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FINAL PHASE I
REMEDIAL INVESTIGATION REPORT

REPUBLIC STEEL QUARRY
ELYRIA, OHIO
EPA 84-5LW6.0

AUGUST 26, 1988

REPUBLIC STEEL QUARRY
REMEDIAL INVESTIGATION REPORT
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EXECUTIVE SUMMARY

PURPOSE OF REMEDIAL INVESTIGATION

The United States Environmental Protection Agency (EPA) has performed a remedial investigation (RI) at the Republic Steel Quarry Site in Elyria, Ohio. The primary objective of the RI was to establish if there are public health and environmental hazards associated with the site. Previous site investigations were limited in scope and produced incomplete data or data with limited use. Data from these previous investigations were conflicting and did not clearly establish the presence or absence of hazards.

The specific objectives of this RI included:

- Determine the presence or absence of chemical contamination at the site;
- Assess contaminant migration through identification of migration pathways and the impact on potential receptors; and
- Perform an endangerment assessment to determine exposure and risk under current use and future use conditions at the site.

SITE BACKGROUND AND DESCRIPTION

The Republic Steel Quarry site is located in the City of Elyria, Ohio which is southwest of Cleveland in Lorain County. The site is located between West River Road and the West Branch of the Black River. The site may be found on the Grafton USGS quadrangle map in Township 6 North, Range 17 West.

The site consists of a four-acre quarry containing water and seven acres of fenced land surrounding the quarry. Water in the quarry has been measured at depths up to 62 ft. The sides of the quarry are nearly vertical and rise to an average of about 25 ft. above the quarry water surface elevation. Quarry walls are composed of Berea Sandstone at and below present water level and to varying heights above the present water level. Quarry walls above the sandstone are composed of vertically stacked, large sandstone blocks. These blocks were placed during quarry operations as retaining walls to support the soil zone.

The Republic Steel Quarry site was operated as a sandstone quarry during an unknown period of time prior to 1950 when the quarry began to be used for pickle liquor disposal. From 1950 to 1975, the Republic Steel Corporation discharged waste pickle liquor and rinse water from pickling operations to the quarry. Pickle liquor is an acid used to dissolve oxides present in the mill scale that forms on steel during the hot rolling process. Republic Steel Corporation was later acquired by LTV Steel Corporation, who is presently operating the steel plant located south of the quarry. The steel plant that discharged pickle liquors to the site is located south of the site while the West Branch of the Black River borders the site to the east. The areas immediately adjacent to the remainder of the site are undeveloped. Both the quarry and Black River are used for recreational purposes such as swimming, based on observations made during the RI activities. The Black River is also

used for fishing; however, fishing was not observed in the quarry during performance of RI activities.

Very little information exists regarding past waste disposal in the Republic Steel Quarry. Republic Steel reportedly discharged approximately 200,000 gallons of pickle liquor into the quarry each year from 1950 to 1975. Waste pickle liquor was reportedly pumped through an above-ground pipe to a ditch located on the east side of the plant which flowed north into the quarry. LTV reportedly stopped disposing pickle liquor in the quarry in January, 1969, and began contract hauling the pickle liquor off site. From 1969 to 1975, the ditch was still used to direct rinse water from steel pickling operations into the quarry. LTV's records indicate that sulfuric acid was used to pickle the steel and was disposed in the quarry.

There have also been unconfirmed reports that dumping of unknown materials occurred at the site.

SUMMARY OF RI ACTIVITIES

The field activities of the RI were performed from June through August, 1987. The major activities utilized to collect data during the RI included:

- Profiling of quarry water quality and depth;
- Performance of a magnetometer survey to identify metal objects on the quarry bottom;
- Reconnaissance of quarry surface geology;
- Sampling of surface water from the quarry and the Black River;
- Sampling of sediment from the quarry and the Black River;
- Sampling of surface soils adjacent to the quarry;
- Installation of eight monitoring wells and sampling of groundwater;
- Property boundary research.

MAJOR FINDINGS

Samples of surface water, sediments, surface soils and groundwater were collected and analyzed to estimate the types and extent of contamination due to the site. The conclusions with respect to the contamination of each media are included in the following items.

Surface Water: Surface water samples were collected from the quarry and Black River adjacent to the site during June 1987. Resampling was performed during March 1988 for semi-volatile organic analyses due to laboratory quality control problems that occurred during the initial analyses. To estimate the extent and nature of contamination, two analyses of the results were performed. Initially, the quarry water samples were compared to upgradient

groundwater samples to identify potentially site related chemicals in the quarry. No organic chemicals were identified in the quarry water as being potentially site related. Several inorganic chemicals were identified as being potentially site related. All of these chemicals were detected at elevated concentrations compared to upgradient groundwater, with the greatest concentrations observed near the quarry bottom. The downstream Black River samples were compared to upstream river samples and quarry samples to estimate if the site was affecting river water quality. The results of this comparison indicated that the site was not adversely impacting Black River water quality.

Sediments: Sediment samples from the quarry and the Black River were collected in June 1987 and analyzed for organic and inorganic chemicals. The nature and extent evaluation for sediments was performed in two phases to determine if the quarry sediments were contaminated and to estimate if the quarry had adversely impacted the quality of Black River sediments. Initially, quarry sediments were compared to background soils to identify potentially site related chemicals. This analysis concluded that sediments within the quarry contain elevated levels of volatile and semi-volatile organic and inorganic chemicals. Volatile organic compounds were detected only in the deep quarry sediment samples (greater than 35 ft.) while semi-volatile organics and inorganics were detected in both deep and shallow samples. Concentrations of the inorganic and semi-volatile contaminants of the sediments obtained from deeper portions of the quarry were greater than those from the shallow sediments. Past activities at the site have affected quarry sediment quality.

A comparison of downstream Black River sediments to upstream river and quarry sediments was performed to estimate if the site is adversely impacting Black River sediments. The analysis indicated that no potentially site related organic or inorganic chemicals were detected in the sediments downstream. The site is not affecting sediments in the Black River.

Surface Soils: Surface soil samples were collected in June 1987. Analyses performed on surface soils obtained from areas of the site that are periodically inundated by quarry water or that were exposed to waste discharges in the past detected contaminants above background concentrations. Contaminants detected included volatile and semi-volatile organic and inorganic chemicals. Past disposal activities have affected the quality of surface soils at the site. Semi-volatile and inorganic chemicals were also detected in a sample of the steel yard soils that are sliding into the quarry.

Groundwater: Eight monitoring wells were installed at or near the Republic Steel Quarry Site. All of these wells were sampled in August 1987 and two wells were resampled and analyzed for volatile organics in March 1988. Volatile and semi-volatile organic and inorganic contaminants were detected in groundwater samples downgradient from the quarry at low concentrations in monitoring wells adjacent to the site. These contaminants were not detected in the monitoring well across the Black River, east of the site. Inorganic chemicals were detected in all downgradient wells adjacent to the site and in the well across the Black River; however, a direct connection to the site cannot be made to the inorganics in well B-8. Moreover, it is unlikely that

contaminants from the quarry are passing beneath the Black River within groundwater since well B-8 is hydraulically upgradient from the site.

ENDANGERMENT ASSESSMENT SUMMARY

The potential risks to human and environmental health attributed to chemicals present at the Republic Steel Quarry Site were evaluated under a number of exposure scenarios. Potential pathways of exposure to chemicals originating at the site under both current-use and hypothetical future-use conditions were examined. Table ES-1 presents a summary of the risks associated with the various scenarios evaluated. Additionally, combined risks are presented for those exposure pathways that could potentially apply to the same receptors.

Under current-use conditions, the only exposure scenario resulting in a greater than 10^{-6} risk is the maximum case for ingestion of fish. This risk is primarily due to carcinogenic PNAs which were conservatively estimated using the sediment/surface water exposure model. Additionally, this maximum exposure scenario results in a hazard index greater than one because the estimated chronic daily intake for mercury is greater than available criteria for protection against noncarcinogenic effects. This risk is based on modeling the concentration of mercury from the sediment to water and then to fish tissue using very conservative assumptions. Combined risks to trespassers, assuming the same person would be exposed to soil through direct contact and incidental ingestion, quarry water through swimming, and fish through ingestion were estimated. As indicated in Table ES-1, the combined upperbound excess lifetime cancer risks are 5×10^{-8} to 4×10^{-6} under average and maximum exposure conditions. The combined hazard index is less than one under the average scenario and greater than one under the maximum scenario. Under future-use conditions, the exposure scenarios evaluated that resulted in a greater than 10^{-6} upperbound excess lifetime cancer risk are maximum exposure to future residents through direct contact and incidental ingestion of soil, and average and maximum exposure from the ingestion of groundwater, primarily as the result of high concentrations of methylene chloride, a potential laboratory contaminant. Consequently the combined potential residential risk is 2×10^{-6} to 5×10^{-5} under average and maximum exposure scenarios.

It should be noted that the risk from exposure to contaminants in soil is primarily due to exposure to cPNAs, which were detected primarily at one area of the site (the south boat launch) and which are ubiquitous in the environment. In evaluating the combined noncarcinogenic risk, the hazard index is greater than one under the maximum exposure scenarios. With respect to potential impacts on aquatic life in the quarry, of the 11 chemicals with acute AWQC values, only copper exceeded the acute criteria. Tetrachloroethene, nickel, toluene, ncPNA, mercury, pentachlorophenol, and the phthalates are all below the acute level. Ten of the chemicals have chronic AWQC values. Of these, surface water concentrations are below chronic AWQC for ncPNA, tetrachloroethene, butylbenzylphthalate, di-n-butylphthalate, di-n-octylphthalate, and pentachlorophenol. Copper, mercury and diethylphthalate were chemicals that exceeded the AWQC. It should be noted that all chemicals except barium, vanadium, manganese and nickel were calculated using the sediment/water partitioning model. The model is conservative and chemical

TABLE ES-1
SUMMARY OF POTENTIAL RISKS ASSOCIATED WITH THE REPUBLIC STEEL QUARRY
REPUBLIC STEEL QUARRY RI

Exposure Scenario	Total Cancer Risks		Noncarcinogenic Hazard Index	
	Average	Maximum	Average	Maximum
Current-Use (Trespassers)				
Direct Contact with Soil	$2x10^{-8}$	$4x10^{-7}$	<1	<1
Swimming in the Quarry	$1x10^{-10}$	$4x10^{-10}$	<1	<1
Consumption of Fish	$3x10^{-8}$	$4x10^{-6}$	<1	>1
Combined Risk to Trespassers	$5x10^{-8}$	$4x10^{-6}$	<1	>1
Future-Use				
Park Patron - Direct Contact with Soil	$4x10^{-8}$	$1x10^{-6}$	<1	<1
Residential Use - Direct Contact with Soil	$3x10^{-7}$	$2x10^{-5}$	<1	<1
Ingestion of Ground Water	$2x10^{-6}$	$3x10^{-5}$	<1	>1
Combined Residential Risk	$2x10^{-6}$	$5x10^{-5}$	<1	>1

concentrations in the water are not expected to be as large as those predicted by the model.

