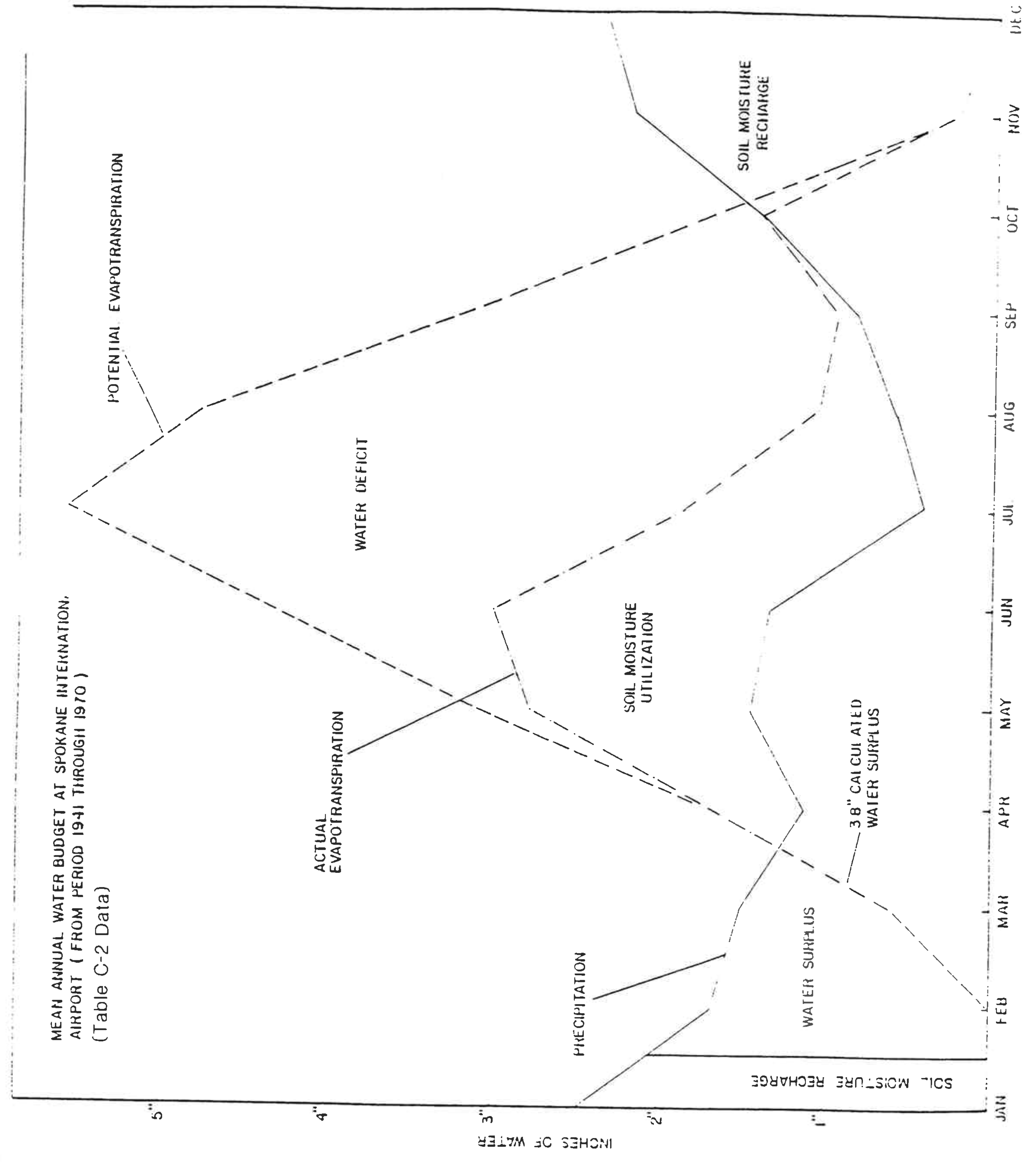
Figure C-2

FIGURE C-3



Source: Robinson & Noble 1979b.

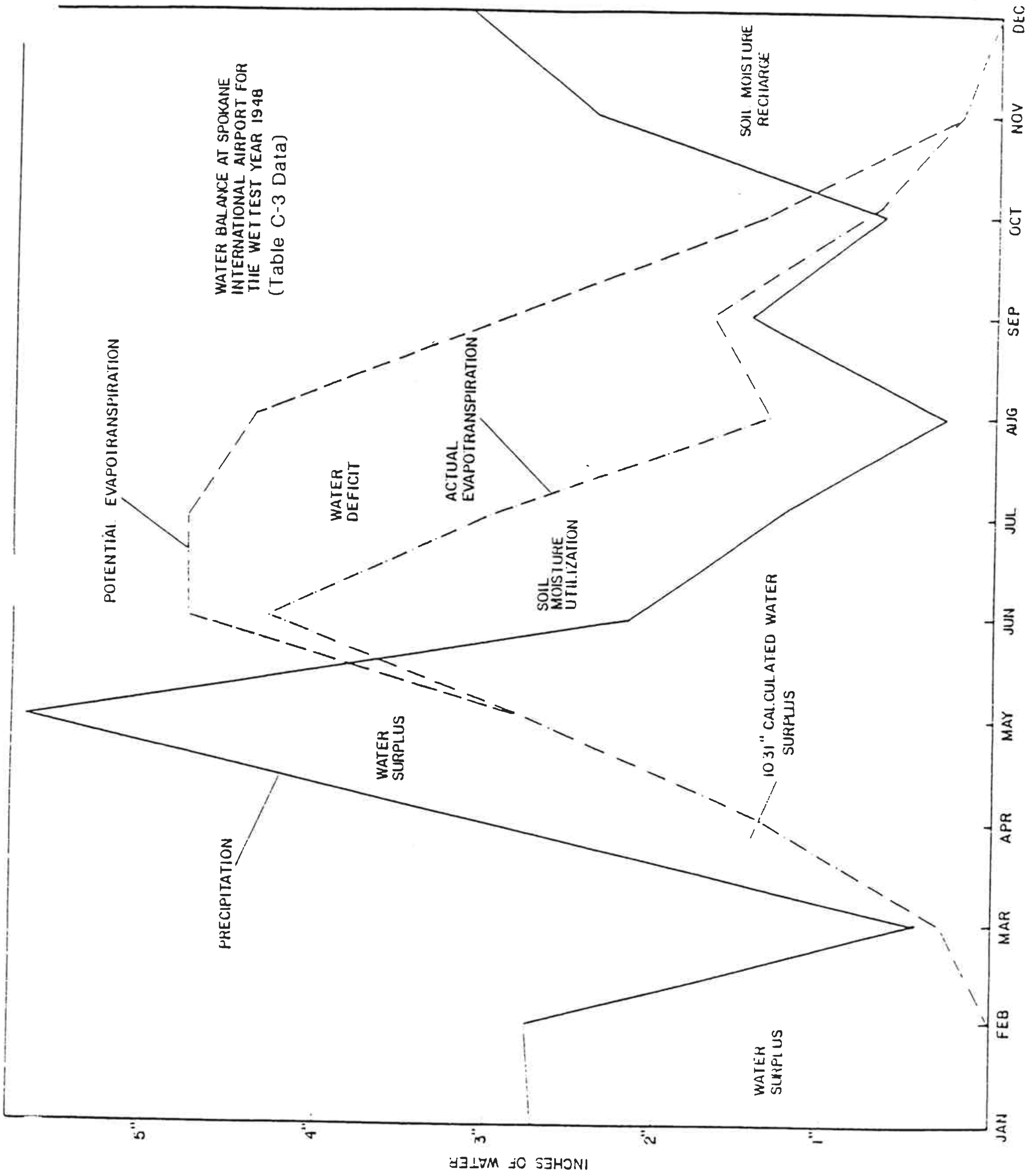
TABLE C-2

	J	F	M	A	M	J	J	A	S	O	N	D	Total	
Temp.	25.4	32.2	37.5	46.1	54.7	61.5	69.7	68.0	59.6	47.8	35.5	29.0	47.3	(1941-70
I	.0	.0	.47	1.97	4.06	6.03	8.75	8.16	5.46	2.34	.24	.0	37.5	
Unj.P.E.	.0	.0	.02	.05	.08	.11	.14	.13	.10	.06	.01	.0		
X	23.1	24.0	30.6	34.2	39.0	39.6	39.9	36.6	31.5	27.9	23.4	21.9		
P.E.	0	0	.61	1.71	3.12	4.36	5.59	4.76	3.15	1.67	.23	0	25.2	
P	2.47	1.68	1.53	1.12	1.46	1.36	.40	.58	.83	1.42	2.20	2.37	17.42	(41-70 m
P-P.E.	2.47	1.68	.92	-.59	-1.66	-3.00	-5.19	-4.18	-2.32	-.25	1.97	2.37	-7.78	
Acc.Pot.W.L.				.59	2.25	5.25	10.44	14.62	16.94	17.19				
St. 6"	6.00	6.00	6.00	5.43	4.11	2.47	1.00	.50	.39	.39	2.36	4.73		
△ St.	1.27	0	0	-.57	-1.32	-1.64	-1.47	-.50	-.11	0	1.97	2.37		
A.E.	0	0	.61	1.69	2.79	3.00	1.87	1.08	.94	1.42	.23	0	13.63	
D	0	0	0	.02	.33	1.36	3.72	3.68	2.21	.25	0	0		
S	1.2	1.68	.92	0	0	0	0	0	0	0	0	0		

Source: Robinson & Noble 197

Temp. - Mean monthly temperature ^{o}F
I - Station index (based on temperature)
Unj.P.E. - Unadjusted potential evaporation
X - Adjustment for latitude of station
P.E. - Potential evapotranspiration
P-P.E. - PPT - Potential Evaporation
Acc.Pot.W.L. - Accumulated potential water loss
St. 6" - Six-inches of water stored in soil profile
A.E. - Actual evapotranspiration
D - Water deficit
S - Water surplus

FIGURE C-4



Source: Robinson & Noble 1979b.

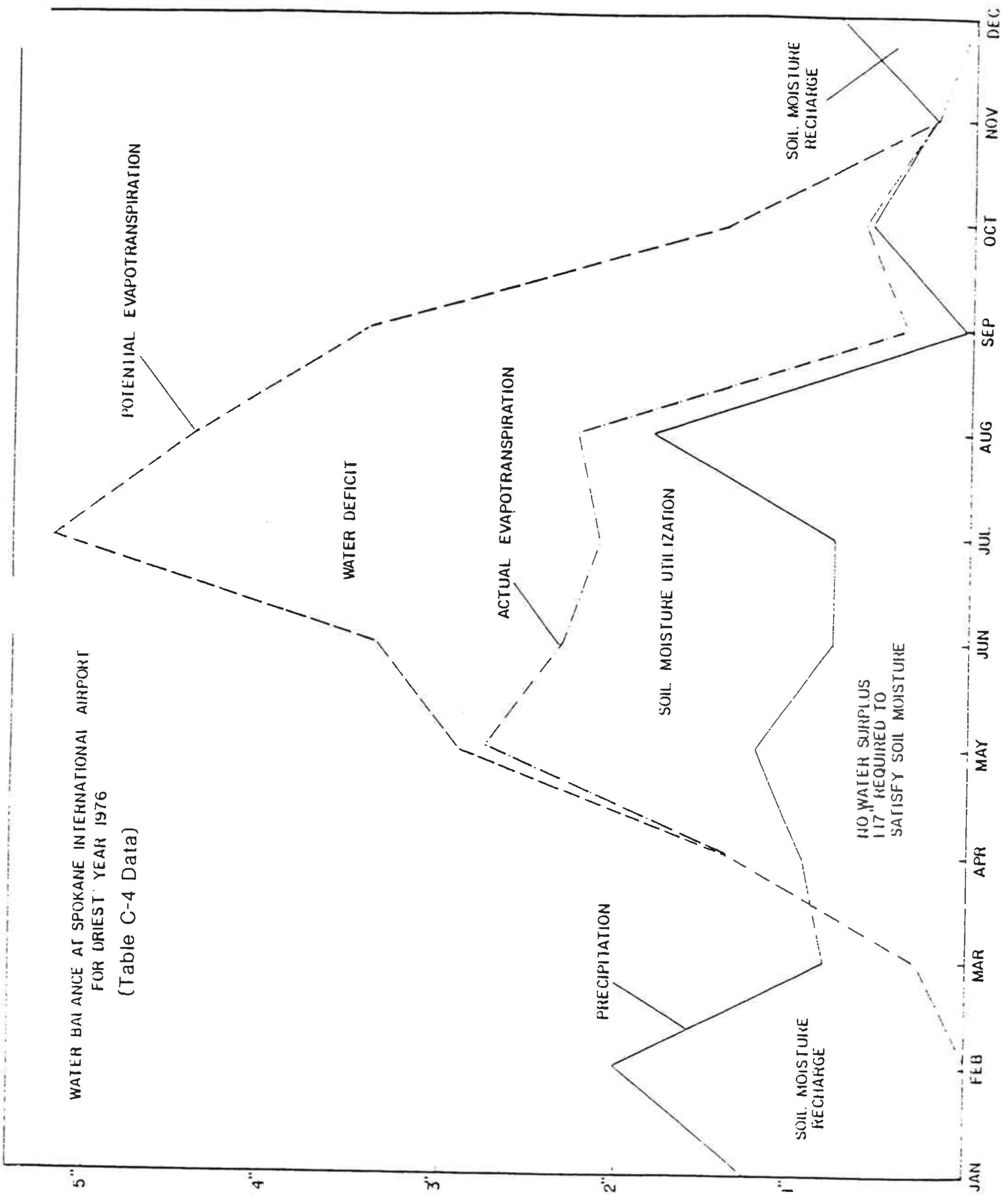
TABLE C-3

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Temp.	27.5	29.0	36.2	43.5	52.8	65.4	65.1	65.2	58.1	47.3	34.8	21.5	45.5
I	.0	.0	.47	1.97	4.06	6.03	8.75	8.16	5.46	2.34	.24	.0	37.5
Unj.P.E.	.0	.0	.01	.04	.07	.12	.12	.12	.09	.05	.01	.0	
X	23.1	24.0	30.6	34.2	39.0	39.6	39.9	36.6	31.5	27.9	23.4	21.9	
P.E.	0	0	.31	1.37	2.73	4.75	4.79	4.39	2.84	1.40	.23	0	22.81
P	2.72	2.75	.45	3.08	5.71	2.17	1.29	.27	1.46	.66	2.38	3.13	26.07
P-P.E.	2.72	2.75	.14	1.71	2.98	-2.58	-3.50	-4.12	-1.38	-.74	2.15	3.13	3.26
Acc.Pot.W.L.						2.58	6.08	10.2	11.58	12.32			
St. 6"	6.00	6.00	6.00	6.00	6.00	3.87	2.13	1.04	.82	.73	2.88	6.01	
Δ St.	-.01	0	0	0	0	-2.13	-1.74	-1.09	-.22	-.09	2.15	3.13	
A.E.	0	0	.31	1.37	2.73	4.30	3.03	1.36	1.68	.75	.23	0	15.76
D	0	0	0	0	0	.45	1.76	3.03	1.16	.65	0	0	
S	2.73	2.75	.14	1.71	2.98	0	0	0	0	0	0	0	10.31

Source: Robinson & Noble 1979b.

Temp. - Mean monthly temperature ^{o}F
I - Station index (based on temperature)
Unj.P.E. - Unadjusted potential evaporation
X - Adjustment for latitude of station
P.E. - Potential evapotranspiration
P-P.E. - PPT - Potential evaporation
Acc.Pot.W.L. - Accumulated potential water loss
St. 6" - Six-inches of water stored in soil profile
A.E. - Actual evapotranspiration
D - Water deficit
S - Water surplus

FIGURE C-5



WATER BALANCE AT SPOKANE INTERNATIONAL AIRPORT FOR DRIEST YEAR 1976

(Table C-4 Data)

Source: Robinson & Noble 1979b.

TABLE C-4

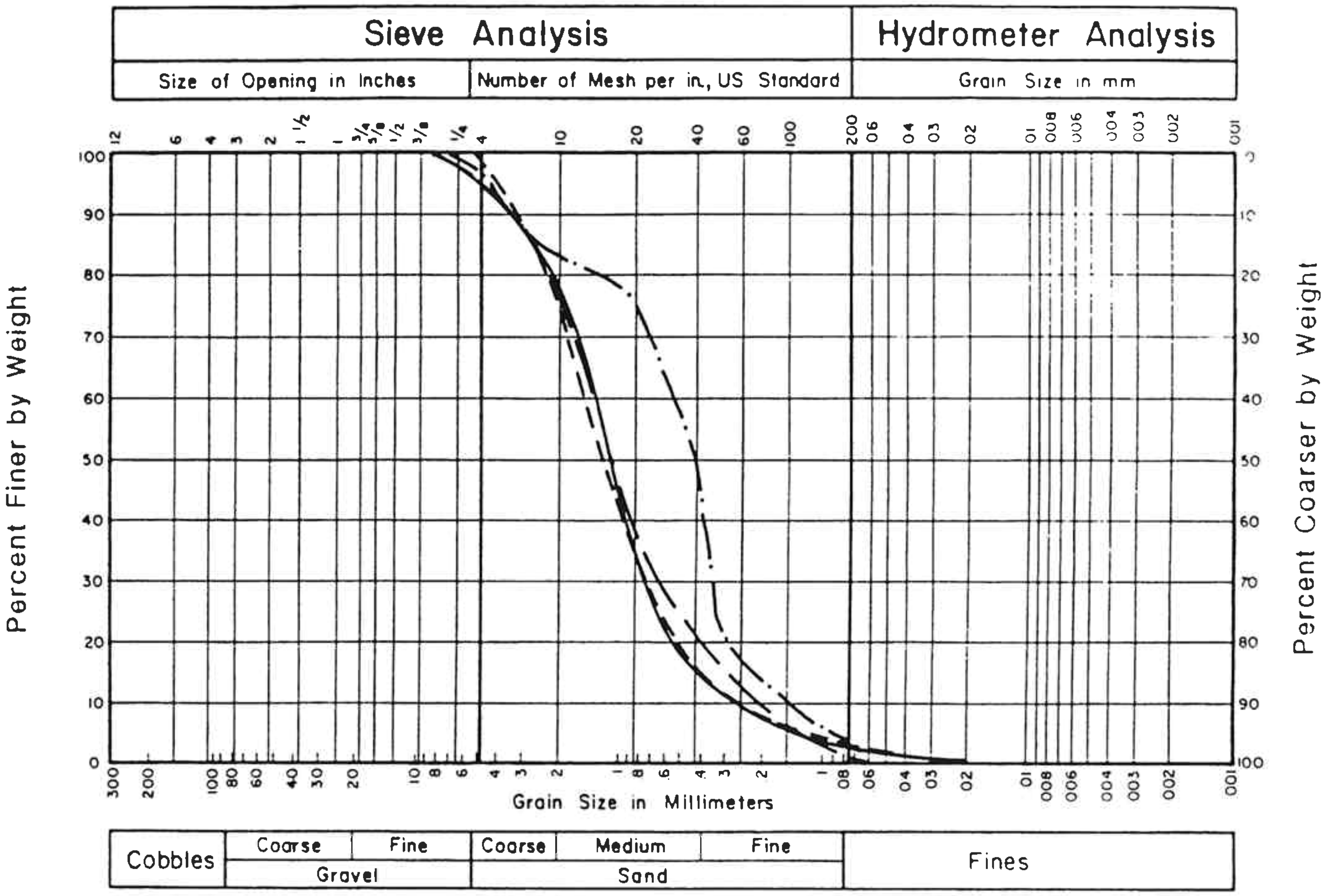
	J	F	M	A	M	J	J	A	S	O	N	D	Total
Temp.	29.6	32.1	35.1	45.2	54.5	58.5	68.8	65.4	63.4	46.8	35.8	29.6	47.1
I	.0	.0	.47	1.97	4.06	6.03	8.75	8.16	5.46	2.34	.24	.0	37.5
Unj.P.E.	.0	.0	.01	.04	.08	.09	.13	.12	.11	.05	.01	.0	
X	23.1	24.0	30.6	34.2	39.0	39.6	39.9	36.6	31.5	27.9	23.4	21.9	
P.E.	0	0	.31	1.37	3.12	3.56	5.19	4.39	3.46	1.40	.23	0	23.03
P	1.28	2.04	.83	.97	1.24	.78	.79	1.83	.05	.59	.22	.60	11.22
P-P.E.	1.28	2.04	.52	-.40	-1.88	-2.78	-4.40	-2.56	-3.41	-.81	-.01	.60	-11.81
Acc.Pot.W.L.				.40	2.28	5.06	9.46	12.02	15.43	16.24	16.25		
St. 6"	6.00	6.00	6.00	5.61	4.08	2.54	1.19	.77	.43	.39	.39	.99	
Δ St.	5.01	0	0	-.39	-1.53	-1.54	-1.35	-.42	-.34	-.04	0	.60	
A.E.	0	0	.31	1.36	2.77	2.32	2.14	2.25	.39	.63	.22	0	12.39
D	0	0	0	.01	.35	1.24	3.05	2.14	3.07	.77	.01	0	
S	-3.73	2.04	.52	0	0	0	0	0	0	0	0	0	-1.17

Source: Robinson & Noble 1979b.

