UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE: 1983

SUBJECT: Review of Kaiser, Mead, Draft RAMP

FROM: Neil Thompson NET 1/1
Superfund Site Management Section, M/S 524

TO: Addressees below

Attached is a copy of the draft RAMP for Kaiser Aluminum, Mead Works. We request your review and comments on the report. Please return your comments by July 29, 1983 for consolidation and delivery to NUS Corporation. It normally requires three weeks from the receipt of comments to complete a final RAMP.

Attachment

Addressees:
Chuck Findley, Superfund Coordinator
Bill Schmidt, Field Operations Section
Roy Jones, Drinking Water Program
Dick Burkhalter, DOE Industrial Section
Jim Malm, DOE Eastern Regional Office

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D-31-4-3-5
KM-5-D

REMEDIAL ACTION MASTER PLAN

KAISER ALUMINUM & CHEMICAL CORPORATION MEAD WORKS

MEAD, WASHINGTON

EPA WORK ASSIGNMENT
NUMBER 01-0V18.0
EPA CONTRACT NUMBER 68-01-6699

NUS PROJECT NUMBER 0701.45

JUNE 1983

NUS CORPORATION

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Cliff Mine Road
Pittsburgh, PA 15275
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SUBMITTED FOR NUS BY:

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EXECUTIVE SUMMARY

This Remedial Action Master Plan (RAMP) for the Kaiser Aluminum and Chemical Corporation, Mead Works (hereafter referred to as Kaiser, Kaiser-Mead, or Kaiser-Mead Works) will serve as a record of the remedial actions taken to date and will determine whether these actions have been adequate to solve the contamination problems associated with the site. It contains the information on actions taken to date and recommends additional actions that may be needed.

Site Description

The Kaiser-Mead plant site is located about 1 mile south of Mead, Washington, in eastern Washington. The site is situated on a tract of land with an area of approximately 240 acres. The plant was built in 1942 and was originally operated by ALCOA. In 1946, Kaiser Aluminum and Chemical Corporation purchased the site and has operated it through the present day.

From 1942 until 1978, pot-linings were disposed of on site on an uncovered plot of ground in the northwest section of the plant property. Additionally, the pots were soaked with water in this vicinity in order to loosen the linings for removal from the pot prior to disposal. This water as well as any precipitation which seeped through the pile could soak into the soils beneath and around the pile.

In the spring of 1978, it was discovered that the groundwater was contaminated with cyanide. The Washington State Department of Ecology (DOE) ordered Kaiser to comply with the following:

1. Cease water soaking of the pot sections until a DOE approved water treatment system is installed and operating.

2. Prevent wastewaters containing more than 50 ppb of cyanide from entering state water (surface and groundwaters).

3. Wastewaters treated for cyanides shall not be discharged or dispersed without prior written approval by DOE.

Kaiser's NPDES permit was also modified to prohibit discharge of sanitary wastes into the sludge lagoon in an effort to reduce further leaching of cyanide from existing ground contamination. Additionally, the Spokane County Health District (SCHD) ordered Kaiser-Mead to cease the discharge of pot-soaking water and to implement a process to prevent precipitation from leaching through the pile of waste pot-linings.

Kaiser-Mead, with the aid of its consultants, Robinson & Noble and Hart-Crowser, prepared plans to remediate the problem. The plans called for the following:

1. A temporary covering of the waste pot-lining pile with a permanent installation to be provided as soon as weather conditions permitted.

2. A building for storage of future waste pot-linings.

3. A groundwater monitoring program.

4. An immediate remedial measure to provide bottled water to those families whose wells were contaminated. This was followed with an offer by Kaiser-Mead to the affected families to provide (1) public water, (2) deionizers for each home, or (3) new wells drilled into the uncontaminated zone of the aquifer.

5. Medical examinations for those families requesting them.

The analytical results from the ongoing groundwater monitoring program have been utilized to identify the plume of contaminated groundwater. The plume has been estimated to vary in width from 800 to 1500 feet and extends approximately 2.5 miles in a northwesterly direction from the plant site. The significant groundwater supply in the area occurs in the Spokane-Rathdrum Prairie Aquifer, which was designated by the U. S. Environmental Protection Agency (EPA) as a "Sole Source" aquifer under Public Law 93-5V3 of the 1974 Federal Safe Drinking Water Act. The aquifer discharges to the Little Spokane River.

Kaiser-Mead's ongoing monitoring program has indicated that in most monitoring and/or private wells the free cyanide residuals are beginning to show a leveling off or decreasing trend. However, it is still too soon to state positively that the remedial measures taken by Kaiser-Mead will allow the cyanide to be diminished to, or approach, background concentrations.

Samples taken from the Little Spokane River upstream and downstream of the point where the aquifer enters the river have not indicated a significant increase in cyanide concentrations. A study of the fish in the river indicates that they have not been stressed or suffered from the cyanide present in the water.

Contaminated soils appear to be contained within the fenced-in area of the Kaiser-Mead plant. Further, these soils are, for the most part, under the asphalt-covered waste pot-lining pile or under the concrete slabs to the south of the pile. Recently, another spot was found to contain waste pot-linings. Plans will be made to properly control any contamination from this source.

The remedial actions taken to date by Kaiser have isolated the known sources of cyanide contamination and should prevent continued exposure of the groundwaters from more cyanide. Further, there are at present no known users of the groundwater in the area of the identified plume. The private wells that were contaminated have been replaced by a public water supply (with the exception of one owner who opted for a new, deeper well). The surface waters do not appear to be contaminated. Fish and stream vegetation do not appear to have been affected. Likewise, airborne contamination does not appear to be of concern. The only known risk would be the use of the contaminated groundwater as a drinking water supply and, as stated, there are no known users of the affected groundwater.

It appears that it would be premature to judge whether the remedial actions will completely control the problem. The Kaiser-Mead groundwater monitoring program should be continued for an undefined period to determine whether the cyanide contamination will decrease and indeed approach background levels. There is some concern that additional unknown sources may be located on site. Kaiser should be encouraged to continually search for, isolate, and eliminate any source of contamination. This should include continued investigation to determine if any sources of water (process, precipitation, storm, etc.) can contact the contaminated soils. If sources are found, they should be eliminated.

At this point, it appears impossible to estimate how long it may take to purge the cyanide from the aquifer. There is a decreasing trend in free cyanide, but occasional increases in or leveling off of cyanide concentrations make it impossible to estimate the time needed. Ongoing analytical results should be closely observed to determine if trends are occuring which may aid in predicting the period of time needed to bring the concentrations down to background levels.

1.0 INTRODUCTION

This Remedial Action Master Plan (RAMP) is prepared in accordance with the rules of the National Contingency Plan (NCP) (F.R. Vol. 47 No. 137, July 16, 1982) published pursuant to Section 105 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980. Remedial actions are those responses to sites on the National Priorities List that prevent or mitigate the release of hazardous substances. The specific aspects of remedial actions are presented as Phase VI, Section 300.68 of the NCP.

The RAMP will be the basis of a scoping decision to be made by the lead agency (EPA or other agency) for requesting funding for remedial actions. In addition, this RAMP and subsequent revisions will serve as the basis of the workscope under the U.S. EPA - State agreements or contracts and as the primary planning document for all remedial action activities at the site and for all related enforcement activities.

This RAMP has been prepared exclusively from existing information. This information includes sampling data; maps and topological information; plant documents; consultant reports; and previous regulatory and remedial actions.

2.0 THE SITE

2.1 Location

The Kaiser Aluminum & Chemical Corporation, Mead Works, (hereafter referred to as Kaiser, Kaiser-Mead, or Kaiser-Mead Works) is located approximately 7 miles north of downtown Spokane, Washington, and about 1 mile south of Mead, Washington, in eastern Washington. To the northwest, at a distance of 2.5 miles from the plant, is the Little Spokane River, which flows westward into the Spokane River. Located about 1.5 miles north-northeast of the plant is Peone Creek (Deadman Creek), which flows westward into the Little Spokane River.

The Kaiser-Mead plant is bordered on the west and northwest by U.S. Highway 2 and on the north by Farwell Road. Parksmith Drive borders the plant site on its eastern side and East Hawthorne Road runs along the southern border of the site. Access to the site is by East Hawthorne Road.

The site lies at 47°45'16" north latitude and 117°22'48" west longitude (U.S.G.S., 1973), within Section 16, Township 26 North, Range 43 East in Spokane County, Washington (Hart-Crowser and Associates, 1980). Figure 2-1 shows the general location of the plant site.

2.2 Site Layout

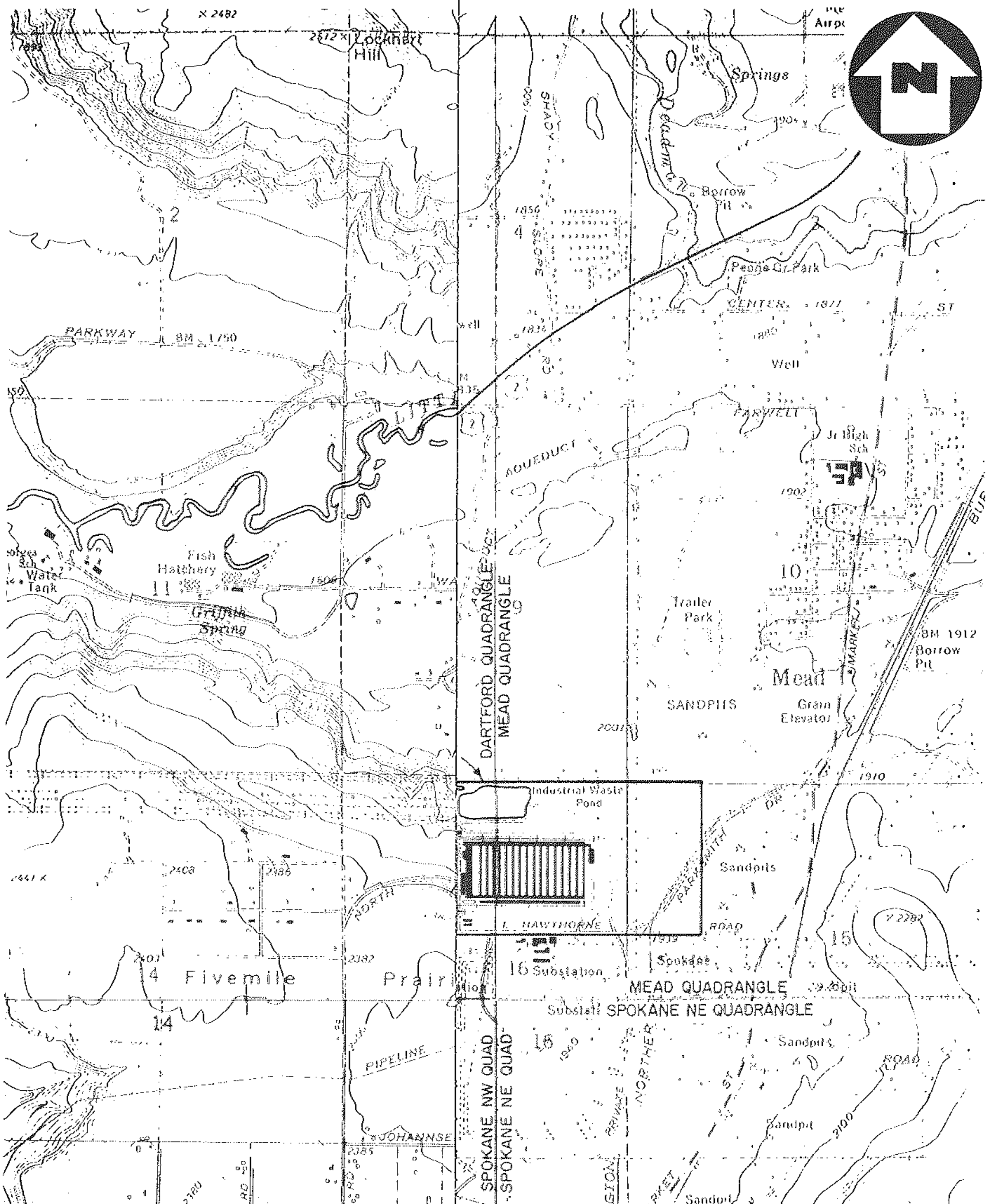
The Kaiser-Mead plant site is situated on a roughly rectangular tract of land with an area of approximately 240 acres. All of the plant production facilities and known waste storage areas are within the confines of the fenced-in portion of the Kaiser property, except for the newly constructed settling basin which is located about one-half mile north of the fence line. The fence-enclosed portion of the Kaiser property is also roughly rectangular, measuring approximately 3900 feet by 2100 feet, with an approximate area of 190 acres. The southern two-thirds of the fenced area is devoted primarily to the aluminum reduction potrooms, supporting production facilities, administrative buildings, and employee parking lots. The northern one-third of the fence-enclosed area is where suspected sources of contamination exist. In the northwest corner of the fenced area is the asphalt-covered pile of pot-linings, the brick and rubble pile, the butt tailings pile, and the pot-lining storage building. Located in the north central portion of the fenced area is the abandoned sludge bed, the abandoned settling basin (Tharpe Lake), the sewage disposal plant, and the area of newly discovered buried pot-linings. Section 5.0 of this RAMP discusses in more detail the areas of the plant site where sources of contamination are known or are suspected to exist (Kaiser Aluminum, Plant Layout Map, 9-22-81).

Northwest of the plant site is the area that has been affected by groundwater contamination. This area is primarily residential, with the nearest housing development located about one-half mile northwest of the plant site. The Kaiser-Mead plant is situated at an elevation of about 1950 feet above mean sea level (MSL). The land terrain northwest of the plant slopes away from the plant and toward the Little Spokane River. About 2 miles northwest of the plant site, the land elevation is about 1800 feet MSL. Over the next one-half mile, to the northwest, the elevation falls sharply to the Little Spokane River, which is at an elevation of less than 1600 feet MSL (U.S.G.S Topographic Map, Dartford, Washington Quadrangle). Section 4.0 of this RAMP discusses in detail the population distributions and land and water uses of this area.

Figure 2-1 illustrates the layout of the Kaiser-Mead plant and the surrounding areas.

2.3 Ownership History

The Kaiser-Mead Aluminum Reduction Plant was built and operated by Alcoa from 1942 until 1946. It was then purchased by the Kaiser Aluminum & Chemical Corporation, which has owned and operated the facility up to, and including, the present. The used pot-linings have been disposed of on site since production began in 1942.



BASE MAP IS A PORTION OF THE FOLLOWING U.S.G.S. QUA

FIGURE 2-1

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2.4 Site Use History

Available information indicates that the Kaiser-Mead plant site has been used solely as an aluminum reduction facility since its construction in 1942. It is presumed that the land was undeveloped before 1942.

2.5 Permit and Regulatory Action History

October 1978

Subsequent to surface and groundwater analyses in the areas surrounding the Kaiser-Mead plant which revealed levels of cyanide substantially greater than those allowed in NPDES Permit No. WA000087-6 issued to Kaiser, and subsequent to submittal and approval of the Spill Prevention and Containment Plan, as required by the permit, the Washington State Department of Ecology (DOE) ordered Kaiser, in accordance with the provisions of RCW 90.48.120(2), to comply with the following:

1) Cease water-soaking of pot sections until a DOE-approved water treatment system is installed and operating.

2) Prevent wastewaters containing more than 50 parts per billion (ppb) of cyanide from entering state water (both surface and groundwaters).

3) Wastewaters treated for cyanides shall not be discharged or disposed of without prior written approval by DOE (D.O. Provost, 10-11-78).

Washington DOE also modified Kaiser's NPDES permit to prohibit discharge of sanitary wastes into the sludge lagoon in an effort to reduce further leaching of cyanide from existing ground contamination. In addition, the Spokane County Health District (SCHD) ordered Kaiser to cease discharge of pot-soaking water and to implement a process to prevent rain from leaching contaminants from the pile of waste pot-linings, possibly by employing a plastic tarpaulin to cover the pile (L. A. Reed, 1-12-79).

November 1978	The SCHD approved Kaiser's plans for sealing the pot-lining pile (F. J. Haydel, 11-6-76).
December 1978	A detailed site investigation by EPA Region X personnel led to the conclusion that no imminent hazard action was warranted at that time (L. A. Reed, 1-12-79).
1978	The EPA designated the Spokane-Rathdrum Aquifer a "sole-source" water supply for the Spokane-Coeur d'Alene area (Hart-Crowser and Associates, 1980).
May 1981	The DOE approved Kaiser's plans for the construction of a pot-lining waste storage building (R. A. Burkhalter, 5-26-76).
August 1981	The EPA clarified the water quality criterion for cyanide to mean 200 µg/l (ppb) free cyanide, that is the sum of HCN and CN^-, and not total cyanide which is the sum of HCN, CN^-, and complexed cyanides (A. B. Rubin, 8-26-81).
September 1982	Kaiser requested that its Mead Works not be nominated to the National Priorities List, citing that the Hazard

	Ranking System overstated the real hazard associated with the situation (D. A. Schmidt, 9-24-82).
November 1982	DOE recommended that the Kaiser-Mead site be removed from the proposed Superfund National Priorities List.
December 1982	Kaiser requested withdrawal of its Mead Works from nomination to the National Priorities List.
December 1982	Despite requests by Kaiser and by DOE to have the Kaiser-Mead site withdrawn from nomination to the National Priorities List, the Kaiser-Mead site was listed as one of 418 hazardous waste sites eligible for cleanup funding under Superfund.
January 1983	Citizens involved with litigation against Kaiser withdraw permission from Kaiser, or any of its representatives, for the taking of any water samples from the citizens' premises (L. W. Woods, 1-28-83).

2.6 Remedial Actions to Date

April 1978	Robinson and Noble, Inc., consultants to Kaiser-Mead, released a report indicating that leachate from waste materials at Kaiser-Mead had entered the local groundwater (Robinson & Noble, 5-1-79).
May 1978	A sampling network of 18 wells and springs within a three-mile radius of the Kaiser-Mead plant was established. Cyanide was found in water from private wells northwest of the plant (Robinson & Noble, 5-1-79).

June 1978 — Kaiser detected abnormally high levels of cyanide, nitrate, fluoride, and sulfate, as well as elevated groundwater temperature in two monitoring wells located near the pot-lining waste pile and the waste lagoon (L. A. Reed, 3-12-79) (Robinson & Noble, 5-1-79).

August 1978 — Kaiser had informed the appropriate health agencies of the presence of cyanide in the test wells. The Spokane County Health District (SCHD) initiated an extensive sampling program concentrating on the area northwest of the Kaiser-Mead plant (L. A. Reed, 3-12-79) (Robinson & Noble, 5-1-79). Also Kaiser discontinued pot-soaking operations and discontinued the discharge of effluent water into the sewage pond (Hart-Crowser, 9-9-80).

September 1978 — The SCHD contacted residents whose water had been sampled, informing them of the levels of cyanide found in their water and recommending that an alternate water source be considered if the levels exceeded 200 ppb total cyanide. Kaiser contacted the same residents, offered to supply bottled water, and offered physical examinations at Kaiser's expense at a local clinic (L. A. Reed, 3-12-79).

October 1978 — Kaiser offered residents with contaminated wells the options of a permanent hook up to public water, a deionizer for the existing well, or a newly constructed well. One individual opted for the new well, while the 25 other affected well owners chose to be connected to public water (L. A. Reed, 3-12-79).

December 1978 — The Hollman Drilling Corporation drilled six test wells on the Kaiser Mead property and drilled two horizontal drains under the pot-lining waste pile and two horizontal drains under the sludge bed (Robinson & Noble, 5-1-79).

January 1979	The pot-lining waste pile was reshaped and covered with a protective plastic tarpaulin as a temporary measure to isolate the waste pot-linings from any precipitation.
April 1979	The pot-lining waste pile was paved with asphalt. An area adjacent to the north side of the pile was paved and fitted with an underdrain system leading to a lined pond. This area was used to temporarily store waste pot-linings until a more permanent storage area could be established.
May 1979	A report by Robinson & Noble, Inc., concluded that the plume of leachate extended approximately north 70° west from the Kaiser-Mead facility. Leachable cyanide was reported present in the sludge bed and in the pot-lining waste pile, and water infiltration through the waste pile seemed to have created a groundwater mound beneath it. The contamination of soil and groundwater appeared to be restricted to the upper portion of the aquifer. Although the remedial actions taken by Kaiser seemed to have curtailed leachate generation, existing leachate was still intransit to the aquifer and downgradient to the Little Spokane River.
August 1979	The public water hook ups to the affected residents were completed.
May-August 1980	An ecological study of the Little Spokane River was conducted by Hartung and Meier. The study concluded that the cyanide concentrations along a 10-mile stretch

of the river presented no ecological or human health hazards. The study was funded by Kaiser.

June 1980

Hart-Crowser & Associates, consultants to Kaiser, began a groundwater study at the Kaiser-Mead Works. They were to determine the geohydrologic framework in the area, assess the groundwater situation, determine data weaknesses, analyze corrective actions to date, and make recommendations for future geohydrologic studies.

September 1980

Hart-Crowser released a report which concluded that the groundwater contamination was primarily a result of the deposition of the pot-lining waste pile, recharge from the pot-soaking operations, and effluent discharge into the wet scrubber disposal pond (sludge bed). The cyanide distribution beneath the plant was restricted to the upper 40 feet of the aquifer and decreased with depth. Clayey zones were found above the major water table which may perch water, in which case they would be the most practical zones to be purged, if necessary. It was recommended that these zones be further studied.

The cyanide plume was estimated to be 800 feet wide at the plant site, increasing to 1500 feet wide in the area northwest of the plant. Groundwater flow velocities were estimated for the three zones in the upper 40 feet of the aquifer, zones A, B, & C, respectively, and based on these velocities, it was determined that the natural purging of the aquifer would be slower than expected. Additional monitoring and testing was recommended to accurately determine the causes and timing of cyanide decreases.

Other data base weaknesses included a lack of control of groundwater flow patterns and a lack of information on permeabilities of the various zones. Hart-Crowser recommended incorporating selective points into a long-range monitoring plan with monthly sampling, adding 16 test holes to determine a water table contour map, and continuing to limit all plant discharges to the groundwater system.

November 1980 — A core-drilling through the asphalt storage slab indicated that the barrier was effective in preventing leaching of the contaminants, which led to the suspicion that the settling basin (Tharpe Lake) was the source of aquifer contamination.

March 1981 — Additional test wells were drilled. Information from these wells revealed the presence of a clay layer which was perching water and directing it through the contaminated soil under the asphalt covered pot-lining pile.

September 1981 — Subsequent to testing which revealed that the settling basin (Tharpe Lake) was leaking 50-60 gpm of water, which was perched and directed under the pot-lining pile, the settling basin was drained and abandoned. A new, lined settling basin was constructed about one-half mile north of the fence line.

November 1981 — Construction of the pot-lining storage building was completed and the pot-linings which had been temporarily stored on the asphalt slab were transferred to the building.

May 1982 — The well sampling program was revised based on the results of past sampling in the area. The recommended frequency ranged from once every two weeks to once per quarter, depending on the expected rate of change of contamination in each area.

December 1982 — Hart-Crowser released a report which summarized and interpreted the occurrences which had taken place since their first report in September 1980.

During this period, the firm had installed additional wells in the area, made water level measurements in selected wells, analyzed groundwater and surface water samples, and evaluated subsurface pipe leakage. Their work supported the previously developed hydrogeologic model of groundwater contamination, which proposed the following: 1) a column of soil under the pot-lining area was invaded by cyanide; 2) an aquitard was perching and directing water that had leaked from Tharpe Lake into this cyanide contaminated soil; 3) the cyanide was being dissolved and transported by the recharge water as it moved to the regional water table through the soil.

Hart-Crowser reported that since Tharpe Lake was abandoned, the perched water zone has dissipated and the groundwater mound caused by recharge from the settling basin has decayed. The plume of contamination has shifted laterally to a more northerly direction because the groundwater flow beneath the plant has shifted. This, coupled with the draining of the soil column above the water table and the decrease in the amount of cyanide moving downward, has caused the significant changes observed in the groundwater since the basin was abandoned.

The cyanide concentrations in three wells which surround the "head" of the plume are decreasing and should continue to show improvement. Hart-Crowser believes these new trends should continue, indicating an improvement in groundwater quality beneath the plant.

3.0 ENVIRONMENTAL SETTING

3.1 Landforms

The states of Oregon, Washington, and contiguous parts of Idaho and California lie within the Northwestern Volcanic Province (King, 1977). In this province volcanic rocks and structures such as lava plateaus, volcanic cones, and ranges formed by uplifting and folding or block-faulting of volcanic materials, comprise the dominant landforms.

The Kaiser-Mead site is located on the northeast edge of the Columbia Plateau subdivision of the Northwestern Volcanic Province (King, 1977). Within the Columbia Plateau much of the older igneous and metamorphic basement rock has been overspread by younger basaltic lava, part of which is so little deformed as to produce a level plateau topography. The surface prairies in the vicinity of the site indicate level geologic units below. However, in some areas the older basement rocks are revealed by erosion, folding, and uplifting.

Specifically, the Kaiser-Mead plant lies on gently sloping unconsolidated material overlying the Hillyard Trough, a bedrock valley between higher areas of bedrock forming the Orchard Prairie to the east and Five Mile Prairie to the west (Hart-Crowser and Associates, 1980). The land surface slopes gently downward in a northerly direction towards the Little Spokane River Valley. The land has a surface elevation of slightly over 2050 feet at the Spokane City line, approximately 1920 feet at the plant site, and approximately 1600 feet at the river, northwest of the site (Hart-Crowser and Associates, 1980). Topographic features in the vicinity of the site can be seen in Figure 2-1.