UNRESOLVED DATA NEEDS

The only risks identified that exceed acceptable criteria at the site under current-use scenarios were associated with the ingestion of fish. Since the risks were estimated using conservative contaminant uptake models and not actual fish samples, it has been decided that fish sampling and analysis will be performed to confirm the presence of the risks due to fish ingestion. This work will be performed in the near future and is outside the scope of this RI.

Under future-use scenarios, ingestion of groundwater by residents at the site was calculated to have a greater than 10^{-6} upperbound excess lifetime cancer risk, primarily due to methylene chloride detected at one downgradient monitoring well during one groundwater sampling program. Resampling failed to confirm the presence of methylene chloride in the monitoring well. USEPA and Ohio EPA have decided that resampling groundwater an additional time is appropriate to confirm or refute the presence of methylene chloride in the downgradient monitoring well. This work will be performed in the near future and is outside the scope of this RI.

CONCLUSION

It is concluded that the site in its current condition presents a limited health risk to the public, with ingestion of fish posing the greatest risk at the site. Under future-use scenarios, the combined residential risks are calculated to pose a greater than 10^{-6} upperbound excess lifetime cancer risk. Based on the results of this study, USEPA and Ohio EPA have determined that a limited remedial action is warranted at the Republic Steel Quarry Site.

1.0 INTRODUCTION

1.1 PURPOSE OF INVESTIGATION AND REPORT

The United States Environmental Protection Agency (EPA), with the assistance of the REM IV contract, has performed a Phase I remedial investigation (RI) at the Republic Steel Quarry Site in Elyria, Ohio, under authority of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA). The primary objective of the Phase I RI was to establish if there are public health and environmental hazards associated with the site. Previous site investigations were limited in scope and produced incomplete data or data with limited use. Additionally, data from these previous investigations were conflicting and did not clearly establish the presence or absence of hazards.

This report details RI activities performed at the Republic Steel Quarry Site, presents the data collected and provides interpretation of the results. The RI provides data for performance of an endangerment assessment evaluating the site risks under current and future site conditions.

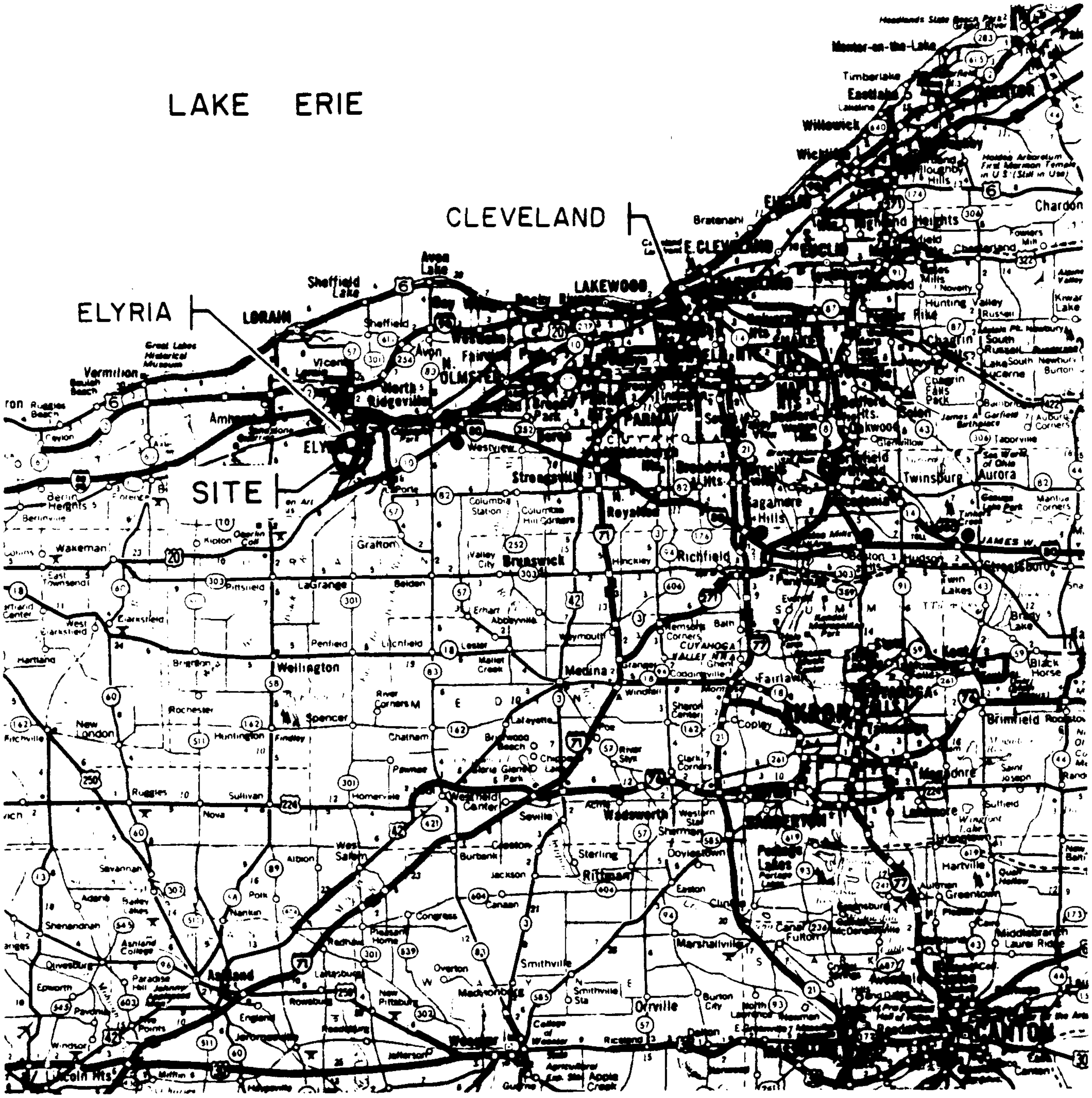
The specific objectives of this RI report are to:

- Provide a summary of site history and waste disposal activities;
- Determine the presence or absence of chemical contamination at the site;
- Assess contaminant migration through identification of migration pathways and the impact on potential receptors; and
- Perform an exposure and risk assessment under current use and future conditions at the site.

1.2 SITE BACKGROUND

1.2.1 Site Location and Description

The Republic Steel Quarry site is located in the City of Elyria, Ohio which is southwest of Cleveland in Loraine County (see Figure 1-1). The site is located between West River Road and the West Branch of the Black River, directly west across the river from Franklin School (see Figure 1-2). The site may be found on the Grafton USGS quadrangle map in Township 6 North, Range 17 West.



SOURCE: ROAD MAP OF OHIO,
SCALE: 1 INCH = 9.7 MILES

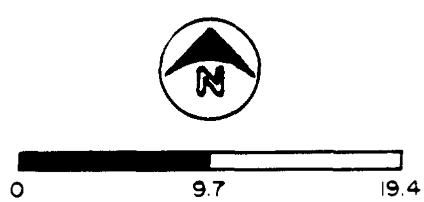
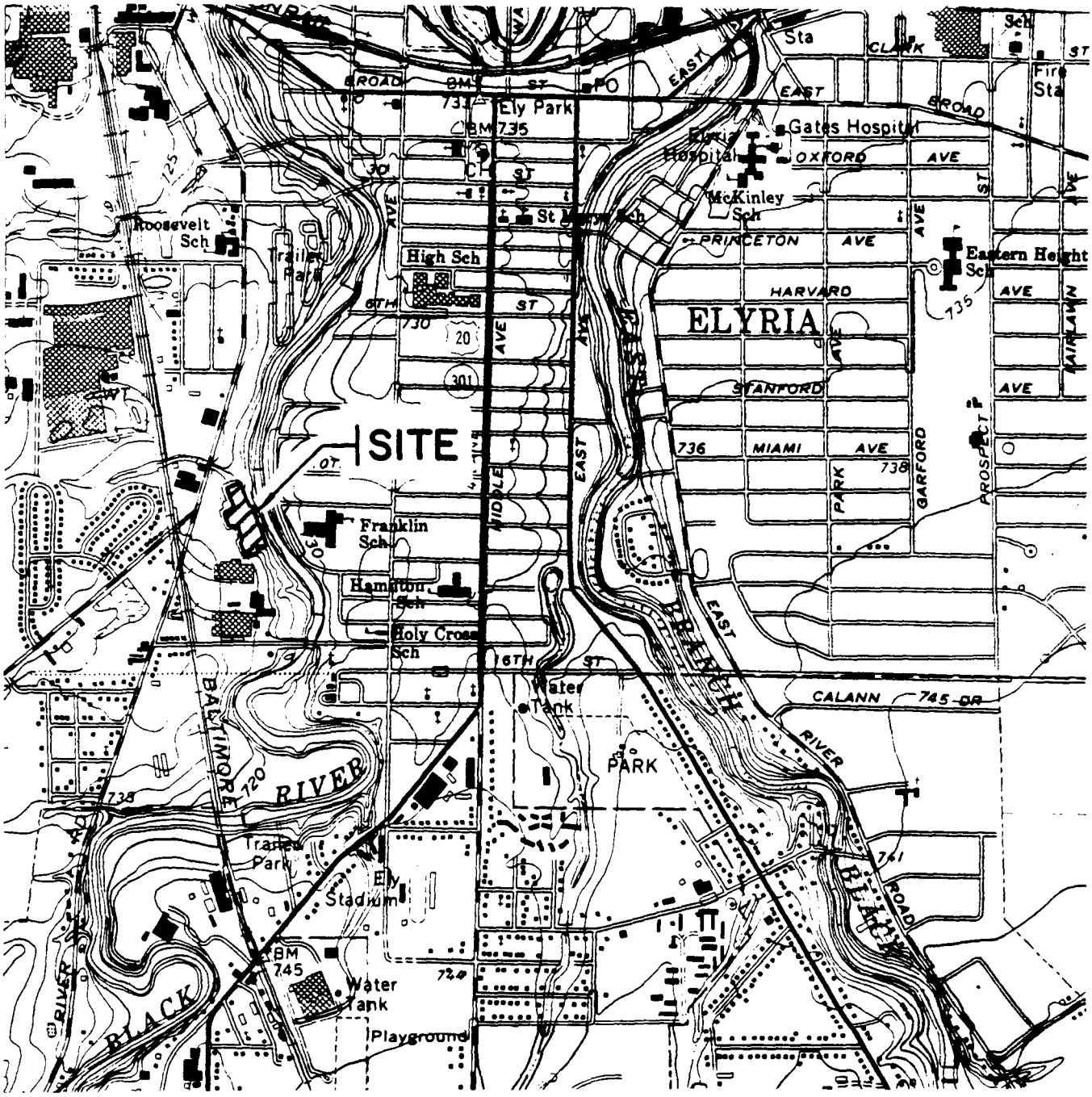


FIGURE 1-1
SITE VICINITY MAP
REPUBLIC STEEL QUARRY RI



SOURCE: U.S.G.S. 7.5' TOPOGRAPHIC MAP GRAFTON QUADRANGLE OHIO, SCALE: 1" = 2000'.