Temp. - Mean monthly temperature ^oF
I - Station index (based on temperature)
Unj.P.E. - Unadjusted potential evaporation
X - Adjustment for latitude of station
P.E. - Potential evapotranspiration
P-P.E. - PPT - Potential Evaporation
Acc.Pot.W.L. - Accumulated potential water loss
St. 6" - Six-inches of water stored in soil profile
A.E. - Actual evapotranspiration
D - Water deficit
S - Water surplus

Grain Size Classification

Zone A



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	ES-9		149.5 - 151.2	Fine to coarse SAND.		
— —			152.3 - 153.3	SAND	SW	
— — —			153.3 - 155.5	SAND	SW	
—·—			155.5 - 157.5	SAND	SP	

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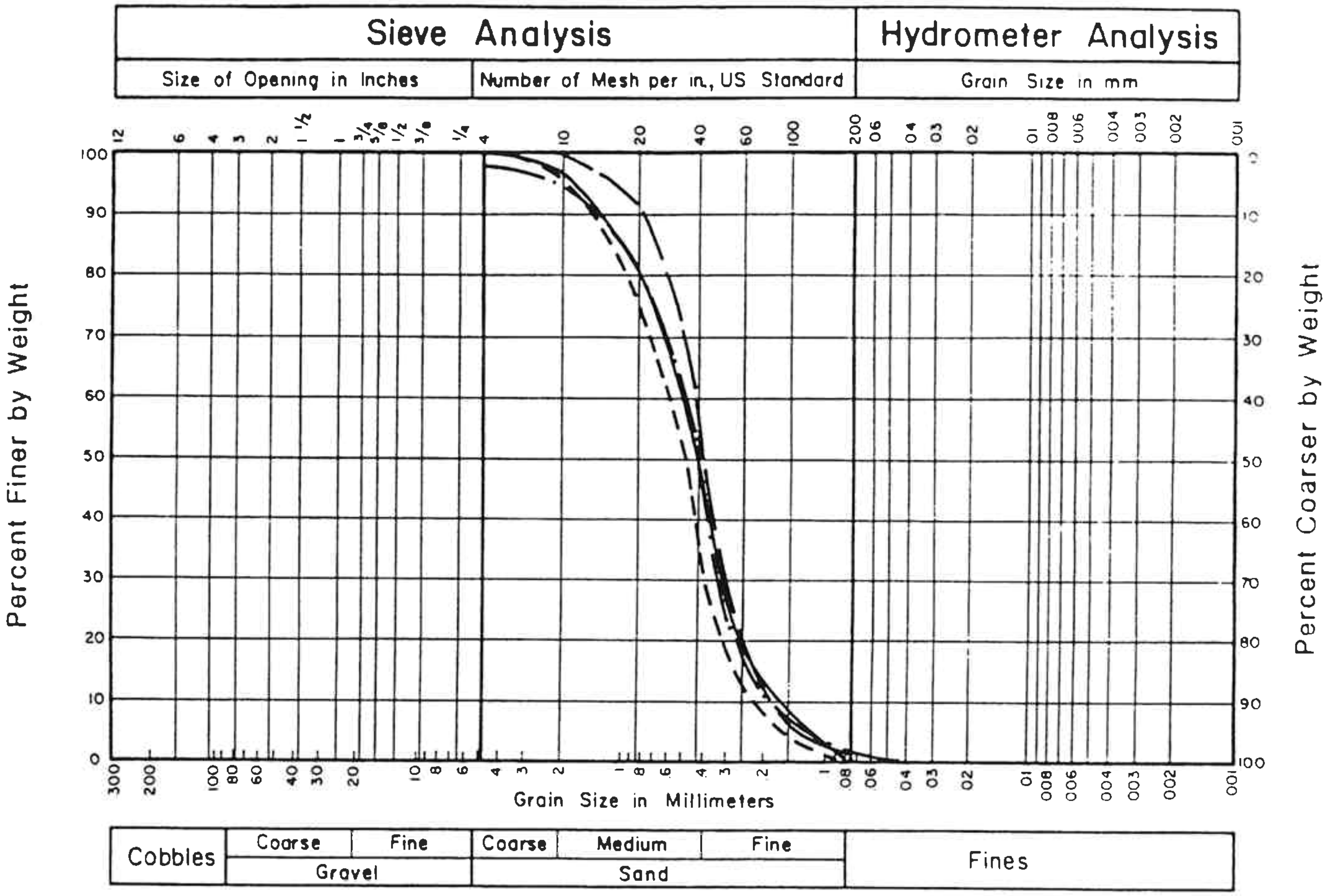
Figure C-6

Grain Size Classification

Zone A



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	ES-10		158.9 - 160.4	Fine to medium SAND.	SP	
— —			164.5 - 166.7	Medium to fine SAND.	SP	
- - - -			166.7 - 168.0	Fine to medium SAND.	SP	
—·—			168.0 - 169.5	Medium to fine SAND.	SP	

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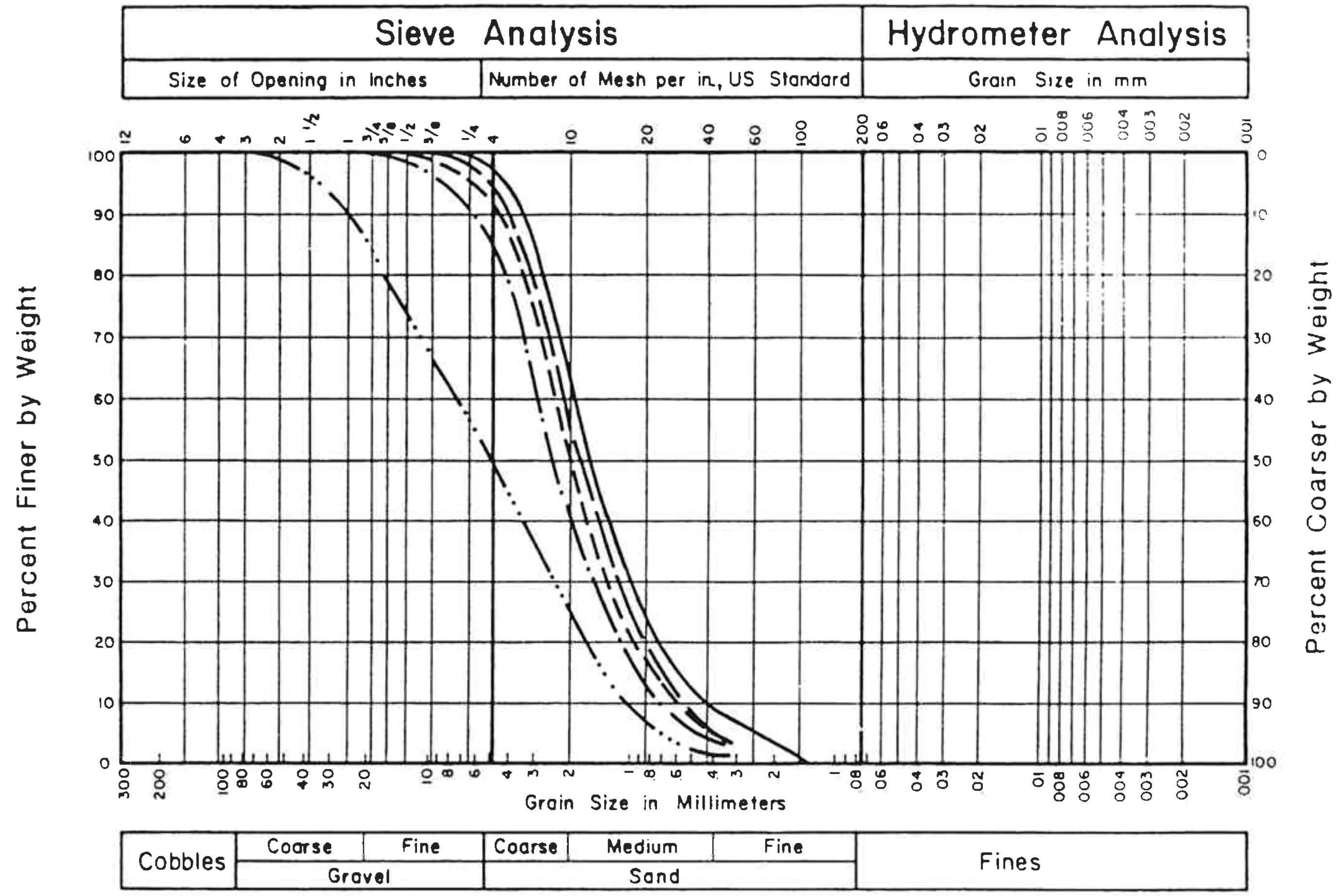
Figure C-7

Grain Size Classification

Zone C



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	Well 5		254.0 - 257.0	Very gravelly SAND.	SP	
— —			248.0 - 251.0	Gravelly SAND.	SP	
– – –			242.0 - 245.0	Slightly gravelly SAND.	SP	
—·—			275.0 - 278.0	Slightly gravelly SAND.	SP	
—···—			272.0 - 275.0	SAND.	SP	

Source: Robinson and Roberts, 1955.

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Figure C-8

Appendix B

ANODE BUTT TAILINGS CHARACTERISTICS

ANDREA BEATTY RINIKER
Director

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Mail Stop PV-11 • Olympia, Washington 98504-8711 • (206) 459-6000

June 22, 1988

Mr. Dick Jeltsch
Kaiser Aluminum and Chemical Corporation
East 2111 Hawthorne Road
Mead, Washington 99021

Dear Mr. Jeltsch:

The Department of Ecology has completed its review of the information submitted regarding the butt tailings pile at the Mead smelter. We are in agreement that the butt tailings are not classified as a dangerous waste and there are no restrictions regarding the sale of this material. Kaiser should exercise reasonable care in the handling and transport of this material to prevent fugitive emissions. Reasonable care should also be exercised to prevent leachate from being generated since the material does contain soluble fluoride. Please keep the department informed as to your progress in removing the material. Since the pile is located in the vicinity of the covered potliner, caution is advised while working in that area.

In response to your other inquiry regarding disturbance of the existing pile, the department also agrees with Kaiser's position that extraction of a portion of the pile does not effect the status of the remaining material. This question may be moot now that question of designation of the butt tailings has been resolved, however, even under the minimum functional standards for solid waste, disturbing part of the pile does not effect the remainder.

I hope this resolves the questions you have posed. If you have any further questions, please do not hesitate to contact myself or Kelly Ryan.

Sincerely,

Theodore J. Mix
Industrial Section

TJM:

17/0622TM

KAISER
ALUMINUM

KAISER ALUMINUM & CHEMICAL CORPORATION

May 18, 1988

Ted Mix
Washington State Dept. of Ecology
Industrial Section
Mail Stop PV-11
Olympia, WA 98504

RE: Mead Butt Tailings Pile

Dear Ted:

As we discussed, we have tested samples of the old pile of butt tailings at the Mead plant site by the Dangerous Waste designation procedures. A fish bioassay and PAH extraction were run on a sample taken in November, 1987. In addition, EP toxicity results from a previous sample are enclosed.

Sample Procedure: The sample was a composite of sixty grab samples taken from all areas and elevations of the pile, from one foot below the surface to as much as five feet below the surface. The sample was homogenized and split down to the appropriate size for the various analyses.

Fish Bioassay: Results of a rainbow trout bioassay conducted by E.V.S. Consultants is attached (Attachment 1). There were no mortalities, indicating that the material is not designated by this procedure.

PAH/HH Extraction: The results of a PAH/HH extraction per WAC 173-303 are attached (Attachment 2). As you can see, the material is not designated by that criterion either.

EP Toxicity: Results of EP toxicity testing (Attachment 3) show metals levels well below the regulatory limits.

Referring to my letter of April 8, I would request your concurrence with the regulatory interpretations proposed.

Sincerely,

RICHARD C. JELTSCH
Staff Environmental Engineer

Enc.
/ch

MEAD WORKS
EAST 2111 HAWTHORNE ROAD, MEAD, WA 99021 PHONE: 509 466-3300

Attachment 1

E.V.S. Consultants
Environmental Services

2335 Eastlake Avenue East
Seattle, Washington 98102
(206) 328-4188

Our File: 2/138-03
W.O.: 880128

April 19, 1988

Mr. R. Jeltsch
Staff Environmental Engineer
Kaiser Aluminum and Chemical Corporation
Mead Works
E. 2111 Hawthorne Road
Mead, Washington
99021

Dear Mr. Jeltsch:

Re: Acute Toxicity Test on Sample J-010 (Butt Tailings)

We have completed one (1) Washington State Department of Ecology Hazardous Waste Toxicity Test on sample J-010 (Butt Tailings) received April 05, 1988.

Standard bioassay procedures were followed in accordance with the Washington State Department of Ecology guidelines for the Static Acute Fish Toxicity Test (1981).

Summary of Results:

Sample	Concentration (mg/L)	No. Deaths/ Total Fish Exposed	Washington D.O.E Classification*
J-010	1000	0/30	no classification
	100	0/30	

*EHW = Extremely hazardous waste (no. death > 10/30 in 100 mg/L sample concentration).
*DW = Dangerous waste (no. deaths > 11/30 in 1000 mg/L sample concentration).

Yours truly,

E.V.S. CONSULTANTS

Cathy A. McPherson

Cathy A. McPherson, B.Sc.
Bioassay Supervisor

CAM:jh

E.V.S. CONSULTANTS
ACUTE LETHALITY BIOASSAY RECORD

Client- KAISER ALUMINUM (MEAD WORKS)

E.V.S. Project #- [illegible]

Work Order #- [illegible]

E.V.S. Analyst(s)- [illegible]

SAMPLE

Identification- POTT TAILINGS (J-C10)

Amount Received- (1 gal.) - solid sample

Date Collected- MAR 31, 1988

Date Received- APRIL 05, 1988

pH- -

Dissolved Oxygen (mg/l)- -

Conductivity (umhos/cm)- -

Other-

Bioassay Type- WDOE MUTT

Test Initiation Date- April 12, 1988

DILUTION AND CONTROL MEDIUM

Fresh Water (dechlorinated)- ✓

Salt Water (Burrard Inlet)- -

pH 7.7

Dissolved Oxygen (mg/l)- 9.1

Conductivity (umhos/cm)- -

Hardness (mg/l as $CaCO_3$)- 100

Alkalinity (mg/l as $CaCO_3$)- -

Salinity (‰)- n/a

Other- water hardness increased to 100.

TEST SPECIES

Rainbow Trout- ✓

Threespine Stickleback-

Daphnia (D. magna)-

Amphipod (R. abronius)-

Other-

TEST CONDITIONS

Temperature (°C)- 14-15

pH Range- 7.1 - 8.0

Dissolved Oxygen Range- 6.6 - 9.3

Conductivity Range- -

Aeration (7.5 cc/min./l)- no

Photoperiod (L:D-in hours)- 14:10

No. Fish/Test Volume- 10/20L

Fish Loading Density (g/l)- 0.25

Other-

Bioassay Results- WDOE classification = pass (no mortalities)

Certified By- Cathy McPherson

E.V.S. Consultants Ltd.

E.V.S. CONSULTANTS

ACUT HALITY BIOASSAY DATA

SAMPI BUTT TAILINGS (J 010)

DATE ECTED MAR 31, 1988

E.V.S. PROJECT NO. 38.03

WORK ORDER NO. 80128

LAB NO.	TEST DATE & TIME	NO. FISH/ VOL.	ppm (% vol/vol) CONC.	PERCENT SURVIVAL (1 to 96 hours)									DISSOLVED OXYGEN (mg/L)					TEMPERATURE (°C)					pH					CONDUCTIVITY (umhos/cm)		ALK mg/L		HARI mg/L	
				1	2	4	8	18	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	96	0	96	0	9
	APRIL 12, 1988	10/20	1000 A						100	100	100	100	9.2	7.3	7.2	7.1	7.1	15	15	14	14	14	7.9	7.1	7.2	7.2	7.2						
			1000 B						100	100	100	100	9.3	7.3	7.3	7.1	7.0	15	15	14	14	14	7.8	7.1	7.2	7.2	7.2						
			1000 C						100	100	100	100	9.2	7.2	7.3	7.1	7.3	15	15	14	14	14	8.0	7.1	7.2	7.3	7.2						
			100A						100	100	100	100	9.2	7.4	7.3	7.3	7.4	15	15	14	14	14	7.9	7.4	7.5	7.4	7.4						
			100B						100	100	100	100	9.1	7.4	7.3	7.3	7.4	15	15	14	14	14	7.8	7.4	7.6	7.5	7.5						
			100C						100	100	100	100	9.1	7.3	7.3	7.3	7.4	15	15	14	14	14	7.7	7.4	7.6	7.6	7.6						
			CONTROL						100	100	100	100	9.1	7.0	6.9	6.6	6.9	15	15	14	14	14	7.7	7.3	7.6	7.6	7.6						

SAMPLE DESCRIPTION

COMMENTS

MEAN FISH LENGTH (mm) 33 RANGE 29-37

MEAN FISH WEIGHT (g) 0.49 RANGE 0.35-0.70

DATA VERIFIED BY Cathy McPherson E.V.S. CONSULTANTS

DATE April 21, 1988

Attachment 2

P, 2

36401

am test inc.

14603 N.E. 87th St. • REDMOND, WASHINGTON 98052 • 206 885-166

ANALYSIS REPORT

CLIENT: Kaiser Aluminum

REPORT TO: Leroy Stone
East 2111 Hawthorne
Mead, WA 99021

DATE RECEIVED: 4/18/88

DATE REPORTED: 4/29/88

P.O. NO.: MM 71403

WASHINGTON STATE D.O.E. HAZARDOUS WASTE EXTRACTION PROCEDURE FOR THE ANALYSIS OF HALOGENATED HYDROCARBONS & POLYCYCLIC AROMATIC HYDROCARBONS, WAC 173-303

Laboratory Sample Number	804342
Client Identification	4/15 J-012
Fraction #1	
Residue (%)	0.1
Organically-bound Halogens* (ug/g as Chloride)	<14.0
Organically-bound Fluoride (ug/g)	<2.0
Fraction #4	
Residue (%)	--
Fraction #6	
Residue (%)	--
4,5,6-Ring PNA Residue (%)	--

*Halogens include Chloride, Bromide & Iodide.

REPORTED BY Beth Robinson
Beth Robinson

BR/pb

cc: Dick [illegible]

Attachment 3

CHNICAL MEMORANDUM

To
C. L. Leak
Mead

Date
August 8, 1980

From
L. R. Barsotti

cc: [redacted]
W. B. Eastman - Mead
B. Lusk - 816 KB
E. B. Paille - 769 KB
H. J. Seim - CFT 20

Subject
Leachate Analysis of Mead Samples
ARD Nos. 105311-24

The attached tables summarize the leachate data obtained on 14 Mead samples as described in your memo of July 7, 1980. Only one sample (E-1157, ARD No. 105313) exceeded the limits specified in the May 19, 1980, Federal Register.

Some leachates contained appreciable fluoride.

You requested a cyanide determination on sample E-1155. We determined a value of <0.004% on the "as received" material because analysis of the pH 5 leachate for cyanide would have been meaningless.

NOTE: E-1155 IS BUTT TAILINGS

LRB:jh

Attachment

ANALYTICAL RESEARCH DEPARTMENT
EPA Leachate Test
Mead Samples

SAMPLE ORIGINATOR W.B. Eastman, Mead

PROJECT NO. 7980 50013

SAMPLE DESCRIPTION	ARD NO.	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver	Fluoride
EP Toxicity Maximum Concentration	mg per liter	5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	—
BUTT E-1155 TAILINGS	105311	<0.01	0.06	0.05	0.01	0.03	< 0.01	<0.01	0.01	11.

Appendix C

ECOLOGICAL SURVEY OF THE LITTLE SPOKANE RIVER

ECOLOGICAL SURVEY OF THE LITTLE SPOKANE RIVER IN RELATION TO CYANIDE INPUTS

August 16-25, 1980

Prepared by:

Rolf Hartung, Ph.D.,
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Associate Professor of Environmental & Industrial Health

3125 Fernwood Ave.
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October 8, 1980

INTRODUCTION

For some time a segment of the Little Spokane River between stream miles 9 and 11.5 has been receiving an input of a mixture of free and complex cyanides via the groundwater and adjacent springs. The area of influx begins below Pineriver Park and ceases near the sewage oxidation lagoons. The concentrations of total cyanides below stream mile 9 are relatively constant on any one sampling date. The concentrations found appear to bear an inverse relationship to stream flow, and thus to the relative importance of groundwater recharge.

The total cyanide concentrations during April and May 1979, and during January and February 1980 were relatively constant below the region of influx at 9-10μg/L. Localized concentrations within the region of influx were much higher. Since the toxicity of cyanides is mostly due to free HCN, and since nearly all cyanide toxicity tests had been run under artificial conditions in the laboratory, the data available from the literature were not very helpful for estimating the impact of cyanides on the Little Spokane River. Consequently it was decided to undertake an ecological survey of aquatic life in the Little Spokane River encompassing upstream control regions which were not exposed to cyanides, the area of influx, and regions below the area of influx. It was decided to do the survey during August of 1980 when the stream flow would be near the annual minimum and largely composed of groundwater recharge. This would constitute the time of highest total cyanide concentrations and presumeably a time of maximum possible impact.

STUDY AREA

This ecological survey was carried out on the Little Spokane River, Washington over a 10.5 mile stretch. The most upstream station was located at river mile point 16.8, whereas the lower site was at mile point 6.3. The most noticeable change between these two stations was the considerable increase in discharge, which appeared to have nearly doubled. The sizeable increase in flow is attributed to groundwater infiltration, particularly under the base flow condition.

The site selections were based upon assessability (permission of property owners) and the physical nature of the river, that would lend themselves for a comparative upstream and downstream study. From a precursory field reconnaisance, six sampling sites were selected (Table 1, Figure 1). The three stations above Dartford were designated as control sites, whereas those below were considered impacted sites from cyanides. The following is a brief description of the sampling locations.

STATION 1 (Mile Point 16.8) G.T. DAVIS

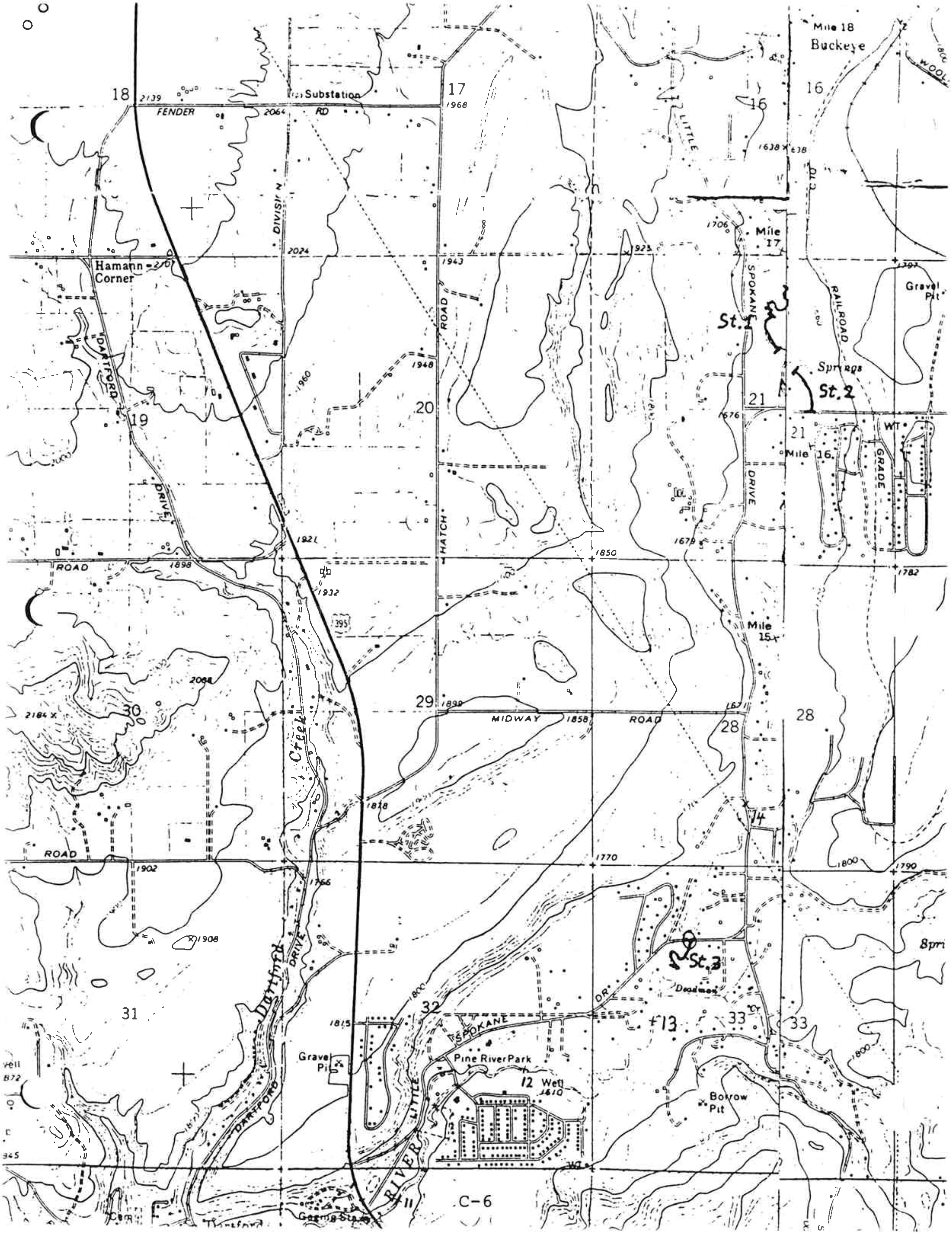
This sampling reach was composed of two sections, an upper area and a middle stretch. The upstream sites are characterized by a slow, meandering river, whose banks are extensively covered by a variety of bushes including alder and witch hazel. The current was low which resulted in a substrate of silt and organic detrites. Average width was 12 m and its depth was