3.2 Surface Waters

Storm water runoff from the Kaiser-Mead facility is collected and piped to a settling basin approximately 2000 feet north of the plant. The effluent from the settling basin enters an underground aqueduct which runs approximately 5700 feet northeast from the basin to Peone Creek (also known as Deadman Creek), and discharges to the creek. The creek has its headwaters in the Selkirk Mountains to the northeast.

Peone Creek flows to the northwest and discharges into the Little Spokane River, just north of mile 13.

The Little Spokane River flows from the northeast to the southwest and passes within 2-1/2 miles of the northwest corner of the Kaiser-Mead plant. In this area the flow in the river is almost entirely derived from springs emanating from the outcrop of the Spokane-Rathdrum Prairie Aquifer. Mean flow of the river is about 627 cubic feet per second near Dartford (Drost and Seitz, 1978). The aquifer is further described in Section 3.3.

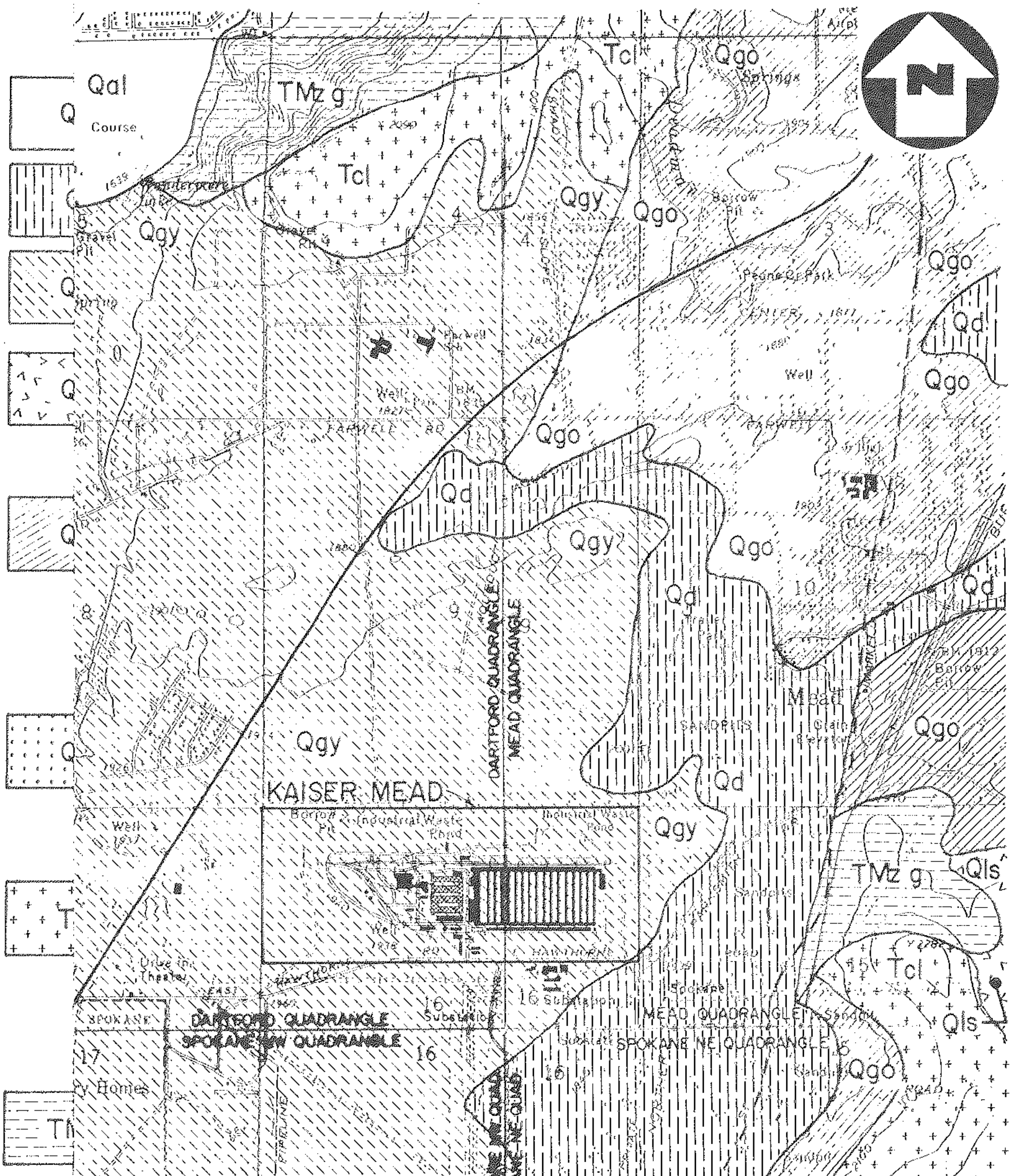
The Little Spokane River enters the Spokane River about 1 mile downstream of the town of Nine Mile Falls, which is about 8 miles northwest of the Kaiser plant.

The Spokane River continues westward until it joins with the Columbia River, about 46 miles northwest from the center of Spokane.

The locations of the Little Spokane River, Peone Creek, and the Kaiser-Mead plant are shown in Figure 2-1.

3.3 Geology and Soils

The surficial geologic units in the Spokane area range in age from alluvial material of the Holocene Epoch, Cenozoic Era, to metamorphic rocks of Precambrian Time. The surficial geology of the Spokane area is shown in Figure 3-1. The surficial geology reflects a complex history of metamorphism, volcanism, and glaciation. Griggs mapped and described the geology of the area in 1973. His descriptions of geologic units, from oldest to youngest, follow.



..., 1973; AND SPOKANE NW, WASH., 1974. GEOLOGY TAKEN FROM GEOLOGIC MAP OF THE SPOKANE QUADRANGLE,

FIGURE 3-1

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The oldest rocks outcropping in the site vicinity belong to the Precambrian Prichard Formation. These metamorphic rocks underly the southern portion of the City of Spokane, just southeast of the area depicted in Figure 3-1. The metamorphosed rocks consist mainly of mica schist, quartz-plagioclase-biotite gneiss, and quartzite.

The next oldest units, which outcrop to the east, north, northwest, and west of the site, are Mid-Mesozoic to early Tertiary Age granite rocks (TMzg). These rocks range from small plutons to batholithic complexes, composed predominantly of quartz monzonite to granodiorite, but also include differentiates ranging from diorite to alaskite. The granite rocks are usually medium- to coarse-grained and in large part porphyritic.

The Columbia River Basalt Group and Latah Formation (TCl) overspread the older metamorphic and granitic rocks during the Miocene and Pliocene Epoch. These units were mapped together in the Spokane area. Older outcropping rocks have been revealed from under the basalt by erosion, folding, and uplifting.

The Columbia River Group consists of flows of dense, dark, tholeiitic basalt, usually from 50 to 150 feet thick, and all essentially flat lying. These basalts welled up through fissures and are considered "plateau or flood basalts." The upper, capping flows are olivine-bearing and the underlying flows are olivine-poor. Included with the basalt, but not shown separately, are the interlayered or underlying lacustrine beds of the Latah Formation. These are poorly indurated siltstone, claystone, sandstone, and minor conglomerate. The exposed thickness of the Columbia River Group ranges from the wedge-out of top flows when they abut mountains and ridges, to as much as 1,000 feet in exhumed valleys.

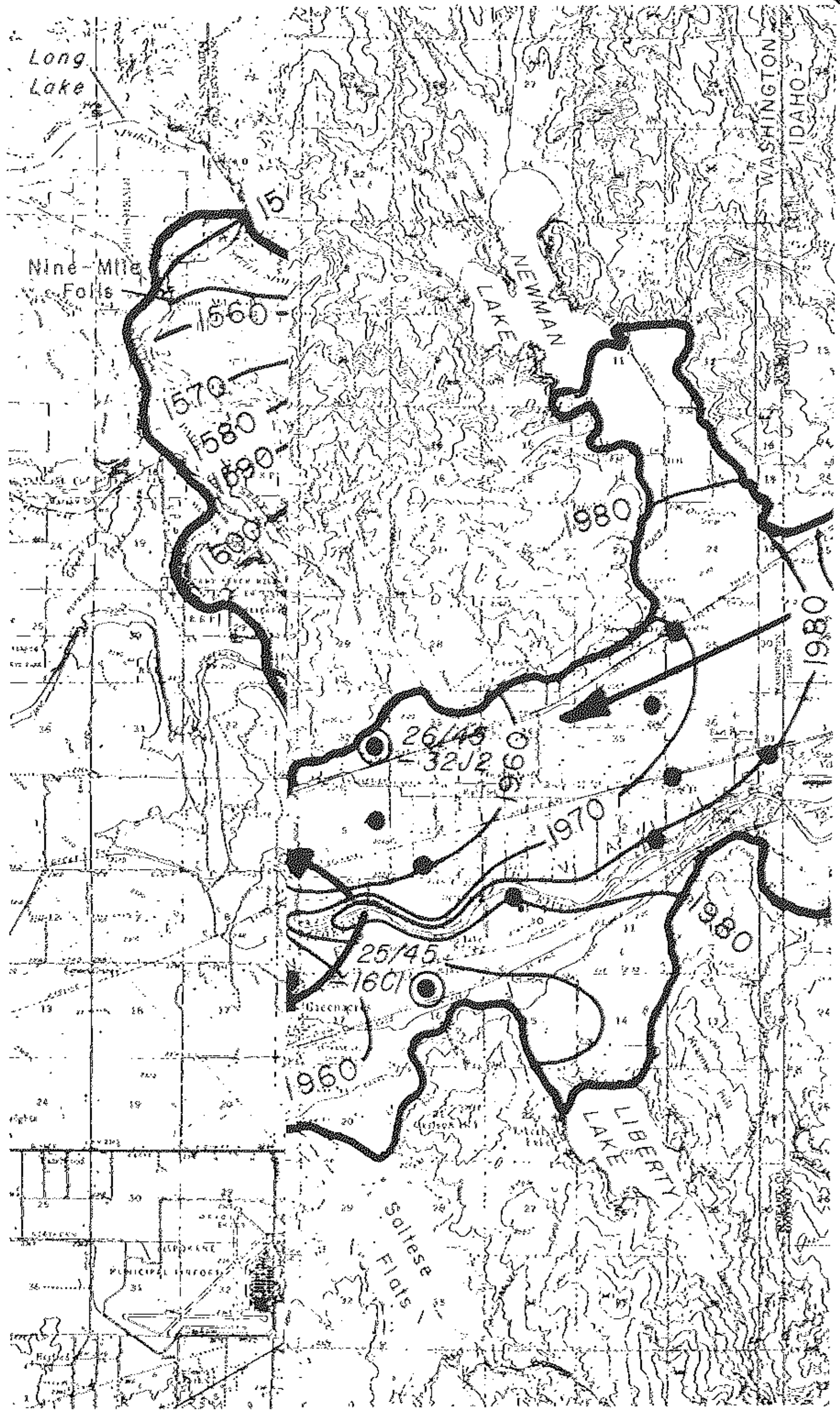
Palouse Formation (Qp) loess deposits of silt and fine sand occur on Five Mile Prairie, and west and southwest of the site. The loess also includes a number of overlapping soil zones of differing ages. Some of the zones have well-developed clay and caliche layers. The Palouse Formation mantles the basalt plateau and the lower, gentler slopes of hills and ridges of pre-Tertiary rock. It has a maximum thickness of 250 feet.

Older glacial deposits (Qgo) occur northeast, northwest, and west of the Kaiser Facility. These deposits are glaciofluvial and glaciolacustrine in origin. They consist of usually stratified and well-sorted deposits of silt, sand, and gravel. They also include some kame deposits and morainal located material along the margins of the Spokane Valley and Rathdrum Prairie to the northeast and in their tributary valleys. In some areas the older glacial deposits are overlain by remnants of Spokane Flood deposits. Remnants of these deposits lie along the margin of the Rathdrum Prairie and Spokane Valley, but these have not been delineated in Figure 3-1.

The flood deposits consist of very poorly sorted gravel laid down in the Pleistocene Epoch. The floodwaters came from Glacial Lake Missoula in northern Idaho and northwest Montana. Ice impounding the glacial lake collapsed, sending water westward towards the Columbia Plateau near Spokane. Some of the water also moved west down the Spokane River and into the Columbia River (McKee, 1972). This water also cut into the basalt bedrock and stripped off much of the underlying loess and older glacial deposits.

Younger Pleistocene Epoch landslide deposits (Qls) are exposed to the east of the site and to the west, along the western boundary of Five Mile Prairie. The deposits are found in areas of slump along valley walls, or surrounding the bluffs and prairies north of Spokane. These deposits consist of broken basalt and tuff of the Columbia River Group and of siltstone and sandstone of the Latah Formation.

Younger glacial deposits (Qgy) of the late Pleistocene consist of glaciofluvial deposits of sand and gravel within the valleys of the Spokane and Little Spokane Rivers. The Spokane-Rathdrum Prairie Aquifer consists of these younger glacial deposits. The extent of the aquifer can also be seen in Figure 3-2.



BASE MAP IS A PORTION OOUNDWATER FLOW DIRECTIONS, AND WATER LEVEL OBSERVATION-WELL LOCAN SEA LEVEL.

LEGEND: —1800 DISCONTINUED OBSERVATION WELL

FIGURE 3-2

GENERALIZED GRM SITE, MEAD, WA

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Just east of the Kaiser-Mead facility are Holocene Epoch sand dunes (Qd). These are reworked glaciofluvial and glaciolacustrine sand and silt. These dunes north of Spokane are elongate in the northeast direction, which indicates they were formed by prevailing southwesterly winds.

The youngest deposits in the area consist of silt, sand, and gravel stream alluvium (Qal) being deposited now, as well as the silt and peat filling in ponds and lakes.

3.4 Groundwaters

The significant groundwater supply in the Spokane area occurs in the Spokane-Rathdrum Prairie Aquifer, an unconsolidated deposit of glaciofluvial origin. The U.S. EPA has designated this aquifer as a "Sole Source" aquifer under Public Law 93-523 of the 1974 Federal Safe Drinking Water Act. This designation gives the responsibility of protecting this aquifer from any detrimental effects caused by any Federally financed projects. Descriptions of its physical characteristics and groundwater flow patterns, regionally and specific to the Kaiser-Mead area, are discussed below.

3.4.1 Physical Characteristics of the Spokane-Rathdrum Prairie Aquifer

The Spokane-Rathdrum Prairie Aquifer lies in eastern Washington and northern Idaho, extending from Lake Pend Orielle in Idaho, through the Spokane Valley, and to the Little Spokane River. It covers an area of approximately 350 square miles ('208' Final Report, 1979). The boundaries of the aquifer in Washington State are shown in Figure 3-2.

The aquifer probably overlies the semiconsolidated, fine-grained Latah Formation in most areas. However, in some areas, the aquifer has abrupt lateral contacts with sloping bedrock surfaces, but in other areas it grades laterally into less permeable unconsolidated materials, which are not easy to distinguish from the aquifer itself.

As shown in Figure 3-2, Five Mile Prairie splits the aquifer into two portions just northwest of Spokane. It is assumed that a basalt rock ridge underlies the prairie and that the aquifer materials are divided around this ridge (Drost and Seitz, 1978).

The aquifer boundaries in the Hillyard Trough are for the most part comprised of flow basalts or granitic intrusives. However, one-half mile south of the Town of Mead to about one mile northwest of the Town of Mead, the boundary is composed of glacio-lacustrine deposits which make up the Peone Prairie (Hart-Crowser & Associates, 1980).

The aquifer is composed of unconsolidated glaciofluvial deposits, consisting mostly of fine to coarse sand and gravel which are poorly to moderately sorted. Cobbles and boulders generally are scattered throughout the aquifer, but some beds are composed almost entirely of cobbles and boulders. A few clay lenses are also scattered throughout the deposit.

The sand and gravel is relatively free of fine sand and silt, except in the uppermost five feet, where fine-grained materials fill the voids in the sand and gravel (Drost and Seitz, 1978).

In the Hillyard Trough, the sediments become progressively finer grained toward the north, where the aquifer is composed mostly of stratified sand, but includes some gravel, some silt, and a few boulders (Drost and Seitz, 1978).

The aquifer thickness has been estimated in several areas. Seismic surveys indicate that it is approximately 400 feet thick near the Idaho-Washington State Line and about 780 feet thick in the Hillyard Trough. A clay-like low permeability formation has been detected below the 310 foot depth. The aquifer thins outward towards its margins (Drost and Seitz, 1978).

The Army Corp of Engineers evaluated other geologic units for potential aquifers adjacent to the Spokane-Rathdrum Aquifer in 1976. The Corps concluded that the igneous and metamorphic rock are capable of supplying only a very sparse population. The basalts yield large quantities of water at some locations, but are unable to sustain the rates due to a low rate of recharge. Glacial drift in the largest valleys, such as in the Little Spokane River Basin, may have enough capacity for water supplies (Drost and Seitz, 1978).

3.4.2 General Hydrologic Characteristics of the Spokane-Rathdrum Prairie Aquifer

The Spokane-Rathdrum Prairie Aquifer receives recharge from several areas, but most inflow is derived from east of Spokane, in Idaho. Drost and Seitz (1978) report that the aquifer receives recharge from the Coeur d'Alene River basin and from lakebed seepage from the Pend Orielle and Hayden Lakes, all in Idaho. It is believed Pend Orielle Lake makes the greatest contribution. In Washington, the aquifer receives recharge in places from the Spokane and Little Spokane River, Hangman Creek, and from the Peone Prairie. Smaller quantities of recharge come from the percolation of surface water runoff, irrigation water, precipitation, and underflow from adjoining highlands.

Figure 3-2 shows the general groundwater flow paths and top of water table elevations. The groundwater flows southwestward from Idaho into Washington, generally westward along the Spokane River Valley. At Spokane the flow is diverted north (into the Hillyard Trough) and northwestward around the basalt ridge underlying Five Mile Prairie. The groundwater flows generally parallel to the trend of the Hillyard Trough. Esvelt (1978) indicates that the path of divergent groundwater flow, south of Five Mile Prairie, may not be a continuous part of the Spokane-Rathdrum Prairie Aquifer. Near the Kaiser-Mead plant, groundwater inflows from the Peone Prairie, east of Mead. This tributary flow alters the flow of groundwater in the Spokane-Rathdrum Prairie Aquifer and causes it to assume a more northwesterly direction.

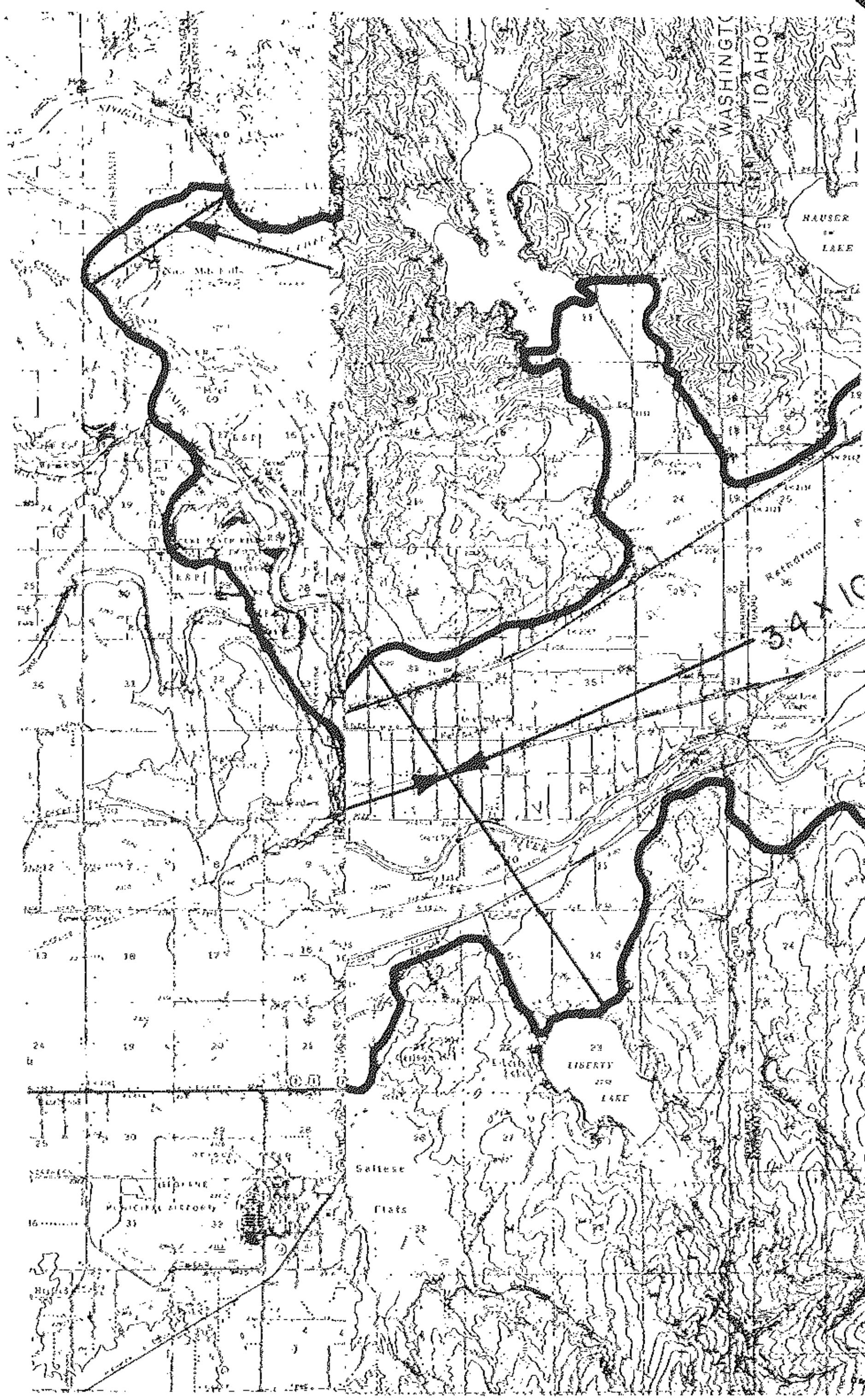
Water flowing northwest from Spokane discharges into the Spokane River and Little Spokane River north of Five Mile Prairie. The water flowing through the Hillyard Trough emerges as springs along the south side of the Little Spokane River.

The water table gradient in the aquifer ranges from about 2 feet per mile to more than 60 feet per mile. The water table is deepest in northern Idaho (300 to 400 feet), becoming gradually shallower downgradient, with depths of about 120 feet at at the Washington-Idaho border and about 40 feet at Spokane. The depth to the water table increases to about 150 feet in the Hillyard Trough. During the year, the water table fluctuates on the order of 5 to 10 feet (Drost and Seitz, 1978).

Estimates of the volume and velocity of flow and aquifer transmissivities have been estimated on several occasions. Generally these estimates indicate that the aquifer permeability decreases from the City of Spokane to the Little Spokane River. Also the flow rates are lower near the periphery of the aquifer.

Drost and Seitz (1978) summarized the estimates made by several agencies. The U.S. Geological Survey (USGS) used a computer model to calculate the transmissivity of the aquifer, which is the rate at which water is transmitted through a unit width of the aquifer under a unit gradient. Values calculated by the USGS ranged from 0.13 million to 11 million square feet per day, based on calculated flow rates, pumping tests, and observed water table gradients. Figure 3-3 shows these calculated rates of transmissivity in several areas of the aquifer within Washington State. The western end of the aquifer has the lowest transmissivity, and the greatest transmissivity of 13 million square feet per day occurs near the Washington-Idaho State line.

Assuming a saturated thickness of the aquifer of 280 feet and an average transmissivity of 3.4 million square feet per day, a water table gradient of 7 feet per mile, and a porosity of 0.25 for the aquifer at the State line, the calculated



BASE MAP IS A PORTION OF PLA 77-829) AS PUBLISHED BY THE U.S. GEOL. SURVEY
AVERAGE TRANSMISSIVITIES RE

LEGEND:

FIGURE 3-3

GENERALIZED AQUIFE, MEAD, WA

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velocity is 64 feet per day. The groundwater velocity in the Hillyard Trough is 47 feet per day, assuming a saturated thickness of 160 feet, a transmissivity of 0.4 million square feet per day, a water table gradient of 30 feet per mile, and a porosity of 0.30 (Drost and Seitz, 1978).

The U.S. Army Corps of Engineers used a different set of aquifer characteristics and calculated the velocities of 90.5 feet per day and 41.1 feet per day at the State line and in the Hillyard Trough, respectively (Drost and Seitz, 1978).

Calculations were also made of the volume of groundwater flow at the State line, in the Hillyard Trough, and recharging and discharging from the aquifer. Drost and Seitz (1978) calculated a groundwater flow volume of about 960 and 350 cubic feet per second at the State line and in the Hillyard Trough, respectively. However, the U.S. Army Corps of Engineers calculated volumes of 1,000 and 200 cubic feet per second, in the respective locations. Robinson and Noble (1979) also indicated a volume of about 200 cubic feet per second flowing through the Hillyard Trough. The current estimates of groundwater flow volume at the State line and in the Hillyard Trough are about one-half those calculated by Drost and Seitz ('208' Final Report, 1979).

The USGS also estimated that 23 cubic feet per second flows into the Hillyard Trough from the Peone and Orchard Prairies (Hart-Crowser and Associates 1980).

The USGS estimated a net discharge from the aquifer to the Spokane and Little Spokane Rivers to be 1,010 to 1,090 cubic feet per second. The Little Spokane river gains approximately 310 cubic feet per second from the aquifer below Dartford. Considering groundwater outflow into underlying formations, pumping losses, and other domestic uses, the aquifer has a total, average natural discharge of about 1,320 cubic feet per second (Drost and Seitz, 1978).