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SCALE IN FEET

SITE LOCATION

FIGURE 1-2
SITE LOCATION MAP
REPUBLIC STEEL QUARRY RI

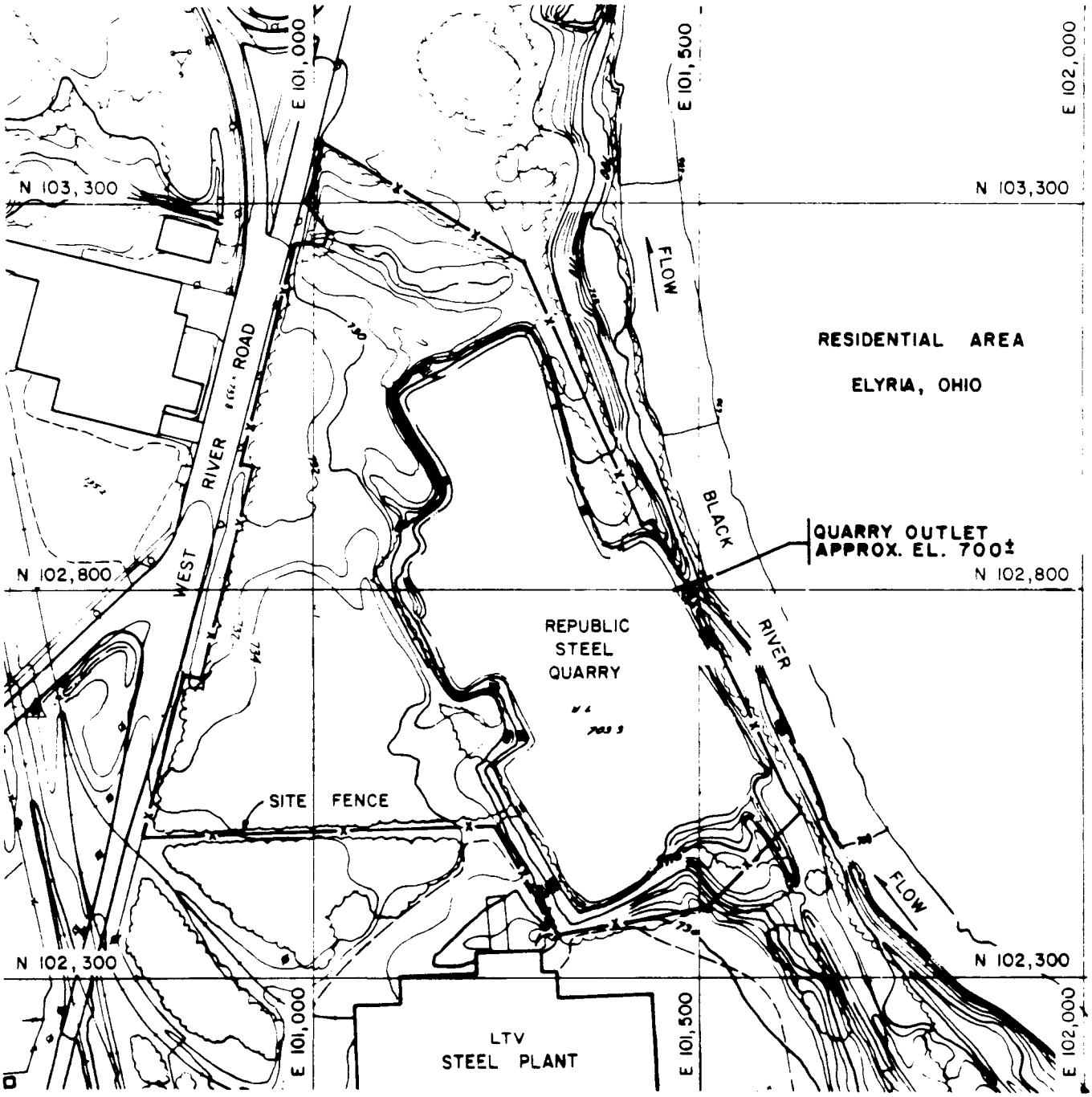
The site consists of a four-acre quarry containing water and seven acres of fenced land surrounding the quarry. Water in the quarry has been measured at depths up to 62 ft. The sides of the quarry are nearly vertical and rise to an average of about 25 ft. above the quarry water surface elevation. Quarry walls are composed of Berea Sandstone at and below present water level and to varying heights above the present water level. Quarry walls above the sandstone are composed of vertically stacked, large sandstone blocks. These blocks are approximately 2 ft. high and 3 ft. wide, and were placed during quarry operations as retaining walls to support the soil zone. The soil zone consists primarily of brown silty sands and silty clays, ranging in thickness from zero to 25 feet.

From 1950 to 1975, the Republic Steel Corporation discharged waste pickle liquor and rinse water from pickling operations to the quarry. Pickle liquor is an acid used to dissolve oxides present in the mill scale that forms on steel during the hot rolling process. Republic Steel Corporation was later acquired by LTV Steel Corporation, who is presently operating the steel plant located south of the quarry. As Figure 1-3 illustrates, the steel plant that discharged pickle liquors to the site is located south of the site while the West Branch of the Black River borders the site to the east. The areas immediately adjacent to the remainder of the site are undeveloped. Although the site is fenced, it is still accessible through holes in the fence and areas where the bottom of the fence is 1 to 3 ft. above ground surface. Both the quarry and Black River are used for recreational purposes such as swimming, based on observations made during remedial investigation (RI) activities. The Black River is also used for fishing; however, fishing was not observed in the quarry during performance of RI activities.

There are two hydraulic systems in the quarry. Concrete outlet works equipped with a gate valve are located along the east quarry wall where the ground surface elevation dips to about 700 feet above mean sea level (MSL). Water was draining from the outlet works into the river during the July, 1986 site visit and throughout RI field activities. A 4 inch diameter steel pipe is located at the southeastern-most corner of the quarry extending down into the water. This pipe is believed to have been used for withdrawing water from the quarry to the Republic Steel plant, rather than being used for discharging pickle liquor wastes. Neither system is apparently operational.

1.2.2 Site History

The Republic Steel Quarry site was operated as a sandstone quarry during an unknown period of time prior to 1950 when the quarry began to be used for pickle liquor disposal. The stone cut from the quarry was the Berea Sandstone which was used locally and regionally as a building material due to its massive bedding, absence of intercalated shales, and well-sorted composition.



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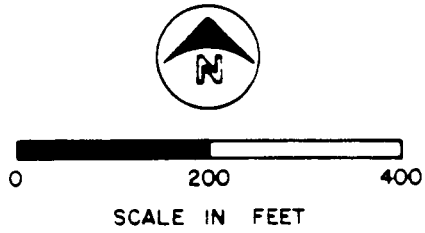


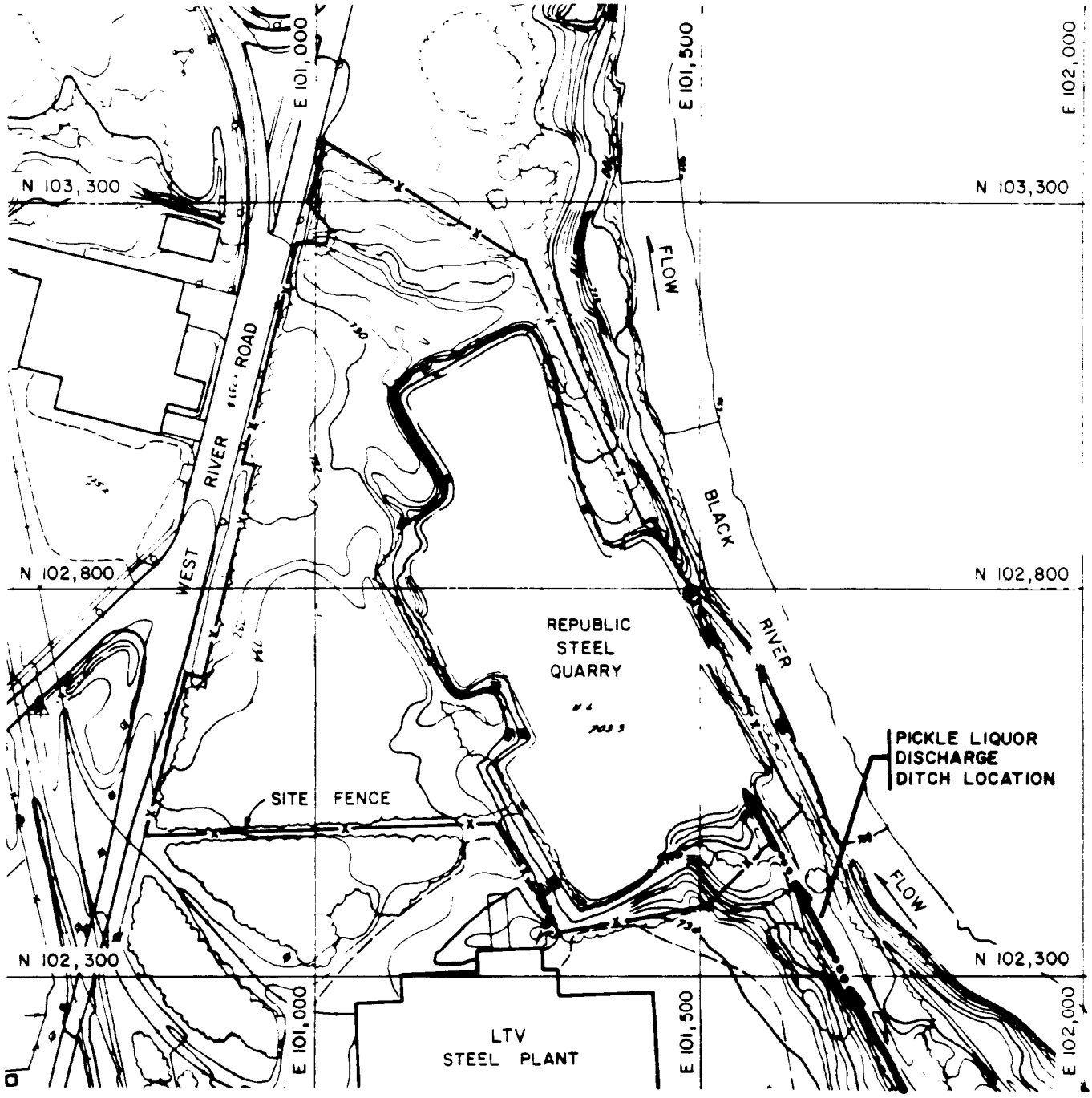
FIGURE 1-3
SITE MAP
REPUBLIC STEEL QUARRY RI

LTV Steel and the City of Elyria were contacted to obtain data on quarry operations. Neither source had data identifying when the quarry operated; however, LTV personnel indicated that they thought the quarry operated during the depression era (1930s). At approximately the middle of the western edge of the quarry wall, "1929" is cut into the stone. This inscription may signify a date when quarry operations were in progress, although it is not known for certain. The marking was observed a few feet above the quarry water level during the geologic reconnaissance discussed in Section 7.1.