TABLE 1 Description of Sampling Stations on the Little Spokane River

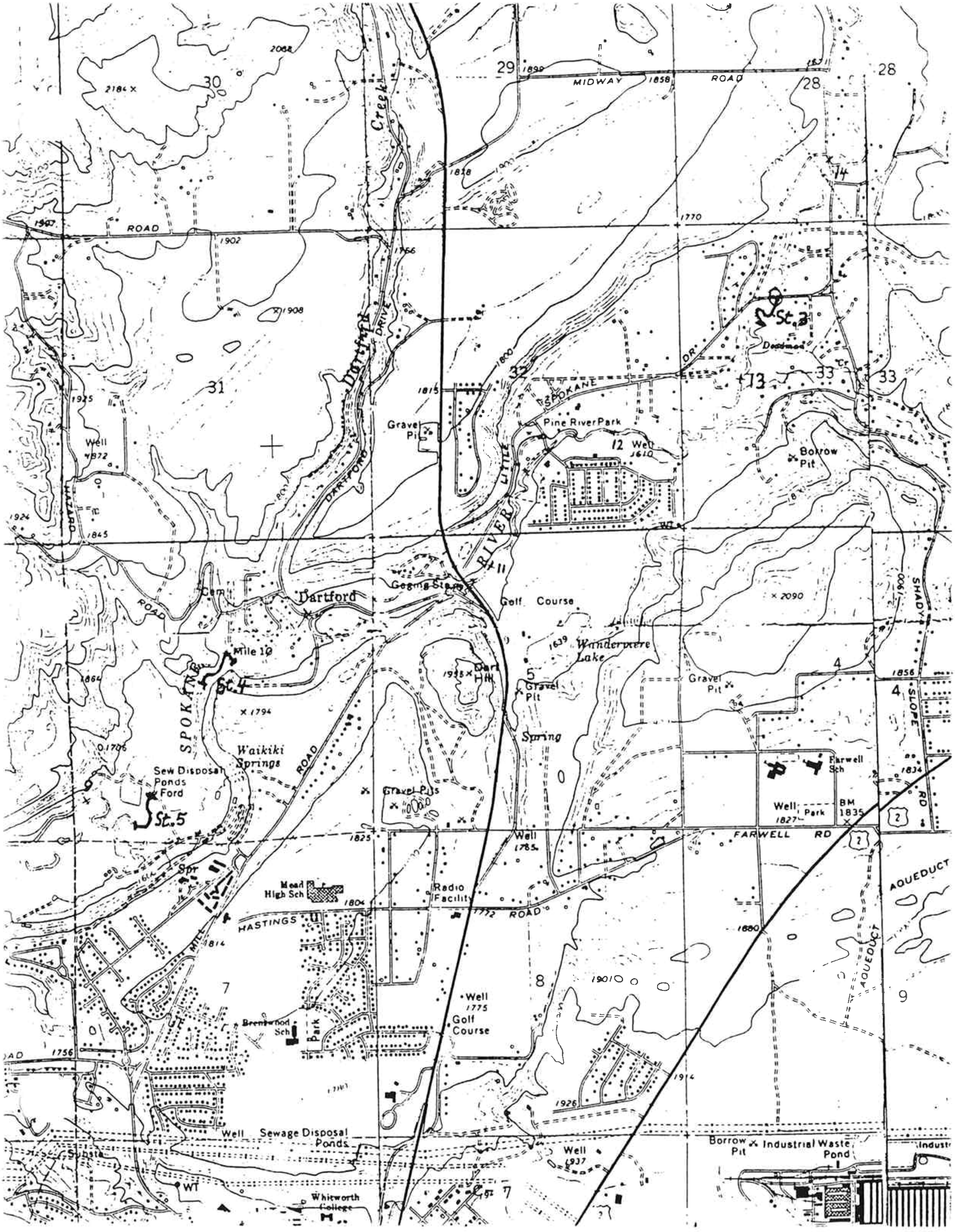
Station	Mile Point	Description
1	16.8	Approximately 1.0 km north of Colbert Road Bridge (Co. Br. No. 3703) within G.T. Davis property
2	16.3	Area north between Colbert Road Bridge and Davis Bridge
3	13.4	River stretch between Little Spokane Drive Bridge and downstream edge of Hagen's property
4	10.0	River stretch between Rivilla Park and downstream of Popp's Point
5	9.2	Downstream reach from Access Bridge Road (oxidation lagoons), approximate distance 0.2 km
6	6.3	Sampling area included both main stream and side channel sampling within St. George's School property

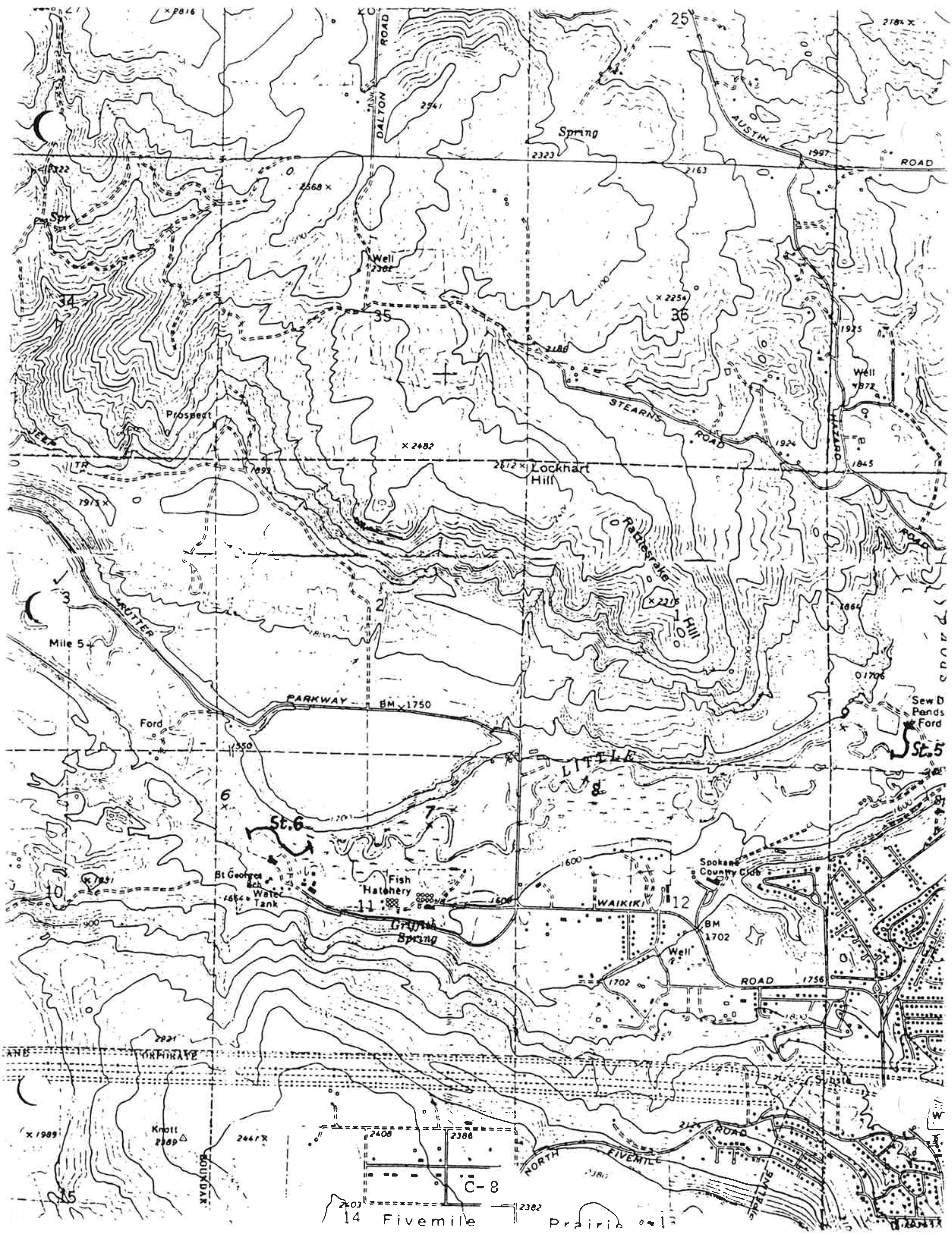
Figure 1

The following three pages consist of copies of sections of U.S.G.S. 15' quadrangle maps showing the locations of the sampling sites.


18
2139
FENDER
2064
Substation
RD
17
1968
16
LITTLE
1638 X 638
Mile 18
Buckeye
16
WOOL
OLD
DIVISION
Hamann Corner
2024
1943
923
1706
Mile 17
SPOKANE
St. 1
RAILROAD
Gravel Pit
DARTFORD
ROAD
1960
1948
Springs
St. 2
21
21
1676
WT
Mile 16
GRADE
19
20
DRIVE
DRIVE
HATCH
1921
1679
ROAD
1898
1850
1782
1932
395
Mile 15
2068
2184 X
30
29
1899
MIDWAY
1858
ROAD
1671
28
28
Creek
1828
14
ROAD
1902
1770
1800
1790
1766
X 1908
Dartford
DRIVE
St. 3
Deadman
DR
Spri
31
32
1815
SPOKANE
+13
33
33
1800
Gravel Pit
Pine River Park
12 Well 1610
Borrow Pit
LITTLE
DARTFORD
RIVER
WT
11
Cem
Dartford
Game Sta.
Well
872
945

C-6


30
2184 ×
2062
29
1899
MIDWAY
1858
ROAD
28
28
Creek
1828
1907
ROAD
1902
1770
1766
× 1908
DRIVE
Dartford
St. 3
Deadman
Cr
DR
SPOKANE
32
33
33
13
14
31
1800
1815
Gravel Pit
Pine River Park
12
Well 1610
Borrow Pit
LITTLE
1925
Well 1872
DARTFORD
HAZARD
1924
1845
RIVER
11
ROAD
Cem
Dartford
Golf Course
× 2090
1900
SHADY
Mile 10
1639
Wandermere Lake
1864
SPOKANE
St. 4
1938 × Dart Hill
5
Gravel Pit
Gravel Pit
4
1856
4
SLOPE
× 1794
Spring
ROAD
0.1706
Waikiki Springs
Sew Disposal Ponds
Ford
St. 5
Gravel Pits
Farwell Sch
1834
RD
Well
1827
Park
BM 1835
2
2
1825
Well 1785
FARWELL
RD
AQUEDUCT
Spr
Mead High Sch
Radio Facility
1804
1772
ROAD
HASTINGS
MILL
1814
1880
7
8
1901
AQUEDUCT
9
Well 1775
Golf Course
Brentwood Sch
Park
1756
1914
1926
Well
Sewage Disposal Ponds
Substa
Well 1937
Borrow Pit
Industrial Waste Pond
Indust
WT
Whitworth College
7


27
26
25
DALTON ROAD
2541
Spring
AUSTIN
1997
ROAD
2323
2163
2568
Spr
Well
2302
34
35
36
2254
2186
1925
Well
1872
STEARNS ROAD
Prospect
2482
1924
HAZARD
1845
JEEP TR
1899
2512
Lockhart Hill
1915
Rattlesnake Hill
ROAD
3
2
2316
1864
RUTTER
Mile 5
PARKWAY
BM 1750
1706
Sew D Ponds
Ford
Ford
1550
St. 5
LITTLE
6
St. 6
7
1600
Spokane Country Club
St Georges Sch
Water Tank
Fish Hatchery
10
11
1600
WAIKIKI
12
1654
BM 1702
Griffith Spring
Well
1702
ROAD
1756
2921
CORPORATE
Subst
1989
Knott 2389
2461
2408
2388
ROAD
NORTH FIVEMILE
BOUKDAR
15
2403
2382
14 Fivemile
Prairie

1.3 m. Some of the holes exceeded a depth of 2 m. The length of the reach sampled was approximately 200 m (Figure 2).

The middle reach differed from the one above in that there was a noticeable increase in velocities which produced a substrate of rocks, sand and some large boulders. Although the width did not change appreciably, the reach was shallower. The length sampled was 50 m (Figure 3).

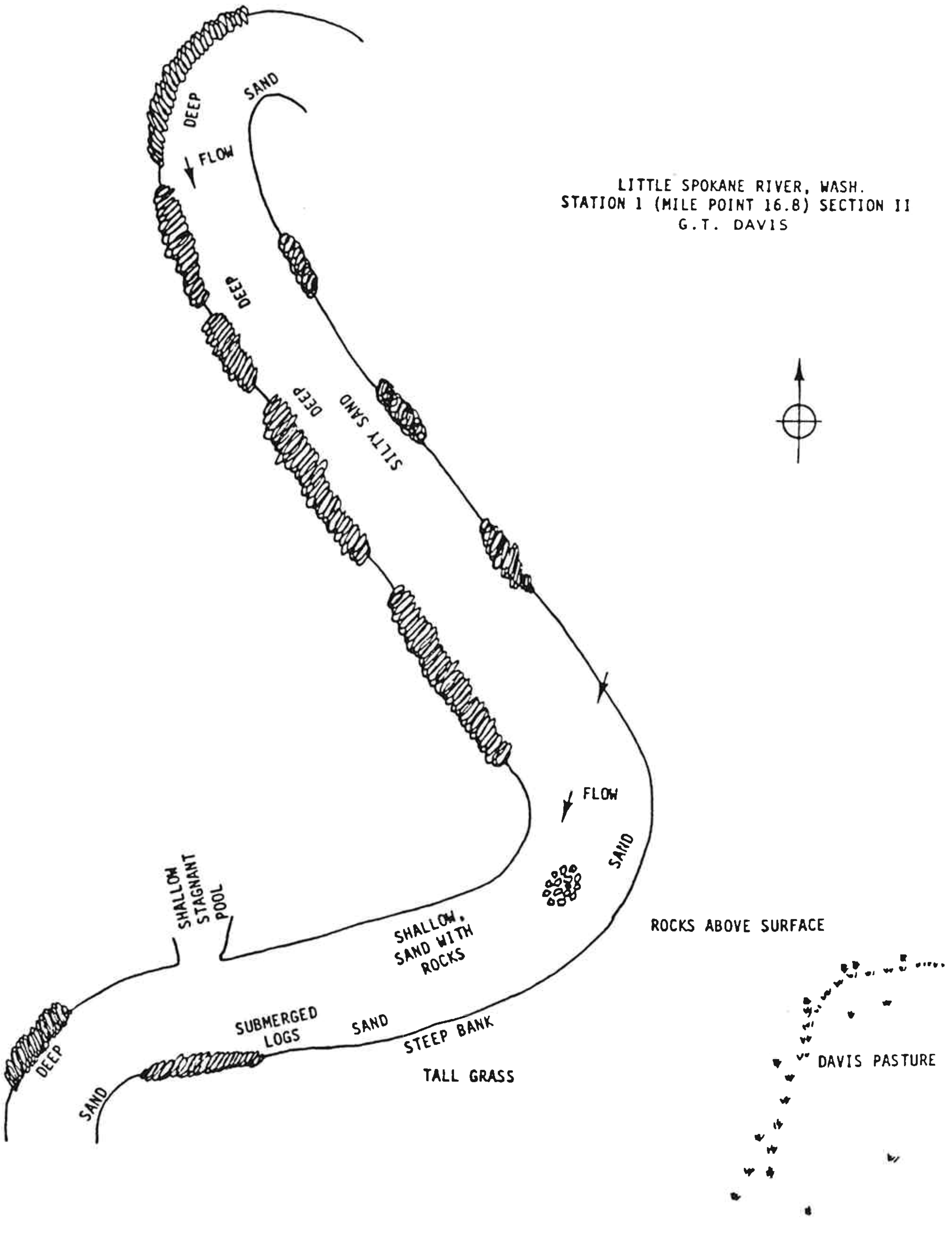
STATION 2 (Mile Point 16.3) G.T. DAVIS

This downstream reach of 200 m in length was characterized by fast moving water over rubble and large stones which were covered with periphytic growth. The width of this section was approximately 25 m and very shallow. Bank cover, although not quite as dense as on the above section, was composed of alder, willow and witch hazel. Large clumps of grass would overhang some banks, providing somewhat of a different habitat as that found above (Figure 4).

STATION 3 (Mile Point 13.4) HAGAN'S

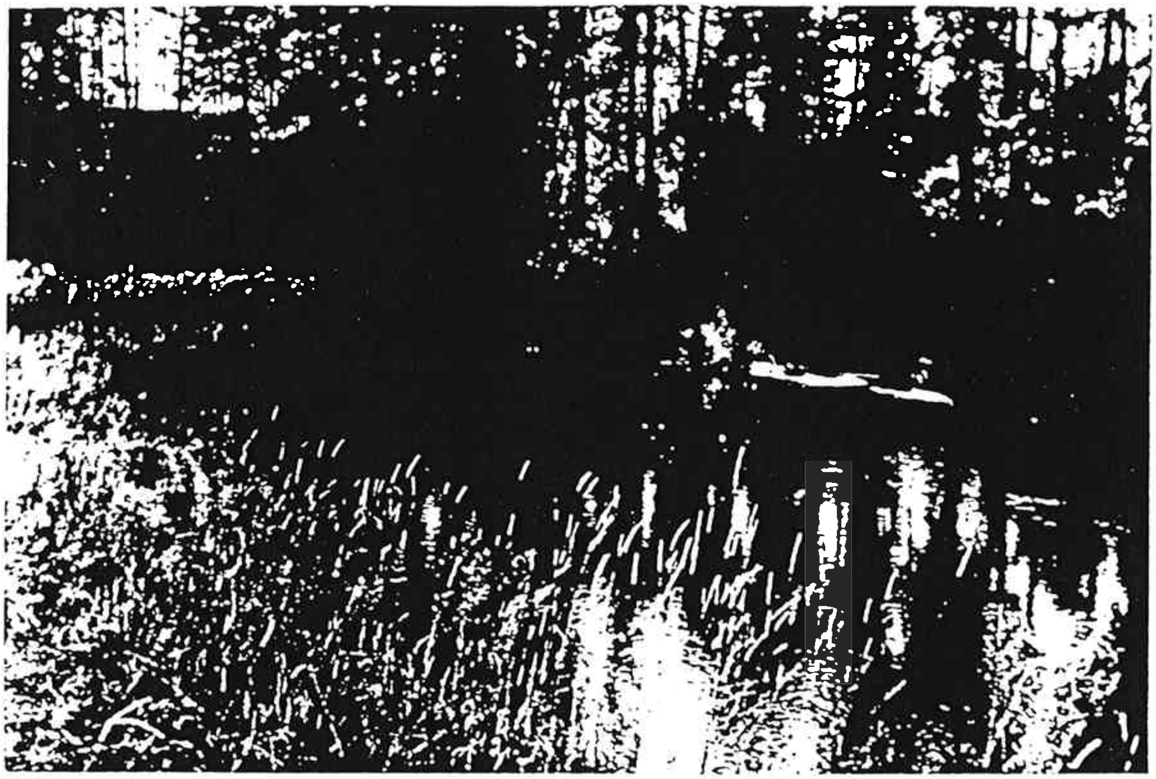
A 250 m section was sampled at this site which extended from the Little Spokane Drive bridge to the downstream site of Hagan's property. This reach was composed of an upper straight stretch of fast moving water with rubble substrate to a lower section of river that was meandering slowly through pasture land. The bottom in this area was composed of sand and silt and nutrient contribution from land runoff were utilized by extensive aquatic weed beds (*Potamogeton sp.*)

FIGURE 2



LITTLE SPOKANE RIVER, WASH.
STATION 1 (MILE POINT 16.8) SECTION II
G.T. DAVIS

Station 1; upper quiet reach.



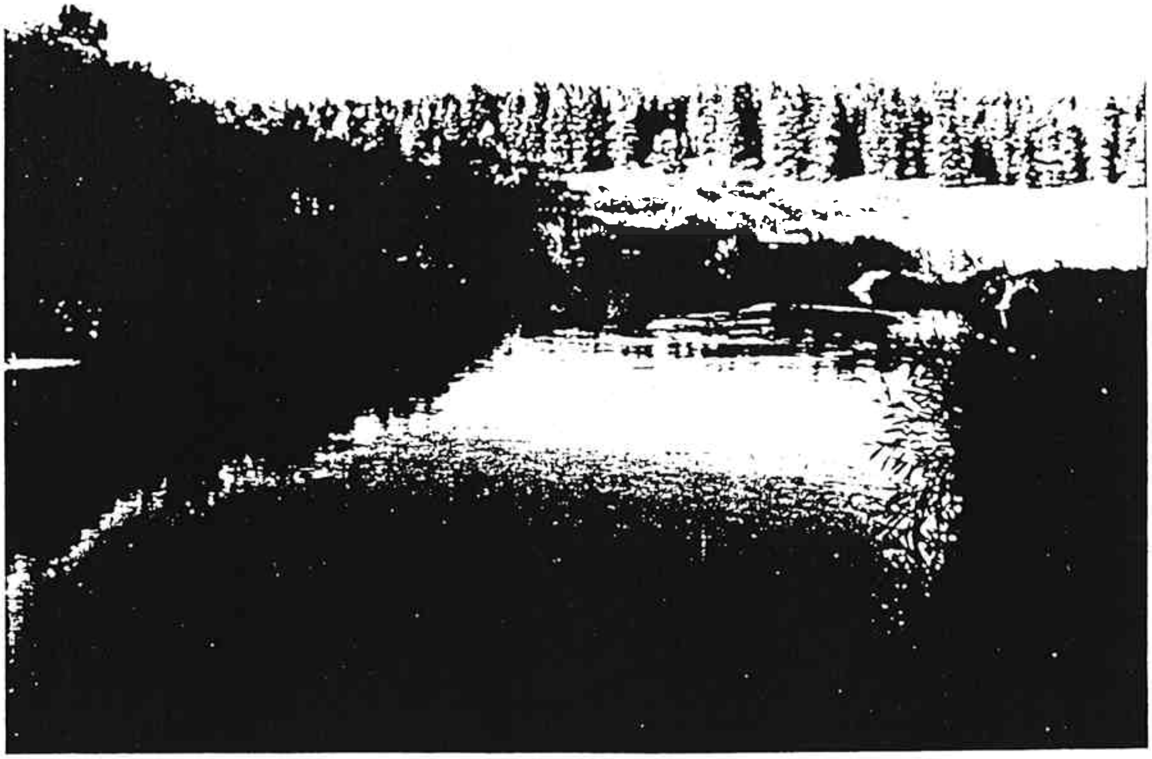
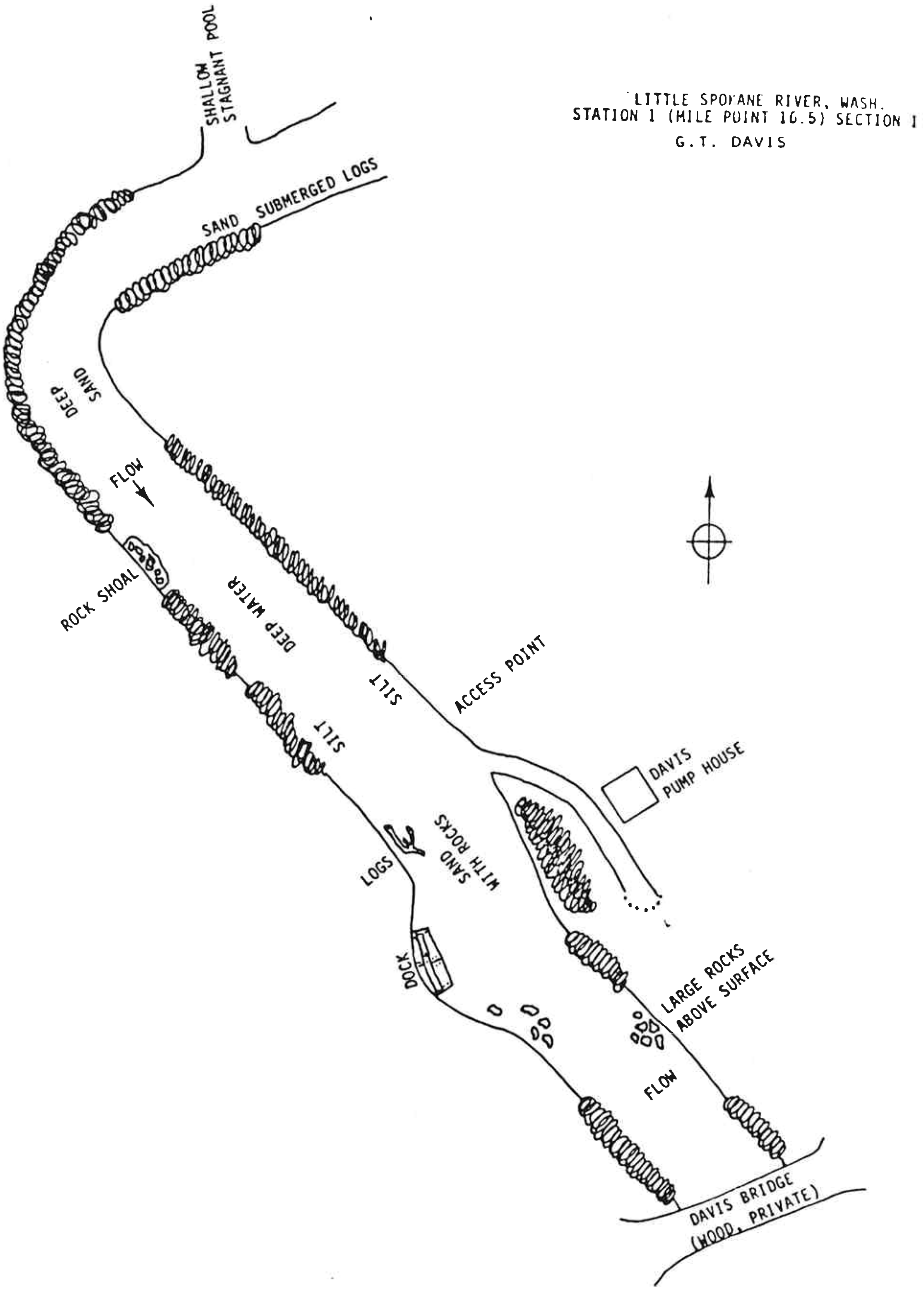


FIGURE 3


LITTLE SPOKANE RIVER, WASH.
STATION 1 (MILE POINT 16.5) SECTION I
G.T. DAVIS
SHALLOW STAGNANT POOL
SAND
SUBMERGED LOGS
DEEP SAND
FLOW
ROCK SHOAL
DEEP WATER
SILT
SILT
ACCESS POINT
DAVIS PUMP HOUSE
LOGS
SAND WITH ROCKS
DOCK
LARGE ROCKS ABOVE SURFACE
FLOW
DAVIS BRIDGE
(WOOD, PRIVATE)

Station 1; shallower, rocky reach.