3.4.3 Aquifer Characteristics Determined by Geologic and Hydrologic Investigations at the Kaiser-Mead Site

Detailed investigations of the geologic and hydrologic conditions of the aquifer were conducted at the Kaiser-Mead facility and in the area between the facility and northwest to the Little Spokane River. These investigations were conducted by Robinson and Noble, Inc., followed by additional and ongoing work by Hart-Crowser and Associates, Inc.

The investigation included test borings, monitoring well installations, pump testing, geophysical logging, soil sampling and analysis, and water quality and flow analysis from monitoring wells, test borings, springs, and private domestic wells.

Robinson and Noble (1979) supervised the installation of eight test wells, some of which contain multiple monitoring intervals (TH1 through TH8). A generalized geologic cross-section of the area penetrated by TH1 through TH6 is shown in Figure 3-4. The locations of the monitoring wells discussed in this section are illustrated in Figure 6-1.

The test holes penetrated a stratified section approximately 200 feet deep. The depth to the water table is about 145 feet below ground surface. In the unsaturated zone the sediments consist of sand, silty sand, and occasional gravel, with two relatively-continuous, interbedded clay layers. These finer grained (clayey) zones could act as aquitards and "perch" water above the major water table (Hart-Crowser and Associates, 1980). Moisture tests performed by Robinson and Noble in TH-1 and TH-2 suggest that higher moisture zones exist immediately above these clayey layers.

In 1981 Hart-Crowser and Associates installed seven monitoring wells on top of the aquitard zones to monitor the effects of dewatering and abandoning Tharpe Lake. Hart-Crowser personnel believed that leakage from the basin "perched" on top of these aquitards and flowed into a contaminated soil zone beneath the pot-lining storage area.

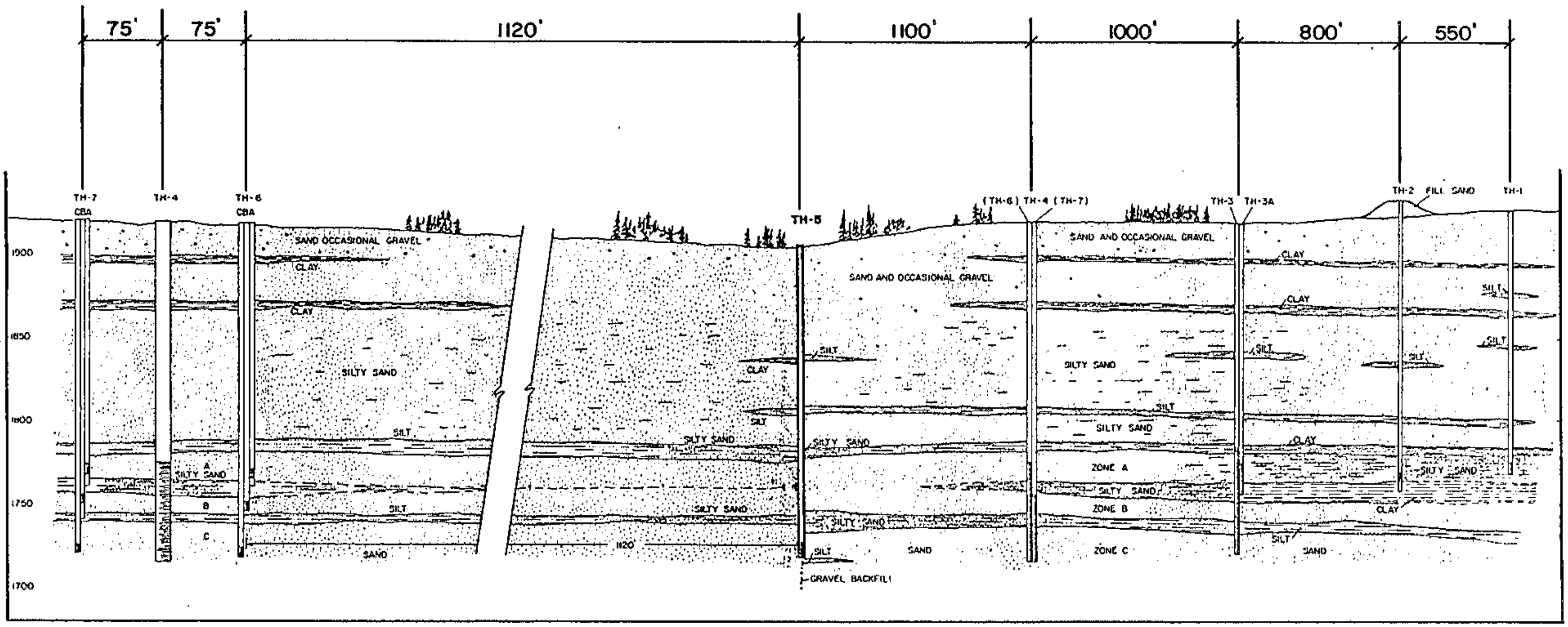

FIGURE REPRODUCED FROM STATUS REPORT OF AQUIFER CONTAMINATION AT KAISER ALUMINUM AND CHEMICAL CORP. MEAD WORKS THROUGH MAY 1, 1979 BY ROBINSON & NOBLE, INC.

FIGURE 3-4

GENERALIZED GEOLOGIC CROSS SECTION KAISER ALUMINUM SITE, MEAD, WA

NO HORIZONTAL SCALE, 1"=100' VERTICAL

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The screens of wells HC1A, HC4, and HC6 were installed on top of a sandy silt to silty clay aquitard at tha depth of about 50 feet. This finer-grained zone varied from several inches to three feet thick. HC2 was installed on top of a silty clay to clayey silt aquitard at a depth of approximately 60 feet. In this well the aquitard is 2 feet thick. Wells HC3, HC5, and HC9 were set on a sandy silt to clayey silt aquitard at a depth of about 70 feet. This aquitard ranged in thickness from 2 1/2 inches to 2 feet.

These finer-grained zones were also detected while installing other wells into the regional aquifer. A layer consisting of sandy silt to silty clay was detected at a depth of approximately 45 feet in wells HC7, HC8, HC12, and HC 14. Water was encountered, during drilling, on top of this zone in the latter two borings. This aquitard layer is several inches thick.

A silty clay to clayey silt zone at about 50 feet was detected in wells HC1, TH1, TH3, TH4, TH7, and TH8. This zone varied from a few inches to 2 feet thick. Water was encountered in HC1 above this zone during drilling.

In wells HC2A, HC10, TH2, and TH5 a silty clay to clay zone was detected from 60 to 65 feet. This layer ranged from a few inches to 2 feet thick. During drilling, water was encountered above this zone in HC2A and HC10.

After Tharpe Lake was drained and abandoned, wells HC1A and HC6 became dry. Also, wells finished in the A zone, in the vicinity of Tharpe Lake, have shown a decline in water levels. Wells close to the basin showed the greatest decline, while wells farther away showed a smaller decline on the order of 0.5 feet (Hart-Crowser & Associates, 1982). The extent and continuity of these finer-grained zones beyond the Kaiser-Mead Site is not certain. The amount of water perched upon these zones depends on seasonal variations and local recharge.

The upper portion of the regional aquifer appears to be vertically stratified into three sandy to silty-sandy zones termed "A", "B", and "C" (Hart-Crowser & Associates, 1980). These zones are separated by two sandy silt and clay aquitards.

Zone A ranges in thickness from 5 feet at TH-6 to 17 feet at TH-3A, and has an average thickness of 12 feet. This zone consists of a silty sand to medium to coarse sand. A 10-foot-thick silty sand and clay aquitard underlies Zone A, from an elevation of approximately 1,760 to 1,750 feet.

Zone B, below the upper aquitard, ranges in thickness from 11 feet at TH-3 to 20 feet at TH-6, and has an average thickness of about 15 feet. This zone consists of relatively clean, medium to coarse sand. The lower aquitard underlies Zone B. This aquitard is also 10 feet thick, existing between elevation 1,740 and 1,730, and consisting of a sandy clay.

Below the lower aquitard is Zone C. It is primarily composed of a medium sand and appears to be part of the major aquifer. The zone may be as much as 80 feet thick beneath the plant site (Hart-Crowser and Associates, 1980).

Water measurements taken in the test holes indicate that the hydraulic heads in each of the zones (as measured in TH-6) are different. The water level in the upper saturated Zone "A" is about 7.5 to 10 feet higher than either the "B" or "C" zone, respectively. The head in the "C" zone is 2 feet higher than the head in the "B" zone, indicating a small amount of artesian pressure (Robinson and Noble, Inc., 1979). Hart-Crowser and Associates (1980) concluded that the differing heads indicate that the groundwater flow is downgradient from Zone "A" to "B" and upgradient from Zone "C" to "B". Water levels in TH-3A, 1000 feet to the southeast of TH-6, also show this relationship. Measurements of water level fluctuations indicate the greatest change in Zone "C" and the least in Zone "A". These fluctuations are believed to be more related to a general rise in the aquifer as a whole (Hart-Crowser Associates, 1980).

The groundwater gradient in the vicinity of the plant is estimated to be 0.005 and increases to greater than 0.009 toward the spring discharge points in response to the aquifer's thinning and becoming less permeable. An average gradient of 0.007 is estimated between the plant and springs (Hart-Crowser and Associates, 1980).

Hart-Crowser and Associates (1980) estimated the permeability of the aquifer to be 19,300 gallons per day per square foot (0.03 feet per second) based upon pumping test data for Kaiser Well No. 6, and 8,700 gallons per day per square foot (0.01 feet per second) for Well 7G2 (Whitworth Municipal Well).

Using an average permeability of 14,000 gallons per day per square foot, a gradient of 0.007, and a specific yield of 0.20, the average groundwater velocity in the aquifer is approximately 65 feet per day (Hart-Crowser and Associates, 1980).

Pumping test data for the TH-8 well indicates that the permeability of the A zone is approximately 1,200 gallons per day per square foot. The "A" zone has a water level gradient of 0.003 (as measured between TH-8 and TH-6A). Using this data, Hart-Crowser and Associates (1980) estimated the flow velocity in the "A" zone to be 3 to 4 feet per day.

Using permeability, aquifer thickness, hydraulic gradient information, and flow path width, it is estimated that 6.3 million gallons per day flow through the "C" zone (portion of the major aquifer) and 34,500 gallons per day flow through the "A" zone (Hart-Crowser and Associates, 1980). Groundwater flow estimates for the "C" zone are approximately 150 to 200 times that in the "A" zone.

Data obtained from springs and private wells northwest of the test holes indicate that the aquitards "pinch out" somewhere between the Kaiser plant and the Pope residential well (8G3), located about 1.2 miles northwest of the plant.

3.4.4 Soils

Figure 3-5 is a map of a portion of the Spokane-Rathdrum Prairie Aquifer showing the soils overlying the aquifer, particularly in the region of the Kaiser-Mead plant.

Drost and Seitz (1978) simplified the 29 soil units, originally mapped by Donaldson and Grease in 1969, into four major types. The descriptions are summarized as follows:

Immediately underlying the site are loamy sand or sandy loam soils. These soils have an infiltration rate of 2.5 to 10.0 inches/hour.

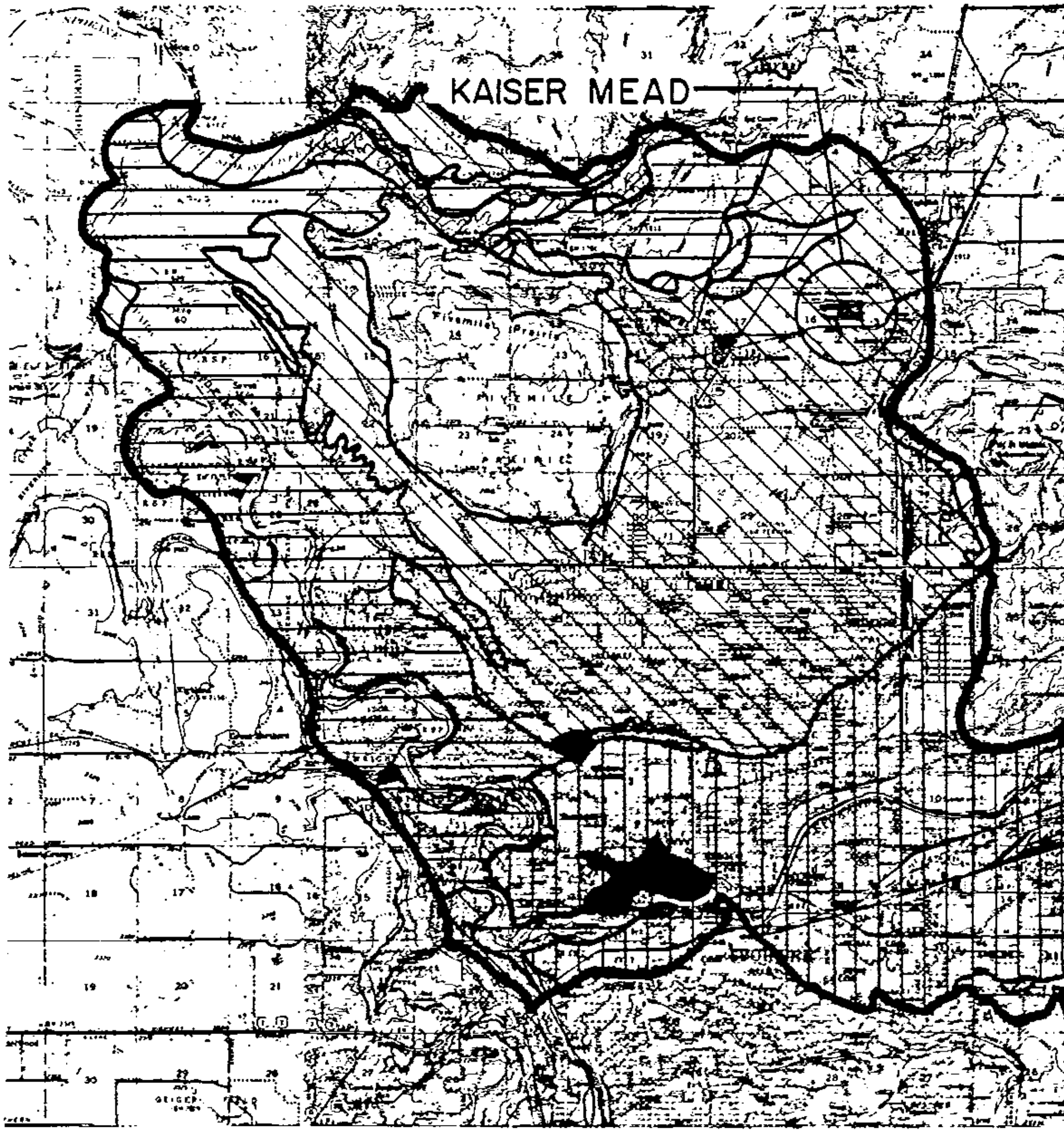
The remaining soils found in the vicinity of the site include a silt loam, silty clay loam or muck (infiltration rate - 0.8 - 2.5 inches/hour), a gravelly sandy loam or gravelly loamy sand (5.0 - >10.0 inches/hour), and a cobbly loam or gravelly loam (2.5 - 5.0 inches/hour). Other areas are still unmapped or bedrock exists near the land surface.

The permeabilities are probably greater below the upper 3 to 6 feet, where general observations indicate an increase proportion of void space and a decrease in fine-grained materials.

The soils were described during the installation of well HC-18 by Hart-Crowser and Associates. The description indicated that the soils consist of predominantly fine to coarse sand, interbedded with relatively thin silt layers, with moisture contents ranging from 2 to 19 percent by weight.

3.5 Climate and Meteorology

According to the National Oceanic and Atmospheric Administration (NOAA), the climate in Spokane, Washington combines some of the characteristics of damp, coastal-type weather and arid interior conditions.



BASE MAP IS A PORTION OF PLATE 5 - MAP OF SPOKANE VALLEY - RATHDRUM PRAIRIE AQUIFER SHOWING SOILS OVERLYING THE AQUIFER (OPEN-FILE REPORT 77-829) AS PUBLISHED BY THE U.S. GEOL. SURVEY

SOIL DESCRIPTION	ESTIMATED INFILTRATION RATE (INCHES/HOUR)
SILT LOAM, SILTY CLAY LOAM OR MUCK	0.8 - 2.5
LOAMY SAND OR SANDY LOAM	2.5 - 10
GRAVELLY, SANDY LOAM OR GRAVELLY, LOAMY SAND	5.0 ->10
COBBLY LOAM OR GRAVELLY LOAM	2.5 - 5.0

SOIL DESCRIPTION	ESTIMATED INFILTRATION RATE (INCHES/HOUR)
BEDROCK AT OR NEAR SURFACE	NEARLY ZERO
UNMAPPED AREAS	-
AQUIFER BOUNDARY	

FIGURE 3-5

SOILS OVERLYING THE SPOKANE - RATHDRUM PRAIRIE AQUIFER KAISER ALUMINUM SITE, MEAD, WA

SCALE: 1" = 2 MILES

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Prevailing westerly and southwesterly circulations bring most of the air masses to the Spokane area. The moisture moving towards Spokane is frequently from the Gulf of Alaska and the eastern Pacific Ocean, but much is precipitated out as the storms are lifted across the Coast and Cascade Ranges. The annual precipitation totals in the Spokane area are generally less than 20 inches and are less than 50 percent of the amounts received west of the Cascades (NOAA, 1981).

Infrequently, dry continental air masses from the north or east influence the Spokane area. When these air masses penetrate into eastern Washington, the result may be high temperatures and very low humidity in the summer and subzero temperatures in the winter.

Generally, the Spokane weather has the characteristics of a mild, arid climate during the summer months and a cold, coastal type in the winter. Approximately 70 percent of the total annual precipitation falls between the first of October and the end of March, half of which falls as snow. The growing season usually extends over nearly six months, from mid-April to mid-October (NOAA, 1981).

Daytime high temperatures in the summer range from 80 to 90°F, and the nighttime lows range from 45 to 60 degrees. In the winter, daytime highs are from 25 to 45 degrees and the nighttime lows range from 15 to 25° ('208' Final Report, 1979).

3.6 Land Use

The land in the vicinity of the Kaiser-Mead facility is used for residential, commercial, recreational, and industrial purposes. The locations of various land users can be seen on the Dartford, Mead, Spokane NW, and Spokane NE USGS 7.5 minute topographic quadranges.

Downtown Spokane is located approximately 7 miles south of the plant, and the town of Mead is located about 1 mile to the northeast. The nearest residential area to the plant is the Camelot development, approximately 1/2 to 1 mile northwest of the site. Additional residences exist at various distances in all directions from the plant.

Several schools exist within approximately 2 miles from the plant, including the Mead Junior High School to the northeast, the Farwell School to the north, the Mead High School and Brentwood School to the northwest, and Whitworth College to the west.

Some of the commercial areas within approximately 2 miles of the Kaiser-Mead plant include sand and gravel quarries, a drive-in theater, a radio facility, and various businesses within Spokane and Mead.

The recreational areas near the plant include Peone Creek Park to the northeast, a park north of the site near the Farwell School, and a golf course to the northwest.

The Kaiser-Mead facility itself includes production facilities, support facilities, administrative buildings, parking lots, and waste storage areas. Other industrial uses for the land in the vicinity of the site include electrical substations and transmission lines, a sewage disposal area to the southwest in Spokane, a magnesium plant to the south, and a refinery about 2 miles to the southeast.

4.0 POTENTIAL RECEPTORS

4.1 Population Distributions

The Kaiser-Mead plant is located about 7 miles north of downtown Spokane, Washington, and about 1 mile southwest of Mead, Washington, in eastern Washington State, less than 20 miles from the Washington-Idaho border.

The population of Spokane County is estimated at 315,800, and the population of the City of Spokane is estimated at 176,900; Mead, Washington, has a population of about 1200 (1981 Rand McNally Road Atlas). The number of people living within a 3-mile radius of the plant site is estimated to be about 10,000. This estimation was obtained by identifying 2700 buildings within a 3-mile radius of the site and assuming 3.8 persons per building (Documentation Records for HRS, 6-28-82).

The nearest residential area to the Kaiser-Mead plant site is the Camelot residential community, which is located 1/2 to 1 mile northwest of the site. (Spokane County Plat Maps). The population of this community is estimated at 200, based on 53 homes with 3.8 persons per home (USGS Topographic Map, Dartford, Washington 7.5 minute quadrangle, 1973).

4.2 Water Users

4.2.1 Groundwater

The site is located above the Hillyard Trough of the Spokane-Rathdrum Aquifer, which has been designated by the EPA as a "Sole Source" water supply for the Spokane-Coeur d'Alene area. The entire Spokane-Rathdrum Aquifer is estimated to supply about 340,000 people with water for domestic use and is virtually the sole domestic water source for the Metropolitan Spokane area ('208' report, 1979).

The groundwater contamination attributed to sources located in the vicinity of the Kaiser-Mead Works affects only a small portion of the entire aquifer.

The idealized plume boundary of contaminated groundwater is estimated to be 2.5 miles long and 800 to 1500 feet wide, extending northwest from the plant site to the Little Spokane River (Hart-Crowser and Associates, 1980). Several residential developments are located within the path of the plume. The number of residents living near the plume is estimated at about 800, assuming a path one mile wide extending northwest from the plant site to the Little Spokane River (developed from USGS Topographic map, Dartford, Washington quadrangle, assuming 3.8 people per building). Only 26 dwellings are known to have had drinking water wells with greater than 200 ppb total cyanide (HRS Worksheet, D. A. Schmidt, 9-23-82). At the present time, no known private or public wells in the plume area, with free cyanide concentrations above the potable standard, are being used as a potable water source (D. Kroll, 10-18-82).

In addition to domestic use, wells within the plume area are used for irrigation and, in one isolated case, as a drinking water supply for sheep (K. Walton-McIndoe, 5-5-82).

4.2.2 Surface Water

The only known surface waters on the plant site are the lined holding pond located adjacent to the west side of the asphalt covered pot-lining pile and the newly constructed settling basin located one-half mile north of the fence line. The holding pond receives surface runoff from the pot-lining pile and adjacent paved areas. The settling basin receives storm water runoff from all plant areas, and receives the spray water used to cool the potrooms. During full production, Kaiser estimates that 2 to 3 million gallons per day of spray water are used, all of which are collected in the storm sewer system and channeled to the settling basin. The effluent from the settling basin is discharged to Peone Creek via an underground aqueduct (Personnel communications with D. A. Schmidt, 4-19-83 and 5-23-83).

Peone Creek, at its nearest point to the plant site, is located approximately 1.5 miles northeast of the plant. Peone Creek flows north and west until its confluence at mile 13 of the Little Spokane River.

The Little Spokane River, at its nearest point, is located about 2.5 miles northwest of the plant. This nearest point is at about mile 10 of the Little Spokane River. From this point the river flows westward until its confluence with the Spokane River.

The Little Spokane River is used for recreational purposes and possibly for drinking water and/or irrigation (Documentation Records for HRS, 6-28-82).

Other surface waters in the vicinity of the Kaiser-Mead plant include the numerous springs which outfall along the south bank of the Little Spokane River and a number of other springs located in the area northwest of the plant, including Wandermere Weir and the Waikiki Springs. As far as available information indicates, none of these springs are utilized for recreational, domestic, or irrigative purposes.

No surface waters, other than those previously identified as on site, are located within 1.5 miles of the Kaiser-Mead plant.

4.3 Land Users

Available information indicates that the Kaiser-Mead plant site is used solely for activities related to the production of aluminum. During the site visits conducted in February and March 1983 for the purpose of preparing this RAMP, it was noted that adequate fencing appears to be provided, preventing public access to all production facilities and waste storage areas on site.

To the south of the Kaiser-Mead plant is a public utility substation surrounded by undeveloped land. One-half mile southeast of the site is located the Spokane Evergreen Cemetery. East of the site is primarily undeveloped land, with a few private residences and some light industry located about 3/4 of a mile away. The land to the northeast is also undeveloped between the plant site and the Town of Mead. There are some sandpits identified about 3/4 of mile east and northeast of the site. North of the site the land is also undeveloped and has been reportedly frequented by off-road motorcyclists. West and northwest of the site the land is undeveloped for about 1/4 to 1/2 mile, beyond which there are numerous residential communities (USGS Topographic Maps, Spokane, Dartford, and Mead 7.5 minute quadrangles).

5.0 HAZARDOUS SUBSTANCES

5.1 Location On Site

Located in the northwest corner of the fence-enclosed area of the plant site is the waste pot-linings storage building. This building is used to store any newly generated waste pot-linings until such time that the pot-linings can be regenerated or can be disposed of in some other manner. The building is roofed to prevent precipitation infiltration of the pot-linings. The building also has an impermeable slab base which is underlain with a polyethylene liner. Any moisture that infiltrates the space between the slab and the liner is sewered to observation points so that immediate action can be taken to divert any waters to a treatment system.

Directly east of the pot-lining storage building are the butt tailings pile and the brick and rubble pile. No hazardous substances are known to exist in the butt tailings pile; however, borings through the brick and rubble pile indicate the presence of pot-lining materials within the pile (Kaiser Well Logs).

Adjacent to the east side of the brick and rubble pile, in the north-northwest portion of the plant site, is the asphalt covered waste pot-linings pile. The pile covers about 6 acres and has relatively steep-sloped sides with a flat top. Any runoff from the pile is collected in asphalt-lined trenches around the perimeter of the pile and is directed to a lined holding pond located directly to the east of the pile. Borings through the asphalt-covered pile indicate that the pile and the soil under it are contaminated with cyanides. In addition, there is an asphalt-covered tract of land adjacent to the north side of the pile which had been used to temporarily store pot-linings while the pot-lining storage building was being completed. The soil quality beneath this asphalt-covered tract of land is unknown. Adjacent to the south side of the asphalt-covered pile is a concrete slab which covers the area where the former pot-soaking and dumping activities had taken place. The soil quality under this concrete slab is unknown; however, it is believed to be contaminated. This concrete slab is also the location of the present pot-dumping activities. Well logs from monitoring wells in the vicinity of this slab show moderate levels of cyanide in the soils.