Very little information exists regarding past waste disposal in the Republic Steel Quarry. Republic Steel reportedly discharged approximately 200,000 gallons of pickle liquor into the quarry each year from 1950 to 1969 (Gubane, 1984). It is unknown if samples of this waste stream were collected and analyzed. LTV Steel personnel were contacted to obtain information on waste pickle liquor disposal operations at the quarry (LTV, 1987). Waste pickle liquor was reportedly pumped through an above-ground pipe to a ditch located on the east side of the plant which flowed north into the quarry. The approximate location of the pickle liquor discharge ditch is shown on Figure 1-4. LTV reportedly stopped disposing pickle liquor in the quarry in January, 1969, and began contract hauling the pickle liquor off site. From 1969 to 1975, the ditch was still used to direct rinse water from steel pickling operations into the quarry. In 1976, the pickle liquor discharge ditch was dammed about 100 feet south of the site fence. The dam reversed flow in the ditch to the south. LTV currently discharges water into the ditch which conveys the flow in a southeasterly direction until it is discharged to the Black River.

The Republic Steel Quarry used sulfuric acid (H_2SO_4) as the pickling acid. The spent pickle liquors were highly corrosive, having a pH of less than 2.0. Based on conversations with LTV Steel personnel, iron concentration within the pickling liquors can be in the percent range. No detailed chemical analyses of this waste stream were available from LTV. However, general information may be found in EPA's Listing Background Document for spent pickle liquor (K062). The document states that the spent pickle liquors, due to their low pH, meet the corrosivity characteristic defined in 40 CFR 261.22 and are therefore hazardous. Additionally, EPA data indicated that significant levels of toxic heavy metals, lead and chromium are present in the spent pickle liquors in a highly mobile form. Typical concentrations for chromium in spent pickle liquors from sulfuric acid processes are from 26 to 269 mg/l. For lead, typical concentrations are below 2.0 mg/l. This waste stream is highly variable from plant to plant, and depends upon the type of steel being processed and finished steel surface quality desired. As such, the typical concentrations listed above may or may not be representative of the actual pickle liquor discharges which occurred to the quarry.

There have also been unconfirmed reports that dumping of unknown materials occurred at the site.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

PICKLE LIQUOR DISCHARGE DITCH

0 200 400
SCALE IN FEET

FIGURE 1-4
PICKLE LIQUOR DISCHARGE DITCH LOCATION
REPUBLIC STEEL QUARRY RI

In 1981, Republic Steel Corporation notified EPA of its past disposal activities to comply with Section 103(C) of the Comprehensive Environmental Responsibility, Compensation, and Liability Act (CERCLA). In response to Republic Steel's notification, Ecology and Environment, Inc. (E & E), the Field Investigation Team (FIT) contractor performed a site investigation for EPA in late 1983 and installed three monitoring wells. Samples were collected from the quarry and the three monitoring wells. No organic contamination was detected at the site; however, heavy metals such as chromium, arsenic, lead, cadmium, magnesium, aluminum, and iron were detected at higher levels in the groundwater at one downgradient monitoring well than in the upgradient wells (see Section 1.2.3).

The site was evaluated using the Hazard Ranking System (HRS) in 1984. On October 15, 1984, EPA proposed that the Republic Steel Quarry be included in Group II of the National Priorities List (NPL). The HRS score calculated was above the threshold value for inclusion on the NPL based on public health hazards related to groundwater consumption and recreational use of the Black River. The hazards identified were related to inorganic chemicals.

At the request of LTV Steel, IT Corporation (IT) conducted an investigation of the site in November 1984 that included sampling and chemical analysis of quarry water samples and EPA installed monitoring wells. This investigation concluded that EPA's score should be recomputed based on evidence obtained in their investigation. According to IT, the recomputed score would not be high enough for the site to be included on the NPL. On December 13, 1984, LTV Steel submitted a letter to EPA stating their objection to the quarry's inclusion on the NPL. Included with the letter was a copy of IT's report as supporting evidence. The letter stated that the results of IT's study concluded that the quarry had virtually returned to its original natural condition.

EPA reviewed the IT data and concluded that EPA's original HRS score for the Republic Steel Quarry was correctly calculated, and that the site should remain on the NPL Group II list. On January 8, 1986, EPA submitted a letter to the State of Ohio Clearing House for review under the State Intergovernmental Review Process. In this letter, EPA proposed a RI/FS for the Republic Steel Quarry.

On March 5, 1986, a Resolution of the Board of the Northeast Ohio Areawide Coordinating Agency (NOACA) certified their support of EPA's proposal for investigating the quarry.

On May 9, 1986, Ohio EPA reviewed the Statement of Work for the RI/FS and indicated their willingness to support and assist the program in a letter to U.S. EPA Region V.

1.2.3 Results of Previous Investigations

Past investigation efforts have focused on surface water and groundwater contamination problems. These investigations were performed by Republic Steel, EPA FIT, and IT Corporation representing LTV Steel Corporation.

The results of these investigations are included in Appendix A of this report and are summarized in the following subsections.

Surface Water

In March 1976, surface water samples were collected from five locations within the quarry. The results of the analyses are presented on Table A-1 in Appendix A. These samples were collected from the surface, at a depth of 25 feet, and at the bottom of the quarry. Quarry samples were acidic (pH about 4 to 4.5), with total acidity of about 60 mg/l and total iron concentration of about 20 mg/l. Quarry water samples collected from a depth of 25 feet were much more acidic (the pH ranged from 2.1 to 2.6) than the surface samples, the total acidity ranged from 520 mg/l to 1830 mg/l, and total iron ranged from 160.0 mg/l to 680.0 mg/l. The pH of bottom samples (depths of 36 to 50 feet) was similar to the pH of samples collected from the 25 foot depth, total acidity was slightly higher, and the concentration of total iron was much higher (833.0 mg/l to 1320.0 mg/l). Higher total iron concentrations in the bottom samples may have been due to sediment stirred up during sampling. It is not known who collected and analyzed these samples and whether these samples were filtered prior to analysis. Additionally, the outlet from the quarry to the West Branch of the Black River was sampled and analyzed for these same parameters. Results were similar to the other surface water samples.

Republic Steel collected quarry water samples from eight locations in April 1976. The results of these analyses are presented on Table A-2 in Appendix A. Samples were collected primarily at shallow depths (2, 4, 6 and 8 or 10 feet below the surface) and occasionally from the bottom. These samples were analyzed for pH, total acidity, and total iron. The pH of the shallow samples (to a depth of 10 feet) was close to neutral, total acidity of these samples ranged from 5 to 21 (units not reported but assumed to be mg/l), and the total iron ranged 0.72 to 4.82 (units assumed to be mg/l). Once again bottom samples were acidic (lowest pH of 2.34), maximum total acidity was 2660 (mg/l assumed), and the maximum total concentration of iron detected was 8110 (mg/l assumed). The pH of the water at the outlet from the quarry was 7.41 and the pH of samples collected from upstream and downstream locations in the West Branch of the Black River were 8.59 and 8.37, respectively.

Ecology and Environment, Inc. (E & E) FIT sampled quarry water at two locations at the surface of the quarry in August 1983. The samples were analyzed for 21 metals; however, no pH readings were obtained. Metals concentrations were generally low (less than 1 ppm), with the exception of iron. The elevated iron concentration may be related to use of the acids for cleaning the steel since iron is a major constituent of steel. The concentration of iron from the sample obtained at the north end of the quarry was 419 mg/l. The results of this sampling are presented on Table A-3 in Appendix A.

Prior to RI activities, the most recent sampling effort was performed by IT Corporation (IT) in November 1984. Quarry water was sampled by IT from the surface and at a depth of 10 feet at five locations. Samples were

analyzed for 10 metals and pH. The pH of these samples ranged from 6.2 to 6.5. Metals concentrations were generally low (less than 1 ppm) with the exception of iron. The maximum concentration of iron was 2.2 mg/l in a sample collected from a depth of 10 feet. The results of this sampling are presented on Table A-4 in Appendix A.

Groundwater

E & E collected monitoring well samples in December 1983. These samples were analyzed for organic contaminants, but none were detected. Metals were present in groundwater samples but concentrations do not demonstrate the presence of offsite contamination. IT collected additional groundwater samples in November 1984. Analyses indicate some metals in the sample collected from the presumed upgradient well (B-3) were present in higher concentrations than the downgradient wells (B-1 and B-2). However, these wells were essentially open, shallow boreholes which do not allow sampling of a discrete interval and which could allow considerable dilution to occur. Results of these sampling events are presented on Table A-5 in Appendix A.

1.3 REPORT ORGANIZATION

The remainder of this report presents the scope of the Phase I RI, and the findings and conclusions as a result of its implementation. The RI report is organized as follows:

SECTION 2.0, PHYSICAL CHARACTERISTICS OF THE STUDY AREA, presents results of the investigation of key parameters for the site including demography, physiography, natural resources, climatology, and geology.

SECTION 3.0, QUARRY BACKGROUND INVESTIGATIONS, presents results of investigations performed during the RI regarding variation in quarry depth, the types of materials that may be located on the bottom of the quarry, quarry chemistry and morphology, and property boundaries.

SECTIONS 4.0 through 7.0 present and discuss findings on the surface water, sediment, soil, and groundwater. Analytical results, conclusions, and observations are also presented along with an estimate of the types and extent of contaminants present.

SECTION 8.0, CONTAMINANT TRANSPORT AND FATE, presents potential pathways for migration of contaminants from the site with specific emphasis on selected indicator chemicals. This section discusses the general environmental behavior of the types of contaminants identified at the Republic Steel Quarry Site.

SECTION 9.0, ENDANGERMENT ASSESSMENT, characterizes existing and potential effects of chemicals present at the site for the no-action alternative. This media by media evaluation of the no-action alternative allows for the estimation of incremental risk reduction that can result from remediation of specific onsite media. The discussion includes identification of potential receptors, and public health and environmental impacts.