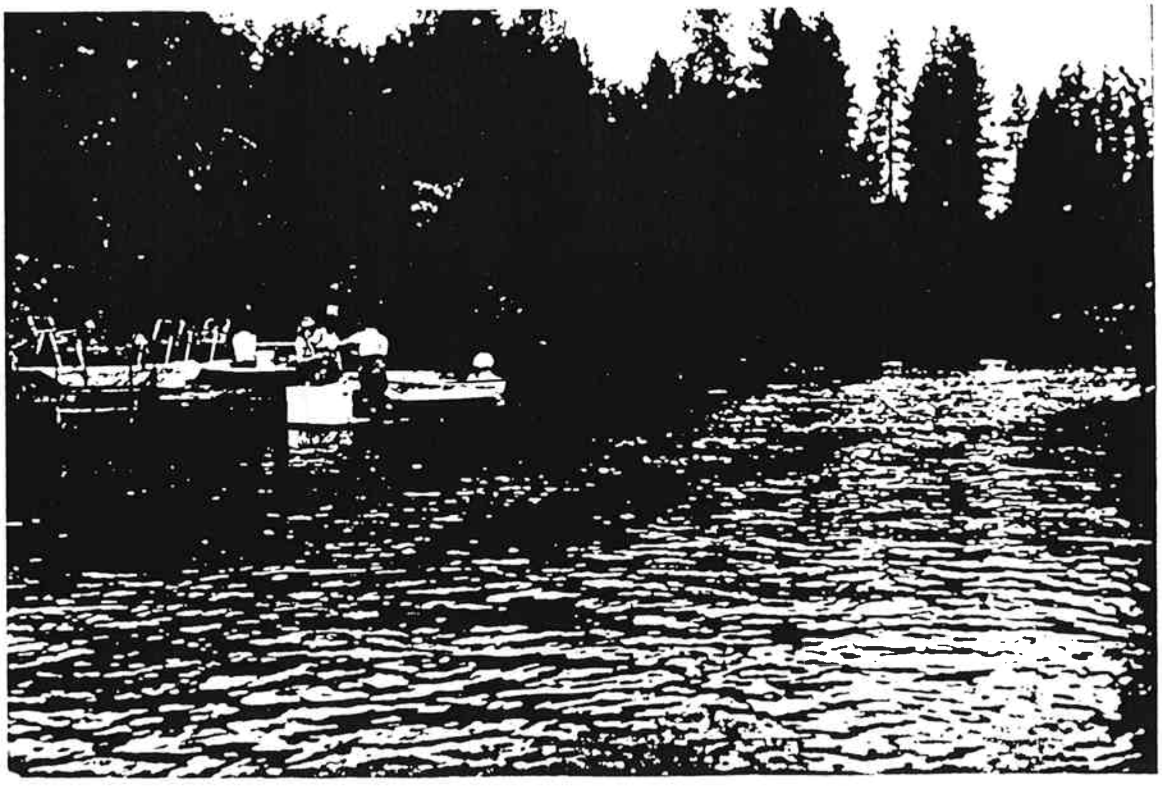
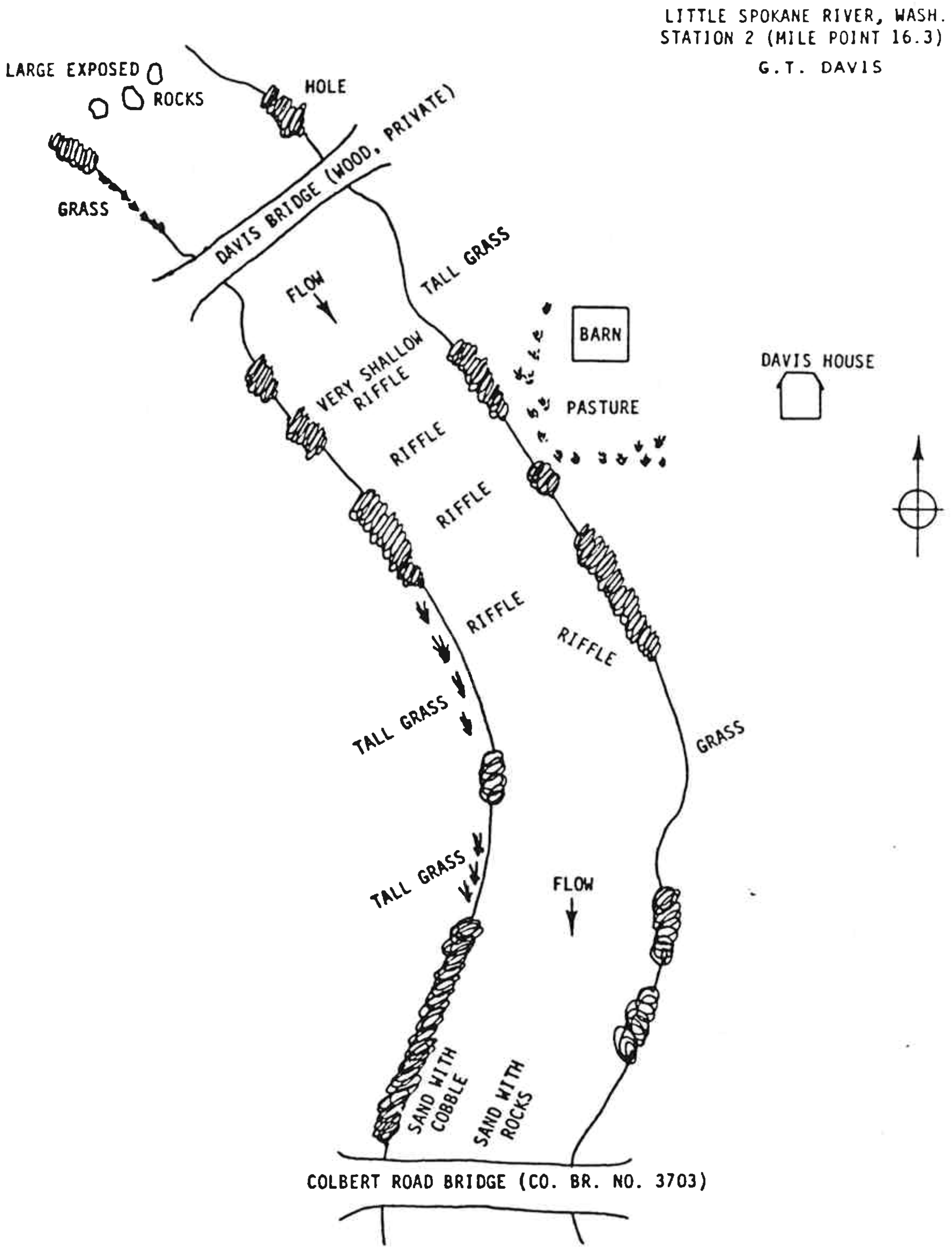
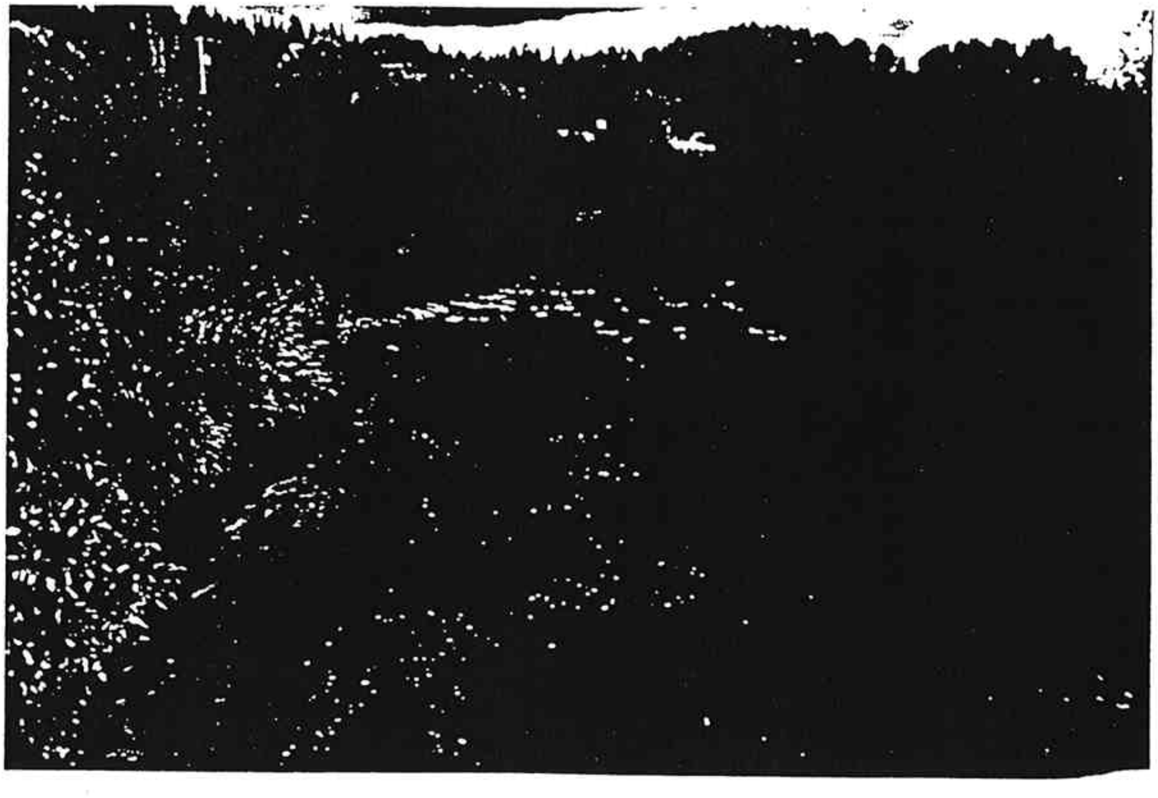


FIGURE 4


LITTLE SPOKANE RIVER, WASH.
STATION 2 (MILE POINT 16.3)
G.T. DAVIS
LARGE EXPOSED ROCKS
HOLE
GRASS
DAVIS BRIDGE (WOOD, PRIVATE)
TALL GRASS
FLOW
BARN
DAVIS HOUSE
VERY SHALLOW RIFFLE
PASTURE
RIFFLE
RIFFLE
RIFFLE
RIFFLE
TALL GRASS
GRASS
TALL GRASS
FLOW
SAND WITH COBBLE
SAND WITH ROCKS
COLBERT ROAD BRIDGE (CO. BR. NO. 3703)

Station 2

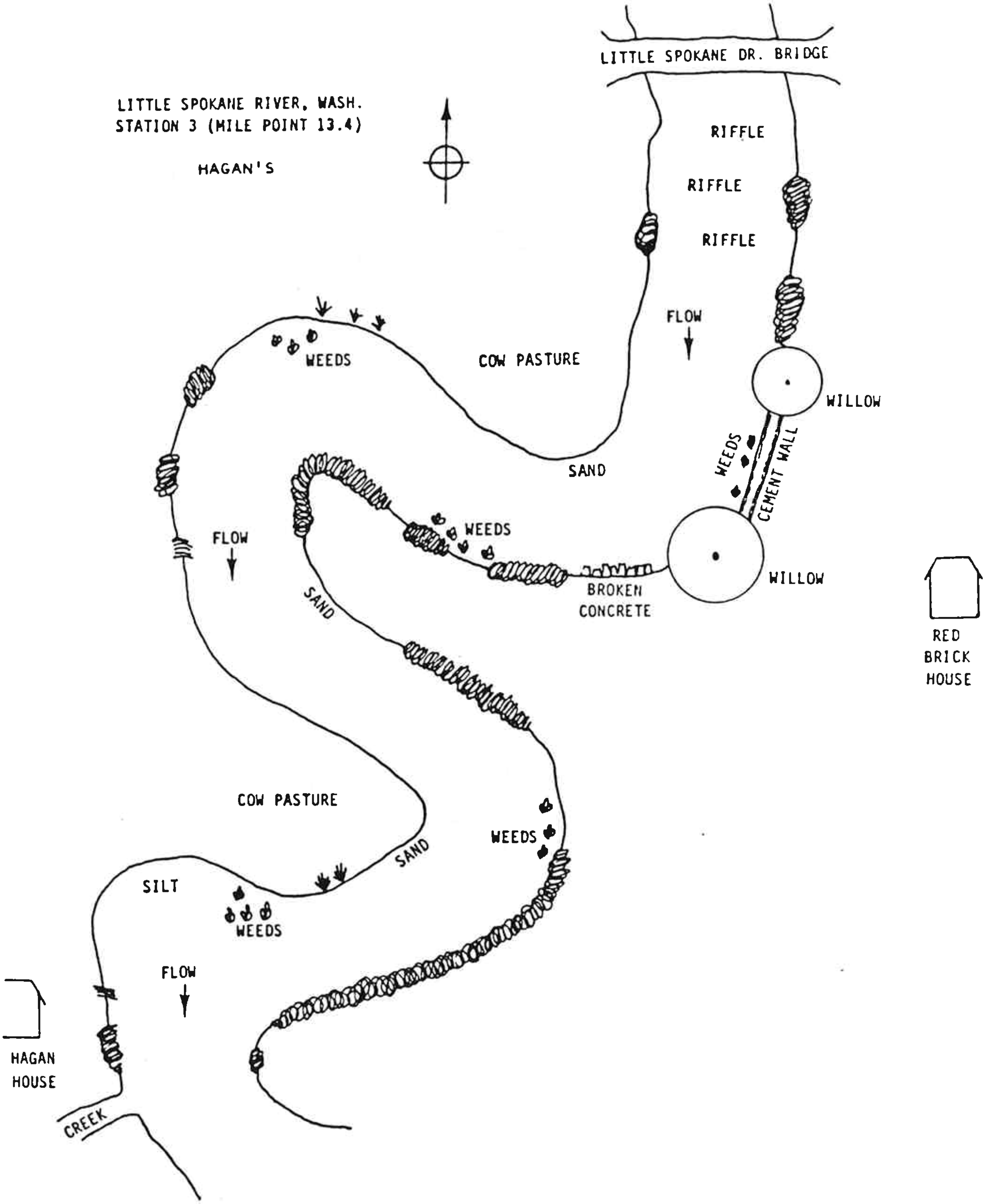


(Figure 5). These aquatic plants provided an ideal cover for perch, pumpkinseed, small suckers and some chisel mouth. Bank cover was extensive on the inside of the meander, whereas the rest of the river was exposed to open pasture. The 15 m width of the river was nearly constant, with the depth varying from 0.2 to 1.7 m. The water had somewhat more turbidity than that observed at Station 2.

STATION 4 (Mile Point 10) POPP'S

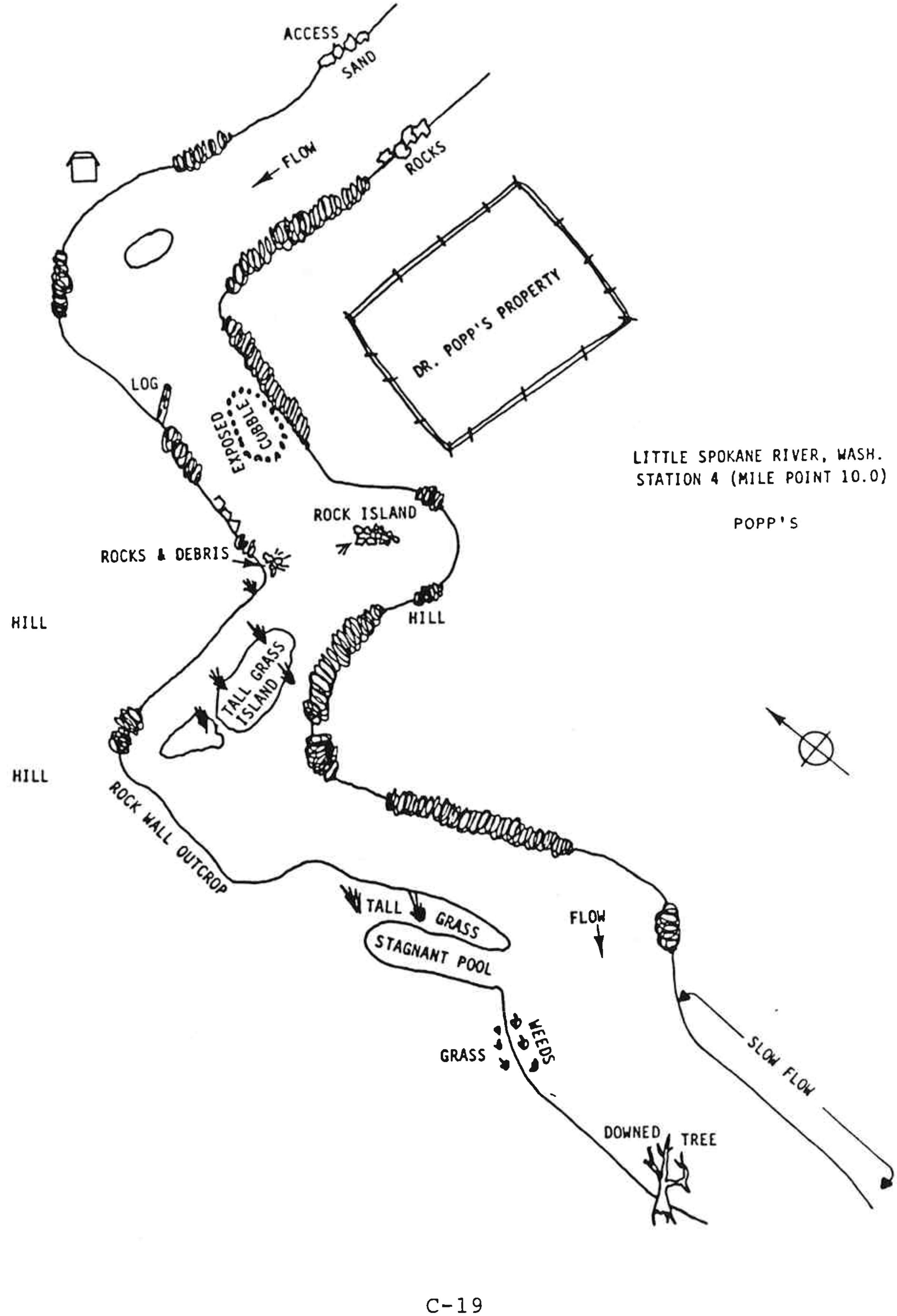
This reach is located downstream of the Dartford gage and in the area of greatest groundwater inflow, which is quite noticeable by the increase in the discharge. The 300 m stretch sampled contained slow moving water (pool areas) to very fast currents. Again bottom substrate was somewhat variable but ranged from granular sand to gravel and rubble (Figure 6). One area had an extensive weed bed (*Potamogeton sp.*) which produced a similar habitat and fish as those observed at Station 3. Several large boulders within the stream bed would cause the formation of large deep pools (greater than 2.5 m) and counter currents to the main flow. This river stretch passes through rock outcroppings which were sparingly covered by ponderosa pine. Bank cover when present, was composed of similar woody plants as those found in upstream stations. The water was clear and had a bluish-green color.

FIGURE 5


LITTLE SPOKANE DR. BRIDGE
LITTLE SPOKANE RIVER, WASH.
STATION 3 (MILE POINT 13.4)
HAGAN'S
RIFFLE
RIFFLE
RIFFLE
FLOW
WEEDS
COW PASTURE
WILLOW
WEEDS
CEMENT WALL
SAND
WEEDS
FLOW
BROKEN CONCRETE
WILLOW
RED BRICK HOUSE
SAND
COW PASTURE
WEEDS
SAND
SILT
WEEDS
FLOW
HAGAN HOUSE
CREEK

Station 3

FIGURE 6


ACCESS
SAND
FLOW
ROCKS
DR. POPP'S PROPERTY
LOG
EXPOSED CUBBLE
ROCK ISLAND
ROCKS & DEBRIS
HILL
HILL
TALL GRASS ISLAND
HILL
ROCK WALL OUTCROP
TALL GRASS
STAGNANT POOL
FLOW
SLOW FLOW
GRASS
WEEDS
DOWNED TREE
LITTLE SPOKANE RIVER, WASH.
STATION 4 (MILE POINT 10.0)
POPP'S

Station 4

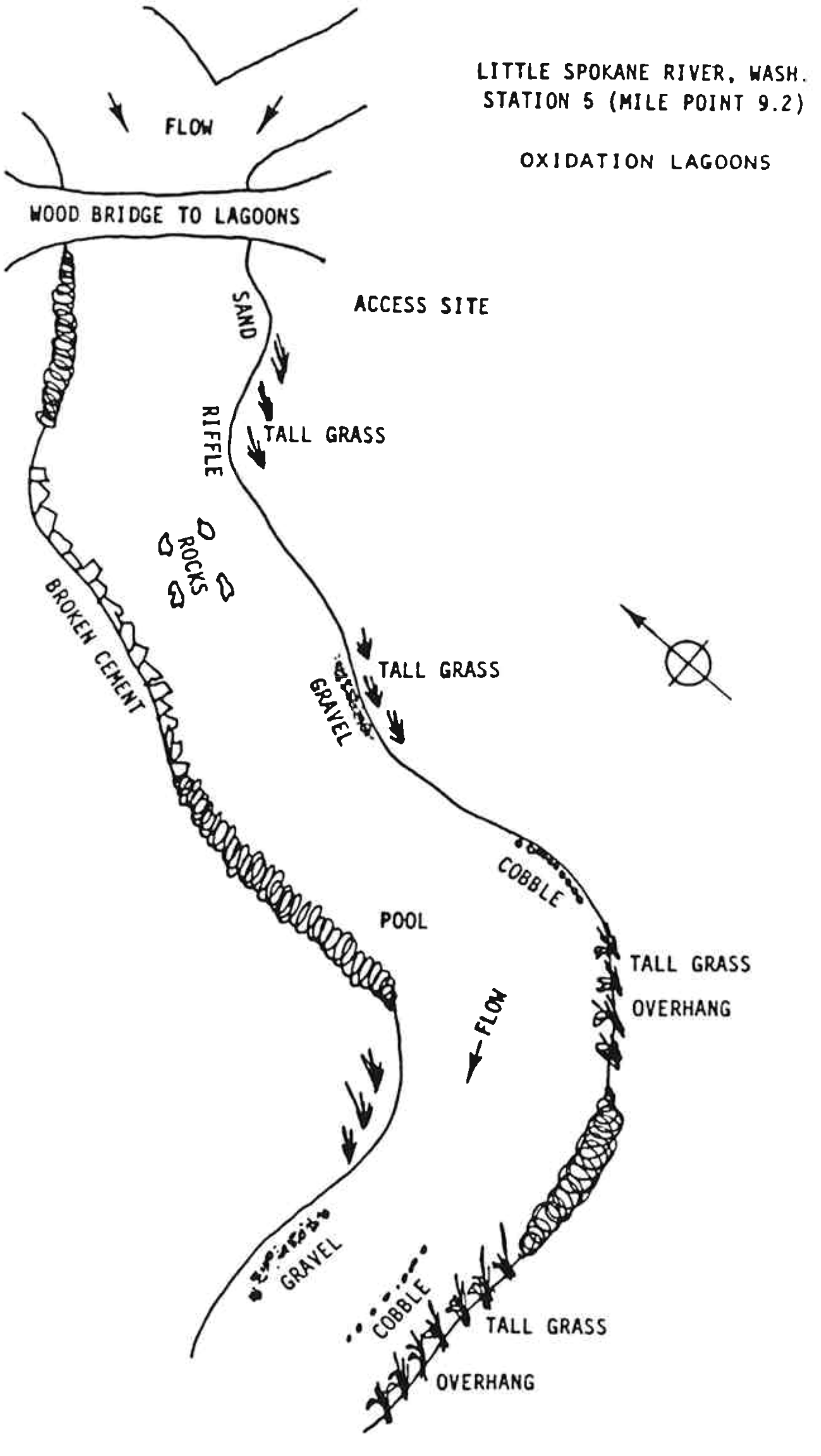
STATION 5 (Mile Point 9.2) OXIDATION LAGOONS

The distance sampled at this site was 150 m. The river width averaged 15 m and flowed at a fairly constant velocity of 0.7-0.8 m/sec. Substrate was variable, ranging from granular sand to gravel and small rubble, with little attached growth (periphyton). The deeper areas were well shaded with alder and willow, while other stream bank areas were covered with long grasses (Figure 7). Morphologically, this area was somewhat similar to Station 1 middle reach.