Directly east of the asphalt covered pot-lining pile is a tract of land in which buried pot-linings were discovered in August 1982. At the time of this writing, these newly discovered pot-linings remain in place on about 15,000 square feet of uncovered land. These pot-linings are buried 12 to 18 inches below the surface and are believed to range from 1 to 5 feet in thickness. The soil below the buried pot-linings has shown cyanide contamination (D. A. Schmidt, 8-25-82). Reportedly, the Washington DOE has the final decision as to what will be done with these linings (D. A. Schmidt, Personal Communications, 4-19-83).

East of the newly discovered buried pot-linings, in the north central portion of the Kaiser-Mead plant, is the abandoned sludge bed. The bed covers about 10 acres and is currently uncovered and unlined. The depth of sludge in the bed is estimated to range from 12 to 27 feet (Hart-Crowser & Associates, Inc., 1980). The log for monitoring well HC17, located in the bed, shows no cyanide contamination though a report by Robinson and Noble, Inc., reported some cyanide contamination at varying depths in the bed.

North of the newly discovered pot-linings is the location of the abandoned settling basin (Tharpe Lake), which had covered about 18,000 square feet. After the basin was drained and abandoned in September 1981, it was backfilled with soil. The quality of the soil under the abandoned settling basin is unknown, although slight cyanide contamination of the soil around the basin has been shown.

In addition to these identified areas of contamination, the possibility exists that presently unidentified areas of buried pot-linings or of soil contamination may exist on site.

Section 6.0 of this RAMP discusses in detail the levels of contamination in these areas.

Figure 5-1 illustrates the areas of soil contamination and pot-lining deposition discussed herein.

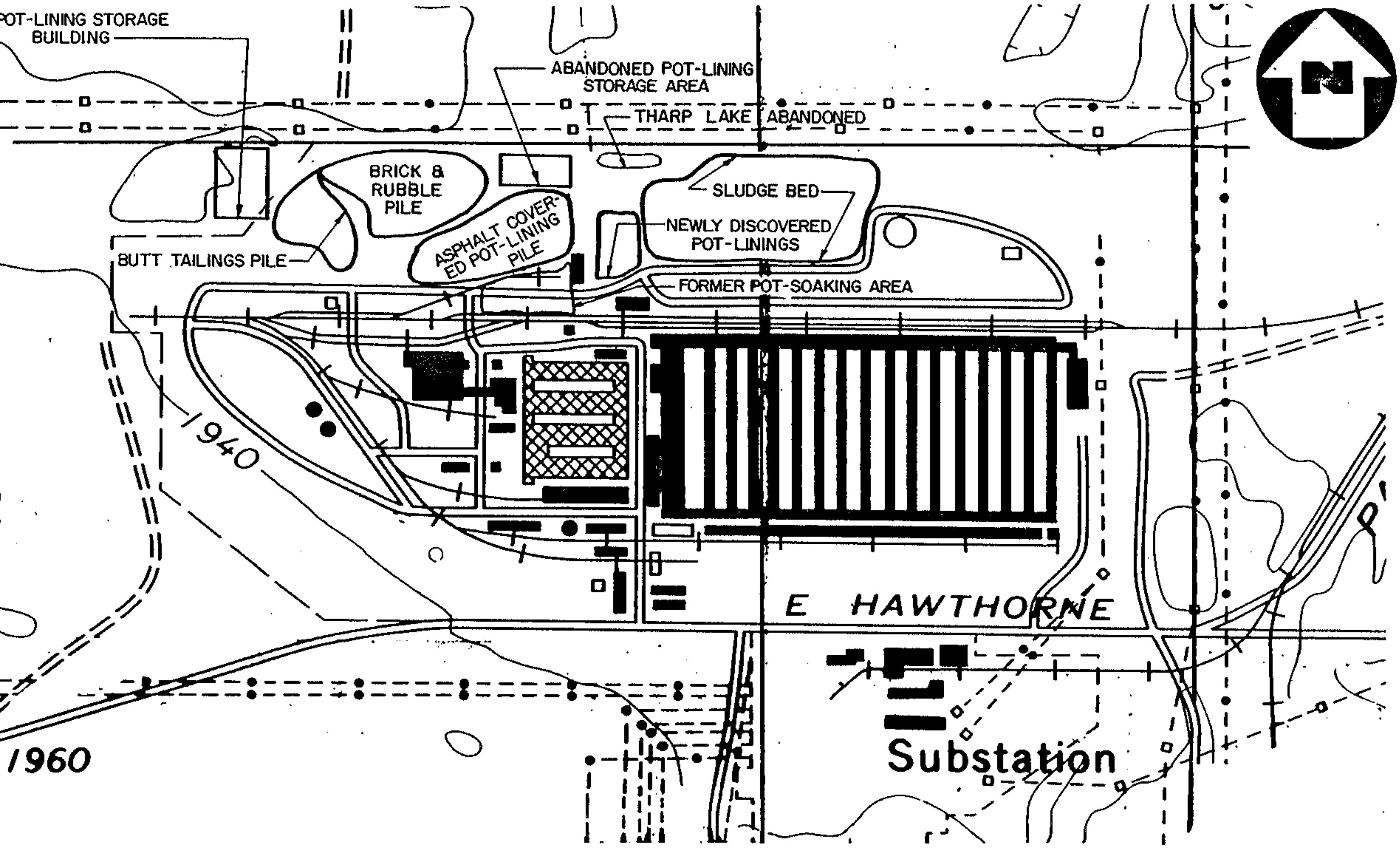

FIGURE 5-1

GENERAL ARRANGEMENT
KAISER ALUMINUM SITE, MEAD, WA
NOT TO SCALE

NUS CORPORATION
A Halliburton Company

5.2 Physical, Chemical, and Hazardous Characteristics

5.2.1 Form

The hazardous substances identified at the Kaiser-Mead Works are in the form of wasted pot-linings removed from aluminum reduction pots. These pot-linings exist as a solid and consist primarily of carbon, fluorides of aluminum and sodium, silicon, iron, and cyanides. The cyanides are estimated to be present in the pot-lining material at levels ranging from 0.1 to 0.5 percent by weight, with an average level of about 0.2 percent by weight (E. M. Pickett, 12-13-78), (Kroll, 10-5-82).

In addition to the pot-linings, there are areas in which the soil has been contaminated by cyanide as a result of exposure to pot-soaking liquors or pot-lining leachate.

5.2.2 Chemical Compounds

The term "cyanide" is very general and has been used to refer to any compound containing the cyano group, which consists of a nitrogen atom triple bonded to a carbon atom. In the context of this report, three classes of cyanides will be considered: free cyanide, simple cyanide, and complex cyanide.

Free cyanide refers to hydrogen cyanide and its dissociation products. Hydrogen cyanide (HCN) is a weak acid which can dissociate in solution to the hydronium ion and the cyanide ion as shown in equation (1):

$$HCN \rightleftarrows CN^- + H^+ \qquad (1)$$

The degree to which the dissociation takes place is strongly dependent on the pH. At high pH values the cyanide ion and hydronium ion are favored. At pH 9.36 (at 20°C) the concentration of molecular HCN in solution equals the concentration of the cyanide ion. As the pH lowers, molecular HCN is favored, with 99^+ percent of the hydrogen cyanide existing as molecular HCN at pH 7.0 (Ecological Analysts, 1979).

Simple cyanides are represented by the formula $A(CN)_x$, where A is a cation and x, the valence of A, represents the number of cyano groups present in the molecule. Simple cyanides, particularly the alkali cyanides, ionize in water to release cyanide ions as shown in equation (2):

$$A(CN)_x \rightleftarrows A^{+x} + X(CN^-) \quad (2)$$

Solubility is influenced by pH and temperature. The hydrolytic reaction of cyanide ions with water produces hydrogen cyanide according to equation (3):

$$CN^- + H_2O \rightleftarrows HCN + OH^- \quad (3)$$

Subsequent behavior in solution would then be the same as for hydrogen cyanide.

In solution, simple cyanides would be detected as free cyanide because the dissociation reaction releases the cyanide ion.

Complex cyanides can generally be represented by the formula $A_yM(CN)_x$, where A is the cation present y times, M is a metal ion (ferrous and ferric iron, copper, cadmium, lead, nickel, silver, manganese, zinc, and others), and x is the number of CN groups present. The water-soluble, complex cyanides release the complex ion $M(CN)_x$ rather than the CN group, as illustrated in equation (4):

$$A_yM(CN)_x \rightleftarrows {}_yA^{+x} + \{M(CN)_x\}^{-y} \quad (4)$$

The complex cyanide ion may then undergo further dissociation, releasing the cyanide ion. The stability of complex cyanide ions in aqueous solution is variable, with many remaining rather stable. In particular, the hexacyanoferrates are extremely stable in the absence of visible or ultraviolet light. However, exposure to visible or ultraviolet light can cause further dissociation of the complex iron cyanide ion to release the free cyanide ion (Ecological Analysts, 1979). In addition, further dissociation of complex cyanide ions becomes more favorable at lower pH values. (AIME, 1981).

A strong pH dependence has been reported for the complexation of iron with cyanide. At high pH values the complexation reaction is slow and incomplete. The maximum hexacyanoferrate formation is reported as occurring at pH 9 (Ecological Analysts, 1979).

It is generally accepted that molecular HCN is the most toxic form of cyanide. Complex cyanides are relatively nontoxic. The major concern associated with complex cyanides is the possibility of decomposition of the complex cyanide ion in solution, releasing the free cyanide ion. The free cyanide ion, once in solution, will then hydrolyze to form the extremely toxic HCN.

Once in solution, free cyanide, the sum of the cyanide ion and the molecular HCN, can be removed from the water through a number of routes. Molecular HCN in solution will tend to volatilize into the atmosphere, especially in dilute solutions with acid or neutral pH values. The cyanide ion may also undergo oxidation to form cyanate (OCN^-); once cyanate is formed, it will not revert back to the cyanide ion but will, instead, hydrolyze to carbonate and ammonia. Finally, if below lethal levels, the free cyanide may be biodegraded by aquatic organisms (Ecological Analysts, 1979).

Other substances detected, in either the groundwater or the pot-lining leachate, include the following:

- fluoride
- aluminum
- iron
- arsenic
- manganese

- ammonia
- phenol
- 1,1,1-trichloroethane
- pH (caustic)
- temperature

5.2.3 Hazardous Characteristics

A partial listing of the flammable, reactive, and toxic characteristics of hazardous substances found in the groundwater or in the pot-lining leachate is shown in Table 5-1.

A more detailed discussion of the human health hazards associated with these substances can be found in Section 7.0 of this RAMP.

5.3 Source, Quantity, and Concentrations

Kaiser Aluminum and Chemical Corporation, Mead Works, as well as the previous plant owner, has disposed of pot-linings from failed aluminum reduction cells on a tract of land in the northwest portion of the plant site. This method of disposal for the spent pot-linings has been used from 1942 through 1978. These spent pot-linings are an unavoidable waste product generated by the aluminum reduction process utilized at this plant. The cyanide present in the pot-linings does not serve any useful function in the aluminum reduction process but is, instead, unintentionally formed during the reduction process as a result of the high temperature contact of the carbon in the pot-linings with the nitrogen in the atmosphere.

The waste pot-linings which are currently being generated are stored in the covered pot-lining building. As of September 1982 the quantity of pot-linings stored in the building is estimated at 20,000 tons (D. A. Schmidt, HRS Cover Sheet, 9-23-82).

TABLE 5-1

HAZARDOUS CHARACTERISTICS OF POLLUTANTS
DETECTED IN GROUNDWATER OR POT-LINING LEACHATE SAMPLES
IN THE VICINITY OF THE KAISER MEAD WORKS

Pollutant	Flammability/Reactivity	Toxicity/Carcinogenicity
Hydrogen Cyanide (free cyanide)	Flammable and explosive; however, not in concentrations expected on site. Reacts violently with acetaldehyde. Can react with water, steam, acid, or acid fumes to produce highly toxic fumes of cyanide. Can polymerize or decompose explosively upon contact with alkaline materials. Can explode when exposed to heat, flame, or oxidizers.	Highly toxic via oral, dermal or inhalation routes. Protoplasmic poison, combining with enzymes associated with cellular oxidation, thereby rendering oxygen unavailable to tissues, causing death by asphyxiation. Upon cyanide removal, normal functions are completely restored, provided death has not occurred.
Ferro- and Ferricyanides	Nonflammable, nonexplosive.	Low order of toxicity while complexed. Highly toxic decomposition products upon contact with acid or acid fumes or when heated to decomposition. Ferrocyanides liberate hydrogen cyanide upon strong irradiation. It has been stated, but not conclusively proven, that ferricyanides can liberate hydrogen cyanide in the stomach as a result of contact with gastric acidity.
Ammonia	Low flammability, moderate explosivity, though not in concentrations expected on site. Forms explosive compounds in contact with a variety of substances including potassium ferricyanide and potassium mercuric cyanide.	Highly toxic via oral and inhalation routes. Very irritating to eyes and mucous membranes of respiratory tract. Emits toxic fumes when exposed to heat.

TABLE 5-1

HAZARDOUS CHARACTERISTICS OF POLLUTANTS
DETECTED IN GROUNDWATER OR POT-LINING LEACHATE SAMPLES
IN THE VICINITY OF THE KAISER MEAD WORKS
PAGE TWO

Pollutant	Flammability/Reactivity	Toxicity/Carcinogenicity
Phenol	Moderately flammable when exposed to heat, flame or oxidizers. Reacts violently with $AlCl_3$ + nitrobenzene and butadiene.	Highly toxic via oral and dermal routes. In acute poisoning the main effect is on the central nervous system. Chronic exposure to vapor or mists results in digestive disturbances, nervous disorders, skin eruptions, and damage to the liver or kidneys.
1,1,1-trichloroethane	Nonflammable. Reacts with oxidizers and chemically active metals. Emits toxic chlorides and phosgene when heated to decomposition. Reacts violently with acetone.	Moderately toxic via oral route. Causes narcosis in high concentrations.
Fluoride	Nonflammable, nonexplosive. Emits highly toxic fumes when heated to decomposition or on contact with acid or acid fumes.	Acute effects result from exposure to hydrogen fluoride. Chronic exposure to high fluoride concentrations results in fluorosis, which consists of sclerosis of the bones, calcification of the ligaments, and mottling of the teeth. Other chronic symptoms include anorexia, anemia, and cachexia, along with gastric, intestinal, circulatory, and nervous complaints, and skin rashes.

(Sax, 1979)

The quantity of pot-linings present in the asphalt-covered pile has been estimated at about 2,557,000 cubic feet, with a weight of 128,000 tons. Assuming that the average cyanide content of the pot-linings is 0.2 percent by weight, the total weight of cyanide in the asphalt-covered pile is about 250 tons (Robinson and Noble, 1979).

The quantity of pot-linings recently found buried east of the asphalt-covered pile has been estimated at 2,000 tons. This pot-lining material contains from 200-500 ppm of cyanide. Assuming an average cyanide content of 350 ppm, or 0.035 weight percent, the total weight of cyanide in these pot-linings is estimated at 0.7 tons (D. A. Schmidt, 8-25-82).

The weight of solids in the sludge bed has been estimated at 200,000 tons, with the amount of total cyanide in the sludge bed being estimated at about 8 tons. (Robinson & Noble, 1979).

The quantity of pot-linings present in the brick and rubble pile is unknown at the time of this writing.

In addition, the possibility exists that pot-linings may be buried elsewhere in the vicinity of the plant site.

Another source of soil and water contamination was the periodic discharge of pot-soaking water. From 1963 through 1978, failed aluminum reduction cells were soaked with water to facilitate the removal of the pot-lining. This soak water, estimated to have an average cyanide content of 2700 ppm (F. J. Haydel, 10-17-78), was discharged to the ground, to the now abandoned sludge bed, and to Tharpe Lake. The soak water discharged to Tharpe Lake is believed to have ultimately found its way to Peone Creek via an underground aqueduct. The pot-soaking operations were discontinued sometime between August and October 1978 following the discovery of the contamination problem and following an order by the Washington State DOE.

An estimate of the amount of cyanide present in the contaminated soils around the plant site cannot be made at this time.

6.0 ENVIRONMENTAL CONCENTRATIONS

6.1 Air

Air pollution concerns center primarily around the volatilization of hydrogen cyanide (HCN) and/or ammonia from wasted pot-linings or from contaminated waters. During the initial site visit on February 24, 1983, strong ammonia odors were identified inside the pot-lining storage building. Analytical data on the air concentrations of ammonia or hydrogen cyanide in the vicinity of the plant site or in the vicinity of contaminated waters are not available; however, air concentration of hydrogen cyanide and ammonia are expected to be of a low enough level in outside air so as not to present a public health hazard.

6.2 Soil

Analytical data on soil contamination are limited to the information in the Kaiser monitoring well logs, and one isolated report by Robinson and Noble, Inc., on cyanide levels in the sludge bed. The monitoring well logs, provided by Hart-Crowser, list cyanide concentration in the soil at varying depths, as well as fluoride concentrations. The logs report cyanide concentrations as micrograms CN per gram of soil (ppm), and fluoride concentrations as percent. Robinson and Noble, Inc., reported the cyanide levels--in ppb--at four different depths in the sludge bed.

6.2.1 Cyanide

Cyanide and its complexes are reported to be very mobile in soils, with mobility increasing in the presence of low pH, free iron oxide, or positively charged clay minerals (Robinson & Noble, 5-1-79).

Figure 6-1 illustrates the locations of the various monitoring wells discussed here.

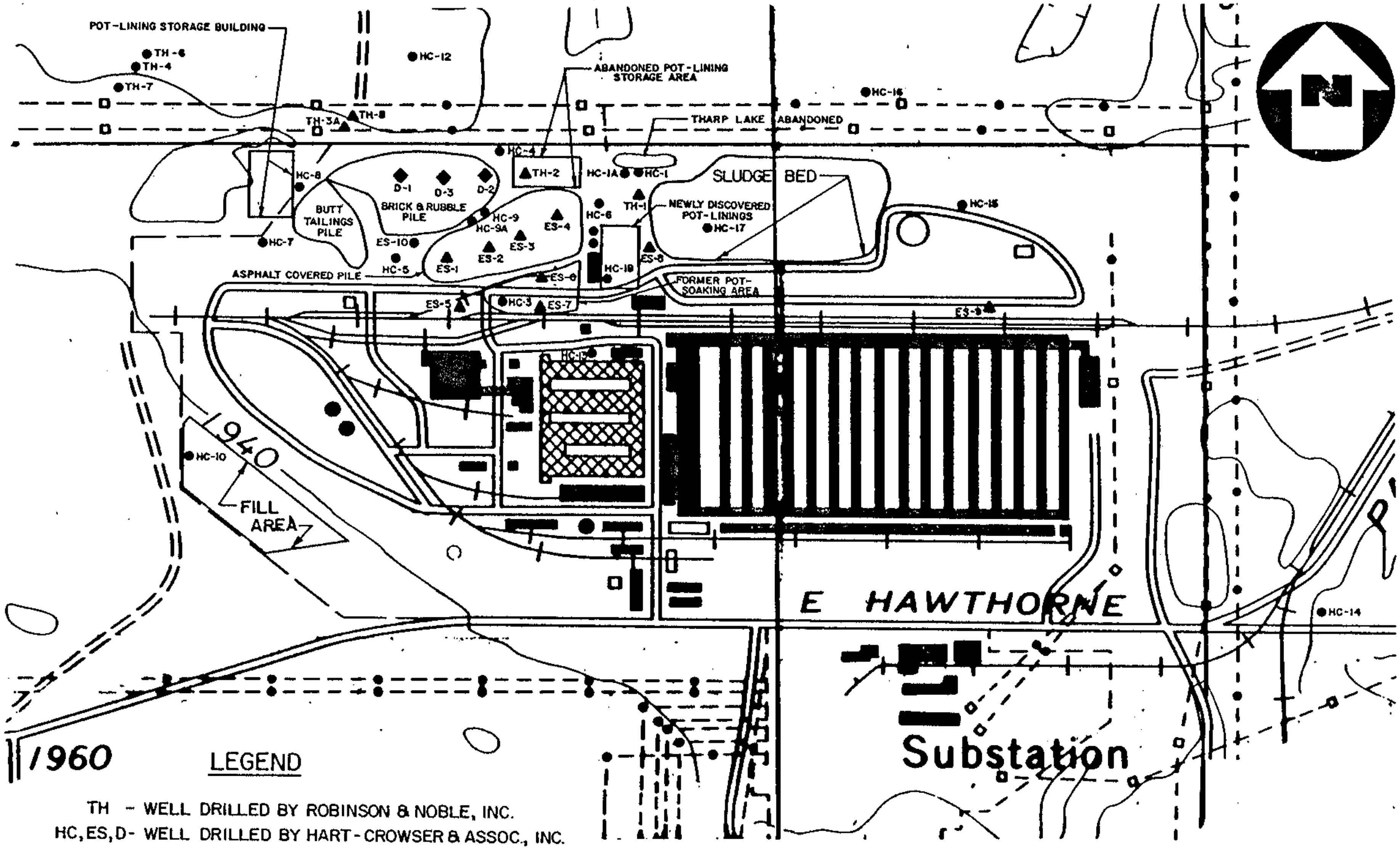

FIGURE 6-1

ONSITE MONITORING WELL LOCATIONS
KAISER ALUMINUM SITE, MEAD, WA
NOT TO SCALE

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The farthest upgradient Kaiser well, HC14, shows soil concentrations of total cyanide being generally less than 1 ppm down to a depth of 120 feet, at which point the total cyanide level rises to 2 ppm.

Moving downgradient, toward the pot-lining pile, the soil concentrations of total cyanide begin to increase. ES9 shows soil cyanide levels ranging from 2 to 45 ppm, with the high reading occurring at a depth of 110 feet. Other upgradient wells, such as HC15, HC16, and HC17, all show soil cyanide levels of less than 1 ppm.

HC18, located in the area of the newly discovered pot-linings, shows elevated soil cyanide concentrations. In the upper 60 feet of the well log, total cyanide levels range from 50 to 761 ppm. Below 60 feet the total cyanide levels range from 1 to 55 ppm, with total cyanide levels of less than 5 ppm prevailing at depths below 125 feet. The log also shows the presence of a clayey silt layer at a depth of 60 feet, which may explain why soil cyanide levels are somewhat elevated only in the upper 60 feet.

In the area of the former pot-soaking activities, the logs for wells ES6 and ES7 show total cyanide levels in the soil. The highest total cyanide readings occur near the surface, with ES7 showing 985 ppm of total cyanide at the surface. At depths below about 20 feet, the total cyanide concentrations in the soil generally range from 10 to 60 ppm.

HC1, which is located along the south side of the former setting basin, shows only slightly elevated total cyanide levels in the soil, ranging from less than 1 up to 14 ppm.

ES1, ES2, ES3, and ES4 are the borings done through the pot-lining pile and they all show total cyanide contamination. ES1 is the deepest of these borings, extending down 125 feet from the top of the pile. The total cyanide levels in the pot-lining material reach as high as about 30,000 ppm. Below the pot-lining material the soil is contaminated. The total cyanide level at the soil/pot-lining interface is about 5,000 ppm; below this level the total cyanide concentration in the soil varies from 60 to 1,300 ppm.

The log for HC9A shows soil contamination present along the northwest side of the pot-lining pile. Total cyanide concentrations range from 3 to 112 ppm, with the highest total cyanide level reported at a depth of 140 feet.

HC7 and HC8, to the west of the pot-lining pile and near the butt tailings pile, show soil cyanide levels generally less than 5 ppm, except near the water table, where the soil cyanide in HC7 reaches 28 ppm and the soil cyanide in HC8 reaches 11 ppm.

D1, D2, and D3 are three borings done through the brick and rubble pile, all three of which indicate the presence of pot-lining material in the pile. D1, the deepest of the borings, shows soil cyanide levels as high as 4,400 ppm near the surface of the pile, with levels ranging from 3 to 36 ppm in the soil under the pile. D3 shows soil cyanide concentrations reaching 490 ppm in the pile itself, with levels of total cyanide ranging from 7 to 945 ppm in the soil under the pile. These three borings were only completed to depths ranging from 35 to 60 feet; therefore, information on the soil cyanide concentrations underneath the pile, at depths below 60 feet, is unavailable.

Robinson and Noble, Inc., reported that tests done on the sludge bed material showed total cyanide levels of 10.5 and 36 ppm at two locations on the surface of the bed. One sample, taken at a depth of 0.5 feet, tested to be 37.7 ppm, while samples taken at depths of 5 and 10 feet showed total cyanide levels of 310 and 0 ppm, respectively. A sample taken from a depth of 13 feet analyzed at 0.5 ppm total cyanide. However, the well log for HC17, which is located in the sludge bed, shows total cyanide levels of less than 1 ppm at all levels down to a depth of 168 feet.

Summarizing the available information on total cyanide levels in the soils around the Kaiser-Mead plant, it appears as though there are several areas of concern because of total cyanide contamination. Areas of moderate to high cyanide contamination include the asphalt covered pot-lining pile, the brick and rubble pile, the former pot-soaking area, and the newly discovered buried pot-lining area. Lower levels of soil cyanide contamination were reported in the sludge bed, in the vicinity of the abandoned settling basin, and around ES9 in the eastern portion of the plant site.

6.2.2 Fluoride

Analytical data on the fluoride concentrations in the soils around the plant site, derived from the same well logs used for the soil cyanide concentrations, indicate that soil areas of cyanide contamination also show elevated fluoride levels.