SECTION 10.0, SUMMARY AND CONCLUSIONS, focuses on the overall extent of contamination and degree of site-related hazards, additional investigation and analysis work that may be needed, and potentially applicable remedial actions.

2.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

2.1 LAND USE

The neighborhoods around the site have historically housed factory workers. Local officials reported that after World War II, rising incomes prompted many of the residents in neighborhoods near the site to move to more affluent areas of the city. Since then, residents living in neighborhoods near the site have been predominantly lower income families.

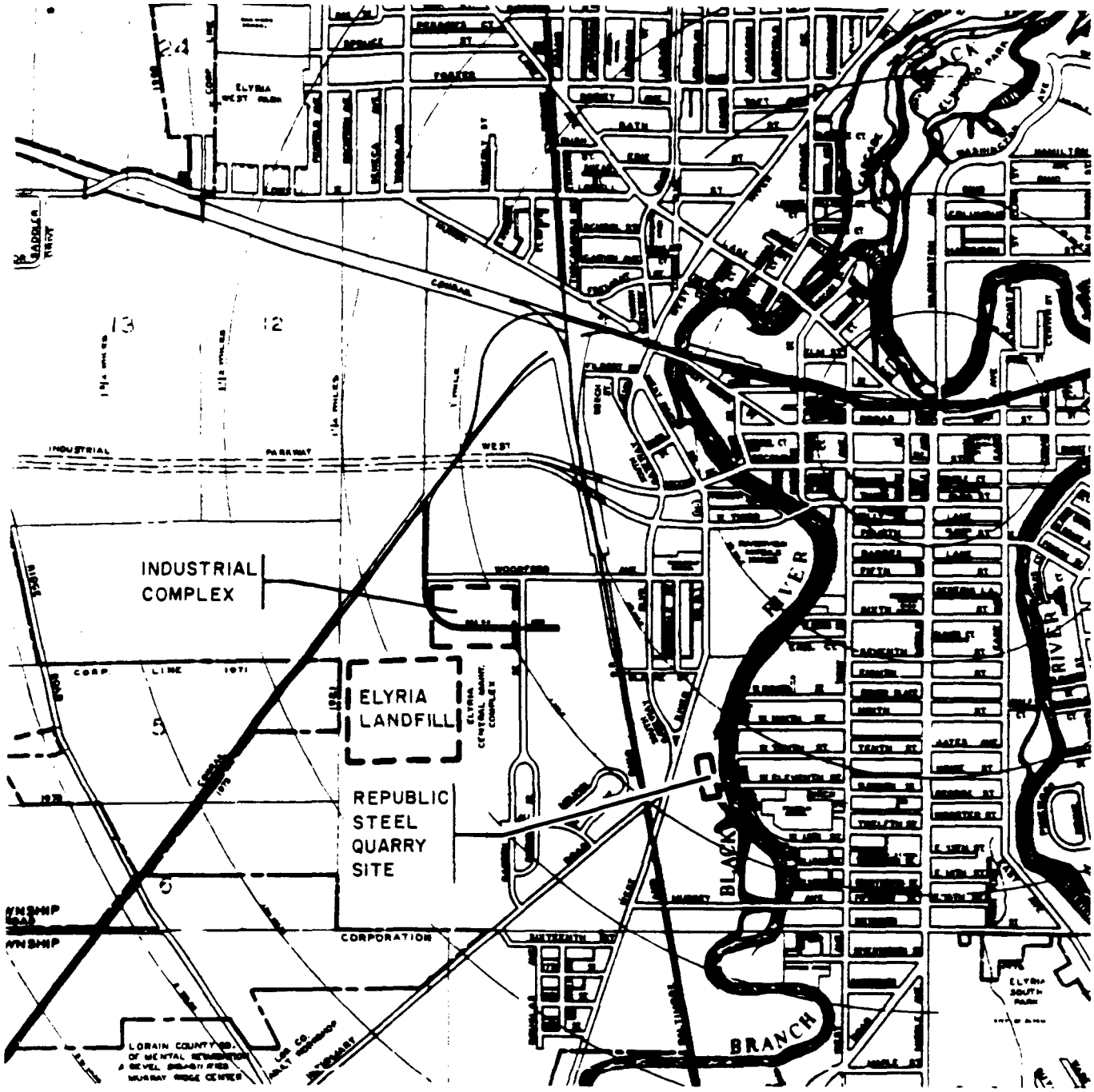
An abandoned municipal landfill is located about 0.6 miles northwest of the site. This landfill was reportedly closed in 1979 when landfill storage capacity was reached. The land surrounding the landfill is flat, and the landfill was observed to have only a very slight mounding of the ground surface. Consequently, the wastes may have been disposed in a pit or quarry rather than in an above-ground landfill. Additionally, an industrial complex is located 0.6 miles northwest of the site (see Figure 2-1).

2.2 REGIONAL PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Lorain County, in which the Republic Steel Quarry site is located, is on the eastern fringe of the till plain area of the Great Central Lowlands (USDA Soil Conservation Service, 1976). The topography is generally flat to gently rolling. The surface slopes gently from a high elevation in the southern part of the county to a low elevation at Lake Erie. Exceptions to the nearly flat topography are gorges of the Black River near Elyria and the site. These gorges expose the underlying bedrock.

Most of the surface of Lorain County is underlain by glacial drift deposited by the Wisconsinian Glaciation approximately 10,000 to 15,000 years ago. This glacial till, called the Hiram till, is compact, tough, clay-rich and contains varying amounts of gravel, cobbles, and boulders. As the glacier retreated northward, glaciated materials were reworked in both lacustrine and fluvial depositional environments.

The northern third of Lorain County is underlain by belts of sandy soils on ridges. The ridges are remnants of glacial lake beaches produced by the action of shore waves and show various stages of the Lake Erie Basin since retreat of the last Wisconsinian glacier. Three major ridge lines can be traced across the county in the site vicinity. The ridge lines have sandy soils, good drainage, and major highways running east and west. One ridge is now the location of Ohio Route 10 which passes south of Elyria; another ridge is along U. S. Route 20 and Ohio Route 113 which passes through Elyria; and the final ridge is located north of Elyria, along Ohio Route 254. In some places ridges are not continuous and are difficult to trace.



SOURCE: CITY OF ELYRIA
1986 STREET MAP

0 1/2 1

SCALE IN MILES

FIGURE 2-1
LAND USE MAP
REPUBLIC STEEL QUARRY RI

2.3 SITE PHYSIOGRAPHY

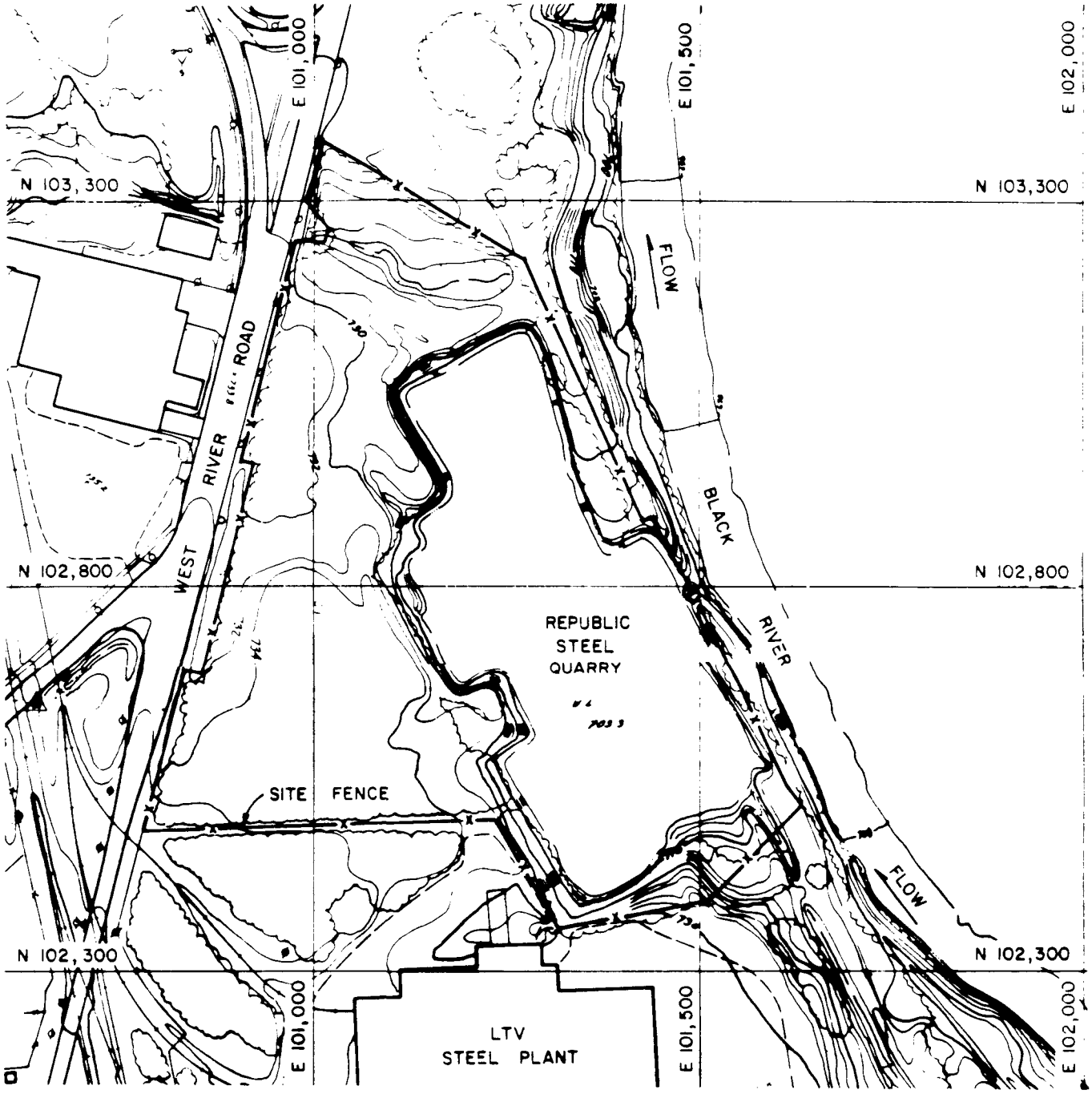
Ground surface elevations surrounding the Republic Steel Quarry range from about 732 feet to about 694 feet above Mean Sea Level (MSL). These elevations are based on mapping obtained from the City of Elyria Engineering Department. The majority of the areas to the north, south and west of the site are relatively flat, with steep slopes located along the bank of the West Branch of the Black River. Figure 2-2 illustrates the site topography.