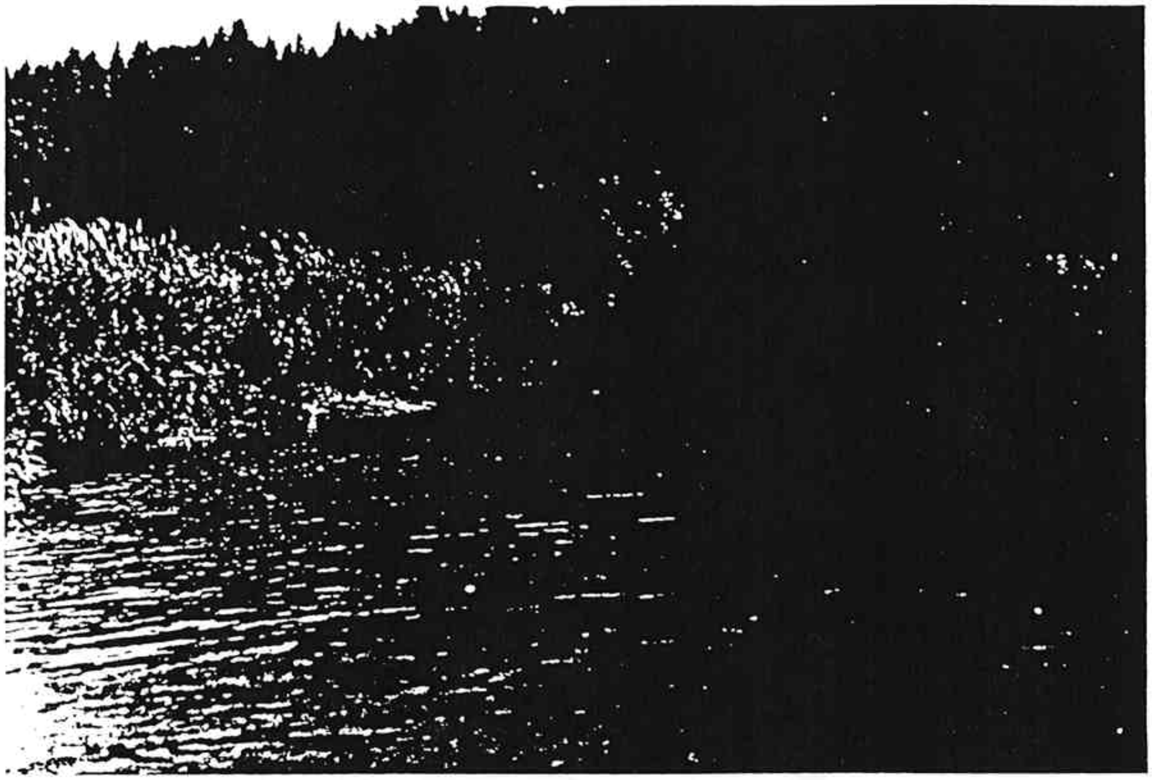
STATION 6 (Mile Point 6.3) ST. GEORGE'S SCHOOL

This river reach sampled was similar to that observed at Station 5. The river looked larger and wider (20-25 m). The depth ranged from 0.2 to deep pools (greater than 2.5 m). The velocity changed little and ranged from 0.6 to 0.8 m per second. The resultant substrate is composed mostly of granular sand intermixed with gravel. No large stones or rubble was noticeable over the 200 m distance of the main channel that was sampled (Figure 8). Vegetative bank cover ranged from large grassy patches to willow and alder. In addition to sampling the main stream, a side channel was also investigated. Its shallower water, with some deeper holes was considered an advantage, since considerable difficulty was encountered in the deeper portions of the main channel. Again, velocity, bottom composition and bank cover were

FIGURE 7


LITTLE SPOKANE RIVER, WASH.
STATION 5 (MILE POINT 9.2)
OXIDATION LAGOONS
FLOW
WOOD BRIDGE TO LAGOONS
ACCESS SITE
SAND
RIFFLE
TALL GRASS
ROCKS
BROKEN CEMENT
TALL GRASS
GRAVEL
COBBLE
POOL
TALL GRASS
OVERHANG
FLOW
GRAVEL
COBBLE
TALL GRASS
OVERHANG

Station 5



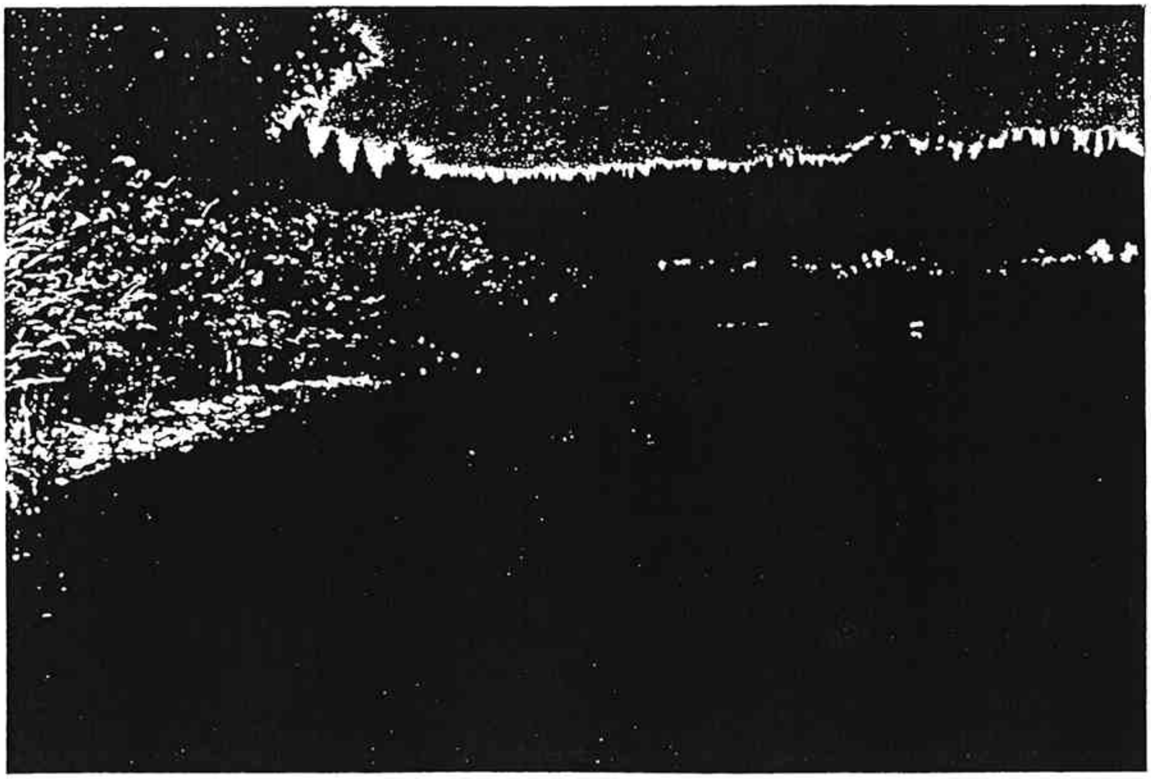
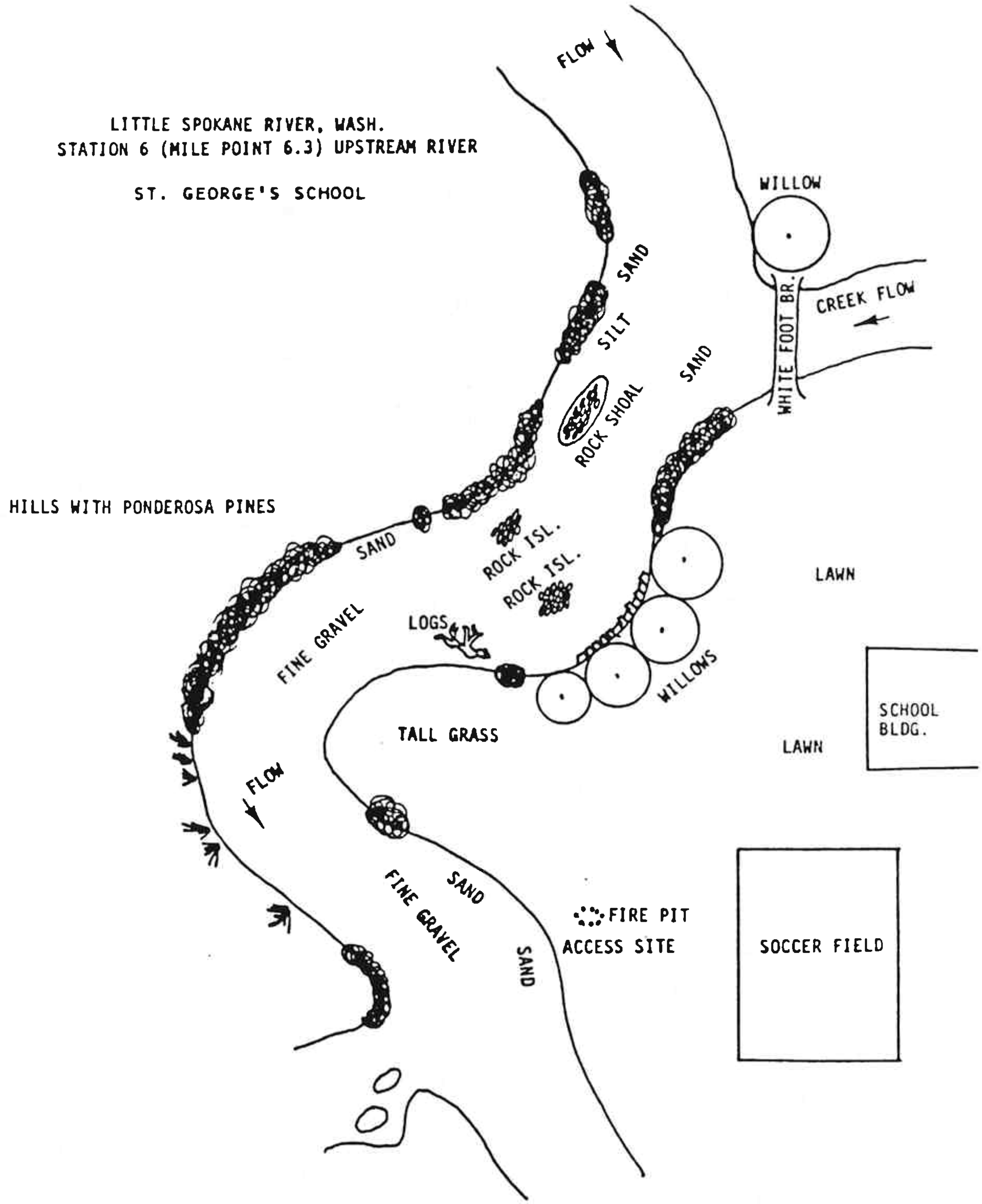
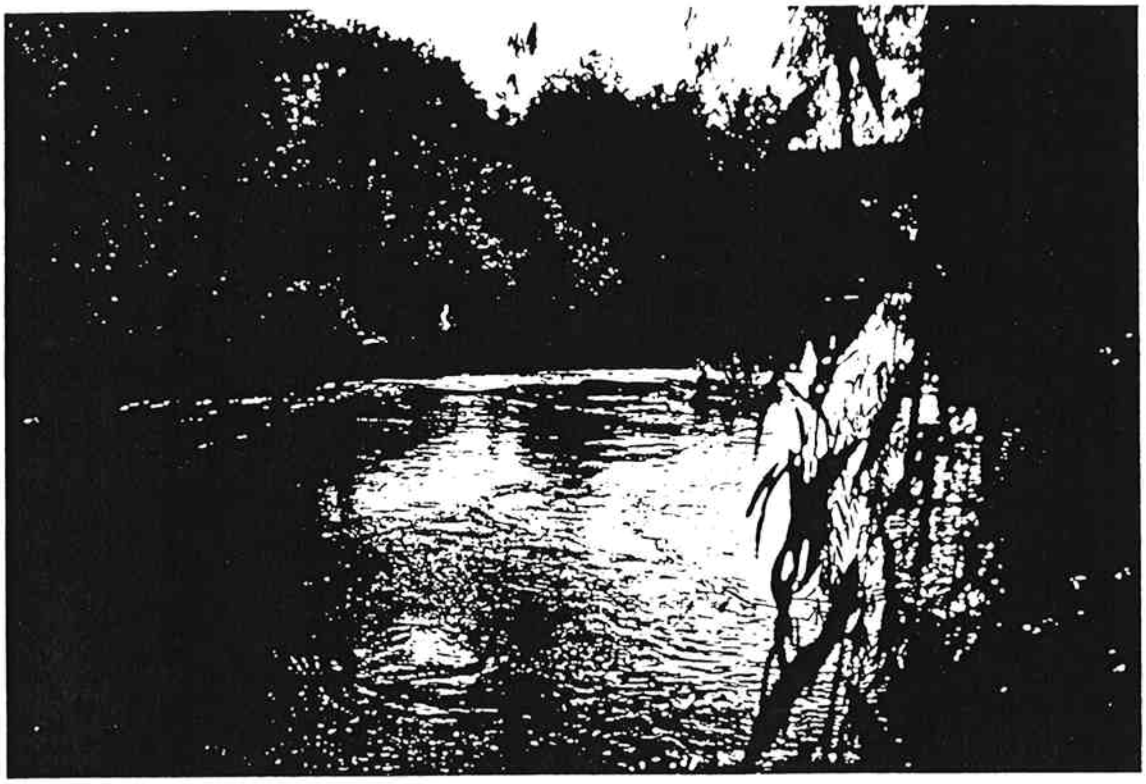


FIGURE 8



LITTLE SPOKANE RIVER, WASH.
STATION 6 (MILE POINT 6.3) UPSTREAM RIVER
ST. GEORGE'S SCHOOL
FLOW
WILLOW
SAND
SILT
CREEK FLOW
WHITE FOOT BR.
SAND
ROCK SHOAL
HILLS WITH PONDEROSA PINES
SAND
ROCK ISL.
ROCK ISL.
LAWN
LOGS
FINE GRAVEL
WILLOWS
SCHOOL BLDG.
TALL GRASS
LAWN
FLOW
SAND
FINE GRAVEL
FIRE PIT
ACCESS SITE
SAND
SOCCER FIELD

Station 6; Main Channel



similar to that of the large river. The width was about 7.5 m and depth ranged from 0.1 to 1.1 m (Figure 9).

METHODS

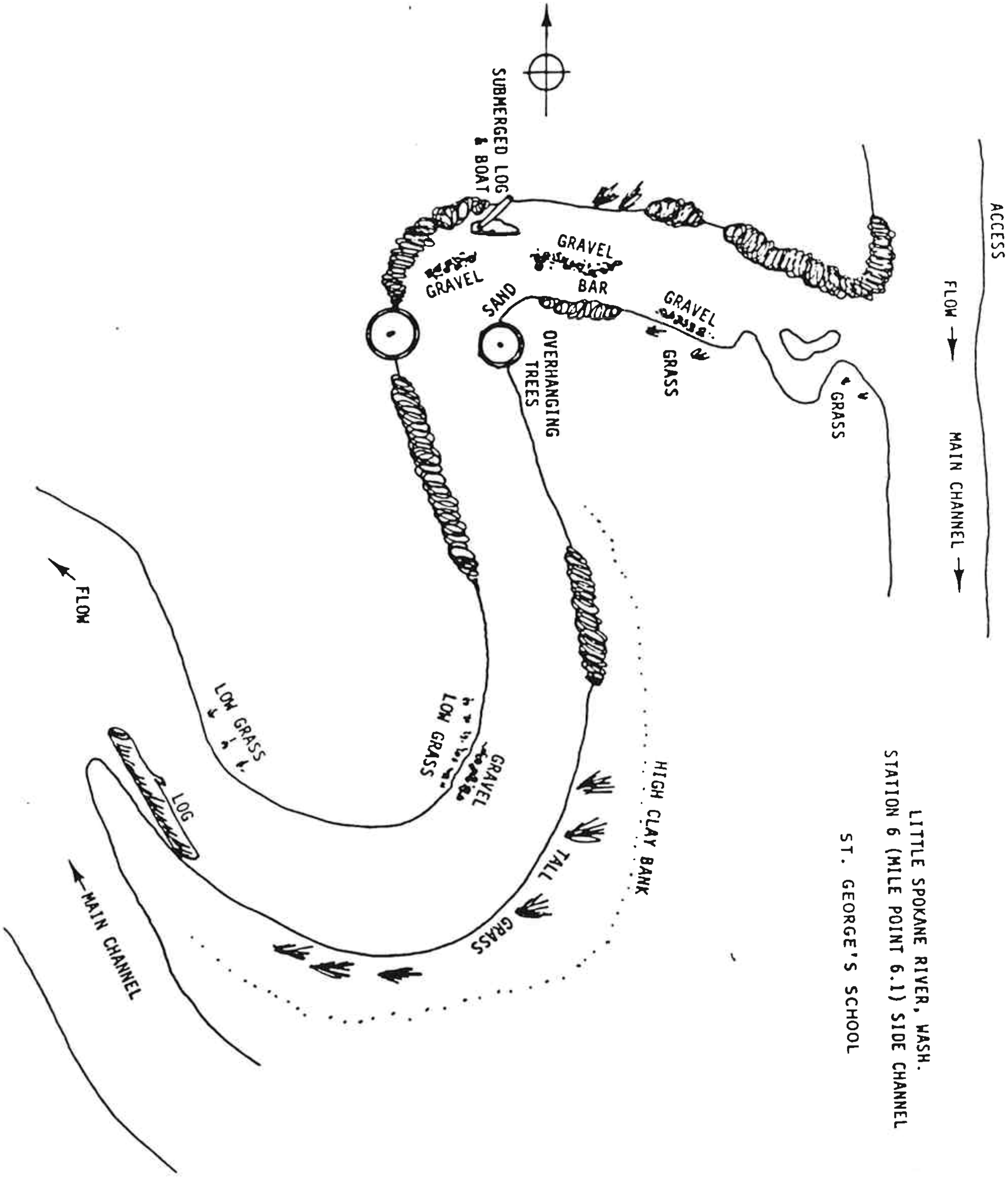
A sampling survey was designed to determine the possible impact of complex and free cyanides on the aquatic community indigenous to the Little Spokane River. Special care was taken to select sampling sites that had similar morphological characteristics (velocity, substrate composition and habitat) so in case a significant impact on the fauna was observed downstream, the effect could be attributed to the cyanides and not to the varying physical parameters.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates have been used extensively as water quality monitors in many varied situations. Their great utility is based upon the ease in which they are collected and secondly they tend to be relatively sessile and therefore are exposed continuously to changing water qualities. Hence, the absence of some of its members can in many cases be attributed to toxic contaminants, whereas a diverse community is indicative of good water quality.

Due to these great characteristics, the macroinvertebrates were collected from all six stations to aid in determining the potential impact of cyanides on the aquatic community. In all cases, five replicate samples, employing a modified Hess sampler, were secured from each of the

FIGURE 9



LITTLE SPOKANE RIVER, WASH.
STATION 6 (MILE POINT 6.1) SIDE CHANNEL
ST. GEORGE'S SCHOOL

Station 6; Side Channel

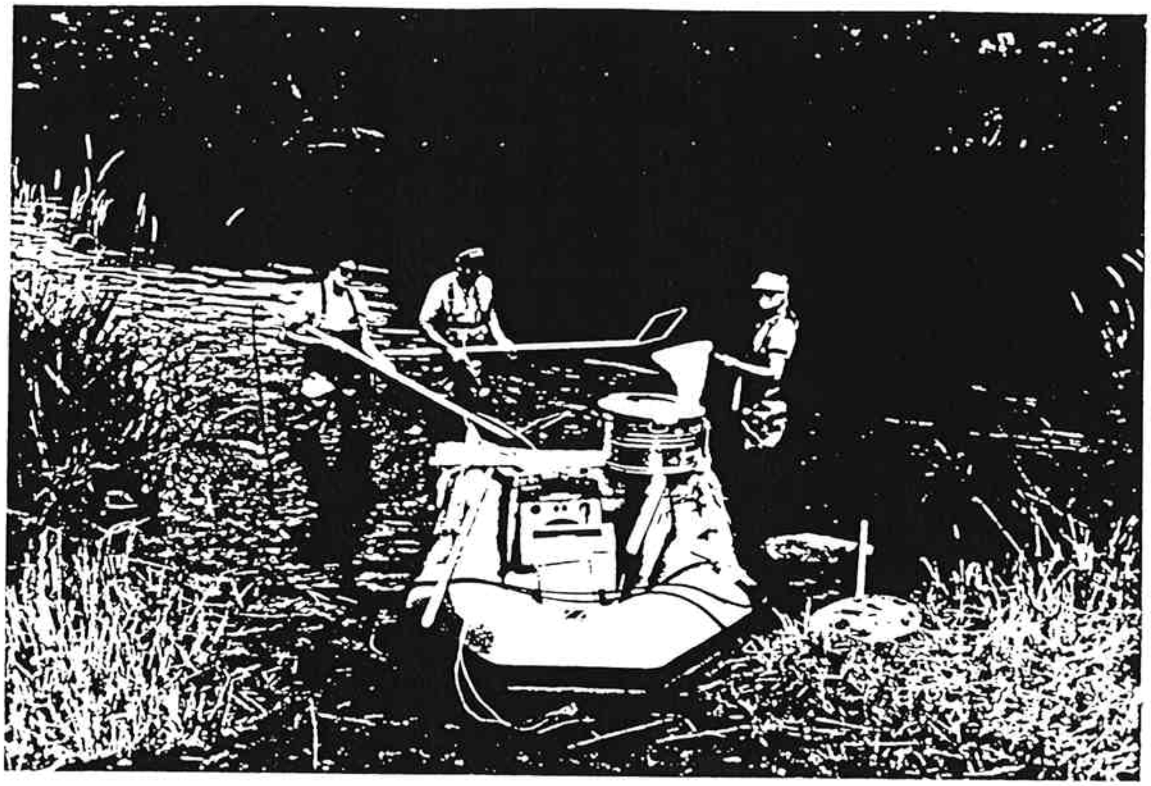
stations. Three of these collections were made in fast flowing water (riffle) while two were taken in a slow moving reach. Upon collection, the organisms were preserved in ethanol (70%) and at a later date handpicked, sorted and identified under a low power microscope using appropriate reference material. Worms (Oligochaeta) and midges (Diptera-Chironomidae) were individually mounted in polyvinyl-lactophenol and identified under 100 to 400x magnification. The organisms were enumerated and identified to the lowest practical taxonomic grouping. In addition, the diversity function (Shannon-Weaver) was calculated. The data are reported in tabular form in the results section.

Besides these quantitative samples, a variety of different substrates (habitats) were sampled employing a small triangular dip net. A similar amount of effort was put forth at each sampling site. The collections were treated in a similar fashion (sorted and identified) and also reported in a tabular form in the results.

Fish Sampling

A comprehensive sampling scheme was employed to assess the potential impact of cyanides on the fisheries resource of the Little Spokane River. Since no single method for fish collection works effectively, several procedures were used. This included seining with a bag seine, netting with a fine-mesh minnow seine and finally electrofishing. Each method has its biases, but if similar at all stations, a comparison between up and downstream communities can be made. Due to the relatively fast current, and the lack of catch, the 8 m bag seine was discarded after its use as a method. The small minnow seine worked somewhat better, but was limited to shallow reaches. Due to the clarity of the water, the efficiency was also not too great, but still it permitted the landings of small fishes which could not be collected with the elctrofishing gear.

A Smith-Root type VI-A electrofisher was employed mostly to take an inventory of the fish species at each designated sampling point. This pulsed D.C. system is an effective collecting device which produces the minimum amount of damage to fishes. Basically, an electrofishing operation consists of a system where a high voltage potential is applied between two or more electrodes that are placed in the water. The resulting field surrounding the electrodes will affect the fish in or near the electric field. The reaction observed in fish varied according to species of fish, the magnitude of the applied voltage and the conductivity of the water. In this study two poles were employed by men wading in the water. One pole was the anode which attracted the fish. Hence, the same person also handled the net. Another individual assisted the "anode" bearing person with the netting operation. The other person who held the cathode was also responsible for the pulling of the Zodiac rubber boat. The power was produced through a gas driven generator that was hauled around in a 10 ft rubber raft. Other gear utilized was the control unit



Electro-fishing gear used in this study.

Release of captured and marked fish

and several water filled tubs to maintain the fish until they were worked up.

The principle employed in this survey was a capture, mark and recapture study. The fish were shocked, netted, measured, identified and marked by clipping the lower portion of the tail fin. After recovery by the fish from this process, they were released downstream from their habitat. This enabled them to locate their niche from which they were collected. After a 4-5 day interval, the same procedures were repeated. Previously marked fish were recorded. Hence, by knowing the number of recaptured fish, an estimate of the fish community could be obtained. The efficiency of capturing shocked fish varied. In very fast moving water and deep holes, the efficiencies were low, whereas in shallow, slower moving waters, the success of capturing shocked fish was very high. For each reach that was shocked, the voltage, pulse width, amps and the actual shocking time were recorded. Data presented in the results will include fish caught per unit time.