The ES borings in the pot-lining pile show fluoride levels as high as 14 percent near the surface, with the fluoride concentration generally decreasing with depth, reaching about 0.02 percent at 110 feet.

The D borings in the brick and rubble pile show fluoride levels in the pile ranging from 1 to 18 percent, with the highest readings occurring at the depths where pot-lining material exists. In the soil below the pile, the fluoride levels fall off quickly, down to about 0.01 percent at 60 feet.

In the area of the newly discovered buried pot linings, the fluoride levels in the soil generally range from 0.01 to 0.2 percent down to a depth of 60 feet, below which the fluoride levels fall off sharply, reaching less than 0.001 percent below 110 feet.

Around the former pot soaking area, fluoride concentrations in the soil generally vary from 0.01 to 0.1 percent, though at the surface, fluoride levels may reach 2 percent.

Most other areas around the plant site, including the sludge bed, generally show soil fluoride concentrations of less than 0.01 percent.

6.2.3 Other Contaminants

No information is available on the soil concentrations of metals or other possible contaminants.

6.3 Groundwater

Since the problem of cyanide contamination in the groundwater downgradient of the plant site was first discovered in 1978, extensive groundwater samplings and analyses have been conducted both off site, at domestic wells and springs, and on site, at monitoring wells. From August 1978 through June 1981 the only parameter regularly analyzed at domestic wells was total cyanide, while Kaiser monitoring wells were analyzed for total cyanide and temperature. From June 1981 to the present, analyses included fluoride and free cyanide as well as total cyanide. Samplings before December 1979 were conducted by personnel from both Kaiser-Mead and the Spokane County Health District. After December 1979 all samplings were conducted by Kaiser-Mead personnel with the exception of samples occasionally collected by domestic well owners. All analyses were conducted and reported by Kaiser-Mead personnel.

6.3.1 Cyanide

Figure 6-1 illustrates the locations of the various Kaiser monitoring wells that are discussed in this section.

HC14 is a Kaiser monitoring well located about 3,700 feet southeast of the pot-lining pile and is therefore upgradient of the suspected cyanide sources. For the purposes of this discussion, HC14 will be considered representative of background cyanide levels in the aquifer, though it may be situated too near to the plant to be truly background. Total cyanide levels in HC14 typically run from 2 to 5 ppb, with readings as high as 23 ppb being reported. Free cyanide concentrations in HC14 are generally in the 1 ppb range, with no analysis showing greater than 4 ppb.

Moving northwest, toward the pot-lining pile, the next monitoring wells encountered are ES9 and HC15, both of which draw from the "A" zone of the aquifer. These wells are roughly 1,800 feet east of the pot-lining pile and are still upgradient of the suspected contamination sources. Total cyanides in ES9 range from 54 to 140 ppb and are definitely above background. There appears to be cyclic trends in the total cyanide concentration, with a slight, overall downward trend being evident. The free cyanide levels in ES9 fluctuate from 1 to 34 ppb, and appear to have some agreement with the overall and cyclic trends seen in the total cyanide levels. The data for HC15 is scarce, with only four sampling results available. The total cyanide levels in HC15 range from 14 to 86 ppb, and also appear to be above background. The free cyanide concentrations in HC15 fluctuate from 2 to 34 ppb.

Continuing east, towards the pot-lining pile, one encounters the HC17 well, which is situated in the abandoned sludge bed, and which also draws from the "A" zone. The data for HC17 is also limited, with the results for only six samplings being available. The total cyanide levels in HC17 appear to be increasing steadily, starting at 19 ppb in August 1982 and rising to 106 ppb in April 1983. Likewise, the free cyanide concentration also is increasing, rising from 1 ppb in October 1982, up to 23 ppb in April 1983.

HC13, another well upgradient of the pot-lining pile, also draws from the "A" zone and is located about 500 feet southeast of the pile. The total cyanide concentration ranges from 5 to 67 ppb, with an overall downward trend being evident. Free cyanide levels generally range from below 1 to 4 ppb, except for two readings in the autumn of 1981 which show values of 28 and 55 ppb.

HC1 draws from the "A" zone, and is located about 300 feet northeast of the pot-lining pile and adjacent to the south side of the abandoned settling basin. Figure 6-2 shows the total and free cyanide concentrations in HC1. The total cyanide levels in HC1 increased after Tharpe Lake was abandoned, starting at 8 ppb in September 1981 and rising to 225 ppb in July 1982. Since July 1982, the total cyanide level has decreased from 225 to 15 ppb. The free cyanide concentrations in HC1 have followed the same trend, rising from 1 ppb in September 1981 up to 130 ppb in September 1982, then falling and hovering in the 3 to 10 ppb range.

HC2A is located adjacent to the west side of the pot-lining pile and draws from the "B" zone of the aquifer. The total and free cyanide levels for HC2A are also illustrated in Figure 6-2. The total cyanide level has steadily declined from 260 ppb in October 1981 to about 50 ppb in April 1983. The free cyanide level has followed much the same trend, decreasing from 135 ppb in October 1981 to the 1 to 4 ppb range more recently.

Moving to the downgradient side of the pot-lining pile, the first wells encountered are HC9A and ES10, both of which are located adjacent to the northwest side of the pile. It is unclear as to whether these wells are drawing from the "A" zone or if one or both of these wells may be also drawing from the "B" zone of the aquifer. Figure 6-3 illustrates the total and free cyanide concentrations in each of these wells. The total cyanide concentration in HC9A ranges from 38,000 ppb up to 118,000 ppb, with a cyclic trend being apparent along with a slight, overall downward trend. The free cyanide levels in HC9A fluctuate considerably between 65 ppb and 6,800 ppb. As with the total cyanide, the free cyanide levels in HC9A appear to follow a cyclic pattern, accompanied by an overall downward trend, especially since July 1982. The total cyanide levels in ES10 show a definite downward trend, falling from a high of 90,000 ppb in August 1981 down to 3,100 ppb in April 1983. The free cyanide also shows a downward trend in ES10, declining from 16,000 ppb in July 1981 to approximately 15 ppb in March 1983. Inexplicably, the free cyanide level in ES10 shot back up to 890 ppb in the most recent analysis (April 1983).

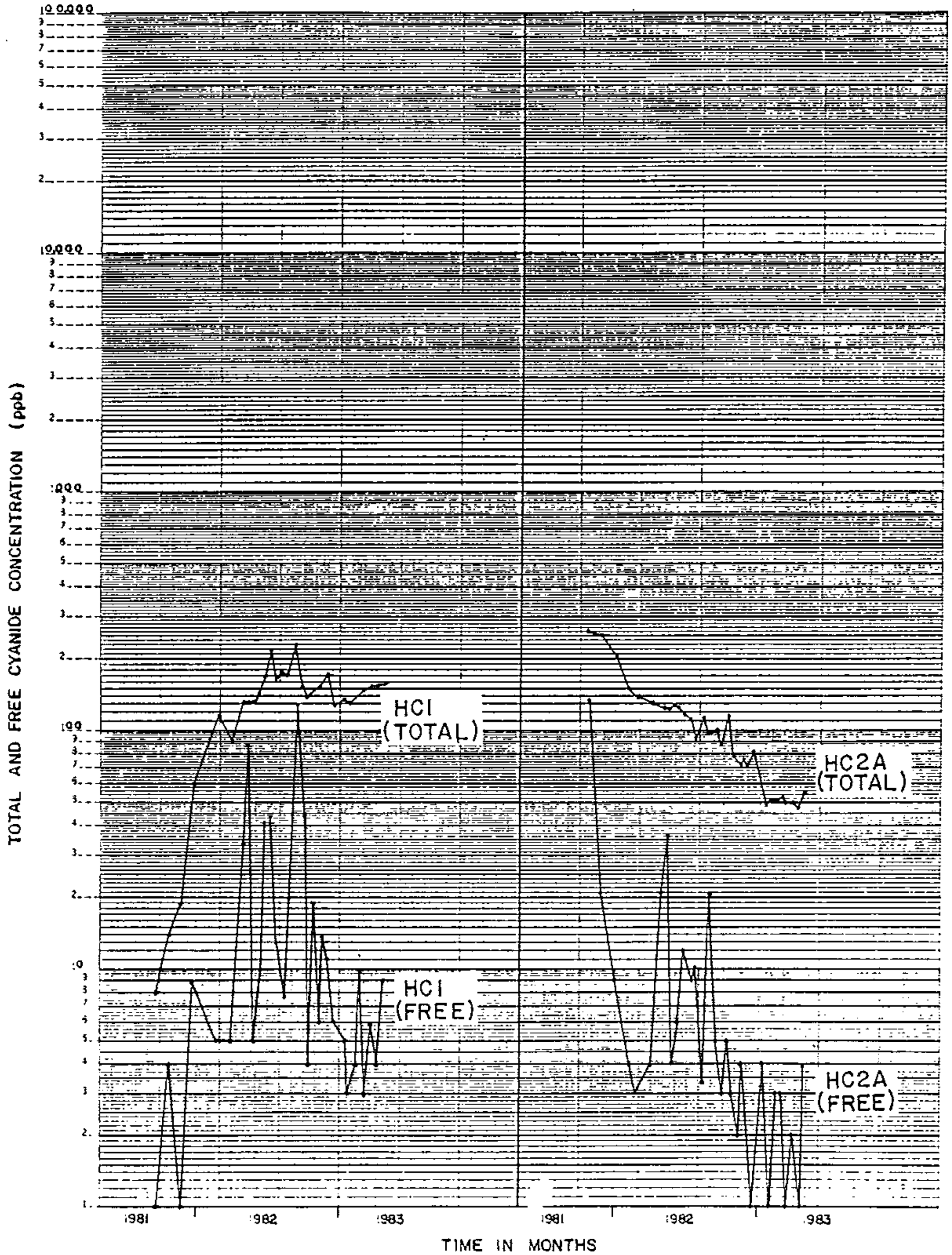

FIGURE 6-2

CYANIDE CONCENTRATION VS. TIME

SEMILOG SCALE

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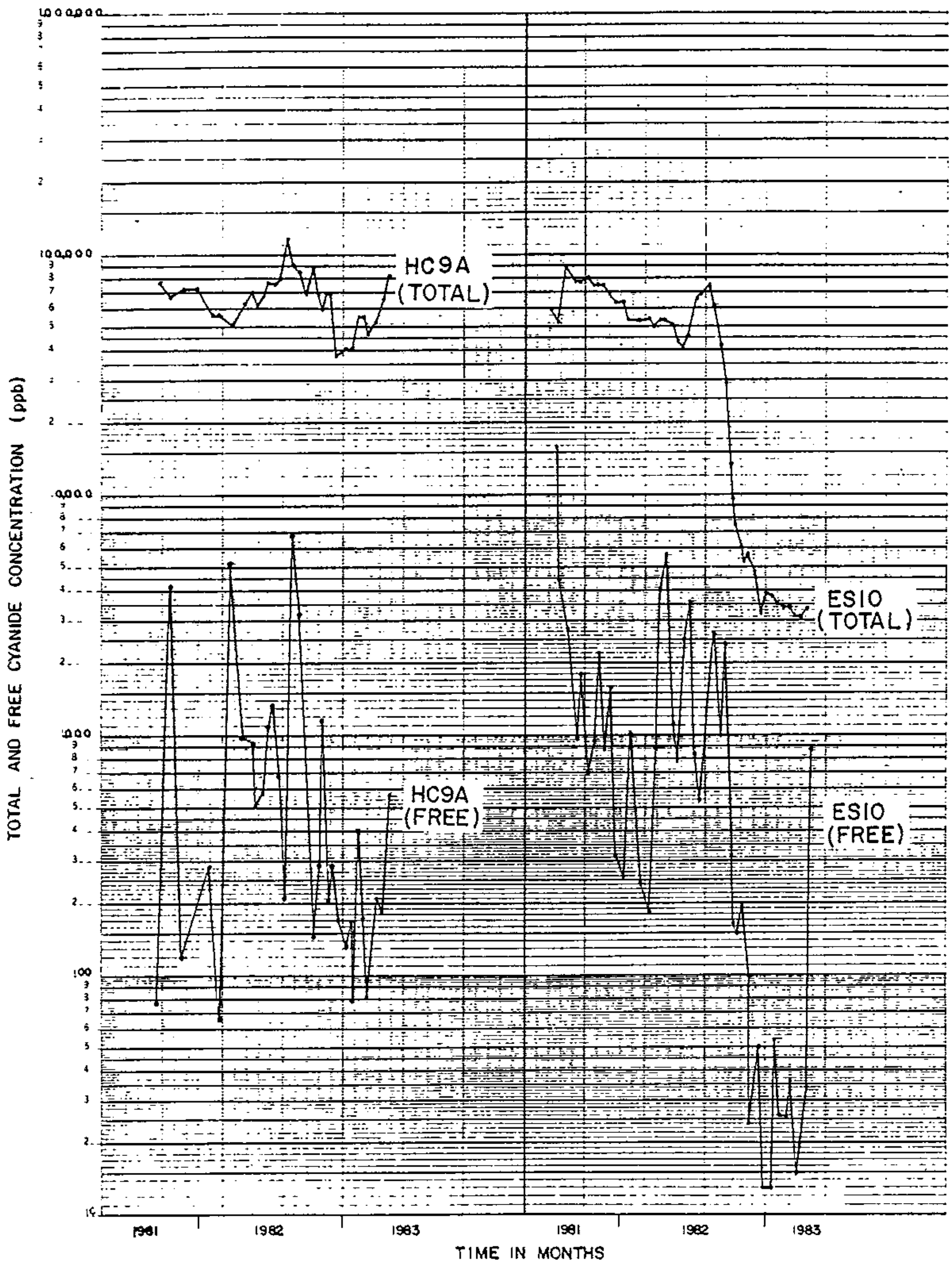

FIGURE 6-3

CYANIDE CONCENTRATION VS. TIME
SEMILOG SCALE

NUS CORPORATION
A Halliburton Company

Farther downgradient of the pot-lining pile and just downgradient of the brick and rubble pile are monitoring wells TH8 and TH3A, both of which appear to draw from the "A" zone. The total and free cyanide levels for these wells are shown in Figure 6-4. TH3A has total cyanide concentrations ranging from 100,000 to 260,000 ppb, with a downward trend being evident from January 1982 to the most recent analysis. The free cyanide levels in TH3A range from about 60 ppb up to one isolated reading at 55,000 ppb. There also appears to be a downward trend in the free cyanide, as well as a cyclic trend. The total cyanide in TH8 generally ranges from 140,000 ppb to 300,000 ppb. The downward trend in TH8 appears to consist of three- to four-month periods where the total cyanide concentration stays fairly stable, followed by a step-like dropoff to a new plateau. The free cyanide in TH8 ranges from 120 ppb to 8,500 ppb, with an overall downward trend, and also some cyclic trending.

TH6 is a Kaiser monitoring well located roughly in the center of the plume about 2000 feet downgradient of the pot-lining pile. TH6 is a nested well subdivided into TH6A, TH6B, and TH6C, which draw water from the "A", "B", and "C" zones, respectively. Figure 6-5 shows the total and free cyanide results for TH6A and TH6B. The total cyanide level in TH6A varies from 5,400 to 17,000 ppb, and shows a cyclic trend along with a slight, overall upward trend. The free cyanide concentrations fluctuate between 24 and 2,800 ppb, and appear to follow the same cyclic trend noted for the total cyanide, although no overall trend is apparent. The total cyanide level in TH6B shows a definite upward trend, starting at about 2,100 ppb in July 1981 and rising to as high as 94,000 ppb in November 1982, with a slight drop-off to the 70,000 ppb range in more recent months. The total cyanide results for TH6A and TH6B seem to contradict Hart-Crowser's belief that the majority of the aquifer contamination exists in the "A" zone around the site. These results may indicate that the "A" zone is leaking into the "B" zone in the vicinity of TH6, possibly as a result of vertical cross-contamination through the bore hole, and that the cyanide contamination prefers to descend in the aquifer rather than

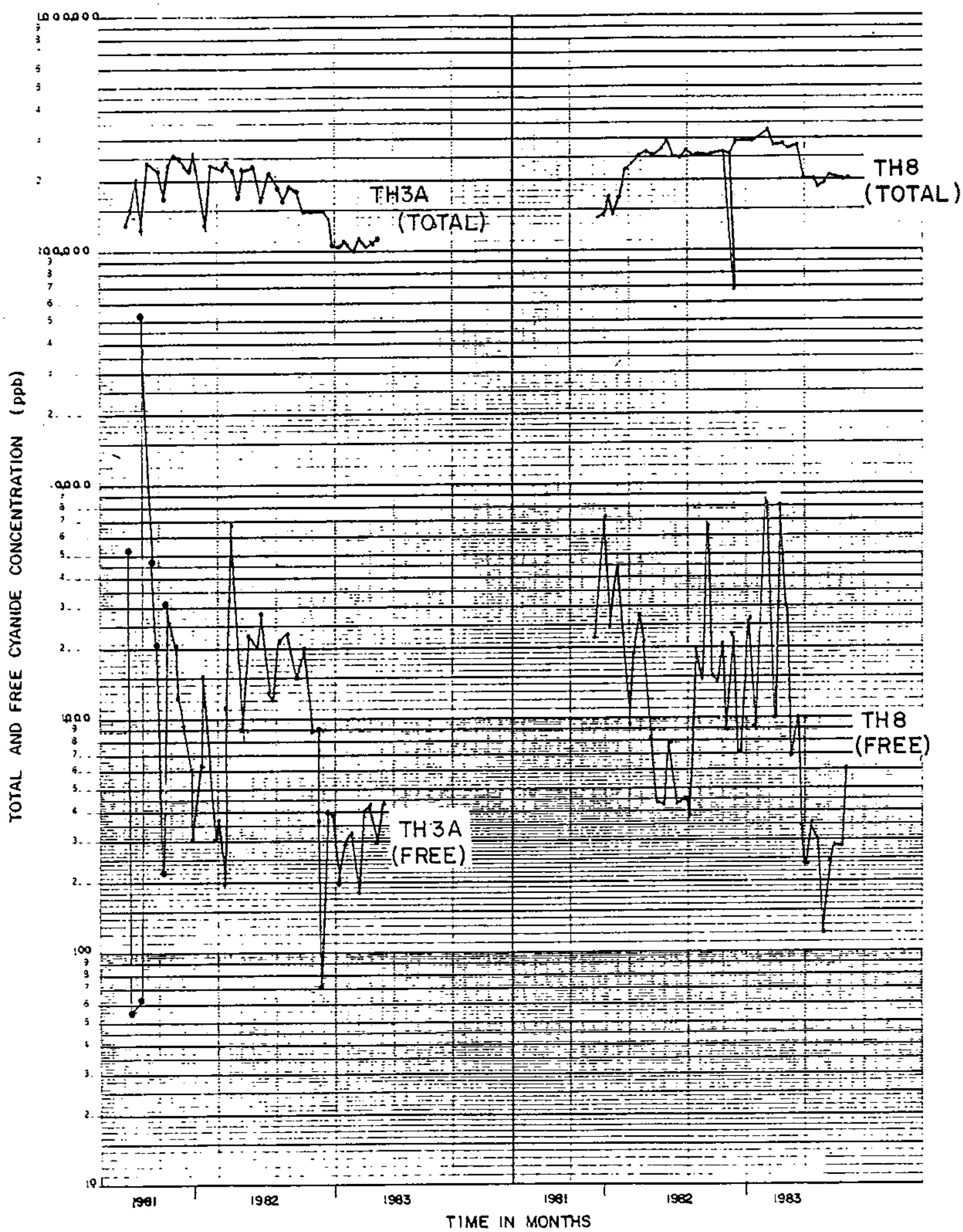

FIGURE 6-4

CYANIDE CONCENTRATION VS. TIME

SEMILOG SCALE

NUS CORPORATION
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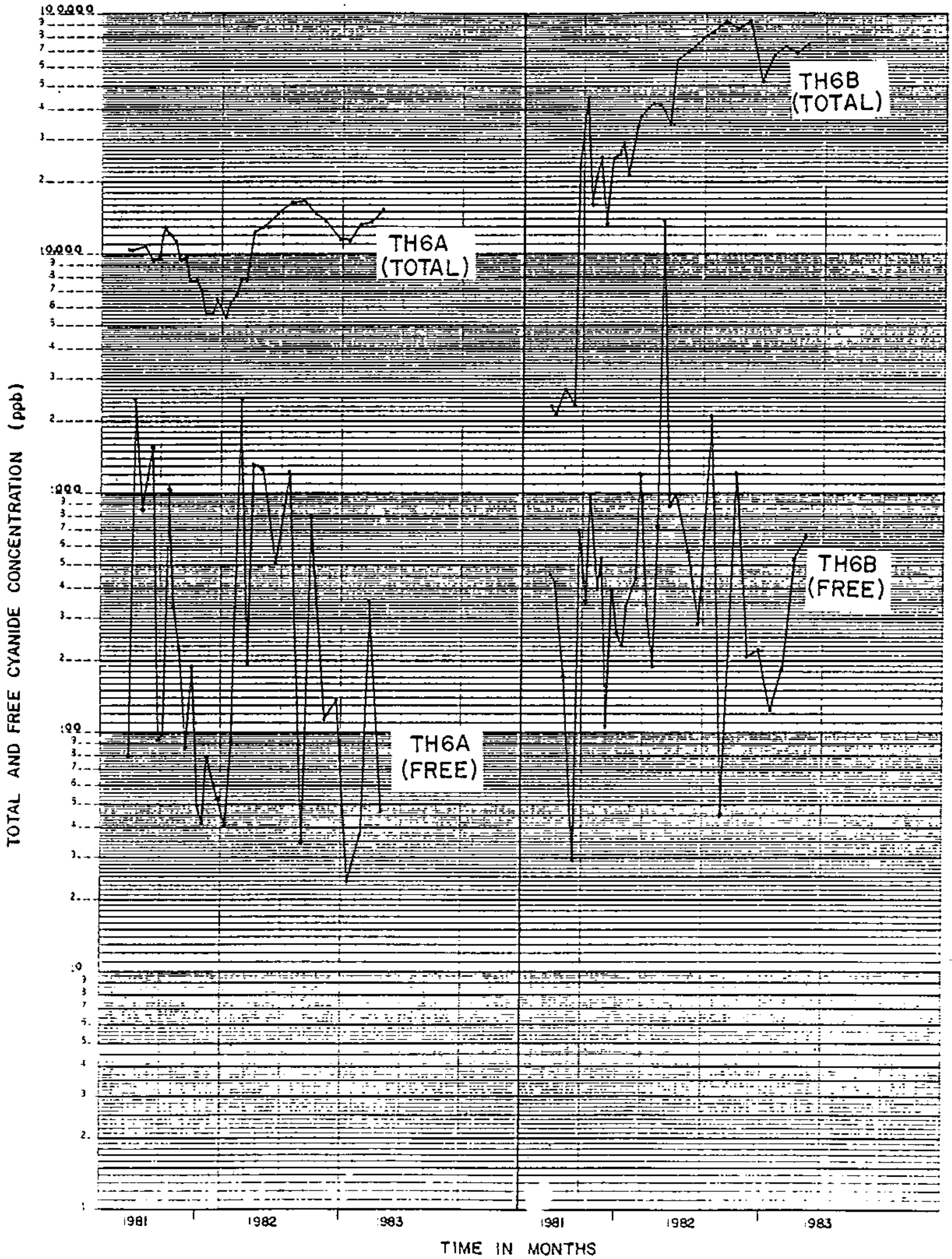

FIGURE 6-5

CYANIDE CONCENTRATION VS. TIME

SEMILOG SCALE

NUS CORPORATION
A Halliburton Company

remain near the surface. The free cyanide concentrations in TH6B fluctuate considerably, reaching as low as 29 ppb, and as high as 14,000 ppb. No cyclic or overall trends are evident in the free cyanide levels in TH6B. TH6C, which draws from the top of the "C" zone, shows total cyanide levels ranging from 21 to 1,200 ppb, with what appears to be cyclic trends, though an overall trend cannot be clearly distinguished. The free cyanide concentrations in TH6C appear to follow the cyclic trends of the total cyanide, with values ranging from 1 to 80 ppb. The fact that TH6C has lower cyanide levels than either TH6A or TH6B does not necessarily disclaim the possibility that the cyanide contamination prefers to migrate downward in the aquifer. The stratification between the "B" and "C" zones may be sufficiently impermeable to prevent leaking, or the higher hydraulic head in the "C" zone, as compared to the "B" zone, may prevent leaking from the "B" to the "C" zone; finally, TH6C draws water from the top of the "C" zone, and any of the contamination that has leaked to the "C" zone may have already migrated below the monitoring well's influence.