Vegetation, immediately adjacent to the quarry perimeter, is mostly grass and small brush; however, larger trees are found around the site and along the river. Vegetation is fairly dense over most of the site.

2.4 SOILS

Topsoils in the immediate vicinity of the site are the Mahoning and Fitchville series (USDA Soil Conservation Service, 1976). The Mahoning series consists of relatively poorly drained, nearly level to gently sloping soils on uplands in Lorain County. These soils formed in moderately fine-textured glacial till, have a low permeability and have a moderate amount of organic-matter. The specific Mahoning series soil present at the site is the Mahoning-Urban land complex (MmA). This complex is composed of 50 to 70 percent nearly level Mahoning silt loam and 25 to 40 percent Mahoning soil material that has been altered as a result of grading and filling. The Fitchville series consists of relatively poorly drained, nearly level to gently sloping soils on the lake plain and on stream terraces throughout Lorain County. Permeability is moderately low in these soils, and runoff is characteristically slow to medium. The specific Fitchville series soil present just north of the site is the Fitchville-Urban land complex (FeA). This complex is composed of about 50 to 70 percent nearly level Fitchville soil and 25 to 40 percent Fitchville soil that has been altered as a result of grading and filling. In places where the original Mahoning and Fitchville soils have been altered, the soils are difficult to identify. As a result of the grading and filling of these soils, the United States Department of Agriculture (USDA) does not indicate any values for any of the tests usually performed for various soil types, stating instead that the soils are too variable to be rated. USDA does state that the water table in these soils is perched during winter and spring; the surface layer in altered areas has a poor structure and becomes sticky when wet and cloddy when dry; and erosion is a problem on sloping areas that are bare of vegetation.

The thickness of the soil zone at the site varies from 0 to about 25 feet. This estimate is based on a review of drilling records for wells installed at the site and the soil interval supported along the quarry walls by the



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

0 200 400
SCALE IN FEET

FIGURE 2-2
SITE TOPOGRAPHY
REPUBLIC STEEL QUARRY RI

large sandstone blocks. Site soils are primarily silty sands and silty clays. The soils underlying the topsoil should be glacial till based on information presented in Section 2.2.

2.5 SURFACE WATER

The major surface water feature at the site is a four acre quarry. The depth of water within the quarry has been measured up to 62 ft. at some locations. Groundwater is the primary source of water within the quarry. In addition to direct rainfall, water also reaches the quarry via runoff during rainfall events from adjacent areas, including the LTV steel plant south of the quarry and an undeveloped area west of the quarry. There are no continuous sources of surface water flow into the quarry.

Water from the quarry discharges into the West Branch of the Black River which merges with the East Branch of the Black River approximately 1.7 miles downstream north of the site. After the confluence of the two branches, the Black River flows north to Lake Erie. The West Branch of Black River flows on the Berea Sandstone adjacent to the site. During low flow conditions, the majority of flow occurs along eroded fractures in the river bed. The depth of flow observed during a July, 1986 site visit was generally 4 to 6 inches. Flow rate was estimated at 2 cubic feet per second (cfs). The river contains pools of water that are several feet deep, even during low flow conditions. Little sediment exists in the river; however, greater amounts of sediments exist in the deep pools.

The nearest gaging station on the West Branch of the Black River is approximately 1.4 miles downstream from the quarry, about 1,600 ft. upstream from the confluence with the East Branch of the Black River. Another gaging station is located 0.8 miles downstream from the confluence of the East and West Branches of the Black River.

Data from the gaging station on the West Branch of the Black River (USGS, 1984) for the year from October, 1983 to September, 1984 indicate that the discharge in the rivers is highly variable throughout the year. Monthly mean discharges in the West Branch varied from about 6 cfs (2,700 gallons per minute (gpm)) in September to about 775 cfs (348,000 gpm) in March. The minimum daily discharge measured was about 3 cfs (1,350 gpm) for a one-day period in August. Low discharge volumes that occur during late summer and early autumn indicate that constant large volumes of water are not always available within the river throughout the year to dilute quarry discharges that may occur. Because the West Branch gaging station was established in 1980, no long-term data are available.

The West Branch drains into the Black River which has an average discharge of 332 cfs. The maximum recorded discharge was 51,700 cfs in July, 1969 while the minimum recorded discharge was 0 cfs during construction of an upstream dam. The minimum daily discharge for the year from October, 1983 through September, 1984 was 7 cfs (3,100 gpm) in August, 1984.

The West Branch of the Black River is used for recreational purposes such as swimming and fishing. The quarry is also used for swimming based on

observations made during the RI. Elywood Park and Cascade Park are located about 1-1/2 miles north of the site, just beyond the confluence of the two branches of the Black River. These parks were constructed on both sides of the Black River and are used for fishing and possibly other recreational activities. People were observed fishing at the parks during RI activities.

The 100 year flood elevation at the site is approximately 709 feet MSL. (U.S. Army COE, 1986). At this elevation, portions of the banks on the east side of the quarry by the outlet works would be submerged, and water would enter the quarry from the river. Although significant quantities of water could enter the quarry during floods, it is unlikely that during floods flushing of the quarry sediments would occur. Since water would enter and exit the quarry via a side entrance during a flood, the flow-through conditions and high velocities necessary for sediment flushing would not occur. Additionally, it is likely during flood conditions that the quarry would be a location for deposition of Black River sediments. However, dilution of the water in the quarry would occur during floods. Figure 2-3, obtained from the USGS in Columbus, Ohio, shows the quarry to be within a flood prone area.

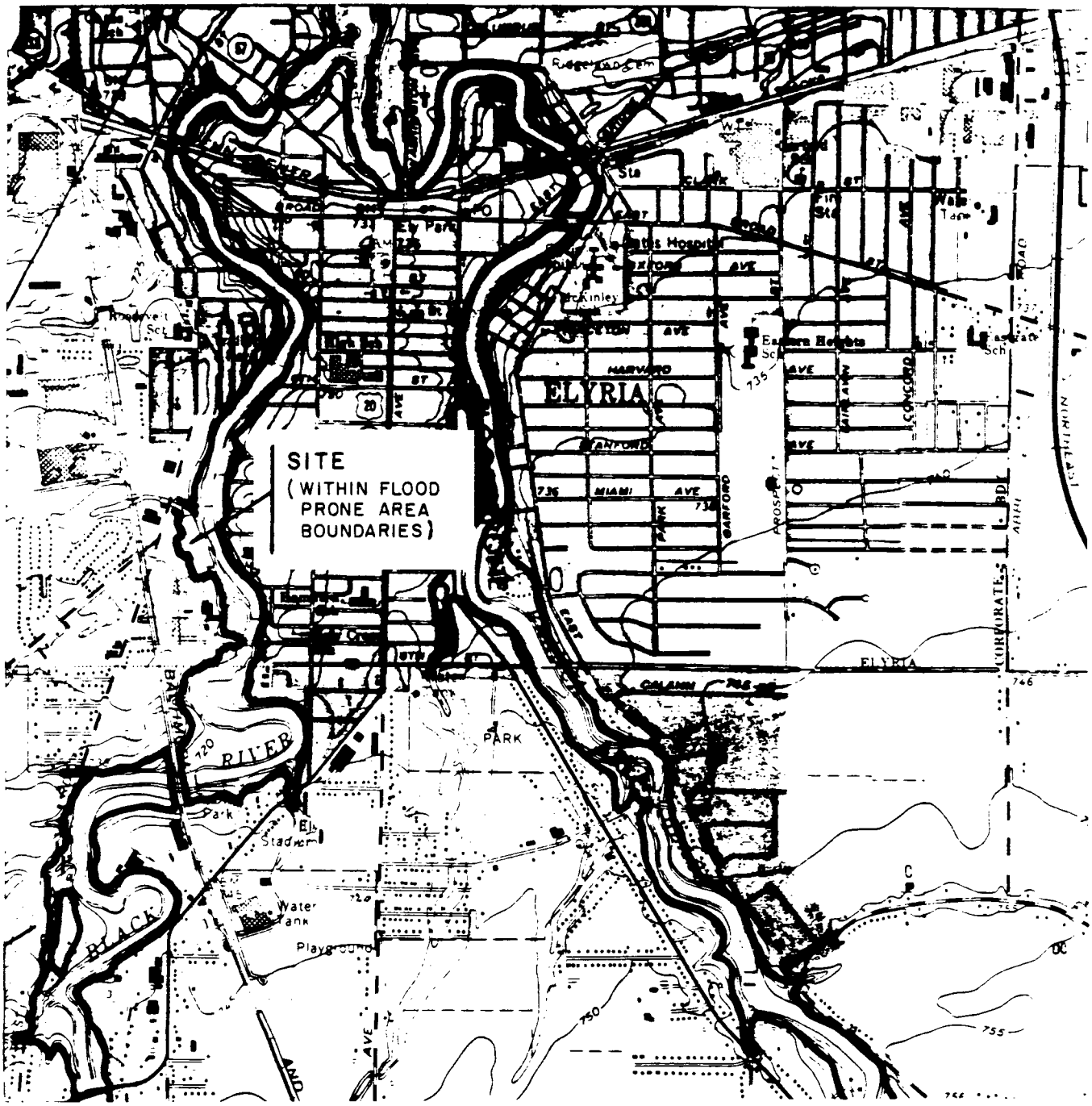
2.6 BEDROCK GEOLOGY

The bedrock of Lorain County is composed predominantly of shale and sandstone of Devonian and Mississippian age (USDA Soil Conservation Service, 1976). The site bedrock is Berea Sandstone. The Berea Sandstone is of Mississippian age and is a quartz sandstone. The matrix cement of the sandstone is siliceous. This sandstone is generally fine grained and homogeneous; however, it varies in thickness and color. Near the City of Elyria, the thickness of Berea Sandstone is approximately 100 ft. (Rau, 1969). Regionally, Berea Sandstone dips gently to the south at about 12 ft. per mile.

Below the Berea Sandstone is the Bedford Shale, which is a red shale of Mississippian age. Below the Bedford Shale is the Cleveland Shale. The Cleveland Shale is a black shale of Devonian Age; however, where rock is exposed to oxidation the carbon is burned out, producing a gray color. This shale is thinly bedded and serves as a small source of petroleum in the area of Grafton, Ohio about seven miles southeast of the site.

2.7 REGIONAL HYDROGEOLOGY

The City of Elyria Water Company supplies treated water for all water users within the three-mile radius of the quarry, except for approximately 360 homes. Of these 360 homes, about 150 are served by Rural Lorain County Water Authority. Both of the water companies obtain their water supplies from Lake Erie. The remaining 190 homes, or about 800 people, are not serviced by water companies (USEPA, 1984). These people may obtain their drinking water from wells completed in the Berea Sandstone.