EVALUATION OF BIOLOGICAL DATA

Diversity H' was calculated according to the Shannon-Weaver function:

$$H' = -\sum_{i=1}^{S} n_i/N \ln n_i/N$$

Species dominance d was calculated by the Berger-Parker Dominance Index:

$$d = n_{max}/ N$$

Species richness was calculated as:

$$s = \ln S$$

Similarity between habitats was evaluated by the Sørensen Coefficient of Similarity C_N:

$$C_N = 2\, n_j/(N_a + N_b)$$

Where:

S = total number of species found in a sample

N = total number of individuals found in a sample

n_i = number of individuals for the i^{th} species

n_{max} = number of individuals for the most abundant species in a sample

N_a = total number of individuals found in a sample from habitat a

N_b = total number of individuals found in a sample from habitat b

n_j = number of individuals from species occuring jointly in habitats a and b.

PHYSICAL AND CHEMICAL CONSIDERATIONS

Since an emphasis was placed on the effect of total and free cyanides, water samples were secured at each station on several dates for its analysis. Besides this parameter, conductivity and dissolved oxygen were measured in situ with Yellow Spring meters, pH with a Beckman electrode and temperature with a standard mercury thermometer. Water samples were also collected for the determination of alkalinity. Current velocities were measured by the floatation technique in which a bouant piece of material was timed over a measured distance.

RESULTS AND DISCUSSION

Physical and Chemical Data

The physical and chemical conditions of the Little Spokane River during the sampling period are summarized in Tables 2 and 3. The variability of the measurements for any one station during the 10 day period of intensive surveillance was very low. The dissolved oxygen concentrations found are near the theoretical maximum for the stream temperatures encountered. Alkalinity and conductivity show very minor upward trends in the zone of cyanide influx. Total cyanide concentrations (sampled from the middle of the stream) show higher values, especially for Stations 5 and 6, than were reported for surveys done during higher flow. The concentrations of total cyanides for any one station were remakably constant during the two days of this study that they were tested. The cyanide concentrations of 19μg/L found at Station 6 are in the zone where all cyanide influxes should have become completely mixed. The fact that this cyanide concentration is about twice that found during periods of higher flow is indicative of the contribution of groundwater flow to total flow, and also supports the contention that the sampling period did cover a time of maximum impact. Previous cyanide

TABLE 2 Physical and Chemical Conditions of the Little Spokane River, Washington During the First Survey (August 16-21, 1980) at Selected Stations

Station	1	2	3	4	5	6
Mile Pt.	16.8	16.3	13.4	10.0	9.2	6.3
Parameters						
Time of Day	1045-1900	1100-1700	0900-1800	1100-1900	1400-1700	0930-1400
Date	8/17/80	8/18/80	8/21/80	8/20/80	8/16/80	8/19/80
Water Temperature (°C)	15	15	15	14.8	16	12.5
Dissolved Oxygen (mg l^{-1})	10.6	11.6	14.2	13.6	11.6	11.2
Conductivity (μmhos cm^{-2})	198	190	190	215	230	205

Physical and Chemical Conditions of the Little Spokane River, Washington During the Second Survey (August 22-25, 1980) at Selected Stations

Time of Day	1400-1930	0930-1400	1700-2100	1200-1700	1300-1700	0900-1400
Date	8/23/80	8/23/80	8/24/80	8/25/80	8/22/80	8/24/80
Water Temperature (°C)	15.2	15.0	17.4	17.4	15.5	14.0
Dissolved Oxygen (mg l^{-1})	12.4	13.5	10.2	12.0	12.6	13.5
Conductivity (μmhos cm^{-2})	198	198	200	231	220	212

TABLE 3 Physical and Chemical Conditions of the Little Spokane River, Washington on Two Designated Sampling Dates During August at Selected Stations

Station	1	2	3	4	5	6
Mile Pt.	16.8	16.3	13.4	10.0	9.2	6.3
DATE: 8/22/80						
Parameters						
Time of Day	0730	0745	0800	0815	0835	0900
Water Temperature (°C)	15	15	15	14.5	14	12.8
Alkalinity (mg l^{-1})	116	116	120	127	129	125
Conductivity (μmhos cm^{-2})	195	196	198	216	220	208
Dissolved Oxygen (mg l^{-1})	12.2	12.8	12.9	13.5	12.6	12.1
Total Cyanide (μg l^{-1})	<1	<1	<1	38	43	19
DATE: 8/24/80						
Parameters						
Time of Day	1000	1015	1030	1045	1115	1130
Water Temperature (°C)	18.6	18.5	17.4	17.7	17.3	14.0
Alkalinity (mg l^{-1})	121	121	119	126	129	127
Conductivity (μmhos cm^{-2})	207	206	200	231	236	214
Dissolved Oxygen (mg l^{-1})	11.2	11.6	11.9	12.1	11.9	12.6
Total Cyanide (μg l^{-1})	<1	<1	<1	38	42	19

TABLE 4 Record of Total Cyanide Concentrations (µg/L or ppb) in the Little Spokane River

Stream Mile	Date of Collection														
	4-4-79	4-9-79	4-16-79	4-17-79	4-25-79	4-30-79	1-2-80	1-15-80	1-28-80	2-11-80	2-25-80	4-21-80	8-21-80	8-22-80	8-24-80
16.8															<1
16.3														<1	<1
13.4													<1	<1	<1
11.6	<1	<1													
11.0	3	2					<1	<1	<1	<1	<1				
10.8												<1		6	3
10.4	3	1					<1	2	2	2	<1	<1			
10.3	16	18	12		45	19	23	57	66	40	36	7			
10.0	10	11	12		12	8	19	17	29	20	10	10		38	38
9.2				16	17	15						14		43	42
7.7	10	13	10		10	10	12	11	10	12	9	8			
6.3	11	10	10		11	10						10		19	18
3.9				11	10	9						8			
1.0												9			
0.0												6			

sampling data are presented in Table 4.

Aquatic Macroinvertebrates

The collection of invertebrates obtained from the rather diverse community may be biased towards the lower diversity since some of the young immatures may have been missed due to their small size or their absence. A survey in late April or late October could have produced a more complex indigenous community in the Little Spokane River than that reported in this survey. Even with this potential shortcoming, the following discussion can be made about the aquatic macroinvertebrates.

Examining the qualitative data, each sampling site shows a diverse community of organisms, with the possible exception of Station 6 (Table 5). The lower diversity at this station (St. George's School) is mostly attributed to the lack of a diverse habitat. As indicated earlier, the bottom substrate was composed of granular sand and small gravel, which does not provide an ideal substrate for numerous mayflies (Ephemeroptera), stoneflies (Plecoptera), net spinningcaddisflies (Trichoptera) and beetles (Coleoptera). The dipterans were the

TABLE 5 Qualitative Macroinvertebrate Results for the Little Spokane River, Washington August 13-24, 1980

Stations	1	2	3	4	5	6
Mile Pt.	16.8	16.3	13.4	10.0	9.2	6.3
Turbellaria						
Dugesia sp.						x
Oligochaeta						
Aeolosoma sp.	x	x	x	x		x
Limnodrilus sp.		x	x			
Lumbriculus sp.		x	x			x
Potamothrix sp.		x	x			
Nematomorpha				x		
Insecta						
Ephemeroptera						
Ametropus sp.			x			x
Baetis sp.	x	x	x	x	x	x
Callibaetis sp.					x	
Centroptilum sp.		x		x		
Ephemerella sp.		x		x	x	
Heptagena sp.		x			x	
Ironodes sp.		x	x			
Paraleptophlebia sp.	x	x	x	x	x	
Pseudocloeon sp.				x		
Tricorythodes sp.	x		x	x	x	
Plecoptera						
Isoperla sp.		x				
Pteronarcys sp.				x	x	
Odonata						
Argia sp.	x					
Calopteryx sp.					x	
Hemiptera						
Graptocorixa sp.		x				
Metrobates sp.				x		
Sigara sp.		x		x	x	x
Trepobates sp.				x		
Trichoptera						
Brachycentrus sp.	x	x	x	x	x	x
Ceraclea sp.		x	x			
Cheumatopsyche sp.	x	x	x	x		
Glossosoma sp.	x		x	x	x	

TABLE 5 continued

Stations	1	2	3	4	5	6
Mile Pt.	16.8	16.3	13.4	10.0	9.2	6.3
Helicopsyche sp.	x	x			x	
Hydropsyche sp.	x	x	x	x	x	x
Leucotrichia sp.		x	x			
Limnephilus sp.			x			
Mystacides sp.	x		x	x		
Ochrotrichia sp.		x			x	
Rhyacophila sp.						x
Coleoptera						
Ampumixis sp.				x	x	
Dytiscus sp.		x				
Gyrinus sp.					x	
Heterlimnius sp.				x		
Narpus sp.				x		
Ordobrevia sp.					x	
Optioservus sp.			x			
Zaitzevia sp.		x	x			
Lepidoptera						
Paragyractis sp.	x	x				
Diptera						
Antocha sp.		x			x	
Cardiocladius sp.		x	x	x		
Chelifera sp.	x				x	
Conchapelopia sp.		x	x	x	x	
Diamesa sp.			x			
Dicrotendipes sp.				x		
Ectemnia sp.		x				
Erioptera sp.					x	x
Eukiefferiella sp.					x	
Hexatoma sp.					x	
Micropsectra sp.				x		x
Microtendipes sp.		x	x			
Monodiamesa sp.	x	x	x	x	x	
Orthocladius sp.		x		x	x	
Parachironomus sp.			x	x		
Paracladopalma sp.		x	x			
Paratanytarsus sp.		x				
Pedicia sp.		x				
Phaenopsectra sp.		x	x	x		
Polypedilum sp.	x	x	x	x	x	
Psectrocladius sp.			x	x		x
Rheotanytarsus sp.	x	x		x	x	x
Simulium sp.	x	x	x	x	x	x
Stictochironomus sp.				x		
Tanypus sp.	x		x			
Tanytarsus sp.	x	x	x	x	x	x

TABLE 5 continued

	Stations Mile Pt.	1 16.8	2 16.3	3 13.4	4 10.0	5 9.2	6 6.3
Gastropoda							
Amnicola sp.		x	x	x	x	x	
Acari							
Hydracarina		x	x	x	x		

most prevalent order recorded at all the collection sites. Although they represent a small amount of biomass (midges and blackflies), they appear to make up a significant portion in the diet of pigmy whitefish, mountain whitefish, and rainbows. This was documented from gut analysis that was performed on some of the fish that did not recover the shocking experience.

Quantitatively, no significant difference in terms of taxa, number or diversity does exist between the upstream Stations 1-3 (Table 6) and those in the area of groundwater intrusion Stations 4-6 (Table 7). Station 2 (Mile Point 16.3) has the highest number of organisms and the most diverse community. The samples were collected in a riffle reach that had fist size stones, which are an ideal habitat for macroinvertebrates. The substrate is large enough to provide both shelter and food (as indicated earlier, rocks were quite slippery due to periphytic growth). In addition, the samples secured from the slow moving area were within an aquatic weed bed that offered similar advantages as the large stones. Therefore, aside from this station, the variability in replicate samples can accommodate small differences in number and different taxa that were recorded over the river stretch. As the case with the qualitative data (Table 5), the aquatic fauna that dominated the quantitative results were the mayflies, caddisflies and dipterans. The difference in terms of number of taxa recorded in both types of samples can be attributed

TABLE 6 Quantitative Macroinvertebrate Results* for the Little Spokane River, Washington August 13-24, 1980

Stations	1					2					3				
Mile Pt.	16.8					16.3					13.4				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Oligochaeta															
Aeolosoma sp.		3		1	5	5			31	93			1	1	
Limnodrilus sp.								6		3	1			3	
Lumbriculus sp.								1	5			1			
Potamothrix sp.								2	13	1		5			
Insecta															
Ephemeroptera															
Centroptilum sp.								1							
Ephemerella sp.								2							
Heptagena sp.								2							
Ironodes sp.							1				5				
Paraleptophlebia sp.						1					2				
Tricorythodes fallax		1											1	1	
Plecoptera															
Isoperla sp.									1						
Hemiptera															
Sigara omani									1						
Lepidoptera															
Paragyractis truckeealis						1	2	2							

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*Samples A, B, and C obtained from riffle area, while samples D and E were collected from a depositing substrate

Samples collected with modified Hess (0.052 m^2)

TABLE 6 continued

Stations	1					2					3				
Mile Pt.	16.8					16.3					13.4				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Trichoptera															
Brachycentrus americanus				11					5	1	9	2		1	
Ceraclea sp.						1		1			1	1			
Cheumatopsyche sp.							1	10			7	1	1		
Glossosoma sp.			1								1	1			
Helicopsyche borealis		1						2							
Hydropsyche sp.			1			3	1	12	2		5		2		
Leucotrichia pictipes						3		5			3				
Mystacides sp.															1
Ochrotrichia sp.								1	1						
Coleoptera															
Dytiscus sp.							2	1							
Optioservus sp.											1				
Zaitzevia sp.								2	1		1				
Diptera															
Antocha sp.								1			1				
Cardiocladius sp.						2									
Conchapelopia sp.						1			1						
Diamesa sp.														12	
Ectemnia															
Microtendipes sp.										1					
Monodiamesa sp.	2				1			2	10	3		1		2	1
Orthocladius sp.								2	3						
Parachironomus sp.											2		1	1	2
Paracladopalma sp.							1							1	1
Paratanytarsus sp.									1						
Pedicia sp.								1							
Phaenopsectra sp.															1

TABLE6 continued

Stations			1					2					3		
Mile Pt.			16.8					16.3					13.4		
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
<u>Polypedilum</u> <u>sp</u>.	7	1		2	1			5	13	7	2			10	7
<u>Psectrocladius</u>														1	
<u>Rheotanytarsus</u>	1							1	1	1					
<u>Simulium</u> <u>sp</u>.					1	6	3	4	19	3					
<u>Tanytarsus</u> <u>sp</u>.	4	2		1	1	2		1	2	4	1			17	8
Gastropoda															
<u>Amnicola</u> <u>sp</u>.						12	7	15			4			1	
Acari															
Hydracarina		1	1	1	2	1		1	2				1		
Total number	14	9	3	16	11	38	19	83	112	117	46	12	7	51	21
Number of taxa	4	6	3	5	6	12	9	25	18	10	16	7	6	12	7
Diversity (H')	1.17	1.68	1.10	1.04	1.32	2.11	1.75	2.77	2.26	0.91	2.47	1.70	1.75	1.86	1.54
Dominance index (d)	0.50	0.33	0.33	0.69	0.45	0.32	0.37	0.18	0.28	0.79	0.20	0.42	0.29	0.33	0.38
Species richness (s)	1.39	1.79	1.10	1.61	1.79	2.48	2.20	3.22	2.89	2.30	2.77	1.95	1.79	2.48	1.95

TABLE 7 Quantitative Macroinvertebrate Results* for the Little Spokane River, Washington August 13-24, 1980

Stations	4					5					6				
Mile Pt.	10.0					9.2					6.3				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Turbellaria															
Dugesia sp.											1		1		
Oligochaeta															
Aeolosoma sp.				5							6		4		
Lumbriculus sp.											1				
Insecta															
Ephemeroptera															
Ametropus sp.														1	
Baetis sp.	5	8	4			1	10	3			2	3	2		
Callibaetis sp.							1								
Centroptilum sp.			1												
Ephemerella sp.	3							1							
Heptagena sp.							1								
Tricorythodes sp.							1								
Hemiptera															
Sigara washingtonensis														1	
Trichoptera															
Brachicentrus americanus	11	10	1			3		2		1			2		
Cheumatopsyche sp.	2	2	1												

---

*Samples A, B, and C obtained from riffle area, while samples D and E were collected from a depositing substrate

Samples collected with modified Hess (0.052 m^2)

TABLE 7 continued

Stations	4					5					6				
Mile Pt.	10.0					9.2					6.3				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Glossosoma sp.	6	1	2			2	4					1			
Helicopsyche borealis							1								
Hydropsyche sp.	21	11	10	1		2	4								
Rhyacophila sp.							2	1							
Coleoptera															
Apumixis sp.	1	1	1	1			1								
Heterlimnius sp.															
Narpus sp.				1											
Ordobrevia nubifera								1							
Diptera															
Antocha sp.							4								
Cardiocladius sp.		1													
Chelifera sp.						1	1				1	2	3		1
Conchapelopia sp.							3								3
Dicrotendipes sp.				4								2	1		
Eukiefferiella sp.										1					
Hexatoma sp.						1	3								
Micropsectra sp.			1	8							3		2		
Monadiamesa sp.				2	4				1	1					
Orthocladius sp.	4		1									2			
Phaenopsectra sp.				1											
Polypedilum sp.		1	2						2						
Psectrocladius sp.				3											
Rheotanytarsus sp.	2	1					1					3	1		
Simulium sp.	5	4	2		1		2					1			1
Stictochironomus sp.					4										
Tanytarsus sp.			1	3	4					5	11	1	1		

TABLE 7 continued

Stations	4					5					6				
Mile Pt.	10.0					9.2					6.3				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Acari															
Hydracarina	1							1				1			
Total number	61	40	27	29	13	10	39	9	3	8	25	16	17	2	5
Number of taxa	11	10	12	10	4	6	15	6	2	4	7	9	9	2	3
Diversity (H')	2.00	1.86	2.08	2.05	1.29	1.70	2.41	1.68	0.64	1.07	1.55	2.10	2.07	0.69	0.95
Dominance index (d)	0.34	0.28	0.37	0.28	0.31	0.20	0.26	0.33	0.67	0.63	0.24	0.44	0.25	0.50	0.60
Species richness (s)	2.40	2.30	2.48	2.30	1.39	1.79	2.71	1.79	1.10	1.39	1.95	2.20	2.20	0.69	1.10

to the larger area and diverse habitats that were sampled with the triangular net. As indicated, the modified Hess Sampler encloses only a surface area of 0.05 m^2. Therefore, according to these data presented, the potential impact of increased cyanide concentration on the macroinvertebrate fauna does not appear to exist.

FISH

The existing literature indicates that fish are very sensitive to the effects of cyanide. The toxic form is known to be free cyanide in the form of HCN (Doudoroff et al., 1966). If a mixture of free and complex cyanides is present, then the toxicity of the mixture cannot be readily predicted. In laboratory tests fish have been found to be the most sensitive organisms tested to date. The critical life stage appears to be the reproductive period and the early life of the embryo. Thus, effects on reproduction have been found in the range of 5-20µg/L free cyanide for Brook Trout, Fathead Minnow, and Bluegill (Koenst et al., 1977; Lind et al., 1977; Kimball et al., 1978). However, essentially nothing is known regarding the reactions of fish populations to constant and low concentrations of a mixture of free and complex cyanides under natural conditions.

The sampling of the fish populations in the Little Spokane River did present some problems due to local stream conditions. The most effective means of collecting samples of fish under the prevailing conditions was electrofishing.

The use of a large bag seine was impossible due to stream velocity, and a smaller seine was of use only intermittently. Thus, even though electroshocking was done with pulsed DC at a shocking rate which was optimized for smaller fish, the method was most efficient at collecting medium sized to large fish. The entire range of fish normally subject to recreational fishing was well sampled. The methodology appeared to become inefficient for fishes less than 10-15 cm in length. Even though very small fish could not be collected effectively, they were regularly observed in large numbers in the shallow areas throughout the sampling range, including the area of cyanide influx.

The parameters used for the electroshocking and the catch per unit effort (CUE) are noted in Table 8. Since the shocker permitted timing the duration of delivery of shocking current, CUE was measured as no. of fish caught per second of shocking. No significant trends are obvious in Table 8, especially when one considers that the recovery of shocked fish by netting becomes more difficult as the water depth increases. Areas of deeper water generally occurred for station 1 and 5, and for the main channel section of station 6. As a generalization, for this section of the Little Spokane River, the CUE seemed to be influenced most by water depth, aquatic plant growth, and stream velocity.

TABLE 8 Catch per Unit Effort (CUE) by Electroshocking.

	Station					
	1	2	3	4	5	6
First Collection						
No. of fish caught	56	95	260	114	48	52
Shocking time (sec)	1276	649	1148	650	1137	854
CUE	0.044	0.092	0.226	0.175	0.042	0.061
Shocking voltage	672-804	672	672-840	672	504	672
Pulse width (msec.)	3-4	6	6	6	3	6
Second Collection						
No. of fish caught	61	77	231	243	31	64
Shocking time (sec)	613	417	859	1068	448	1051
CUE	0.100	0.185	0.269	0.228	0.069	0.061
Shocking voltage	672	504-672	672	840	672	672
Pulse width (msec.)	6	6	6	6	6	6

The fish collection data are summarized in Table 9 in which all of the data pertaining to each station are combined. The data are presented in detail by size class in Table 10. The diversity indices, species richness, and dominance indices vary slightly from station to station, but do not appear to establish clear trends in relation to cyanide concentrations. In addition to these indices of species composition, the fish populations occuring at the various stations were compared on the basis of the Sørensen Coefficient of Similarity (C_N). This coefficient compares samples of biota collected from different sites on the basis of the kinds and number of organisms that both sites have in common. The assumption being that if both sites harbor similar species in similar abundance, then in fact both sites are ecologically identical or very similar. Mathematecally, the greater the dissimilarity, the lower the Sørensen coefficient. First, the coefficients from collections 1 and 2 were compared for identical stations (Table 11) in order toestablish the variability of this measure of similarity under local conditions. The the total fish collection data set for stations 1-6 was examined (Table 12). The index clearly performs as expected in that stations which are geographically further apart tend to be less similar. However, the range of values found between these stations is only slightly greater than that found among the collections illustrated in Table 11. Thus, by any of these measures, no indication of a cyanide related impact is apparent.

TABLE 9 Fish Samples from the Little Spokane River (all samples for each location combined)

Stations	1	2	3	4	5	6
Mile Pt.	16.8	16.3	13.4	10.0	9.2	6.3
Salmonidae						
Rainbow Trout (*Salmo gairdneri*)		8		17	4	15
Brown Trout (*Salmo trutta*)				1		
Pygmy Whitefish (*Prosopium coulteri*)		6	6	5	7	3
Mountain Whitefish (*Prosopium williamsoni*)	4	1	13	14	4	11
Esocidae						
Grass Pickerel (*Esox a. vermiculatus*)				2		
Cyprinidae						
Carp (*Cyprinus carpio*)	1		4	1		
Chiselmouth (*Acrocheilus alutaceus*)	16	96	107	83		1
Redside Shiner (*Richardsonius balteatus*)			42	14		
Northern Squawfish (*Ptychocheilus oregonensis*)	16	21	60	29	4	4
Longnose Dace (*Rhynichthys cataractae*)				4		
Tench (*Tinca tinca*)			4			
Catastomidae						
Longnose Sucker (*Catostomus catostomus*)			1	8		
Bridgelip Sucker (*Catostomus columbianus*)	43	33	119	109	8	2
Largescale Sucker (*Catostomus macrocheilus*)	8	36	52	28	12	32
Ictaluridae						
Brown Bullhead (*Ictalurus nebulosus*)			3			
Centrarchidae						
Pumpkinseed (*Lepomis gibbosus*)			4			
Bluegill (*Lepomis macrochirus*)			1			
Largemouth Bass (*Micropterus salmoides*)	5					
Black Crappie (*Pomoxis nigromaculatus*)	3					

TABLE 9 , continued

Stations	1	2	3	4	5	6
Mile Pt.	16.8	16.3	13.4	10.0	9.2	6.3
Percidae						
Yellow Perch (*Perca flavescens*)	4	13	67	3	3	3
Cottidae						
Mottled Sculpin (*Cottus bairdi*)	4	31	17	34	36	45
Total number	104	245	500	362	78	116
Number of species	10	9	15	15	8	9
Diversity (H')	1.81	1.77	2.07	2.01	1.68	1.63
Dominance index (d)	0.41	0.39	0.24	0.30	0.46	0.39
Species richness (s)	2.30	2.20	2.71	2.71	2.08	2.20

Table 10; Fish Collections

Station 1; Stream Mile 16.8; 1st Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Marked
Rainbow Trout									
Brown Trout									
Pygmy Whitefish									
Mountain Whitefish				2	1				2
Grass Pickerel									
Carp									
Chiselmouth		4	7						11
Redside Shiner									
Northern Squawfish		5	10						14
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker		1	4	1	13				17
Largescale Sucker									
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie				1					1
Yellow Perch		3	1						3
Mottled Sculpin		3							2

Table 10, continued

Station 1; Stream Mile 16.8; 2nd Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Recapt.
Rainbow Trout									
Brown Trout									
Pygmy Whitefish									
Mountain Whitefish				1					1
Grass Pickerel									
Carp								1	-
Chiselmouth		2	1	2					0
Redside Shiner									
Northern Squawfish							1		0
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker		1	6	4	11	3			3
Largescale Sucker			1		2	5			-
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass		1							-
Black Crappie				2					0
Yellow Perch									
Mottled Sculpin		1							0

(-) not found in first collection.