The trends in TH2 and HC12 appear to be similar, so these two monitoring wells have been grouped together for this discussion. TH2 is located about 100 feet north of the pot-lining pile, and HC12 is located about 800 feet north-northwest of the pile; both wells draw from the "A" zone. Figure 6-6 illustrates the free and total cyanide concentrations in these two wells. The total cyanide level in TH2 had increased considerably since Tharpe Lake was abandoned, starting at about 4 ppb in August 1981 and reaching 12,500 ppb in September 1982; however, since September 1982 the total cyanide has fallen sharply down to 95 ppb in April 1983. The free cyanide level in TH2 followed much the same pattern, rising from 1 ppb in October 1981 up to 450 ppb in September 1982, and subsequently falling to 3 ppb in April 1983. Hart-Crowser explained this pattern by claiming that the decay of the groundwater mound on the aquitard and the shifting of the groundwater flow under the pile, resulting from the abandonment of Tharpe Lake, caused the cyanide level to temporarily increase in the area around TH2. Hart-Crowser also contends that same situation is affecting readings at HC12. The total cyanide level in HC12 has steadily risen since September 1981, when it was at 21 ppb, up through April 1983, when the level was 5,600 ppb. Similarly, the free cyanide level in HC12 has risen

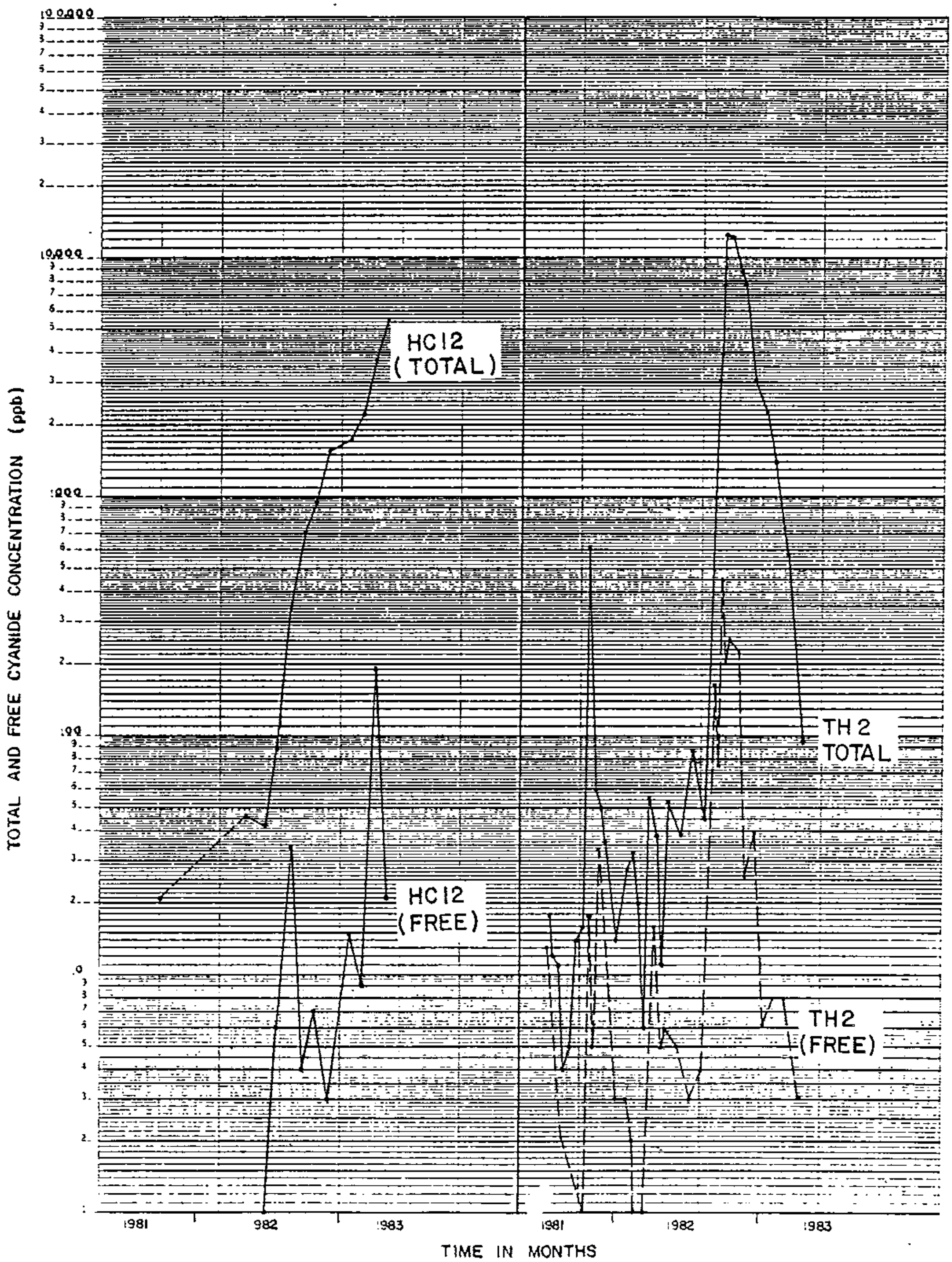

FIGURE 6-6

NUS CORPORATION
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CYANIDE CONCENTRATION VS. TIME

SEMILOG SCALE

from 1 ppb in June 1982, to almost 200 ppb in March 1983. No decline has yet been noticed in the total cyanide at HC12, although Hart-Crowser predicts that a decline should become evident in June or July 1983. The free cyanide concentration did fall off substantially to about 21 ppb in the most recent analyses (April 1983).

HC7 is located about 700 feet west of the pot-lining pile, and HC8 is located about 700 feet west-northwest of the pile, with both wells drawing from the "A" zone. The cyanide levels for each of these wells are given in Figure 6-7. HC7 shows total cyanide levels ranging from about 17,000 ppb up to 49,000 ppb, with some cycling apparent and a definite downward trend occurring, especially since October 1982. The free cyanide concentration in HC7 follows the same cyclic and overall trends, and ranges from 58 ppb up to one isolated reading of 3,400 ppb. The total cyanide levels in HC8 show a sharp decrease since June 1982, when the total cyanide was at 85,000 ppb, down to the most recent reading in April 1983 of 3,300 ppb. The free cyanide levels in HC8 also follow this trend, falling from a high of 4,500 ppb in September 1982 to 35 ppb in March 1983, although the free cyanide has since climbed to 140 ppb in April 1983. As with HC7, HC8 shows some cycling in both total and free cyanide concentrations.

As one continues northwest from the plant site, downgradient towards the Little Spokane River, one enters into the residential areas where private wells have been contaminated. Figure 6-8 illustrates the general area, the idealized plume boundaries, and the locations of the springs and domestic wells included in the following discussion. As stated before, the plume width is between 800 and 1,500 feet, and the plume length extends about 2.5 miles northwest from the Kaiser plant to the Little Spokane River.

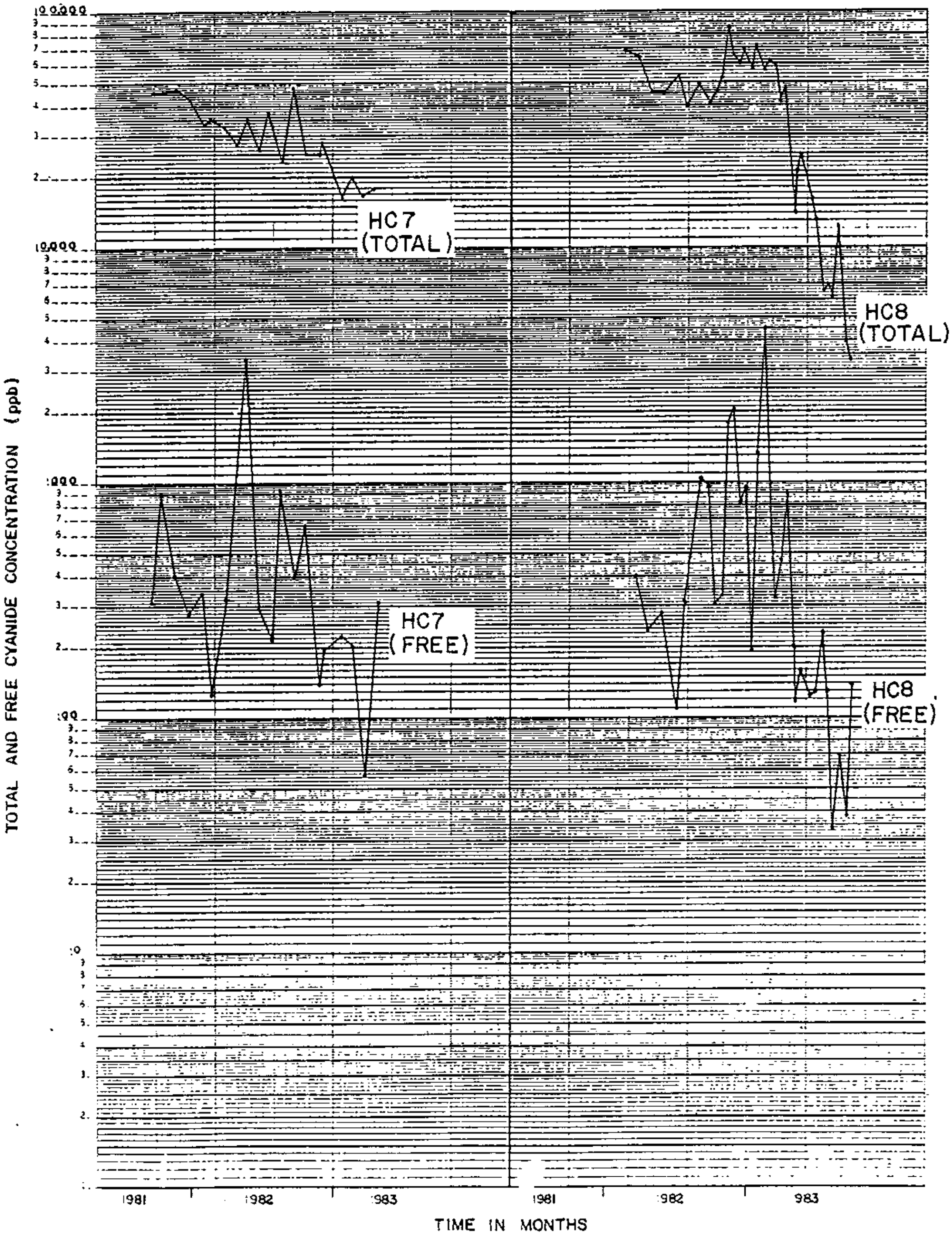

FIGURE 6-7

CYANIDE CONCENTRATION VS. TIME

SEMILOG SCALE

NUS CORPORATION
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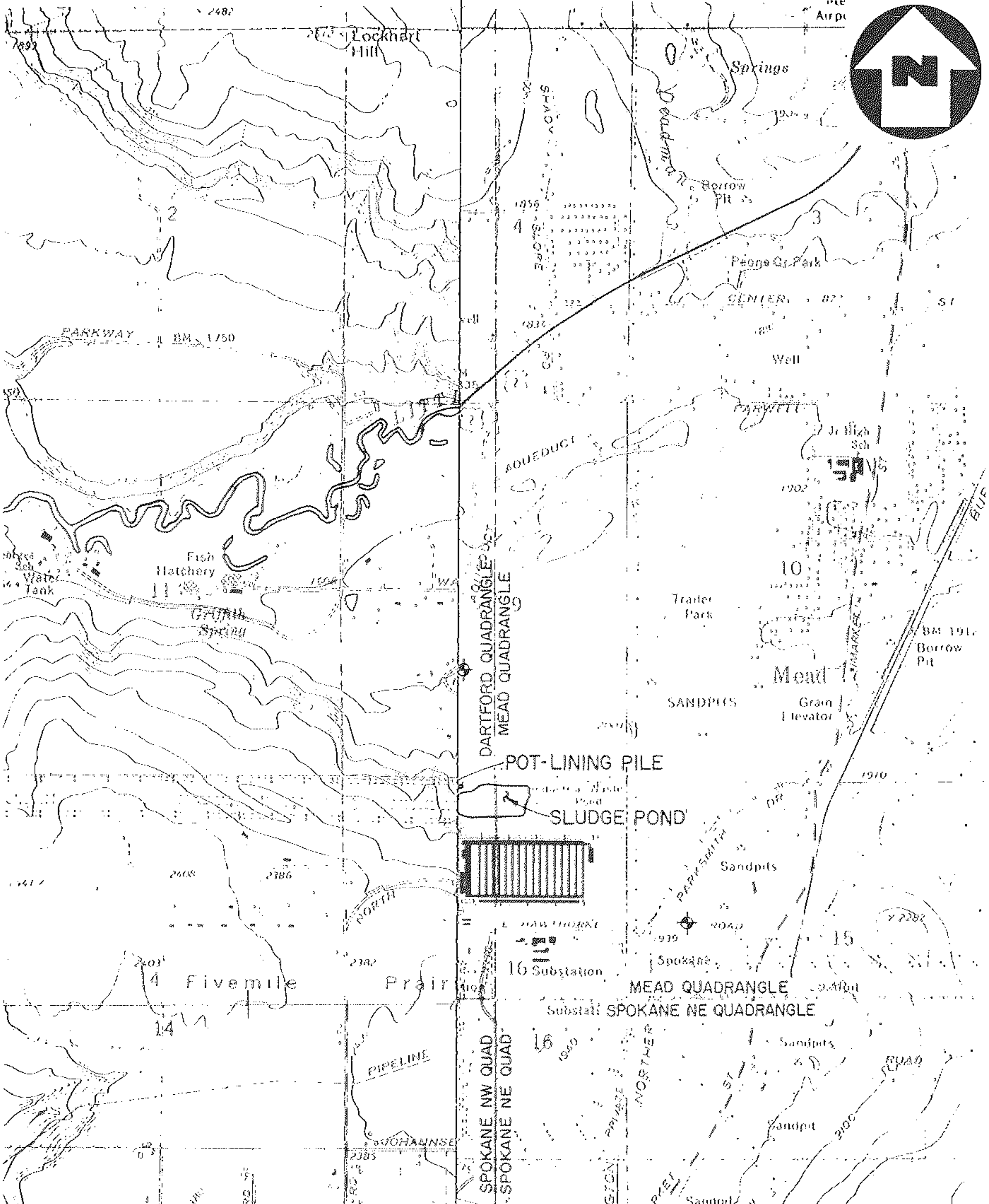


BASE MAP IS A PORTION OF THE FOLLOWING U.S.G.S. QUA

LEGEND:

APPROXIMATE LOCATION O
KAISER ALUMINUM AND CH

APPROXIMATE LOCATION O

FIGURE 6-8

IDEALIZED PLUME BOUNDARIES WA

NUS CORPORATION
A Halliburton Company

Since the beginning of the sampling program on domestic wells, back in 1978, a considerable amount of anaytical data has been generated. Often, a domestic well will have been sampled only once or twice, especially if the results showed very low cyanide concentrations, or a well will have been sampled frequently for a few months, then not sampled at all for a few months. Additionally, many of the domestic wells have no well log, or the well log is of questionable quality.

Three downgradient domestic wells and one spring within the plume boundaries have been chosen to represent the water quality in the contaminated aquifer, while two wells and one spring near or outside of the plume have been selected to help illustrate the boundaries. These points have been chosen mainly because there is consistent analytical information available for them, and because they are distributed along the length of the plume.

The Pope domestic well is located about 1.2 miles northwest of the pot-lining pile, in the center of the plume. Total cyanide levels range from 80 to 800 ppb, with no downward trend evident, although there does appear to be cyclic trends. The free cyanide concentrations range from 1 to 80 ppb, and follow the cyclic trends seen in the total cyanide concentrations. There is no evidence that the free cyanide concentration has ever exceeded the 200 ppb EPA water quality criterion.

In comparison to the Pope well, there is the Lessig well, which is located about 400 feet to the north, and just at the edge of the plume. The Lessig well shows total cyanide levels which range from about 10 ppb up to about 140 ppb, and free cyanide concentrations which generally fall in the 1 to 4 ppb range.

The County Road Shop well is located in the center of the plume, about 1.7 miles downgradient of the pot-lining pile. Total cyanide levels in this well range from 130 to 960 ppb, with cyclic trends being evident, although no overall trend can be discerned. Free cyanide concentrations follow the cyclic trends seen in the total cyanide results, and range from 4 to 290 ppb. One isolated reading of 290 ppb, taken in July 1981, is the only reported sample for this well where the 200 ppb free cyanide water quality criterion was exceeded. Figure 6-9 illustrates the free and total cyanide levels in the County Road Shop well.

The Pecchia domestic well is located in the Wilkinson residential area along Mill Road, and is situated within the boundaries of the plume, about 2 miles northwest of the pot-lining pile. Total cyanide levels in this well vary from 260 to 440 ppb, with not much in the way of trends being apparent. The free cyanide levels range from 3 to 110 ppb, with no evidence of the water quality criterion having been exceeded.

In comparison to the Pecchia well, there is the Prumers well, which is situated about 1,200 feet to the southwest and which is just outside of the plume boundaries. Total cyanide concentrations in the Prumers well fall in the 10 to 50 ppb range, with free cyanide levels ranging from 1 to 4 ppb.

The Van Gelder Spring is located in the center of the cyanide plume, very near to the Little Spokane River. The total and free cyanide concentrations are also given in Figure 6-9. The total cyanide levels range from about 1,200 to 1,700 ppb, and appear fairly stable. The free cyanide levels fluctuate from 17 to as high as 580 ppb, and show very little in the way of recognizable trends. The free cyanide concentrations reported for the spring have exceeded the water quality criterion three separate times, with readings of 580 ppb and 450 ppb in July 1981, and a reading of 250 ppb in August 1982.

The Wandermere Weir is a spring situated about 1.8 miles north-northwest of the pot-lining pile and about one-third of a mile northeast of the idealized plume boundary. Total cyanide concentrations range from 11 to 18 ppb, and free cyanide levels vary from <1 up to 6 ppb. The water quality at this spring is approximately equivalent to that of the background well, HC14.

Summarizing this discussion on the concentrations of total and free cyanides in the groundwater, it appears as though the Kaiser-Mead plant is the source of the

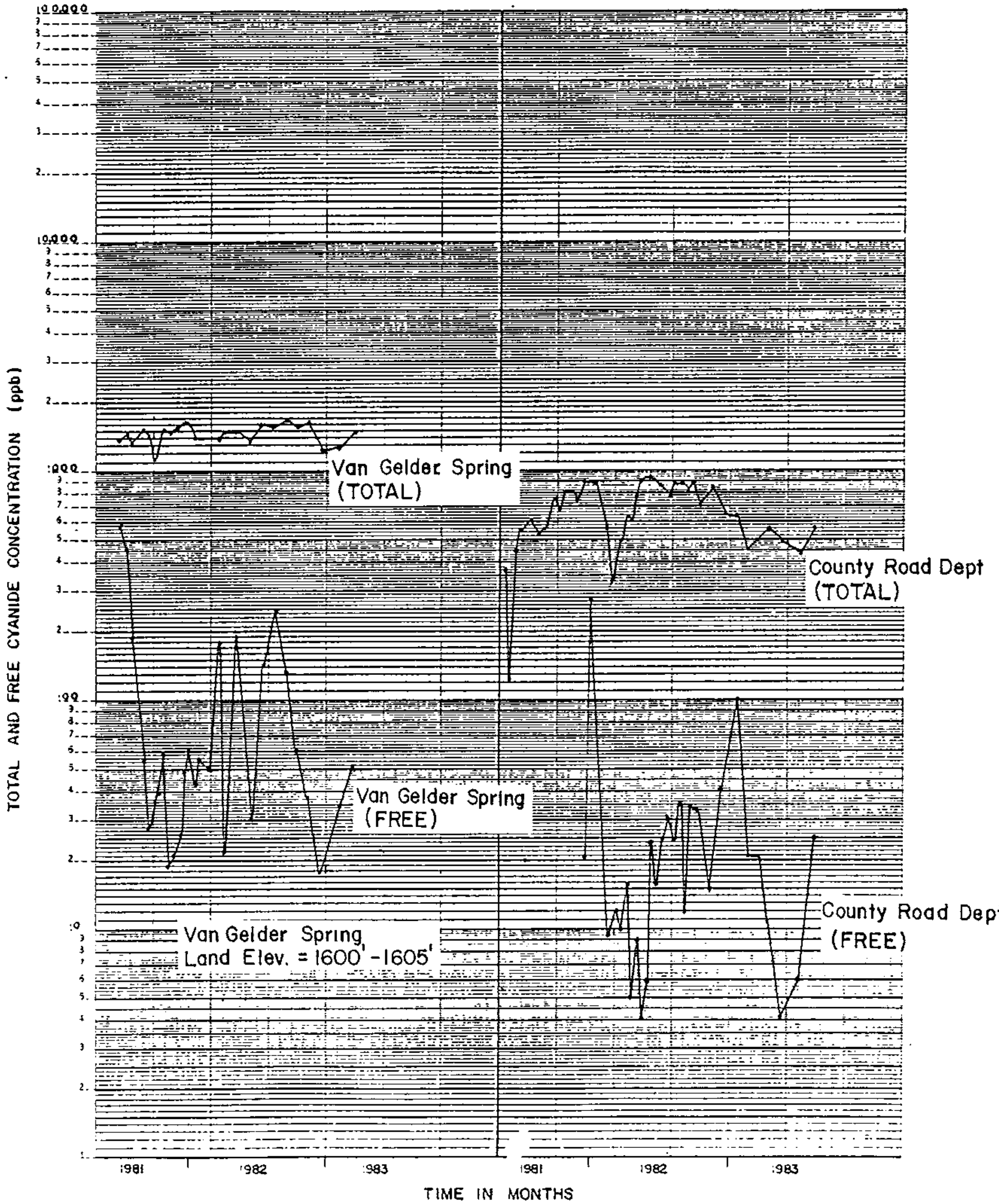


FIGURE 6-9

NUS CORPORATION
A Halliburton Company

CYANIDE CONCENTRATION VS. TIME

SEMILOG SCALE

contamination. The pot-lining pile does appear to be a major cyanide contributor to groundwater. This fact is evidenced by the high concentrations in HC9A and ES10, as compared to wells upgradient of the pile. However, some of these upgradient wells on the plant site do show cyanide levels above background, indicating that some backmixing or backflowing may be occurring, or that other, lesser sources of contamination may exist upgradient of the pot-lining pile. Interestingly, HC9A and ES10 do not show the highest cyanide concentrations, as would be expected of monitoring wells nearest to the downgradient side of the suspected source. Instead, TH3A and TH8, which are downgradient of the brick and rubble pile, as well as the pot-lining pile, show the highest cyanide concentrations. This seems to indicate that either HC9A and ES10 are not representative of the levels of cyanide contamination present, or that the brick and rubble pile is contributing cyanide to the groundwater. Many of the monitoring wells, including HC2A, ES10, TH3A, TH8, TH2, HC7, and HC8, have shown slight to considerable declines in cyanide levels in recent months, while other monitoring wells, including HC17, HC1, and HC12, have shown increases in cyanide levels recently. This may, however, be attributable to hydrologic changes resulting from the abandoning of Tharpe Lake. There also appear to be some cyclic trends evident in the monitoring wells; this could be the result of seasonal precipitation variations which periodically wash a "slug" of cyanide into the aquifer, or it could be the result of low flow periods in the aquifer which would mean less available water to dilute the cyanide. Once the cyanide leaves the plant site and travels downgradient, it is substantially diluted, with the free cyanide water quality criterion being only occasionally exceeded in downgradient domestic wells. The cyanide plume boundaries appear to be fairly well defined downgradient, and, to date, no clearly defined upward or downward cyanide concentration trends can be identified in the contaminated domestic wells or springs.

6.3.2 Fluoride

The fluoride concentrations in the Kaiser monitoring wells and the downgradient domestic wells seem to follow the same pattern as seen for the cyanide contamination.

HC14, the farthest upgradient monitoring well, shows an interesting fluoride trend. Since the well's inception in September 1981, the fluoride level has fallen steadily from 3.12 ppm down to about 1 ppm in more recent analyses. One possible explanation is that the water from Tharpe Lake that was perched on the aquitard was backflowing towards HC14 and causing slightly elevated fluoride levels; then, when Tharpe Lake was abandoned, the backflowing action was stopped and the fluoride levels fell accordingly.

Progressing northwest, towards the pot-lining pile, the fluoride levels begin to rise. In ES9 the fluoride concentration stays fairly constant, at about 0.3 ppm. HC15 has slightly elevated fluoride concentrations, mostly around 1 ppm, though one analysis shows 16 ppm. HC17, situated in the sludge bed, has fluoride levels around 10 ppm, which may be a result of the sludge solids containing calcium fluoride (CaF_2). HC1, on the south side of the abandoned settling basin, has concentrations around 3 to 4 ppm. HC2A, which draws from the "B" zone on the west edge of the pot-lining pile, has fluoride levels ranging from 4 to 6 ppm.

Continuing on to the downgradient side of the pot-lining pile, the fluoride concentrations become substantially elevated. HC9A, right next to the northwest side of the pile, shows levels generally in the 50 to 100 ppm range. Likewise, ES10 has fluoride levels which hover in the 30 to 70 ppm range. Farther downgradient, on the northwest side of the brick and rubble pile, TH8 and TH3A show even higher fluoride concentrations, generally ranging from 100 to 300 ppm.

Moving farther downgradient, TH6 shows fluoride levels becoming less elevated. TH6 is located about 2,000 feet northwest of the pot-lining pile, and is nested to sample water from the "A", "B", and "C" zones. TH6A has fluoride levels generally ranging from 10 to 20 ppm. TH6B shows slightly higher fluorides, along with an increasing trend, with fluoride levels rising from the 10 to 30 ppm range in mid 1982 up to the 50 to 60 ppm range in more recent analyses. TH6C shows fluoride levels closer to background, with concentrations generally hovering around 1 ppm. Progressing downgradient to the residential wells, the fluoride levels return to somewhat lower values, staying below 1 ppm. There is no known report of fluoride levels in any domestic well exceeding the water quality standard.

6.3.3 Other Contaminants

Other factors which may be contributing to the degradation of the groundwater quality include elevated temperature and high pH; abnormal levels of the metals arsenic, aluminum, iron, and manganese; and the presence of the contaminants phenol, ammonia, nitrates, nitrites, and 1,1,1-trichloroethane. However, for the most part, analytical data concerning these contaminants are limited.

Elevated groundwater temperatures were reported for the Kaiser well HC13, which is located about 500 feet southeast of the pot-lining pile. Temperatures at this well range from 70°F to 90°F, while the temperatures in the farthest upgradient monitoring well, HC14, generally fall in the 47°F to 60°F range. Kaiser wells downgradient of the pot-lining pile show temperatures around 50°F to 70°F. The elevated groundwater temperatures at HC13 may be the result of its proximity to the carbon baking furnaces, which may be acting as a heat sink into the groundwater. The slightly elevated temperatures in the wells downgradient of the pot-lining pile may be due to some type of exothermic rection, such as the dissolution of contaminants into the groundwater.