SOURCE: U.S. DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY. MAP OF FLOOD PRONE AREAS GRAFTON OHIO QUADRANGLE

N

0 2000 4000

SCALE IN FEET

FIGURE 2-3
FLOOD PRONE AREA MAP
REPUBLIC STEEL QUARRY RI

Records indicate that numerous private wells are operated within a three mile radius of the site, including wells located along West Ridge Road, Murray Ridge Road, Russia Road, Route 20, West River Road, and Elyria County Club subdivision (ODNR, 1987 and EPA, 1984). The wells in use along these roads are located more than ½ mile south or west of the site (see Figure 2-4). There are no documented supply wells drawing from the Berea Sandstone for land irrigation purposes within the three mile radius of the site.

Two private residential wells that are still in use are located within 4,000 ft. of the site. These two wells are located at 2015 and 2020 West River Road, and are the nearest wells to the quarry that are still in use. These wells are upgradient from the site.

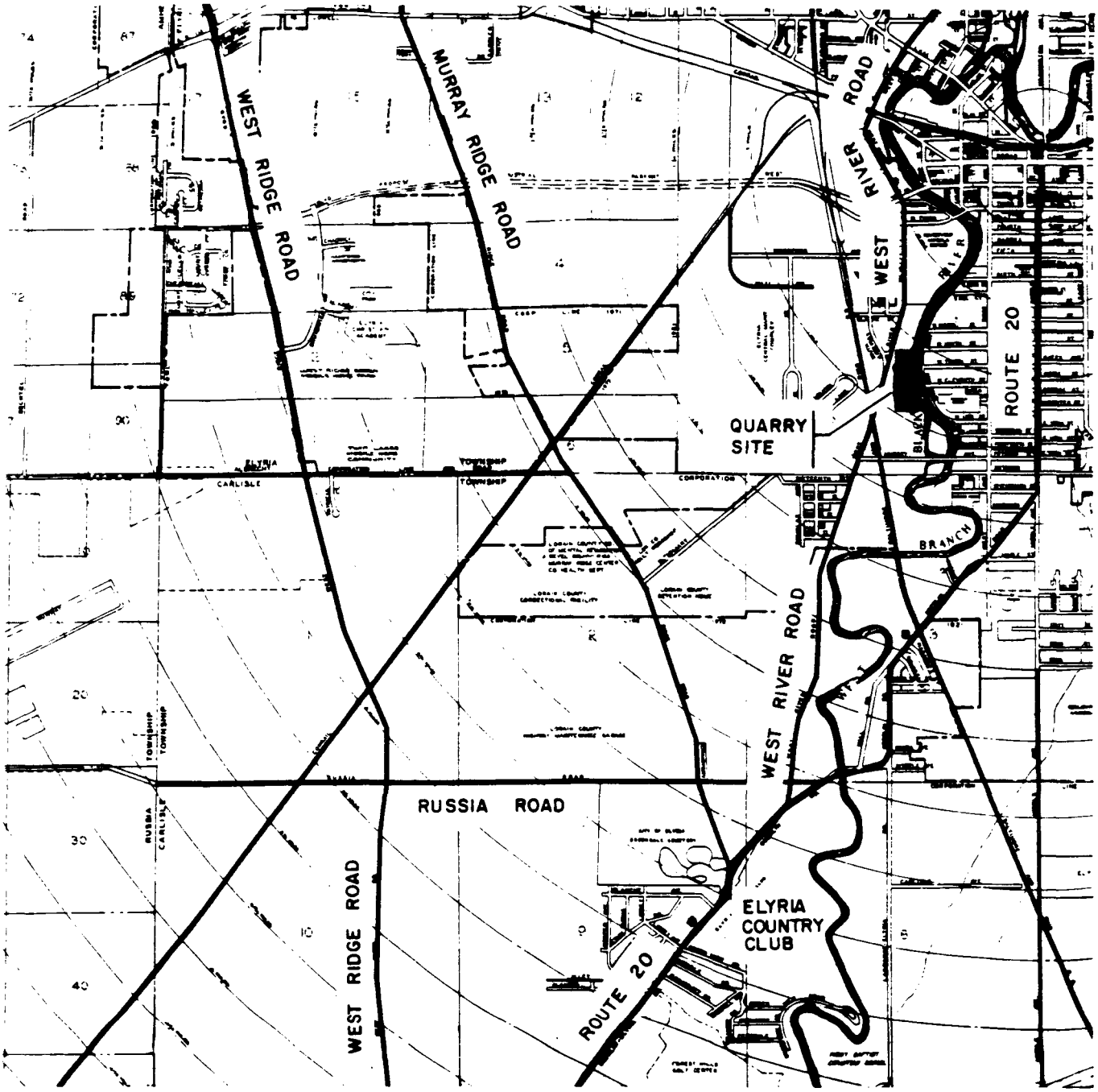
The Berea Sandstone in Lorain County has relatively low well yield, low specific capacity, low permeability, and low transmissibility compared with values reported for Berea Sandstone in other northeastern Ohio counties (Rau, 1969). Typical values for parameters for Berea Sandstone in Lorain County are shown below:

Averaged Reported Well Yield:	10 gpm
Specific Capacity:	0.4 gpm per ft. of drawdown
Average Hydraulic Conductivity:	27 gpd per sq. ft.
Average Transmissibility:	1,100 gpd per ft.

Berea Sandstone thickness is an important factor in determining the well yield; generally, the thicker the unit, the more water it will yield. In Lorain County, however, the Berea Sandstone is more than 100 ft. thick in places, yet well yields are relatively low. Other geologic and hydrologic factors, including the degree of cementation, fracturing, and amount of saturation, evidently are more important than aquifer thickness in determining the yield of Lorain County wells (Rau, 1969).

Recharge to the Berea Sandstone occurs from precipitation percolating directly into the sandstone aquifer along an outcrop or indirectly into the aquifer where they are overlain by other geologic units. Optimal conditions for recharge to the Berea exist where outcrop areas are relatively wide, the sandstone is fractured and jointed near the surface, and the ground surface has low relief.

Flow duration studies of streams in Lorain County indicate that little water is contributed to stream flow by the Berea Sandstone, owing either to low permeability of the Berea or because the sandstone is only partly saturated in the outcrop area (Rau, 1969). The sparseness of gravel and sand in overlying glacial deposits along the relatively wide outcrop belt of the Berea Sandstone may also account for the meager groundwater contribution to the streams in Lorain County.



SOURCE: CITY OF ELYRIA
1986 STREET MAP

0 1
SCALE IN MILES

FIGURE 2-4
PROXIMITY OF SITE TO
ROADS ON WHICH PRIVATE
WELLS ARE LOCATED
REPUBLIC STEEL QUARRY RI

The Bedford Shale and Cleveland Shale underlying the Berea Sandstone are reported to have low well yields and low permeabilities, and are believed to act as confining layers beneath the Berea Sandstone.

2.8 CLIMATE

The climate of Lorain County is characterized by large annual, daily, and day-to-day ranges in temperature (Davis, 1976). Northerly winds off Lake Erie tend to lower daily high temperatures in summer and raise temperatures in winter. When winds are southerly, the lake has little effect on temperature in the county. Summer in Lorain County is moderately warm and humid, while winter is typically cold and cloudy. The average daily maximum and minimum temperatures for each month at Elyria, Ohio are presented in Table 2-1.

Precipitation in Lorain County varies widely from year to year. Normally precipitation is abundant and well distributed throughout the year. Fall tends to be the driest season. Average monthly precipitation and snowfall are also presented in Table 2-1. Generally humidity in Lorain County rises and falls inversely with daily temperature, with higher relative humidity in winter months and lower humidity in summer months.

TABLE 2-1
TEMPERATURE AND PRECIPITATION DATA
ELYRIA, OHIO
REPUBLIC STEEL QUARRY

	Temperature		Precipitation	
Month	Average Daily Maximum (F)	Average Daily Minimum (F)	Average Monthly Total (in.)	Average Monthly Snowfall (in.)
January	35.4	19.3	2.68	9.5
February	37.7	20.7	2.29	8.0
March	45.1	26.8	2.94	8.8
April	59.6	37.4	3.71	1.6
May	71.5	47.4	3.06	0.1
June	80.9	56.3	3.15	0.0
July	84.3	60.3	2.69	0.0
August	82.6	58.6	3.57	0.0
September	77.1	52.6	2.84	0.0
October	66.3	42.2	2.54	0.4
November	51.1	32.6	2.84	4.7
December	38.0	22.6	2.25	9.4
Year:	60.8	39.7	34.56	42.5

Reference: Davis, 1976

3.0 QUARRY BACKGROUND INVESTIGATIONS

Several tasks were performed to investigate quarry conditions either to provide background data on the quarry itself, or to form the basis for other sampling and investigation activities. These activities included the measurement of quarry depth at various locations, a depthfinder survey, a magnetometer survey to identify underwater metal objects and a property survey. Additionally, water quality of the quarry was analyzed to evaluate quarry morphology and limnology. This section summarizes the results of quarry background data collection activities.