Within the confines of the study area the estimate of the population of Mountain Whitefish is 2 (Sampling error is likely to be moderate).

Table 10, continued

Station 2; Stream Mile 16.3; 1st collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Marked
Rainbow Trout			2	1	2				5
Brown Trout									
Pygmy Whitefish									
Mountain Whitefish									
Grass Pickerel									
Carp									
Chiselmouth		8	35	1					39
Redside Shiner									
Northern Squawfish		1	5		3	2			10
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker		1	8						6
Largescale Sucker			2		4	9	1		16
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch		4	1						5
Mottled Sculpin	1	9							8

Table 10, continued

Station 2; Stream Mile 16.3; 2nd Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Recapt.
Rainbow Trout			2	1					0
Brown Trout									
Pygmy Whitefish			5						-
Mountain Whitefish				1	1				-
Grass Pickerel									
Carp									
Chiselmouth		8	42	2					3
Redside Shiner									
Northern Squawfish		2	7		1				1
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker		1	15	4	4				0
Largescale Sucker					2	17	1		1
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch		7	1						0
Mottled Sculpin	4	17							0

(-) not found in first collection.

Within the confines of the study area the population estimate of Chiselmouth is 676 (sampling error is likely to be moderate); of Squawfish is 100 (sampling error is likely to be high); of Largescale Suckers is 320 (sampling error is likely to be high).

Table 10, continued

Station 3; Stream Mile 13.4; 1st Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Marked
Rainbow Trout									
Brown Trout									
Pygmy Whitefish			2						2
Mountain Whitefish				2	2				4
Grass Pickerel									
Carp								3	3
Chiselmouth		10	39	1					41
Redside Shiner		7	12						18
Northern Squawfish		7	14		2	4			27
Longnose Dace									
Tench			2		1				3
Longnose Sucker			1						1
Bridgelip Sucker		1	55	3	2				60
Largescale Sucker					12	11			22
Brown Bullhead				1					1
Pumpkinseed			2						2
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch		10	28						38
Mottled Sculpin		8	2						9

Table 10, continued

Station 3; Stream Mile 13.4; 2nd Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Recapt.
Rainbow Trout									
Brown Trout									
Pygmy Whitefish			4						0
Mountain Whitefish			1	5	3				1
Grass Pickerel									
Carp								1	0
Chiselmouth		23	33	1					3
Redside Shiner		9	15						0
Northern Squawfish		5	19	1	4	3			3
Longnose Dace									
Tench						1			0
Longnose Sucker									
Bridgelip Sucker		3	46	5					1
Largescale Sucker			1	1	10	17	3	1	4
Brown Bullhead				2					0
Pumpkinseed		1	1						0
Bluegill		1							-
Largemouth Bass									
Black Crappie									
Yellow Perch		16	13						0
Mottled Sculpin	2	5							0

(-) not found in first sample

Within the confines of the sampling area the population estimate of Mountain Whitefish is 36 (sampling error likely to be moderate); of Chiselmouth is 779 (sampling error likely to be high); of Squawfish is 288 (sampling error likely to be moderate); of Bridgelip Suckers is 3,240 (sampling error likely to be very high); and of Largescale Suckers is 182 (sampling error likely to be low).

Table 10, continued

Station 4; Stream Mile 10.0; 1st Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Marked
Rainbow Trout			5	1					6
Brown Trout									
Pygmy Whitefish			2						2
Mountain Whitefish				7					2
Grass Pickerel				2					2
Carp						1			1
Chiselmouth		13	8	6					23
Redside Shiner		7							7
Northern Squawfish		3	5		2				10
Longnose Dace									
Tench									
Longnose Sucker		3	1						3
Bridgelip Sucker		12	8	1	4				15
Largescale Sucker					1	10	1		12
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch									
Mottled Sculpin		10							9

Table 10, continued

Station 4; Stream Mile 10.0; 2nd Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Recapt.
Rainbow Trout		1	10						2
Brown Trout				1					-
Pygmy Whitefish			3						0
Mountain Whitefish				5	2				0
Grass Pickerel									
Carp									
Chiselmouth	1	47	10	2					0
Redside Shiner		5	2						0
Northern Squawfish		4	8	1	3	3			0
Longnose Dace	3	1							-
Tench									
Longnose Sucker		4							0
Bridgelip Sucker		24	51	4	4	1			2
Largescale Sucker			1		3	10	2		2
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch		1	2						-
Mottled Sculpin	1	23							0

(-) not found in 1st collection.

Within the confines of the sampling area the population of Rainbow Trout is 33 (sampling error likely to be low); Bridgelip Sucker 630 (sampling error likely to be relatively high); Largescale Sucker 176 (sampling error likely to be moderate). No estimates can be provided for other species on the basis of mark/recapture data.

Table 10, continued

Station 5; Stream Mile 9.2; 1st Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Marked
Rainbow Trout				2					2
Brown Trout									
Pygmy Whitefish			4						1
Mountain Whitefish									
Grass Pickerel									
Carp									
Chiselmouth									
Redside Shiner									
Northern Squawfish			2						2
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker		1			1	1			1
Largescale Sucker						1			1
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch		2	1						3
Mottled Sculpin		32							23

Table 10, continued

Station 5; Stream Mile 9.2; 2nd Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Recapt.
Rainbow Trout					1				0
Brown Trout									
Pygmy Whitefish			3						0
Mountain Whitefish				3	1				-
Grass Pickerel									
Carp									
Chiselmouth									
Redside Shiner									
Northern Squawfish					2				0
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker		1		1	3				0
Largescale Sucker			1	1	1	7	1		0
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch									
Mottled Sculpin		4							0

(-) not found in first collection.

Table 10, continued

Station 6; Stream Mile 6.3, side channel; 1st Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Markec
Rainbow Trout		1	3						4
Brown Trout									
Pygmy Whitefish		2							2
Mountain Whitefish			2	5					6
Grass Pickerel									
Carp									
Chiselmouth									
Redside Shiner									
Northern Squawfish									
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker									
Largescale Sucker					1	13	1		15
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch		1							1
Mottled Sculpin	2	6							8

Table 10, continued

Station 6; Stream Mile 6.3, side channel; 2nd collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Recapt.
Rainbow Trout		3	1	1					0
Brown Trout									
Pygmy Whitefish									
Mountain Whitefish				2					-
Grass Pickerel									
Carp									
Chiselmouth									
Redside Shiner									
Northern Squawfish					1				0
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker									
Largescale Sucker					2	4			0
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch		2							-
Mottled Sculpin	6	18							1

(-) not found in 1st sample

The estimated population of Mottled Sculpins within the confines ofthe sample area is approximately 144. The sampling error for this estimate is large. No estimates can be provided for other species on the basis of mark/recapture data.

Table 10, continued

Station 6; Stream Mile 6.3, main channel; 1st Collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Marked
Rainbow Trout			2						
Brown Trout									
Pygmy Whitefish									
Mountain Whitefish									
Grass Pickerel									
Carp									
Chiselmouth									
Redside Shiner									
Northern Squawfish		1							1
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker									
Largescale Sucker					2	2			4
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch									
Mottled Sculpin	1	6	1						6

Table 10, continued

Station 6; Stream Mile 6.3, main channel; 2nd collection

length (cm)	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60+	Recapt.
Rainbow Trout			3		1				0
Brown Trout									
Pygmy Whitefish			1						-
Mountain Whitefish				1	1				-
Grass Pickerel									
Carp									
Chiselmouth		1							-
Redside Shiner									
Northern Squawfish					2				0
Longnose Dace									
Tench									
Longnose Sucker									
Bridgelip Sucker		1	1						-
Largescale Sucker					3	4			2
Brown Bullhead									
Pumpkinseed									
Bluegill									
Largemouth Bass									
Black Crappie									
Yellow Perch									
Mottled Sculpin	1	4							0

(-) not found in 1st sample

The estimated population of Largescale Suckers in the confines of the sampling area is approximately 14. The sampling error for this estimate is likely to be relatively low. No estimates can be provided for other species on the basis of mark/recapture data.

Table 11 Sørensen Coefficients of Similarity between Collections 1 and 2 for the same Stations

Station	Coeff. *
1	1.65
2	1.94
3	1.99
4	1.88
5	1.82
6 (main stream)	1.69
6 (side channel)	1.92

(*) maximum = 2.00

Table 12 Sørensen Coefficients of Similarity Among Stations

Station	1	2	3	4	5	6
1	2.00	1.87	1.77	1.70	1.60	1.69
2	1.87	2.00	1.82	1.87	1.41	1.91
3	1.77	1.82	2.00	1.89	1.41	1.53
4	1.70	1.87	1.89	2.00	1.44	1.81
5	1.60	1.41	1.41	1.44	2.00	1.93
6	1.69	1.91	1.53	1.81	1.93	2.00

A qualitative examination of the species and sizes of fish present in this stretch of the Little Spokane River indicates a varied and rich population of fish including a modest number of sought after game fish, especially in the area exposed to cyanides, but also subject to greater stream flows. While most of the fish found in the river would normally be classified as rough fish or forage fish, the river nevertheless supports a seemingly healthy, abundant, varied and productive population of fish.

CONCLUSIONS

Between August 16 and August 25, 1980 an intensive ecological survey of fish and aquatic macro-invertebrates was conducted on the Little Spokane River. The relatively minor variations in biota for the stretch of the river which was examined appeared to be exclusively due to environmental differences such as water depth, stream flow, or presence of aquatic plant beds. The mixture of free and complex cyanides known to be present in low parts per billion concentrations in approximately the lower 10 miles of the river did not produce any noticeable effects on the populations of fish and aquatic macro-invertebrates. Since fish are known to be the most sensitive species in their reactions to cyanide, the absence of an effect on fish populations indicates that the present levels of contamination by free and complex cyanides does not constitute an undue ecological or public health hazard.

REFERENCES

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Appendix D

ACTION-SPECIFIC ARARs

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Capping	Placement of a cap over waste (e.g., closing a landfill, or closing a surface impoundment or waste pile as a landfill, or similar action) requires a cover designed and constructed to: o Provide long-term minimization of migration of liquids through the capped area o Function with minimum maintenance o Promote drainage and minimize erosion or abrasion of the cover o Accommodate settling and subsidence so that the cover's integrity is maintained o Have a permeability less than or equal to the permeability of any bottom liner system or natural sub-soils present.	Significant management (treatment, storage, or disposal) of hazardous waste will make requirements applicable; capping without disturbance will not make requirements applicable, but technical requirements are likely to be relevant and appropriate.	40 CFR 264.228(a) (Surface Impoundments) 40 CFR 264.258(b) (Waste Piles) 40 CFR 264.310(a) (Landfills)	Relevant and Appropriate Applicable	Implementation of capping in-place is a probable action for at least a portion of the facility. The RCRA capping requirements would be relevant and appropriate to capping the wastes in place for wastes placed in the piles prior to Nov. 19, 1980, and for wastes which cannot be classified as hazardous wastes. A RCRA cap would serve to isolate and contain wastes and limit infiltration of precipitation. Excavation and reconsolidation of the wastes onsite, in a location outside the current area of contamination, would make these requirements as well as the landfill construction and operation requirements applicable for wastes that can be designated as hazardous. If the wastes are excavated and reconsolidated in their current location, the capping requirements are applicable. The major determining factors are the location of the final disposal and the classification of the waste materials.
	Eliminate free liquids, stabilize wastes before capping (surface impoundments).		40 CFR 264.228(a)		
	Restrict postclosure use of property as necessary to prevent damage to the cover.		40 CFR 264.117(c)		
	Prevent run-on and runoff from damaging cover.		40 CFR 264.228(b) 40 CFR 264.310(b)		
	Protect and maintain surveyed benchmarks used to locate waste cells (landfills, waste piles).		40 CFR 264.310(b)		

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Clean Closure (Removal)	General performance standard requires minimization of need for further maintenance and control; minimization or elimination of postclosure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products.	Disturbance of RCRA hazardous waste (listed or characteristic) and movement outside the unit or area of contamination.	40 CFR 264.111	Relevant and appropriate	The RCRA clean closure requirements would be relevant and appropriate to wastes which cannot be classified as hazardous wastes.
		May apply to surface impoundment; contaminated soil including soil from dredging or soil disturbed in the course of drilling or excavation and returned to land.		Applicable	In the event that the wastes being removed are determined to be hazardous wastes, the requirements of this section would be applicable.
	Disposal or decontamination of equipment, structures, and soils.		40 CFR 264.111		
	Removal or decontamination of all waste residues, contaminated containment system components (e.g., liners, dikes), contaminated subsoils, and structures and equipment contaminated with waste and leachate, and management of them as hazardous waste.	Not applicable to undisturbed material.	40 CFR 264.228(a)(1) and 40 CFR 264.258		
		Disposal of RCRA hazardous waste (listed or characteristic) after disturbance and movement outside the unit or area of contamination.			
	Meet health-based levels at unit.		40 CFR 244.111		
Closure With Waste in Place (Capping)	Eliminate free liquids by removal or solidification.		40 CFR 264.228(a)(2)	Relevant and appropriate	See discussion under Capping.
	Stabilization of remaining waste and waste residues to support cover.		40 CFR 264.228(a)(2) and 40 CFR 264.258(b)		
	Installation of final cover to provide long-term minimization of infiltration.		40 CFR 264.310		
	Postclosure care and groundwater monitoring.		40 CFR 264.310		

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Consolidation	Area from which materials are removed should be cleaned up.	Disposal by disturbance of hazardous waste (listed or characteristic) and moving it outside unit or boundary of contaminated area.	See Closure	Relevant and appropriate	If nonhazardous wastes are excavated and moved outside the current area of contamination, these requirements will be relevant and appropriate. These regulations are intended to ensure that, when wastes are consolidated at a central location, the satellite areas (former locations of the wastes) are cleaned up.
				Applicable	If the wastes which are excavated for consolidation are determined to be hazardous wastes, this regulation will be applicable.
	Consolidation in storage piles/ storage tanks will trigger storage requirements.		See Container Storage, Tank Storage, Waste Piles in this exhibit.	Relevant and appropriate	RCRA requirements for storage in containers, tanks, or piles will be relevant and appropriate for nonhazardous wastes excavated from the site and stored prior to consolidation and/or disposal.
				Applicable	If excavated materials can be classified as hazardous wastes, the requirements will be applicable.
	Placement on or in land outside unit boundary or area of contamination will trigger land disposal requirements and restrictions.	After November 8, 1988.	40 CFR 286 (Subpart D)	Relevant and appropriate	Certain solvent wastes, dioxin wastes, and the "California List" wastes will not be eligible for disposal in landfills or other land-based facilities after November 8, 1988. This requirement may be relevant and appropriate to some nonhazardous wastes which are similar to the restricted wastes and which are excavated for reconsolidation and disposal outside the current area of contamination.
				Applicable	If any of the wastes are determined to meet the definitions of the restricted hazardous wastes, the requirements will be applicable.
	Devise fugitive and odor emission control plan for this action if existing site plan is inadequate.		CAA Section 101[a] and 40 CFR 52[a]	Applicable	Odor regulations are intended to limit nuisance conditions from air pollution emissions. Fugitive emission controls are one feature of the state implementation plan used to achieve/ maintain the ambient air quality standards for particulate matter.

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Consolidation (Continued)	File an air pollution emission notice (APEN) with state to include estimation of emission rates for each pollutant expected.		40 CFR 52[a]	Applicable	State will have particular interest in emissions for compounds on its hazardous, toxic, or odorous list. Preliminary meeting with state prior to filing APEN is recommended in the regulation. Meeting would identify additional issues of concern to the state.
	Include with the filed APEN the following: 1. Modeled impact analysis of source emissions 2. Provide a best available control technology (BACT) review for the source operation	This additional work and information is normally applicable to sources meeting the "major" criteria and/or to sources proposed for nonattainment areas.	40 CFR 52[a]	Relevant and appropriate	State may identify further requirements for permit issuance after first review. These provisions follow the federal prevention of significant deterioration (PSD) framework with some modifications. Additional requirements could include ambient monitoring and emission control equipment design revisions to match lowest achievable emission requirements (LAER). While a permit is not required for an onsite CERCLA action, the substantive requirements identified during the permitting process are applicable.
	Predict total emissions of volatile organic compounds (VOCs) to demonstrate emissions do not exceed 450 lb/hr, 3,000 lb/day, 10 gal./day, or allowable emission levels from similar sources using reasonably available control technology (RACT).	Source operation must be in an ozone nonattainment area.	40 CFR 52[a]	Applicable	The control technology review for this regulation (RACT) could coincide with the BACT review suggested under the PSD program.
	Verify through emission estimates and dispersion modeling that hydrogen sulfide emissions do not create an ambient concentration greater than or equal to 0.10 ppm.		40 CFR 61[a]	Applicable	

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Container Storage (Onsite)	Containers of hazardous waste must be:	RCRA hazardous waste (listed or characteristic) held for a temporary period before treatment, disposal, or storage elsewhere (40 CFR 264.10) in a container (i.e., any portable device in which a material is stored, transported, disposed of, or handled).		Relevant and appropriate	These requirements would be relevant and appropriate for any nonhazardous waste which might be containerized and stored onsite prior to treatment or final disposal.
	o Maintained in good condition		40 CFR 264.171		
	o Compatible with hazardous waste to be stored		40 CFR 264.172	Applicable	If any of the wastes are determined to be classified as hazardous wastes, the requirements would be applicable. Containerized hazardous substances or hazardous wastes while onsite must be stored in a structure that is designed, operated, and maintained in accordance with 40 CFR 264.171-178.
	o Closed during storage (except to add or remove waste)		40 CFR 264.173		
	Inspect container storage areas weekly for deterioration.		40 CFR 264.174		
	Place containers on a sloped, crackfree base, and protect from contact with accumulated liquid. Provide containment system with a capacity of 10 percent of the volume of containers of free liquids.		40 CFR 264.175		
	Remove spilled or leaked waste in a timely manner to prevent overflow of the containment system.				
	Keep containers of ignitable or reactive waste at least 50 feet from the facility's property line.		40 CFR 264.176		
	Keep incompatible materials separate. Separate incompatible materials stored near each other by a dike or other barrier.		40 CFR 264.177		
	At closure, remove all hazardous waste and residues from the containment system and decontaminate or remove all containers and liners.		40 CFR 264.178		

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Containment (Construction of New Landfill Onsite) (See Closure With Waste in Place)	Install two liners or more, a top liner that prevents waste migration into the liner, and a bottom liner that prevents waste migration through the liner.	RCRA hazardous waste (listed or characteristic) currently being placed in a landfill.	40 CFR 264.301		This requirement regulates the design, construction, operation, and maintenance of a new hazardous waste landfill. Reconsolidation and placement of wastes in a previously contaminated area is discussed under Capping and, Closure With Waste in Place.
	Install leachate collection systems above and between the liners.		40 CFR 264.301	Relevant and appropriate	This requirement would be relevant and appropriate to the construction, operation, and maintenance of a new landfill located outside the current pile area at the facility that would contain nonhazardous wastes excavated from the piles.
	Construct run-on and runoff control systems capable of handling the peak discharge of a 25-year storm.		40 CFR 264.301		
	Control wind dispersal of particulates.		40 CFR 264.301	Applicable	If any of the excavated wastes are determined to be hazardous wastes, these requirements would be applicable.
	Inspect liners and covers during and after installation.		40 CFR 264.303		
	Inspect facility weekly and after storms to detect malfunction of control systems or the presence of liquids in the leachate collection and leak detection systems.		40 CFR 264.303		
	Maintain records of the exact location, dimensions, and contents of waste cells.		40 CFR 264.304		
	Close each cell with a final cover after the last waste has been received.		40 CFR 264.310		
	No bulk or noncontainerized liquid hazardous waste or hazardous waste containing free liquids may be disposed of in landfills.		40 CFR 264.314		
	Containers holding free liquids may not be placed in a landfill unless the liquid is mixed with an absorbent or solidified.		40 CFR 264.314		

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Containment (Construction of New Landfill Onsite) (See Closure With Waste in Place) (Continued)	Treatment by best demonstrated available technology before placement.	Placement, after November 8, 1988, of RCRA hazardous waste subject to land disposal restrictions.	40 CFR 268 (Subpart D)	Relevant and appropriate	Certain solvent wastes, dioxin wastes, and "California List" wastes are subject to land disposal restrictions, which specify a level of treatment that must be attained before these wastes can be disposed of in a landfill or other land-based facility. These requirements may be relevant and appropriate to some non-hazardous wastes that are similar to the restricted wastes.
				Applicable	If any of the excavated wastes are determined to be hazardous wastes subject to the land disposal restrictions, these requirements will be applicable. In that case, the wastes will have to be treated to the specified level or disposed of by incineration or an equivalent non-land-based method.
	Devise fugitive and odor emission control plan for this action if existing site plan is inadequate.		CAA Section 101[a] and 40 CFR 52[a]	Applicable	See discussions under Consolidation.
	File an air pollution emission notice (APEN) with state to include estimation of emission rates for each pollutant expected.		40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Include with the filed APEN the following: 1. Modeled impact analysis of source emissions 2. Provide a best available control technology (BACT) review for the source operation	This additional work and information is normally applicable to sources meeting the "major" criteria and/or to sources proposed for nonattainment areas.	40 CFR 52[a]	Relevant and appropriate	See discussions under Consolidation.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Containment (Construction of New Landfill Onsite) (See Closure With Waste in Place) (Continued)	Predict total emissions of volatile organic compounds (VOCs) to demonstrate emissions do not exceed 450 lb/hr, 3,000 lb/day, 10 gal./day, or allowable emission levels from similar sources using reasonably available control technology (RACT).	Source operation must be in an ozone nonattainment area.	40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Verify through emission estimates and dispersion modeling that hydrogen sulfide emissions do not create an ambient concentration greater than or equal to 0.10 ppm.		40 CFR 61[a]	Applicable	See discussions under Consolidation.
	Verify that emissions of mercury, vinyl chloride, and benzene do not exceed levels expected from sources in compliance with hazardous air pollution regulations.		40 CFR 61[a]	Relevant and appropriate	See discussions under Consolidation.
Containment (construction of new surface impoundment onsite) (see Closure With Waste in Place and Clean Closure)	Use two liners, a top liner that prevents waste migration into the liner and a bottom liner that prevents waste migration through the liner throughout the postclosure period.	RCRA hazardous waste (listed or characteristic) currently being placed in a surface impoundment.	40 CFR 264.220	Relevant and appropriate	If a new, onsite surface impoundment is constructed to hold influent and/or effluent from a treatment process or to hold groundwater or leachate that is not a hazardous waste, these requirements are relevant and appropriate to construction, operation, and maintenance of the impoundment.
	Design liners to prevent failure due to pressure gradients, contact with the waste, climatic conditions, and the stress of installation and daily operations.		40 CFR 264.221	Applicable	If any of the liquids to be held in the impoundment can be classified as hazardous wastes, these requirements will be applicable.
	Provide leachate collection system between the two liners.		40 CFR 264.221		
	Use leak detection system that will detect leaks at the earliest possible time.		40 CFR 264.221		

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Dike Stabilization	Design and operate facility to prevent overtopping due to overfilling; wind and wave action; rainfall; run-on; malfunctions of level controllers, alarms, and other equipment; and human error.	Existing surface impoundments containing hazardous waste or creation of new surface impoundments.	40 CFR 264.221	Relevant and appropriate	These requirements would be relevant and appropriate to the construction and operation of a new surface impoundment or the operation and maintenance of an existing surface impoundment onsite to contain groundwater, leachate, or the influent or effluent of a treatment system that is not a hazardous waste.
	Construct dikes with sufficient strength to prevent massive failure.		40 CFR 264.221	Applicable	If any of the materials to be contained in a surface impoundment are classified as hazardous wastes, the construction, operation and maintenance requirements would be applicable.
	Inspect liners and cover systems during and after construction.		40 CFR 264.226		
	Inspect weekly for proper operation and integrity of the containment devices.		40 CFR 264.226		
	Remove surface impoundment from operation if the dike leaks or there is a sudden drop in liquid level.		40 CFR 264.227		
	At closure, remove or decontaminate all waste residues and contaminated materials. Otherwise, free liquids must be removed, the remaining wastes stabilized, and the facility closed in the same manner as a landfill.		40 CFR 264.228		
	Manage ignitable or reactive waste so that it is protected from materials or conditions that may cause it to ignite or react.		40 CFR 264.227		