A priority pollutant scan run on water samples from the Binsfield/Chevillet well, the Pioneer Realty well, and the County Road Department well detected only 1,1,1-trichloroethane, in addition to cyanide. The concentrations of 1,1,1-trichloroethane were well below the water quality criterion, ranging from 0.3 to 1.2 ppb, and are not considered to be of significance. The analyses were conducted by the Spokane County Health District (SCHD) in December 1978.

Robinson and Noble, Inc., in their report released in 1979, stated that measurable concentrations of phenols had been detected in three domestic wells downgradient of the Kaiser-Mead plant. The report did not define in which wells the phenol had been found or the actual phenol concentrations. The report stated that the phenol may have originated from industrial activities not related to the Kaiser-Mead plant.

Metals analyses conducted on downgradient drinking water wells in November 1978 showed most metals were present at levels below the drinking water standards. Concentrations of iron were found above the drinking water standard in five of the thirteen wells tested. Iron levels ranged from 0.05 to 3.2 ppm. The only other metal detected above the drinking water standard was manganese, and the standard was only exceeded in one isolated case where the manganese level reached 0.78 ppm. The analyses were conducted and reported by the Spokane County Health District.

Leachate collected from the horizontal borings under the pot-lining pile was analyzed by the EPA Region X laboratory in December 1978. Aluminum was detected at 94,000 ppb, arsenic was found at 98 ppb, and ammonia was analyzed at 632 ppm. No other information is available on the levels of these contaminants in the groundwater. A complete listing of the results for this analysis is presented in Table 6-1.

Robinson and Noble, Inc., reported that elevated pH readings had been detected in Kaiser monitoring well TH3, with values ranging from 8 to 11.3. Twenty-five samples from downgradient domestic wells within the plume were analyzed for pH by Kaiser's Center for Technology in September 1978. One sample showed a pH of 8.1, while all others had pH levels ranging from 10.5 to 12.2 (T. A. Palmer, 10-27-78).

6.4 Surface Water

The surface waters discussed here will only include Peone Creek and the Little Spokane River. The springs which outfall from the aquifer are addressed in the groundwater discussion (Section 6.3).

Peone Creek had been connected to Tharpe Lake by an underground aqueduct and is therefore suspected as being the ultimate discharge point of the pot-soaking

TABLE 6-1

KAISER POT-LINING LEACHATE ANALYSIS

Metals	Concentration (ppb - Except Where Noted)	Parameter	Concentration (ppb - Except Where Noted)
Antimony	15	Cyanide	130
Arsenic	98	Phenolics (AAP)	5
Cadmium	7	Chloride	10 ppm
Copper	27	Fluoride	2720 ppm
Manganese	16	Sulfide	44 ppm
Nickel	25	Ammonia	632 ppm
Selenium	25	Toluene	0.4
Silver	13	Acetone	200 (Estimated)
Thallium	<1	Phenol	0.02
Beryllium	1	Unknown	2.5×10^6 (Estimated)
Chromium	11		
Lead	40		
Mercury	0.36		
Zinc	20		
Calcium	250		
Aluminum	94,000		

All other compounds were found to be present in concentrations below established reporting limits.

EPA Region X Laboratory, December 22, 1978 water which had been dumped into Tharpe Lake. At present, Peone Creek receives the effluent from the newly constructed settling basin via an underground aqueduct.

Water samples from Peone Creek, both upstream and downstream of the underground aqueduct discharge point, show very little, if any, cyanide contamination. Generally, up-and-downstream sampling points agree closely, with total cyanide concentrations usually less than 1 ppb and never greater than 10 ppb, and free cyanide concentrations below the detectable limit.

The Little Spokane River receives cyanide contamination from the aquifer through two routes. First, contaminated springs which outfall from the aquifer ultimately flow to the Little Spokane and second, the aquifer itself discharges directly to the river.

Surface water samples from the Little Spokane River indicate that the cyanide plume meets the river at mile 10.3. Upstream of mile 10.3, total cyanide concentrations are generally less than 1 ppb, with free cyanide concentrations below the detectable limit. Downstream of mile 10.3 total cyanide concentrations range from 3 ppb to 150 ppb, with one isolated sample taken 50 yards downstream from the Dr. Popp property on September 10, 1982, analyzing at 376 ppb total cyanide. Free cyanide concentrations downstream of mile 10.3 range from below the detectable limit up to 14 ppb. Kaiser's analytical data on the Little Spokane River only extends as far downstream as about mile 9. Analytical data on free and total cyanide levels downstream of mile 9 and in the Spokane River downstream of its confluence with the Little Spokane are unavailable.

6.5 Biota

Available information indicates that no fish kills or plant stress have occurred in the area. An ecological survey of the Little Spokane River in relation to cyanide inputs was conducted over a 16-month period from April 1979 to September 1980.

This survey, conducted by Rolf Hartung, Ph.D., Professor of Environmental Toxicology; and Peter G. Meier, Ph.D., Associate Professor of Environmental and Industrial Health, concluded that the mixture of free and complex cyanides in the low parts per billion concentrations found in 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 respect to their reactions to cyanide, the absence of an effect on the fish populations indicates that the present levels of cyanide contamination in the Little Spokane River do not constitute an undue ecological or public health hazard.

Only one plant test was reported in the criterion document. According to Fitzgerald (1952) 90 percent of the blue-green algae were killed when exposed to a free cyanide concentration of 7,790 ppb. No plant life is exposed to more than 1 percent of this level; therefore, no plant stress is suspected. Since it is uncommon to find cyanide in edible plants, except for certain naturally occurring organonitriles, and since "there are no studies of cyanide reporting biomagnification in the food chain" (Ecological Analysts, 1979), no health risk is associated with the ingestion of fish or plant life from this area.

7.0 PUBLIC HEALTH CONCERNS

7.1 Air Pollution

Free cyanide can enter the air as hydrogen cyanide (HCN); the surface of the Little Spokane River and the springs along its south bank lend themselves to this process. At concentrations known to be in these waters, however, no appreciable amounts will evolve. It is also noted that HCN is lighter than air and will immediately rise and disperse upon volatilization.

Oxidation of free cyanide to cyanogen and cyanate reduces the concentration of free cyanide in solution; once cyanate is formed it will not revert back to free cyanide (Ecological Analysts, 1979) but will instead undergo hydrolysis to form carbon dioxide (CO_2) and ammonia (NH_3), given time and proper conditions, as illustrated in the following equations:

$$OCN^- + 2H^+ + H_2O \rightarrow CO_2 + NH_4^+$$

and

$$OCN^- + OH^- + H_2O \rightarrow CO_3 + NH_3.$$

As with the HCN, no appreciable amount of CO_2 or NH_3 is expected to emanate from the surface waters because of the low concentrations in these waters.

Two point sources of ammonia vapors have been identified on site. These two point sources are the pot-lining storage building and the asphalt-covered pot-lining pile. Ammonia vapors known to accumulate within the pot-lining storage building are believed to be formed via the above described reaction, following the contact of the cyanide in the pot-linings with moisture and condensate from the ambient air. Ammonia levels in the air inside the building are not known but are expected to be in the ppm range (NUS site visits, 1983). The asphalt covered pot-lining pile has four gas vents which act to release any ammonia vapors in the pile. These two point sources of ammonia vapors are not considered to be a threat to public health since they are on site and the vapors are expected to disperse to below detectable levels shortly after being released to the atmosphere.

7.2 Soil Contamination

As discussed in Section 6.2 of this RAMP, several areas of moderate to high surface soil contamination exist around the plant site. In particular, surface soil concentrations of total cyanide have been identified in the area of the former pot-soaking activities, where one analysis shows 985 ppm of cyanide at the surface, and in the area of the newly discovered pot-linings, where levels as high as 760 ppm total cyanide have been reported. Also, soils in the sludge bed have shown elevated concentrations of cyanide. Exposed areas of high fluoride levels also include the area of newly discovered pot-linings (0.01 to 2 percent) and the former pot-soaking area (0.01 to 0.1 percent).

However, no risk to the general public is believed to be present as a result of these contaminated soils because the soils are all located within the fence-enclosed boundaries of the Kaiser-Mead plant and are, therefore, inaccessable to the general population. The only risk to the general public from these contaminated soils is the possibility of the soils leaching cyanide into the groundwater. In addition, the soils in the vicinity of the springs and river banks within the boundaries of the plume may contain small amounts of cyanide; however, this is not expected to be of any significance. Levels of cyanide and fluoride are high enough on site in the exposed soils described above to pose a dermal hazard.

7.3 Groundwater Contamination

The following contaminants have been found in the groundwater and/or the pot-lining leachate:

- Cyanide (free and total)
- Fluoride
- Aluminum

- Phenol
- 1,1,1-trichloroethane
- Chromium, lead and manganese
- Iron and barium
- Ammonia

Cyanide

Free cyanide, which has been found to comprise about three percent of the total cyanide, has been detected in the groundwater. Water samples from private wells and springs generally contain less than the level of 200 ppb free cyanide specified by the Federal Safe Drinking Water Act (FSDWA); however, occasional samples from domestic wells and springs within the plume boundaries have exceeded the free cyanide limit.

Hydrogen cyanide is highly toxic (LD_{50} ORAL HUMAN 1 to 2 mg/kg), with the mean lethal dose by mouth for adults being in the range of 120 to 200 mg, with death rarely being delayed for more than an hour. In respiratory exposure to hydrogen cyanide gas, death occurs in 10 to 60 minutes at ambient air concentrations of 100 ppm to 300 ppm. In non-fatal poisonings recovery is generally rapid and complete. Hydrogen cyanide's acute effect is caused by the inhibition of the enzyme cytochrome oxidase, which in turn impairs oxidative metabolism. Poisoning resembles acute hypoxia, which is the absence of oxygen. Cyanide is not suspected to have any carcinogenic, bioaccumulative, or chronic effects.

Fluoride

Elevated fluoride concentrations have been found in the groundwater around the plant site; however, no private drinking water wells have been found to have fluoride concentrations above the FSDWA standards of 0.7 ppm to 1.3 ppm (dependent on air temperature). Kaiser monitoring wells show high levels of fluoride above normal background, but not at toxic levels.

Aluminum

A Suggested No Adverse Response Level (SNARL) for aluminum in drinking water is reported as 35 ppm for 24 hours and 5 ppm for a 7-day period, with no data available for the chronic situation (Drinking Water and Health, Vol. 4, 1980). Aluminum was detected in the leachate from the pot linings at a level of 94 ppm. No data are available on the aluminum concentrations in the groundwater.

Phenol

Robinson and Noble, Inc. reported that measurable concentrations of phenols have been observed in three wells in the study area. The report stated that this contaminant may have originated from an oil refining and storage area, or some other industrial activity in the area, not related to the Kaiser-Mead plant (Robinson and Noble, Inc., 1979). Water Quality Criteria for the protection of public health lists a level of 3.5 ppm for phenol. Insufficient data exist on the concentrations of phenol in the groundwater to make a proper assessment of the health risk associated with this contaminant; however, if the water is not consumed, then no risk is involved.

1,1,1-trichloroethane

This organic compound was found in three wells in the area. The Binsfield well, the Pioneer Realty well, and the County Road Shop well have been found to contain 1,1,1-trichloroethane, which has a low toxicity and is not considered to be a carcinogen. The long-term or chronic SNARL is placed at 3.3 ppm for an adult and 1 ppm for a child. The levels found in the three wells were in the 0.0001 ppm range and would therefore not pose a threat to public health.

Chromium, Lead, Manganese, and Arsenic

These contaminants were found slightly above the FSDWA limits on the site. Dilution by the groundwater brought the levels of these metals down to below the recommended levels for safe drinking water by the time they reached existing downgradient drinking water wells.

Iron and Barium

These metals were detected in downgradient private wells. Barium was never detected above the FSDWA maximum contaminant level (MCL) of 1 ppm. High levels of iron have been found each time cyanide has been detected. The large amount of iron may be in association with complex iron cyanides.

Ammonia

Although ammonia has not been tested for in any water samples, it is a known by-product of cyanate hydrolysis and is expected to be present. Quality criteria for water recommends a maximum level of 0.02 ppm in surface water for the protection of freshwater aquatic life; no criteria for the protection of human health are available for ammonia.

Summary

The drinking water standards for free cyanide and iron have been exceeded. The principal toxic contaminant, free cyanide, has, on isolated occasions in the past, been detected at levels above the maximum contaminant limit (MCL) in private wells downgradient of the plant site, and because of the erratic behavior of the free cyanide concentration in the groundwater, the MCL may again be exceeded in the future. Iron levels in downgradient private wells have also exceeded the MCL, and phenol has been detected in private wells, though the exact phenol concentrations are not known. For these reasons a public health risk does potentially exist if the groundwater downgradient of the Kaiser-Mead plant is used for drinking water.

7.4 Surface Water Contamination

Several springs in the path of the cyanide plume are contaminated with free cyanide. Spring water is known to have exceeded the MCL of 200 ppb recommended for drinking water, and the criteria for the protection of freshwater aquatic life have also been exceeded. For free cyanide (the sum of cyanide present as HCN or CN^-), the guidelines for the protection of freshwater aquatic life are reported as 3.5 ppb for a 24-hour average, with the free cyanide concentration not exceeding 52 ppb at any given time. The Dart, Van Gelder, and Popp springs have exceeded the 24-hour average criterion; however, only the Van Gelder spring has been shown to exceed the 52 ppb criterion.

The Little Spokane River receives cyanide inputs via two processes. First, the contaminated springs which outfall from the aquifer eventually flow into the river, and second, the river receives groundwater directly from the aquifer. Analytical results from river water samples indicate that the cyanide plume meets the river at stream mile 10.3 (Hartung and Meier, 1980). Available information on the free cyanide concentrations in the river show levels which range from below detectable limits up to 14 ppb. Therefore it appears as though the 24-hour average criterion of 3.5 ppb free cyanide for the protection of freshwater aquatic life may be, at times, exceeded in the river. No river water samples have been shown to exceed the 52 ppb limit. No information is available on the free cyanide concentrations downstream of mile 9 of the Little Spokane River.

An ecological survey of the Little Spokane River was completed in August 1980 by Rolf Hartung, Ph.D., Consultant in Environmental Toxicology; and Peter G. Meier, Ph.D., Associate Professor of Environmental and Industrial Health. They concluded that the mixture of free and complex cyanides known to be present in low parts per billion concentrations in the lower 10 miles of the Little Spokane River did not produce any noticeable effects on the populations of fish and micro-invertebrates (Hartung and Meier, 1980).

7.5 General Risk Assessment

Air: No health risk is imposed upon the general public since the concentrations in surface waters are too low to volatilize hazardous quantities of hydrogen cyanide. However, site workers may require respiratory protection in areas of suspected ammonia generation.

Soil: No health risk is imposed upon the general public because the contaminated soils are confined to the fenced-in Mead Plant and the public is not exposed to it. Site workers may require dermal protection in areas where contaminant levels are above concentrations known to constitute a hazard.

Groundwater: The groundwater is contaminated with free cyanide, iron, and possibly phenol, and poses a health threat to the general public if water from private wells or springs downgradient of the plant site and within the plume boundaries is used for drinking.

Surface Water: The Little Spokane River is only slightly contaminated with free cyanide, does not show ill effects from this contamination, and does not pose a threat to the general population. Cyanide is not bioaccumulative; therefore, the food chain is not being poisoned.

In general, if the public wells and springs within the plume boundaries are not used for drinking water, no health risk exists. These are the only accessible sources of contaminants with high enough concentrations to begin to have an adverse effect on the local residents. Disposal and storage areas on site have considerably higher concentrations of contaminants and pose risks to site investigators and site workers. Adequate precautions to eliminate exposure to these materials is needed.

8.0 EVALUATION OF EXISTING DATA BASE

The following section briefly discusses the available data on the contamination at the Kaiser-Mead Works. Each of the environmental categories--air, soil, groundwater, surface water, and biota--are briefly discussed in terms of the available information, followed by a short discussion on the additional data needs to fully characterize the contamination problem in that category.

8.1 Air

No information is available on the air quality around the areas of contamination on site. Air pollution does not appear to be a threat at the plant site although, air monitoring for HCN and NH_3, especially around the pot-lining pile and in the storage building, may be an appropriate measure to prove that no hazard exists.

8.2 Soil

The available soil data originate from Kaiser-Mead's consultants. Hart-Crowser reported cyanide and fluoride levels at varying depths during the installation of monitoring wells and test borings. These data are presented with the well logs and can be clearly followed. Robinson and Noble, another Kaiser consultant, gave one isolated soil quality report on the sludge bed. Both of these data sources indicate that substantial soil contamination exists at various areas on site.

Additional soil quality information would be useful for the soil under the butt tailings pile and the brick and rubble pile. Also, soil quality in any areas where pot-linings are discovered would be valuable.

8.3 Groundwater

Extensive groundwater data are available from Kaiser's monitoring program. From August 1978 through June 1981, Kaiser analyzed for total cyanide in domestic wells and monitoring wells. From July 1981 up through the present, Kaiser has analyzed for total and free cyanide, as well as fluoride, in groundwater samples. Sampling and analyzing procedures have been reported, and sample splits have been done with other laboratories.

Beyond Kaiser's data, information on groundwater quality is limited. Metals analyses were performed by the Spokane County Health District (SCHD) on thirteen domestic downgradient wells in November 1978. The SCHD also did a priority pollutant scan on three downgradient domestic wells. Leachate from the pot-lining pile was once analyzed by the EPA Region X laboratory, and pH analyses were run on 25 domestic well samples by Kaiser's Center for Technology Laboratory.

Although Kaiser's groundwater monitoring program is quite extensive and should definitely be continued, some additional data needs are evident. Not all aquifer zones around the site have been adequately monitored, and additional groundwater parameters, including ammonia, aluminum, and pH, need further investigation.

8.4 Surface Water

Extensive surface water data have also been generated by Kaiser-Mead. Surface water samples were analyzed for total cyanide, then later for free cyanide and fluoride also, as described in the groundwater discussion.

Surface water sampling and analysis should be continued although additional parameters should be checked, including ammonia, aluminum, and pH.

8.5 Biota

The available data on biota are limited to one ecological survey, funded by Kaiser, on the Little Spokane River. No reports of plant stress are known to exist.

At the present time, it is felt that no additional data on the biota are necessary to characterize the contamination problem.

9.0 HEALTH AND SAFETY PROCEDURES

9.1 Personal Health and Safety Protection

Free cyanide is the principal contaminant to which workers should not be over exposed. Ambient air concentrations of 100 ppm to 300 ppm hydrogen cyanide can cause death in as little as 10 minutes. Hydrogen cyanide will readily pass through the skin, mucous membranes, and eyes adding to the overall exposure. However, because of the caustic nature of the pot-lining material, very little of the free cyanide present is expected to exist as molecular HCN; therefore exposure via inhalation of HCN gas in not expected.

Exposure to ammonia fumes via the inhalation route should be investigated. The maximum ammonia level recommended by the Occupational Safety and Health Administration (OSHA) is 50 ppm. If air monitoring, especially in the pot-lining storage building, reveals that air concentrations of ammonia approach or exceeded this limit, then respiratory protection may be required to protect workers while in this area.

Cyanide and fluoride concentrations present in the pot-lining pile, the brick and rubble pile, the area of the former pot-soaking activities, and the area of the newly discovered pot-linings are high enough to be potentially hazardous by dermal contact. Direct skin contact with these materials or the soils in these areas should be avoided.

Groundwater samples from Kaiser monitoring wells contain up to 230 ppm total cyanide and as high as 60 ppm free cyanide. This contaminated water should be considered hazardous and skin contact avoided.

9.2 Health and Safety Monitoring

Monitoring for airborne ammonia and hydrogen cyanide is advised in order to protect the health of workers when excavating, treating, or distributing the contaminated wastes.

10.0 RECOMMENDATIONS AND CONCLUSIONS

10.1 Review of Past Actions

In 1978, cyanide was found in domestic wells in the vicinity of the Kaiser-Mead aluminum reduction facility, and a sampling program was established to characterize the contamination. The sampling program identified a plume of cyanide-contaminated groundwater apparently originating at the Kaiser-Mead plant and heading northwest to the Little Spokane River.

Following the discovery of the cyanide plume, Kaiser-Mead became very interested in identifying and eliminating the source(s) of cyanide contamination, as well as in supplying water to residents whose wells had been contaminated. Kaiser hired a geological consulting firm, Robinson and Noble, Inc., to investigate the contamination problem.

The consultant released a report in 1979 which identified Kaiser-Mead as the cyanide contamination source. The report identified three possible methods of groundwater contamination:

1. A pile of cyanide-containing waste pot-linings, stored in the northwest portion of the plant, was leaching cyanide into the groundwater.

2. A ten-acre sludge bed, found to contain cyanide, was leaching into the groundwater.

3. Pot-soaking water, found to contain high concentrations of cyanide, was being discharged to the ground, to the sludge bed, and to the settling basin, and was probably contributing to the groundwater contamination.

Subsequent to these findings, Kaiser attempted to stop further contamination by discontinuing pot soaking activities, by covering the pot-lining pile with an asphalt layer to prevent further leaching, and by discontinuing further sewage effluent discharges to the sludge bed. No other actions were taken on the sludge bed because the fine-grained material in the bed was considered adequate to prevent infiltration and because the moisture-holding capacity of the bed would further decrease the potential for infiltration. Kaiser also constructed an asphalt-covered and drained area for the short-term storage of the continuously generated pot-linings until a more permanent storage building could be constructed; this building was completed in late 1981.

As Kaiser conducted these on-site activities, it also concerned itself with the off-site impacts of the contamination. Residents who had had their drinking water wells contaminated by cyanide were supplied with bottled water until they could be connected to municipal water or could have a well drilled to the deeper, uncontaminated portions of the aquifer. Most of the affected residents chose to be connected to municipal water. This task was completed by late 1979. Kaiser paid for the cost of drilling new wells or for having affected residents connected to municipal water. Additionally, Kaiser continues to pay the water bills for those residents on public water. Kaiser also funded an ecological survey of the Little Spokane River to determine the effects of the cyanide inputs on the aquatic life of the river. The survey concluded that no ecological or public health hazards were associated with the low levels of cyanide in the river.

In 1980, Kaiser hired another consultant, Hart-Crowser and Associates, to conduct a geohydrologic survey of the groundwater at the Kaiser-Mead plant; Kaiser has retained Hart-Crowser as its groundwater consultant through the time of this writing. Hart-Crowser supplemented the previously installed monitoring wells around the site with additional monitoring wells in order to further characterize the groundwater contamination and to follow the expected attenuation.

When the cyanide levels in the groundwater did not decrease as expected, Hart-Crowser theorized that some form of artificial recharge was responsible. Hart-Crowser felt that precipitation recharge was insufficient to transport enough cyanide to the water table to account for the observed levels of contamination. In addition, the asphalt-covered pile and storage areas were felt to be effective barriers to infiltration. Hart-Crowser identified two possible sources of artificial recharge: 1) leakage from subsurface water pipes and storm sewers; and 2) leakage from Tharpe Lake, an unlined settling basin located about 200 feet northeast of the pot-lining pile. Subsequent to the testing of the pipes beneath the plant, Hart-Crowser felt that pipe and sewer leakage was small and should therefore not have caused the observed high levels of cyanide in the groundwater. An infiltration test of Tharpe Lake indicated that water was leaking through the bottom of the settling basin at a rate of 50 to 60 gallons per minute. Hart-Crowser then formulated the following theory of the contamination mechanism:

- A column of soil beneath the pot-lining pile has been contaminated by cyanide leaching from the pot-linings.
- A silt and clay aquitard, verified by well borings, is present under the pot-lining pile and Tharpe Lake.
- This aquitard was perching the water that was leaking from Tharpe Lake, and was directing this water through the contaminated soil underneath the pot-lining pile.
- The perched water was dissolving the cyanide from the contaminated soil, and was transporting this cyanide to the aquifer.

Based on this theory, Kaiser drained and backfilled Tharpe Lake in the autumn of 1981, and constructed a new settling basin one-half mile to the north of the former basin. After abandoning Tharpe Lake, Hart-Crowser observed hydrologic changes resulting from the removal of this artificial recharge source. These changes included the decay of a groundwater mound which had been formed on the aquitard by the artificial recharge, and a shifting of the groundwater flow beneath the pot-lining pile to a more northerly direction. Once these hydrologic changes had stablized, Hart-Crowser reported a downward trend in cyanide levels for some monitoring wells.

At the time of this writing, Hart-Crowser feels that these past actions are sufficient to prevent any further cyanide contamination, and that the aquifer should begin to flush itself of the contamination. In its December 1982 groundwater report, Hart-Crowser estimated that the cyanide concentrations in monitoring well HC9A, located directly downgradient of the pot-lining pile, should begin to show a decline in cyanide levels sometime between February and May 1983. The most recently available data on HC9A, taken in late April 1983, do not show this predicted decline, and in fact, a steady increase in cyanide for HC9A is evident since December 1982.

10.2 Rationale for Further Investigations and Remedial Actions

As implied in the discussion presented in Section 6.0 of this RAMP, it would be premature to judge whether the remedial actions to date have completely solved the groundwater contamination problem; although it is evident that some improvement in the groundwater quality has occurred since these actions were taken. Particular areas of ongoing concern are outlined in this subsection; recommendations regarding further investigations are discussed in subsection 10.3.

A primary area of concern, as related to continuing aquifer contamination, is the brick and rubble pile. This large heap of miscellaneous debris, mostly refractory brick, may be leaching cyanide into the aquifer. Three borings done through the brick and rubble pile have all shown the presence of pot-lining material, with accompanying cyanide levels that are, in some instances, similar in magnitude to those levels found in the pot-lining pile. Further evidence of groundwater contamination from the brick and rubble pile is demonstrated by the cyanide levels in the nearby monitoring wells. HC9A and ES10, which are adjacent to the upgradient side of the brick and rubble pile, show total cyanide levels generally in the 50,000 to 100,000 ppb range, while TH3A and TH8, which are adjacent to the downgradient side of the brick and rubble pile, show total cyanide concentrations in the 100,000 to 200,000 ppb range. This difference, however, may be caused by an aquitard, which intercepts part of the downward migrating contaminants. These intercepted contaminants may then move laterally along the aquitard before finally continuing downward to the water table.

Another possible contamination source may be the butt tailings pile, which is located next to the west side of the brick and rubble pile. The reasons for suspecting the butt tailings pile are the nature of the material and the process by which it was generated. The butt tailings material is reported as containing about 85 percent carbon, and was generated from 1966 through 1982. This material results from a process in which the coating of impurities on the spent pot-cell anodes were scraped off and discarded in what is now called the butt tailings pile. Since the pot-cell anodes are exposed to the same conditions of high temperature and atmospheric nitrogen which form the cyanide in the pot-linings, it is suspected that cyanide may also be formed in the anode coating. Dale Schmidt, of Kaiser-Mead, states that the anodes are only exposed to high temperatures for 96 hours; while the pot-linings are exposed to high temperatures for about 1000 days; therefore, the cyanide formation in the anodes is insignificant as compared to the pot-linings (D. A. Schmidt, personal communication 5-23-83). Nevertheless, the exact mechanism and kinetics of cyanide formation in the pot-linings and anodes are unknown at this time. An EP Toxicity test conducted on the butt tailings material indicated that the butt tailings pile may be a considerable source of fluorides, though cyanide was not even mentioned (D. A. Schmidt, 5-26-83). This does not necessarily preclude the possibility that cyanide is present in the pile, since the EP Toxicity analysis does not generally include cyanide, and even if it did, the acid conditions of the test may result in the volatilization of cyanide from the sample. Finally, monitoring wells HC7 and HC8, which are located along the west and northwest sides of the pile, show total cyanide levels ranging from 3,000 to 85,000 ppb; however, these high cyanide levels may also be the result of lateral contaminant migration along an aquitard, as previously described in the brick and rubble pile discussion.

The area of newly discovered pot-linings may also be contributing to the degradation of the groundwater quality, though it is reportedly the responsibility of the Washington State Department of Ecology (DOE) to decide what disposal method will be used for these linings (D. A. Schmidt, personal communication, 4-19-83). Hart-Crowser issued a report in March 1983 which basically concluded that it is highly unlikely that these linings represent a significant or potential groundwater contamination source. This conclusion was qualified first by calculating the average natural recharge as 0.1 inches per year, which is felt to be insufficient to allow significant cyanide migration to the water table. Hart-Crowser then theorized that contaminant migration through the soil under these linings was greatly aided by artificial recharge. This resulted in high cyanide levels in the soil down to a depth of about 60 feet. Since these artificial recharge sources were removed (i.e., abandoning Tharpe Lake and discontinuing sewage effluent discharge to the sludge bed) the contaminant migration now moves downward at a rate of less than 0.2 feet per year. Hart-Crowser also cited the analyses from nearby monitoring wells, pointing out that no significant increase in cyanide levels is evident from upgradient to immediately downgradient wells. Hart-Crowser did not mention that a boring through these linings indicates that a clayey silt layer exists at a depth of 60 feet. This layer may be laterally transporting contaminants, so that they are not detected in wells immediately downgradient. The existence of this layer may also explain why the soil cyanide levels are considerably elevated only to a depth of 60 feet.

The fact that these newly discovered buried pot-linings exist indicates that there is a possibility of other undiscovered pot-linings being buried on the site. Monitoring wells ES9 and HC15, which are about 1800 feet upgradient of the pot-lining pile, show total cyanide levels that are above background, indicating that some lesser contamination sources may be located east of the pot-lining pile.

Ongoing sources of artificial recharge around the plant site are also worthy of consideration. During full production, Kaiser uses from 2 to 3 million gallons of water per day, most of which are used to cool the pot-rooms and carbon baking buildings. This water all goes to the plant storm sewers, along with any storm water runoff, and is sewered out to the new settling basin (D. A. Schmidt, personal communication, 5-23-83). Obviously this is a large amount of water, which could result in significant artificial recharge if there were leaks in the subsurface sewers or water mains. With the aid of CH_2M Hill, Kaiser tested the pipes and sewers under the plant, and sealed any identified large leaks. However, the available information indicates that as much as 36.5 gallons per minute may still be leaking from subsurface water mains. Also, the available information implies that only selected segments of the sanitary and storm sewer systems were checked for leakage, and not the entire systems (CH_2M Hill, 4-15-82, 6-10-82, 8-24-82, and 9-8-82).

On a much smaller scale, the Kaiser-Mead plant may be contributing to artificial recharge through its sampling program. Apparently, water purged from monitoring wells prior to sampling is simply discharged to the ground (D. A. Schmidt, personal communication, 5-23-83). Admittedly, this is a rather small quantity of water available for recharge, but it may combine with other natural or artificial recharge events to influence local recharge to the aquifer.

To the southwest of the Kaiser plant is located a tract of land, covering roughly four acres, which is designated the "fill area." This area was reported to have been a ravine which was used to dump excess earth from the excavations during the construction of the pot-rooms (D. A. Schmidt, personal communication, 5-23-83). The only reason that this area is suspect is that there is no available information on the materials in this fill.

Finally, the cyanide concentration increases observed in monitoring well HC12, located to the north of the pot-lining pile, indicate that the contaminant plume may be shifting to the north. This shift could be result of the abandoning of Tharpe Lake, or it could be that the entire aquifer in this area may be undergoing subtle flow direction changes. Nevertheless, if the contaminant plume is shifting to the north, the possibility exists that domestic wells downgradient of the site, which are currently unaffected, may become contaminated at some future time.

10.3 Remedial Investigations

Before the additional suggested remedial investigations are discussed, two points should be made clear. First, through past investigations and actions, it has become evident that Kaiser-Mead personnel are interested in defining and stopping the contamination of the aquifer. Kaiser has funded numerous investigations, conducted many analyses, and paid for past remedial actions. Kaiser has also shown a genuine interest in those residents affected by the groundwater contamination, paying for permanent alternate water supplies and offering medical examinations. There is no reason to believe that Kaiser will not continue to cooperate with actions aimed at mitigating the groundwater contamination problem.

Second, the costs for any subsequent actions must be weighed against the real benefits to be gained from these actions. All affected residents now have permanent supplies of potable water; therefore, no known members of the general public are being unduly inconvenienced or are being exposed to contaminated drinking water. An ecological survey of the Little Spokane River, funded by Kaiser, has determined that no undue ecological or public health hazards are associated with the low levels of cyanide in the river. Also, there is no confirmed instance of injury or death to humans or domestic or wild animals as a result of direct contact with the substances on site. Therefore, before some very expensive remedial action is implemented, the real benefits to be reaped must be carefully reviewed and evaluated.

10.3.1 Monitoring Program

The continuation of the groundwater monitoring program is the most essential action that can be taken at this time. As monitoring data continue to be gathered and analyzed, contamination trends, not readily apparent now, may become evident. Future trends may show that adequate contamination reduction is occurring and that additional remedial actions are not required. On the other hand, if future data do not show sufficient contamination reduction, then further remedial actions may be warranted.

Groundwater quality should continue to be monitored on a regular basis, with a well-defined sampling program being used. In addition, precipitation data should be compiled and evaluated with the sampling data to determine the influence of natural recharge on contaminant levels in the aquifer as well as changes in the plume movement.

Each of the Kaiser monitoring wells should be sampled on a monthly basis. Water levels should be taken before the well is purged, and purge water should be collected for proper treatment and disposal--not simply discharged to the ground.

A network of representative downgradient wells and springs should be established, choosing wells within the plume, outside of the plume, and near the plume boundaries. Also, a reliable upgradient well should be selected for regular sampling; this well should be sufficiently upgradient to be truly representative of background contaminant levels. This network of domestic wells should be sampled at least quarterly, and water level measurements should be made where possible.

At a minimum, all groundwater samples should be analyzed for total cyanide, free cyanide, fluoride, iron, aluminum, ammonia, nitrates, nitrites, and pH. In addition, phenol concentrations in the groundwater downgradient of the site should be investigated to determine if hazardous concentrations of this contaminant exist. Reason for these analyses

10.3.2 Geophysical Investigations

Geophysical investigations may be appropriate both on and off site. Suggested investigations include electromagnetic conductivity, resistivity, and magnetometer surveys. These investigations may be able to determine locations of buried pot-linings, areas of natural and artifical recharge, changes in the local lithology, and elevation of the water table. From this information, zones of perched groundwater may be located and the presence of aquitards may be verified, as well as an exact determination made as to where the aquitards pinch out.

Geophysical investigations should be conducted in the northern one-third of the fence-enclosed plant and in the vicinity of the southwest fill area. Unfortunately, characteristics of the plant, such as the presence of induced magnetic fields may interfere with these investigations. Kaiser reported that an attempt at using a sonar survey to locate subsurface pipes was thwarted by the vibrations from the scrubber fans (D. A. Schmidt, personal communication, 5-23-83). Therefore, the appropriateness and reliability of each geophysical technique must be evaluated under field conditions.

Geophysical investigations would involve setting up an exploration pattern, conducting the survey, and evaluating the resultant data. These techniques may also be used to supplement a drilling program.

If geophysical methods should prove to be inappropriate, pot-linings may be located by using hand augering or other excavation methods. The fact that the recently found pot-linings were buried only 12 to 18 inches below the surface indicates that if any other buried linings exist, they also may be buried at a shallow depth. Therefore, by using shallow borings placed in a grid system, areas of buried pot-linings may be located.

10.3.3 Investigation of the Brick and Rubble Pile and the Butt Tailings Pile

In order to determine the impact of these two piles on the groundwater quality, borings and analyses should be conducted. In the brick and rubble pile, more borings should be done through the pile to determine possible locations of pot-linings. Also, at least one boring should be augered all the way to the "A" zone water table. Continuous split-spoon sampling should be done on this boring, with analyses for cyanide and fluoride content being performed on the soil, as was done for all of the Hart-Crowser monitoring wells. Preferably, this boring down to the water table should be done in an area of the brick and rubble pile which has shown substantial pot-lining deposition.

The material in the butt tailings pile should be specifically analyzed for cyanide content. Also, at least one boring should be done through the pile which extends to the water table. Continuous split-spoon sampling, with subsequent soil analyses for fluoride and cyanide, should also be done on this boring.

Special care must be taken to prevent cross-contamination during augering through the brick and rubble pile and the butt tailings pile. Double casings are recommended for these borings to help prevent the occurrence of cross-contamination.

10.3.4 Investigation of Subsurface Pipe and Sewer Leakage

As previously indicated, the available information implies that not all sanitary and storm sewers have been tested for leakage. If this testing has already been conducted and leakage was found to be negligible, then no further investigations are required. However, if this testing has not been done, then evaluation of leakage in the untested sewers should be performed in accordance with past testing procedures. Efforts should be made to eliminate or correct any detected leakage.

A better method for evaluating leakage from subsurface water mains and sewers would be to conduct an overall material balance on the water used at the plant. Unfortunately, Kaiser does not have adequate metering on all water lines to perform the water balance. Reportedly, installing the needed meters would be very expensive and would require complete plant shutdown (D. A. Schmidt, personal communication, 5-25-83).

10.3.5 Additional Monitoring Wells and Geohydrologic Investigations

does not follow

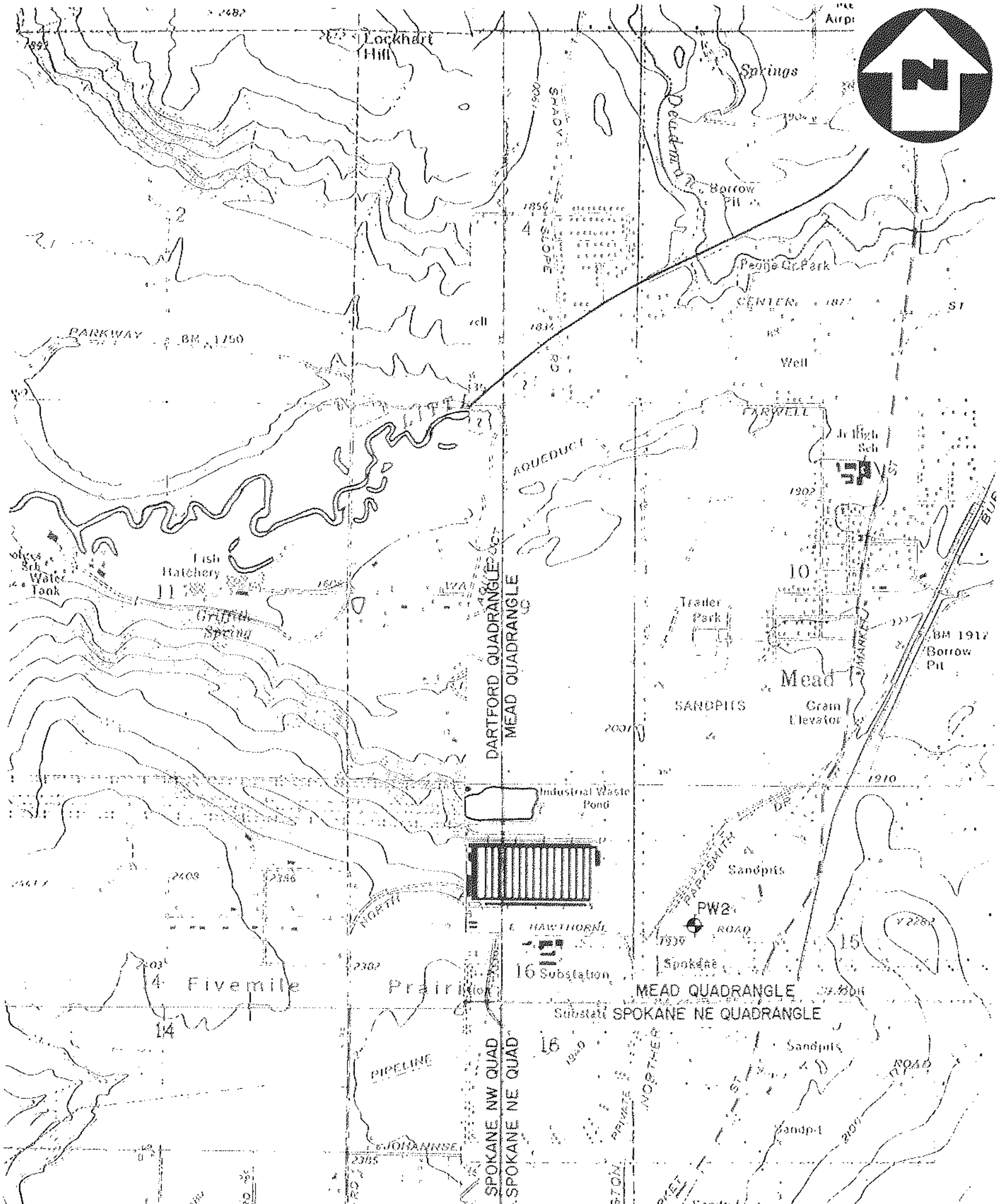
At the present time, no additional monitoring wells or geohydrologic investigations are recommended. However, if ongoing groundwater montoring indicates continuing, unacceptable groundwater degradation, additional monitoring wells and geohydrologic investigations may be needed. The following discussion suggests some monitoring well locations and geohydrologic investigations which would be helpful in defining and stopping the groundwater contamination in the event that ongoing monitoring shows that the contamination problem has not been adequately solved.

Figure 10-1 shows five approximate locations for additional monitoring wells, if they are deemed necessary at some future time. Each location may contain more than one well. The wells may be installed to monitor different zones within the perched groundwater system and the regional aquifer. Other well locations may be required if new areas of contamination are discovered. All of the wells used to monitor the "C" zone should be set deeper than the top of the zone. To detect possible downward migrating contaminants, screens should be set on top of the first confining layer within the "C" zone. Where the upper portion of the aquifer has not been divided by aquitards, the wells should be set on top of the first confining layer of the main aquifer.

In the vicinity of HC12, proposed well location PW1 would be installed to detect a plume shift to the north. Any perched groundwater systems, and the "A", "B", and "C" zones within the aquifer, would be monitored at this location.

Wells at PW2, near the upgradient well HC14, would be installed to measure background water quality in any perched zone and in each zone of the main aquifer.

Wells at PW3 would be installed in the vicinity of TH-3A and TH-8. Monitoring intervals would be established in any perched zones and on top of the first confining layer in the "C" zone. Wells set at this location may detect contamination caused by the brick and rubble pile and possibly the butt tailings pile. Two suggested well locations, PW4 and PW5, are about 4000 feet to the northwest of the Kaiser-Mead plant, within the plume boundaries. As seen in the topographic features in Figure 10-1, a bluff exists in this vicinity. The base of the



BASE MAP IS A PORTION OF THE FOLLOWING U.S.G.S. QUA

APPROXIMATE LOCATION OF KAISER ALUMINUM AND CH

PW1 APPROXIMATE LOCATION OF

PROPO

FIGURE 10-1

NUS CORPORATION
A Halliburton Company

bluff lies at about 1800 feet in elevation, which is aproximately the elevation of the water table beneath the Kaiser-Mead plant. It is likely that the aquitards in the unsaturated zone, and those which divide the upper portion of the main aquifer, "pinch out" along the wall of this bluff. Also, springs may emanate from the aquifer at this point. Therefore, wells at the top of the bluff (PW4) and at the bottom (PW5) will better define the lithology in this area (i.e., where the aquitards exist) and the groundwater migration patterns from the upper to the lower zones in the main aquifer. These monitoring wells would be installed to a confining layer in each of the saturated zones at these two locations.

Where possible, pumping tests would be conducted on selected new or existing wells to better define aquifer characteristics such as hydraulic conductivities, storage properties, and interrelationships between the "A", "B", and "C" zones. The groundwater velocity can be calculated by knowing the hydraulic conductivity, the hydraulic gradient, and the porosity. The pumping test data can be used to confirm and supplement the aquifer permeability and velocity characteristics calculated by Hart-Crowser. In aquifer-aquitard systems, as in the vicinity of the Kaiser-Mead plant, it is possible to obtain information on leakage properties of the system if observations are made in the aquitards as well as in the aquifers (Freeze, Cherry, 1979). Pumping tests may also be conducted to show drawdown influences; for example, to determine if the pumping of certain wells will affect the direction of plume movement. A disadvantage of pumping tests is that they are expensive to conduct, and provisions must be made to dispose of or treat contaminated water. However, falling head tests can be conducted in unsaturated and saturated material to determine permeability. Clean water is introduced into the well in this type of test. In conjunction with well testing, water level measurements should be made on all monitoring wells and selected domestic wells.

Given the spatial distribution of hydraulic conductivity and water levels, as well as knowledge of the flow region and boundary conditions derived from borings and geophysical work, flow nets may be developed on the aquifer (Cherry, Freeze, 1979).

KAISER MEAD

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DRAFT

APPENDIX A

SITE CHRONOLOGY
KAISER MEAD

1942	Aluminum reduction plant built and operated by ALCOA north of the City of Spokane, WA.
1942-1978	Used pot-linings disposed of on a clear tract of land behind the plant.
1946	Kaiser Aluminum and Chemical Corporation, Mead Works, purchased the aluminum reduction plant.
1952-1967	Sludge bed constructed of solid wastes from air pollutant control wet scrubber. Present site covers approximately 10 acres with sludge depths of 12-27 feet. Total weight of solids is 200,000 tons.
1963-1973	Pot-soaking procedure begun and soak water discharged into Peone Creek, via Tharpe Lake.
1965-1978	Pot soaking liquor occasionally discharged to sludge bed.
10/71-1/72	Sludge bed sampled and analyzed by Kaiser-Mead.
1973	Sludge lagoon created.
4/78	Report by Robinson & Noble, Inc. indicated leachate had entered groundwater. Analyses showed abnormal concentrations of cyanide, nitrate, fluoride, and sulfate, as

well as an elevated pH and groundwater temperature. Analyses by WMA Laboratory of Tacoma also showed extremely high conductivity and concentrations of iron, arsenic, barium, chromium, lead, manganese, and selenium above the prescribed DSHS limits.

5/78 Cyanide found in water from private wells northwest of the Kaiser plant. Sampling network of 18 public and private wells and springs within a three-mile radius of the disposal site was established.

6/78 Kaiser detected cyanide in the waste lagoon and the waste pile of pot-linings.

8/78 Health agencies and known affected residents were notified of the potential cyanide problem. Spokane County Health District began a sampling program with more than 150 point sources. Sewage effluent discharges to the sludge bed ceased, as did the occasional discharge of pot-soaking water (except for one isolated discharge). Soak water began to be recycled.

9/78 Bottled water delivered to the affected families.

10/78 Washington Department of Ecology found Kaiser guilty of violating the provisions of its NPDES permit and the Spill Prevention and Containment Plan. Spokane County Health District ordered Kaiser to cease discharge of soak water and to implement a process to prevent water from leaching through the pile of pot-lining wastes. Kaiser ceased pot-soaking operations and now removes pot-linings by dry dumping. Kaiser informed the County Health District of its offer to give the 26 families whose wells were contaminated a choice of a permanent hookup to public water, a deionizer for their existing well, or a new well.

10/78–12/78 Holman Drilling Corporation drilled six test wells and two horizontal drains under the sludge bed and pot-lining waste pile.

12/78 Personnel from EPA Region X made a detailed site investigation of the Kaiser plant and the activities relating to the cyanide contamination of the groundwater. They concluded that the problem was being adequately handled by State and county officials and that no imminent hazard action was warranted at that time.

1978 EPA designated the Spokane-Rathdrum Aquifer a "sole source" water supply for the Spokane-Coeur d'Alene area.

1/79 Pot-lining waste pile reshaped and temporarily covered with protective plastic. Cryolite Recovery Plant put into operation.

4/79 Pot-lining waste pile paved and covered with asphalt and an asphalt slab constructed north of the waste pile for short-term pot-lining storage. Levels of cyanide had not begun to diminish as expected. Public water supplied to affected residents.

5/79 Pot-lining waste pile covered an area of approximately 2.5 acres with a volume of 2,557,000 $ft.^3$ and a weight of 128,000 tons, 256 tons of which were cyanide.

8/79	EPA conducted a site visit of the Kaiser-Mead plant to update information on the pot-lining disposal pile.
11/79	Public water supply hookups to affected families were completed. A second pot-lining storage area constructed on an asphalt slab over an impervious plastic material.
5/80-8/80	Ecological study of the Little Spokane River revealed that cyanide concentrations in a 10-mile stretch of the river presented no ecological or public health hazards.
6/80	Hart-Crowser & Associates, Inc. began a geohydrologic study of groundwater at the Kaiser plant.
10/80	Ten additional test wells were drilled in vicinity of the Kaiser plant.
11/80	Core drilling through the asphalt storage slab showed the barrier to be effective in preventing leaching of contaminants. This led to the suspicion that the settling basin (Tharpe Lake) was the source of aquifer contamination.
3/81	Nine additional test wells were drilled which revealed that a clay layer was directing the water flow under the storage area through contaminated soil, thus transporting the contaminants to the water table. It was decided to replace Tharpe Lake, the old settling basin, with a basin to be constructed 1/2 mile to the north.
5/81	Washington D.O.E. approved plans for the construction of Kaiser's pot-lining waste storage building.

9/81 New settling basin was completed and Tharpe Lake was drained and abandoned. EPA clarified that free cyanide, not bound cyanide, is the more reactive form and is used by the federal government as the basis for establishing water quality standards. This revelation indicated that the affected water supply was much closer to acceptable limits than previously thought.

10/81 Eight families, 34 people in all, filed two separate lawsuits in Spokane County Superior Court against Kaiser. One suit seeks money damages for alleged health problems, property devaluations, and crop and livestock damages resulting from the contaminated groundwater. The second suit seeks a court order forcing Kaiser to remove the source of contamination. As of this writing, both of these suits remain in litigation (Bonino, 10-13-81).

11/81 The pot-lining storage building was completed, and the pot-linings which had been stored on the asphalt slabs were transferred to the building.

5/82 Well sampling program revised, recommending that the frequency be changed from every two weeks to once per quarter, based on historical sampling data of the area.

8/82 While excavating a water pipe at the north end of the Kaiser-Mead plant, a quantity of pot-linings were found buried 12 to 18 inches below the ground surface. These pot-linings cover an area of about 15,000 square feet and weigh approximately 2,000 tons.

9/82	Kaiser requested EPA to withdraw the Mead Works from nomination to the National Priorities List under Superfund.
11/82	EPA Region X toured the aluminum pot-line reduction process with personnel from the Washington D.O.E. and Spokane County Health District. Washington D.O.E. recommended that the EPA remove the Kaiser Aluminum and Chemical Corporation at Mead from the National Priorities List.
12/20/82	EPA designated the pot-lining disposal area at Kaiser Mead as one of 418 hazardous waste locations eligible for cleanup funding under Superfund.
12/82	Hart-Crowser & Associates, Inc. reported that there were significant changes in the groundwater beneath the Kaiser plant since the abandonment of Tharpe Lake.
1/28/83	A group of private well owners, engaged in litigation against Kaiser, withdrew permission from Kaiser and its representatives to continue taking water samples on their property.
2/83	Washington D.O.E. fined Kaiser $1,000 for accidently allowing a small concentration of cyanide to enter Peone Creek, a tributary of the Little Spokane River, in November 1982.