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Direct Discharge of Treatment System Effluent	Applicable federal water quality criteria for the protection of aquatic life must be complied with when environmental factors are being considered.	Surface discharge of treated effluent.	50 FR 30784 (July 29, 1985)	Applicable	See the initial screening table for chemical-specific ARARs.
	Applicable federally approved state water quality standards must be complied with. These standards may be in addition to or more stringent than other federal standards under the CWA.	Surface discharge of treated effluent.	40 CFR 122.44 and state regulations approved under 40 CFR 131	Applicable	If Washington State regulations are more stringent than federal water quality standards, the Washington State standards will be applicable to direct discharges. The Washington Department of Ecology (Ecology) has authority under 40 CFR 131 to implement direct discharge requirements within the state and should be contacted on a case-by-case basis when direct discharges are contemplated.
	The discharge must be consistent with the requirements of a water quality management plan approved by EPA under Section 208(b) of the Clean Water Act.				
	Use of best available technology (BAT) economically achievable is required to control toxic and nonconventional pollutants. Use of best conventional pollutant control technology (BCT) is required to control conventional pollutants. Technology-based limitations may be determined on a case-by-case basis.	Surface discharge of treated effluent.	40 CFR 122.44(a)	Applicable	If treated effluent is discharged to surface waters, these treatment requirements will be applicable. Permitting and reporting requirements will be applicable only if the effluent is discharged at an offsite location. Ecology is the permitting authority and should be contacted on a case-by-case basis to determine effluent standards.
	The discharge must conform to applicable water quality requirements when the discharge affects a state other than the certifying state.	Surface water discharge affecting waters outside the state of Washington.	40 CFR 122.44(d)(4)	Not ARAR	No discharge is expected to affect surface waters outside the state of Washington.
	Discharge limitations must be established for all toxic pollutants that are or may be discharged at levels greater than those which can be achieved by technology-based standards.	Surface discharge of treated effluent.	40 CFR 122.44(e)	Applicable	Exact limitations are based on review of the proposed treatment system and receiving water characteristics and usually are determined on a case-by-case basis. Ecology is the permitting authority and should be contacted to determine effluent limitations.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Direct Discharge of Treatment System Effluent (Continued)	Discharge must be monitored to assure compliance. Discharge will monitor: o The mass of each pollutant o The volume of effluent o Frequency of discharge and other measurements as appropriate	Surface discharge of treated effluent.	40 CFR 122.44(i)	Applicable	These requirements generally are incorporated into permits, which are not required for onsite discharges. The substantive requirements are applicable, however, in that verifiable evidence must be offered that the discharge standards are being met. Ecology is the permitting authority and should be contacted to determine monitoring and operational requirements.
	Approved test methods for waste constituents to be monitored must be followed. Detailed requirements for analytical procedures and quality controls are provided.				
	Permit application information must be submitted, including a description of activities, listing of environmental permits, etc.		40 CFR 122.21		
	Monitor and report results as required by permit (minimum of at least annually).		40 CFR 122.44(i)		
	Comply with additional permit conditions such as: o Duty to mitigate any adverse effects of any discharge o Proper operation and maintenance of treatment systems		40 CFR 122.41(i)		

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Direct Discharge of Treatment System Effluent (Continued)	Develop and implement a best management practices (BMP) program and incorporate in the NPDES permit to prevent the release of toxic constituents to surface waters.	Surface water discharge.	40 CFR 125.100	Applicable	These issues are determined on a case-by-case basis by the NPDES permitting authority for any proposed surface discharge of treated wastewater. Although a CERCLA site remediation is not required to obtain an NPDES permit for onsite discharges to surface waters, the substantive requirements of the NPDES permit program must be met by the remediation action if possible. Ecology is the permitting authority and should be consulted on a case-by-case basis to determine BMP requirements.
	The BMP program must: o Establish specific procedures for the control of toxic and hazardous pollutant spills o Include a prediction of direction, rate of flow, and total quantity of toxic pollutants where experience indicates a reasonable potential for equipment failure o Assure proper management of solid and hazardous waste in accordance with regulations promulgated under RCRA		40 CFR 125.104		
	Sample preservation procedures, container materials, and maximum allowable holding times are prescribed.	Surface water discharge.	40 CFR 136.1-136.4	Applicable	These requirements are generally incorporated into permits, which are not required for onsite discharges. The substantive requirements are applicable, however, in that verifiable evidence must be offered that standards are being met. Ecology is the permitting authority and should be consulted on a case-by-case basis to determine analytical requirements.
Discharge to POTW[c]	Pollutants that pass through the POTW without treatment, interfere with POTW operation, or contaminate POTW sludge are prohibited.		40 CFR 403.5	Applicable	If any liquid is discharged to a POTW, these requirements are applicable. In accordance with guidance, a discharge permit may be required even for an onsite discharge since permitting is the only substantive control mechanism available to a POTW.

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[c] Same regulations apply regardless of whether remedial action discharges into the sewer or trucks waste to an inlet to the sewage conveyance system located upstream of the POTW.

POTENTIAL ACTION-SPECIFIC ARARs
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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Discharge to POTW (Continued)	Specific prohibitions preclude the discharge of pollutants to POTWs that:				Categorical standards have not been promulgated for CERCLA sites, so discharge standards must be determined on a case-by-case basis, dependent on the characteristics of the waste stream and the receiving POTW. Some municipalities may have published standards for noncategorical, nondomestic discharges. Changes in the composition of the wastestream, due to pretreatment process changes or the addition of new waste streams may require renegotiation of the permit conditions.
	o Create a fire or explosion hazard in the POTW				
	o Are corrosive (pH <5.0)				
	o Obstruct flow resulting in interference				
	o Are discharged at a flow rate and/or concentration that will result in interference				
	o Increase the temperature of wastewater entering the treatment plant that would result in interference but in no case raise the POTW influent temperature above 104°F (40°C)				
	o Discharge must comply with local POTW pretreatment program including POTW-specific pollutants, spill prevention program requirements, and reporting and monitoring requirements		40 CFR 403.5 and local POTW regulations		
	o RCRA permit-by-rule requirements must be complied with for discharges of RCRA hazardous wastes to POTWs by truck, rail, or dedicated pipe		40 CFR 264.71 and 40 CFR 264.72		
Excavation	Area from which materials are excavated may require cleanup to levels established by closure requirements.	Disposal by disturbance of hazardous waste and moving it outside the unit or area of contamination.	40 CFR 264 disposal and closure requirements	Relevant and appropriate	If contaminated materials that are not hazardous wastes are excavated from the site during remediation, the RCRA requirements for disposal and site closure (of the excavated area) become relevant and appropriate. See discussions under Capping, Clean Closure, Closure With Waste in Place, etc.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Excavation (Continued)				Applicable	If the excavated materials can be classified as hazardous wastes, the disposal and closure requirements would be applicable.
	Movement of excavated materials to a previously uncontaminated onsite location and placement in or on land may trigger land disposal restrictions.	Materials containing RCRA hazardous wastes subject to land disposal restrictions.	40 CFR 268 (Subpart D)	Relevant and appropriate	The land disposal restrictions restrict disposal of certain hazardous wastes. If wastes are similar to restricted wastes, then the land disposal restrictions may be relevant and appropriate. The restrictions become effective November 8, 1988, for disposal of CERCLA site-derived wastes.
				Applicable	For CERCLA site-derived wastes which can be classified as restricted hazardous wastes, the restrictions are applicable after November 8, 1988. After this date, land disposal is prohibited for these wastes unless they are treated to defined standards. Chemical characterization of the wastes will be necessary to determine the applicability or relevance of this requirement.
	Devise fugitive and odor emission control plan for this action if existing site plan is inadequate.		CAA Section 101[a] and 40 CFR 52[a]	Applicable	See discussions under Consolidation.
	File an air pollution emission notice (APEN) with state to include estimation of emission rates for each pollutant expected.		40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Include with the filed APEN the following: 1. Modeled impact analysis of source emissions 2. Provide a best available control technology (BACT) review for the source operation	This additional work and information is normally applicable to sources meeting the "major" criteria and/or to sources proposed for nonattainment areas.	40 CFR 52[a]	Relevant and appropriate	See discussions under Consolidation.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Excavation (Continued)	Predict total emissions of volatile organic compounds (VOCs) to demonstrate emissions do not exceed 450 lb/hr, 3,000 lb/day, 10 gal./day, or allowable emission levels from similar sources using reasonably available control technology (RACT).	Source operation must be in an ozone nonattainment area.	40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Verify through emission estimates and dispersion modeling that hydrogen sulfide emissions do not create an ambient concentration greater than or equal to 0.10 ppm.		40 CFR 61[a]	Applicable	See discussions under Consolidation.
	Verify that emissions of mercury, vinyl chloride, and benzene do not exceed levels expected from sources in compliance with hazardous air pollution regulations.		40 CFR 61[a]	Relevant and appropriate	See discussions under Consolidation.
Groundwater Diversion	Excavation of soil for construction of slurry wall may trigger cleanup or land disposal restrictions.	Disposal by disturbance of hazardous waste and moving it outside the unit or area of contamination.	See Consolidation, Excavation in this exhibit.	Relevant and appropriate	If waste materials or contaminated soil which are not hazardous wastes are excavated or otherwise disturbed during the construction of a groundwater diversion structure, the requirements of this section would be relevant and appropriate.
				Applicable	If the excavated wastes or contaminated soil can be classified as hazardous wastes, these requirements would be applicable.
Incineration (Onsite)	Analyze the waste feed.	RCRA hazardous waste.	40 CFR 264.341	Relevant and appropriate	If incineration is selected as a remedial alternative, these requirements would be relevant and appropriate to the disposal by incineration of nonhazardous site wastes. The wastes would have to be analyzed prior to incineration to ensure that the wastes cannot be classified as hazardous wastes.
	Dispose of all hazardous waste and residues including ash, scrubber water, and scrubber sludge.		40 CFR 264.351		

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Actions^b	Requirements	Prerequisites	Citation	ARAR	Comments
Incineration (Onsite) (Continued)	No further requirements apply to incinerators that burn only wastes listed as hazardous solely by virtue of the characteristic of ignitability, corrosivity, or both; or the characteristic of reactivity if the wastes will not be burned when other hazardous wastes are present in the combustion zone; and if the waste analysis shows that the wastes contain none of the hazardous constituents listed in Appendix VIII which might reasonably be expected to be present.		40 CFR 264.340	Applicable	If wastes to be incinerated can be classified as hazardous wastes, the requirements of 40 CFR 264.341, 351, and 340 would be applicable.
	Performance standards for incinerators:				
	o Achieve a destruction and removal efficiency of 99.99 percent for each principal organic hazardous constituent in the waste feed and 99.9999 percent for dioxins		40 CFR 264.343		
	o Reduce hydrogen chloride emissions to 1.8 kg/hr or 1 percent of the HCl in the stack gases before entering any pollution control devices		40 CFR 264.342		
	Monitoring of various parameters during operation of the incinerator is required. These parameters include:		40 CFR 264.343		
	o Combustion temperature				
	o Waste feed rate				

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Incineration (Onsite) (Continued)	o An indicator of combustion gas velocity				
	o Carbon monoxide				
	Special performance standard for incineration of PCBs.		40 CFR 761.70		
Operation and Maintenance (O&M)	Postclosure care to ensure that site is maintained and monitored.		40 CFR 264.1	Relevant and appropriate	Postclosure requirements for operation and maintenance of the Kaiser facility are relevant and appropriate to new disposal units with nonhazardous waste or existing units capped in place.
				Applicable	In cases where site wastes are determined to be hazardous wastes and new disposal units are created, the postclosure requirements will be applicable.
Slurry Wall	Excavation of soil for construction of slurry wall may trigger cleanup or land disposal restrictions.	Disposal by disturbance of hazardous waste and moving it outside the unit or area of contamination.	See Consolidation, Excavation in this exhibit.	Relevant and appropriate	See discussions under Consolidation and Excavation.
Surface Water Control	Prevent run-on and control and collect runoff from a 24-hour, 25-year storm (waste piles, land treatment facilities, landfills).	Land-based treatment, storage, or disposal units.	40 CFR 264.251(c)(d) 40 CFR 264.273(c)(d) 40 CFR 264.301(c)(d)	Relevant and appropriate	The requirements for control of run-on and run-off will be relevant and appropriate to all remediation alternatives which manage non-hazardous waste and include onsite land-based treatment, storage, or disposal.
				Applicable	The requirements will be applicable to any remediation measures which include land-based treatment, storage, or disposal of hazardous wastes.
	Prevent overtopping of surface impoundment.		40 CFR 264.221(c)	Relevant and appropriate	This requirement will be relevant and appropriate to the construction and operation of an onsite surface impoundment or to operation of an existing onsite surface impoundment managing nonhazardous wastes.
				Applicable	These requirements would be applicable to the construction or operation of a surface impoundment for the storage or treatment of hazardous waste.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Tank Storage (Onsite)	Tanks must have sufficient shell strength (thickness) and, for closed tanks, pressure controls, to assure that they do not collapse or rupture.	RCRA hazardous waste (listed or characteristic) held temporarily in a tank before treatment, disposal, or storage (40 CFR 264.10).	40 CFR 264.191	Relevant and appropriate	These requirements would be relevant and appropriate to the onsite construction, operation, and maintenance of tanks for the storage or treatment of nonhazardous wastes or waste treatment effluents.
				Applicable	These requirements would be applicable to the onsite construction, operation, and maintenance of tanks for the storage or treatment of hazardous wastes or effluents from the treatment of hazardous wastes or for the storage of hazardous substances used in treatment processes.
	Waste must not be incompatible with the tank material unless the tank is protected by a liner or by other means.		40 CFR 264.192		
	Tanks must be provided with secondary containment to prevent releases.		40 CFR 264.193		
	Tanks must be provided with controls to prevent overfilling and sufficient freeboard maintained in open tanks to prevent overtopping by wave action or precipitation.		40 CFR 264.194		
	Inspect the following: overfilling control, control equipment, monitoring data, waste level (for uncovered tanks), tank condition, above-ground portions of tanks (to assess their structural integrity), and the area surrounding the tank (to identify signs of leakage).		40 CFR 264.195		

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Tank Storage (Onsite) (Continued)	Repair any corrosion, crack, or leak.		40 CFR 264.196		
	At closure, remove all hazardous waste and hazardous waste residues from tanks, discharge control equipment, and discharge confinement structures.		40 CFR 264.197		
	Store ignitable and reactive waste so as to prevent the waste from igniting or reacting. Ignitable or reactive wastes in covered tanks must comply with buffer zone requirements in "Flammable and Combustible Liquids Code," Tables 2-1 through 2-6 (National Fire Protection Association, 1976 or 1981).		40 CFR 264.198		
	Design system to operate odor-free.		CAA Section 101[a] and 40 CFR 52[a]	Applicable	See discussions under Consolidation.
	File an air pollution emission notice (APEN) with state to include estimation of emission rates for each pollutant expected.		40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Include with the filed APEN the following: 1. Modeled impact analysis of source emissions 2. Provide a best available control technology (BACT) review for the source operation	This additional work and information is normally applicable to sources meeting the "major" criteria and/or to sources proposed for nonattainment areas.	40 CFR 52[a]	Relevant and appropriate	See discussions under Consolidation.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Tank Storage (Onsite) (Continued)	Predict total emissions of volatile organic compounds (VOCs) to demonstrate emissions do not exceed 450 lb/hr, 3,000 lb/day, 10 gal./day, or allowable emission levels from similar sources using reasonably available control technology (RACT).	Source operation must be in an ozone nonattainment area.	40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Verify through emission estimates and dispersion modeling that hydrogen sulfide emissions do not create an ambient concentration greater than or equal to 0.10 ppm.		40 CFR 61[a]	Applicable	See discussions under Consolidation.
	Verify that emissions of mercury, vinyl chloride, and benzene do not exceed levels expected from sources in compliance with hazardous air pollution regulations.		40 CFR 61[a]	Relevant and appropriate	See discussions under Consolidation.

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Actions^b	Requirements	Prerequisites	Citation	ARAR	Comments
Treatment	Standards for miscellaneous units (long-term retrievable storage; thermal treatment other than incinerators; open burning; open detonation; chemical, physical, and biological treatment units using other than tanks; surface impoundments; or land treatment units) require new miscellaneous units to satisfy environmental performance standards by protection of groundwater, surface water, and air quality and by limiting surface and subsurface migration.	Use of other units for treatment of hazardous wastes. These units do not meet the definitions for units regulated elsewhere under RCRA.	40 CFR 264 (Subpart X)	Relevant and appropriate	The requirements will be relevant and appropriate to the construction, operation, maintenance, and closure of any miscellaneous treatment unit (a treatment unit that is not elsewhere regulated) constructed for treatment and/or disposal of nonhazardous site wastes.
				Applicable	These requirements would be applicable to the construction and operation of a miscellaneous treatment unit for the treatment and/or disposal of hazardous wastes.
	Treatment of wastes subject to ban on land disposal must attain levels achievable by best demonstrated available treatment technologies (BDAT) for each hazardous constituent in each listed waste.	Effective date for CERCLA actions November 8, 1988, for F001-F005 hazardous wastes, dioxin wastes, and certain "California List" wastes. Other restricted wastes will have different effective dates as to be promulgated in 40 CFR 268.	40 CFR 268 (Subpart D)	Applicable	These requirements are applicable to the disposal of any site wastes which can be defined as restricted hazardous wastes.
				Relevant and appropriate	These requirements are relevant and appropriate to the treatment prior to land disposal of any site wastes which contain components of restricted wastes in concentrations which make the site wastes similar to the regulated wastes. The requirements specify levels of treatment which must be attained prior to land disposal. The only restriction likely to affect the Kaiser facility is one of the California List restrictions. California List Wastes--effective Date November 8, 1988.* Liquid wastes with pH < 2--Treatment to achieve pH J 2. *Other California List Wastes will be restricted from land disposal after July 8, 1989.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Treatment (Continued)	Devise fugitive and odor emission control plan for this action.		CAA Section 101[a] and 40 CFR 52[a]	Applicable	See discussions under Consolidation.
	File an air pollution emission notice (APEN) with state to include estimation of emission rates for each pollutant expected.		40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Include with the filed APEN the following: 1. Modeled impact analysis of source emissions 2. Provide a best available control technology (BACT) review for the source operation	This additional work and information is normally applicable to sources meeting the "major" criteria and/or to sources proposed for nonattainment areas.	40 CFR 52[a]	Relevant and appropriate	See discussions under Consolidation.
	Predict total emissions of volatile organic compounds (VOCs) to demonstrate emissions do not exceed 450 lb/hr, 3,000 lb/day, 10 gal./day, or allowable emission levels from similar sources using reasonably available control technology (RACT).	Source operation must be in an ozone nonattainment area.	40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Verify through emission estimates and dispersion modeling that hydrogen sulfide emissions do not create an ambient concentration greater than or equal to 0.10 ppm.		40 CFR 61[a]	Applicable	See discussions under Consolidation.
	Verify that emissions of mercury, vinyl chloride, and benzene do not exceed levels expected from sources in compliance with hazardous air pollution regulations.		40 CFR 61[a]	Relevant and appropriate	See discussions under Consolidation.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Underground Injection of Wastes and Treated Groundwater[d]	UIC program prohibits:		40 CFR 144.12	Relevant and appropriate	If underground injection of nonhazardous wastes is selected, the requirements for construction, operation, and maintenance will be relevant and appropriate.
	o Injection activities that allow movement of contaminants into underground sources of drinking water (USDW) and results in violations of MCLs or adversely affects health			Applicable	If any wastes extracted from the site or any treatment residues generated at the site can be classified as hazardous wastes, the construction, operation, and maintenance requirements would be applicable to the disposal of these wastes by underground injection.
	o Construction of new Class IV wells and operation and maintenance of existing wells		40 CFR 144.13		The permitting and reporting requirements of the Underground Injection Control Program are not applicable or relevant and appropriate to the construction and operation of an underground injection well located completely within the boundaries of the site. Some permitting and reporting requirements may become applicable if the lateral area of the zone of injection, when projected to the ground surface, extends beyond the site boundaries.
	Wells used to inject contaminated groundwater that has been treated and is being reinjected into the same formation from which it was withdrawn are not prohibited if activity is part of CERCLA or RCRA actions.		40 CFR 144.14		
	All hazardous waste injection wells must also comply with the RCRA requirements.		40 CFR 144.16		
	The director of a state UIC and treated groundwater program may lessen the stringency of 40 CFR 144.23 construction, operation, and manifesting requirements for a well if injection does not occur into, through, or above a USDW or if the radius of endangering influence [see 40 CFR 146.06(c)] is less than or equal to the radius of the well.		40 CFR 144.21		

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[d] Class I wells and Class IV wells are the relevant classifications for CERCLA sites. Class I wells are used to inject hazardous waste beneath the lowermost formation containing, within 1/4 mile, an underground source of drinking water (USDW). Class IV wells are used to inject hazardous or radioactive waste into or above a formation which, within 1/4 mile of the well, contains an underground source of drinking water.

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Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Underground Injection of Wastes and Treated Groundwater[d] (Continued)	Owners and operators must:		40 CFR 144.26		
	o Submit inventory information to the director of the UIC program for the state, including hydrogeologic data for wells, construction record, nature or composition of injected fluids, injection rate and pressure, and groundwater monitoring data		40 CFR 144.27		
	o Report noncompliance orally within 24 hours		40 CFR 144.28		
	o Prepare, maintain, and comply with plugging and abandonment plan				
	Monitor Class 1 wells by:				
	o Frequent analysis of injection fluid				
	o Continuous monitoring of injection pressure, flow rate, and volume				
	o Installation and monitoring of groundwater monitoring wells				
	Applicants for Class 1 permits must:		40 CFR 144.55		
	o Identify all injection wells within the area of review				
	o Take action as necessary to ensure that such wells are properly sealed, completed, or abandoned to prevent contamination of USDW				

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Underground Injection of Wastes and Treated Groundwater[d]	Criteria for determining whether an aquifer may be determined to be an exempted aquifer include current and future use, yield, and water quality characteristics.		40 CFR 146.4		
	Case and cement all Class 1 wells to prevent movement of fluids into USDW, taking into consideration well depth, injection pressure, hole size, composition of injected waste, and other factors.				
	Conduct appropriate logs and other tests during construction and a descriptive report prepared and submitted to the UIC program director.				
	Injection pressure may not exceed a maximum level designed to ensure that injection does not initiate new fractures or propagate existing ones and cause the movement of fluids into a USDW.		40 CFR 146.13		
	Continuous monitoring of injection pressure, flow rate and volume, and annular pressure is required.				

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Waste Pile	Use liner and leachate collection and removal system.	RCRA hazardous waste, noncontainerized accumulation of solid, nonflammable hazardous waste that is used for treatment or storage.	40 CFR 264.251	Relevant and appropriate	The requirements for construction, operation, and monitoring of a liner and leachate collection system would be relevant and appropriate to a new waste pile constructed in a previously uncontaminated area and containing nonhazardous waste at the site. Waste piles may be used only for temporary storage of wastes or for waste treatment. Waste piles may not be used for permanent disposal.
				Applicable	If any of the wastes excavated from the site can be classified as hazardous wastes, these requirements would be applicable to their storage or treatment in waste piles.
	Devise fugitive and odor emission control plan for this action.		CAA Section 101[a] and 40 CFR 52[a]	Applicable	See discussions under Consolidation.
	File an air pollution emission notice (APEN) with state to include estimation of emission rates for each pollutant expected.		40 CFR 52[a]	Applicable	See discussions under Consolidation.
	Include with the filed APEN the following: 1. Modeled impact analysis of source emissions 2. Provide a best available control technology (BACT) review for the source operation	This additional work and information is normally applicable to sources meeting the "major" criteria and/or to sources proposed for nonattainment areas.	40 CFR 52[a]	Relevant and appropriate	
	Predict total emissions of volatile organic compounds (VOCs) to demonstrate emissions do not exceed 450 lb/hr, 3,000 lb/day, 10 gal./day, or allowable emission levels from similar sources using reasonably available control technology (RACT).	Source operation must be in an ozone nonattainment area.	40 CFR 52[a]	Applicable	See discussions under Consolidation.

POTENTIAL ACTION-SPECIFIC ARARs
FOR THE
KAISER ALUMINUM/MEAD WORKS

Actions[b]	Requirements	Prerequisites	Citation	ARAR	Comments
Waste Pile (Continued)	Verify through emission estimates and dispersion modeling that hydrogen sulfide emissions do not create an ambient concentration greater than or equal to 0.10 ppm.		40 CFR 61[a]	Applicable	See discussions under Consolidation.
	Verify that emissions of mercury, vinyl chloride, and benzene do not exceed levels expected from sources in compliance with hazardous air pollution regulations.		40 CFR 61[a]	Relevant and appropriate	See discussions under Consolidation.