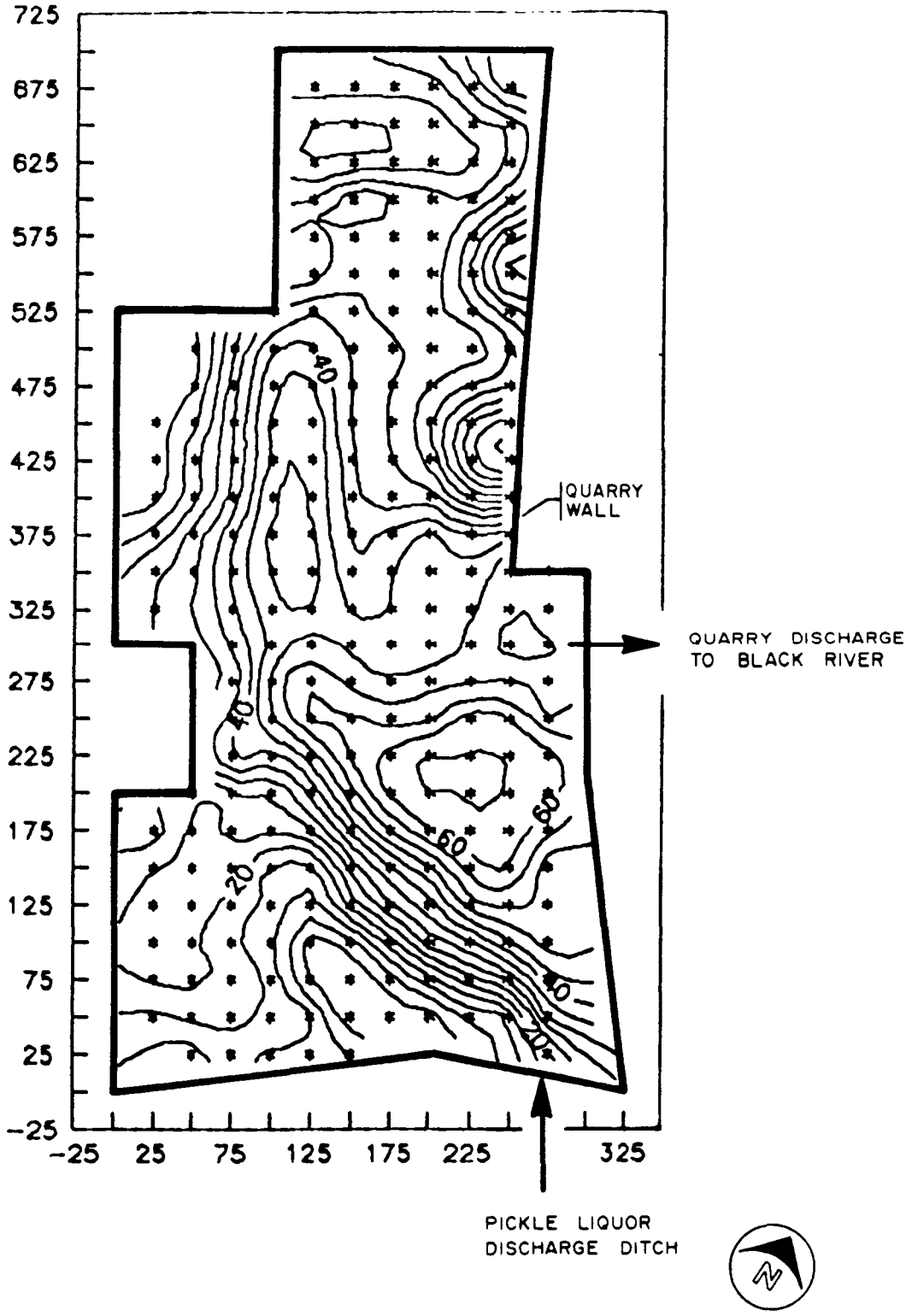
3.1 QUARRY DEPTH MEASUREMENTS

Quarry depth surveys were performed to assist in the planning of quarry water and sediment sampling and well installation activities, and to assist in the reduction of the magnetometer survey data. Quarry depths were used to identify locations for water sampling and to establish the screening interval for monitoring wells. Depth measurements were obtained on a 25 foot grid across the quarry. Depth measurements were made from a boat on the quarry using a weighted tape or PVC pipe. Figure 3-1 illustrates the locations of these survey points and a contour map of the quarry bottom.

A small island is located at grid points east (E) 150 ft., north (N) 50 ft. and E 150 ft., N 75 ft. which is the shallowest area in the quarry. Maximum depth measured was about 65 ft. in the area of E 225 ft., N 200 ft., indicating the most extensive excavation was along the east side of the quarry. There is a steep slope leading from the island to the deepest area of the quarry. In general, the bottom appears somewhat undulatory, but may in fact be more angular as square blocks of sandstone were removed during operations.

3.2 DEPTHFINDER PROFILES

A depthfinder was used to profile the quarry bottom along several transects. The depthfinder was used to determine quarry depth between the discrete survey locations to identify deeper zones within the quarry and attempt to identify debris on the quarry bottom. The maximum depth of the water in the quarry was estimated to be approximately 65 feet. The printouts from the depthfinder revealed an undulatory bottom surface due to the quarrying which confirmed the results of the discreet depth measurements. The quarry bottom surface was irregular and rough. Review of the data did not identify any abnormal variance of the bottom surface to suggest that debris had been dumped. Variations observed in the bottom surface during the depthfinder survey could not be distinguished as being the result of either debris or an uneven bottom created during quarrying operations. Depthfinder printouts were copied and are presented in Appendix B. A map showing buoy locations that are referenced on the depthfinder printouts is included as Figure B-1 in the appendix.



LEGEND:

* DATA POINT

~ ISODEPTH LINES

CONTOUR INTERVAL = 4 FT.

FIGURE 3-1
QUARRY DEPTH CONTOURS
REPUBLIC STEEL QUARRY RI

3.3 MAGNETOMETER SURVEY

3.3.1 Methodology

A magnetic survey was performed on August 10 through August 12, 1987 to determine if drums of waste or other metallic objects were present in the water-filled quarry. Using the same 25 ft. grid locations developed during the depth survey, magnetic readings were obtained using an EDA Omni Plus magnetic gradiometer. This unit automatically records and stores time, date, magnetic field intensities, and corresponding line and position numbers. After completion of the survey, all information was inputted directly to a personal computer (PC) and computer contoured.

The survey was performed using the gradiometer version of the unit. In the gradient technique, the earth's magnetic field is presumed to be undistorted in the absence of metallic objects. Should a ferrous object be within range or massive enough to distort the natural magnetic field, the gradient of the field will change, in proportion to the proximity and/or mass of the object.

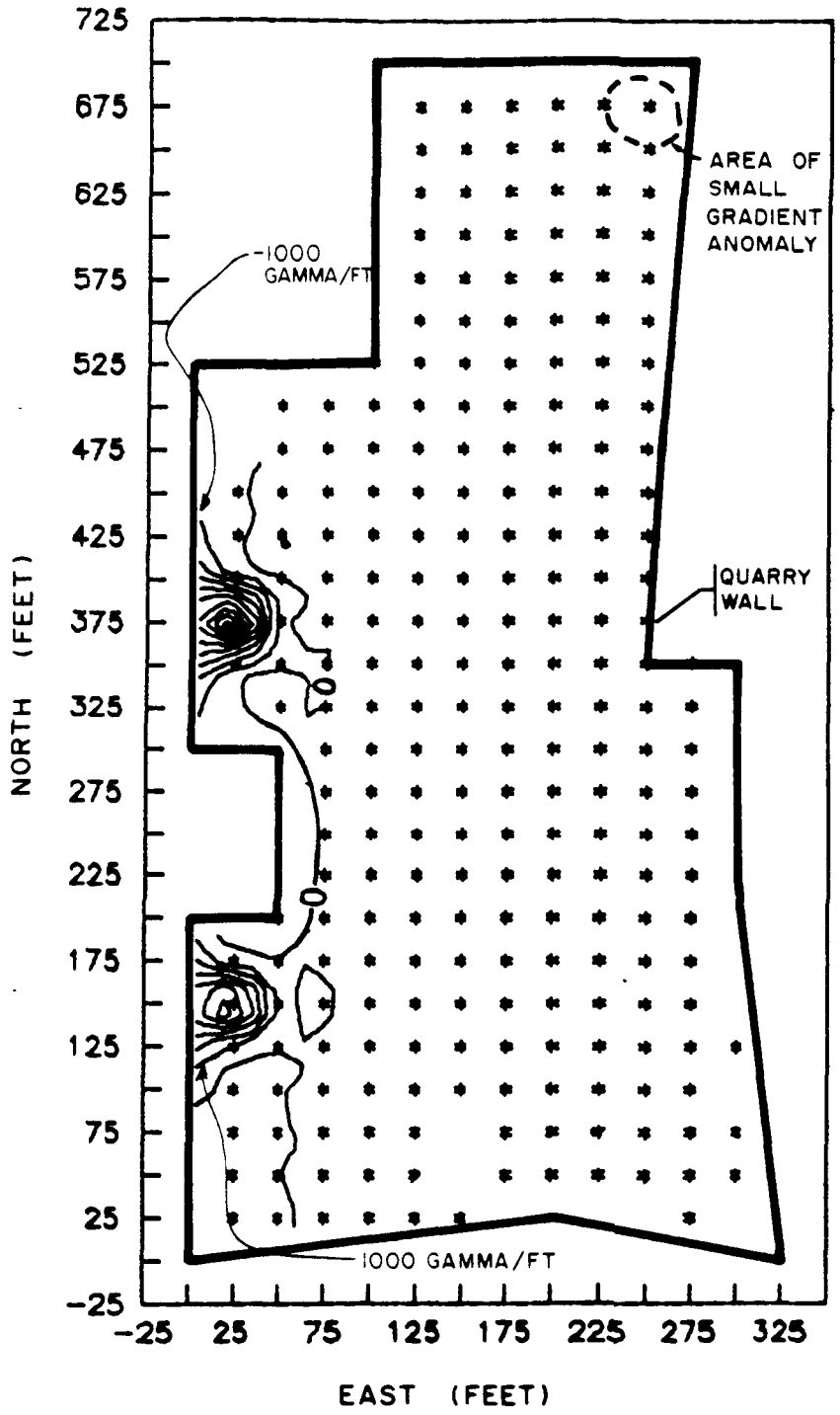
The gradient is measured using two separate field sensors separated by 0.5 meters (1.64 ft.) on the end of a 12 ft. vertical staff. Each sensor reads the total magnetic field at its position. If both fields are the same, the gradient is zero. If there is a difference between the sensors, the gradient is then the difference divided by the sensor separation and is expressed in units of gammas per unit length (in this case, gammas/ft.). The gradient can be either positive or negative depending on the orientation of the magnetic dipole.

3.3.2 Results and Interpretation

Figure 3-2 presents the magnetic isogradient map. The contour interval of the figure is 1,000 gammas/ft. There are only two areas of obvious magnetic anomalies shown by the figure. The anomaly at E 25 ft., N 375 ft. is approximately a -11,500 gamma/ft. anomaly, indicating a large concentration of ferrous material is present at that location. An anomaly is also located at E 25 ft., N 150 ft. with a magnetic gradient of about 9,300 gammas/ft. indicating the presence of a smaller amount of ferrous material than at the E 25 ft., N 375 ft. location.

Figure 3-3 shows the total field isogradient map for the quarry. The same anomaly at E 25 ft., N 375 ft. is evident as a total field value of approximately 37,600 gammas. To the south, the total field values are approximately 35,000 gammas for the area along a line through E 25 ft., N 25 ft. and E 25 ft., N 175 ft.

Both gradient and total field values indicate the presence of large amounts of ferrous material located along the line at E 25 ft. There are gradient anomalies along the line through E 25 ft., N 25 ft. and E 25 ft., N 175 ft.; however, they are overshadowed by the large anomaly at E 25



LEGEND

✱ DATA POINTS

ISOGRADIENT LINES
CONTOUR INTERVAL=1000 GAMMA/FT

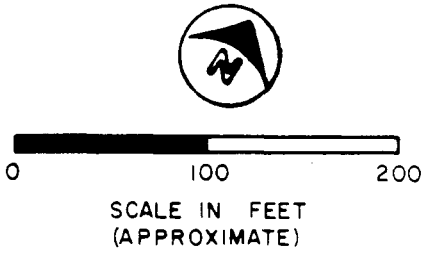
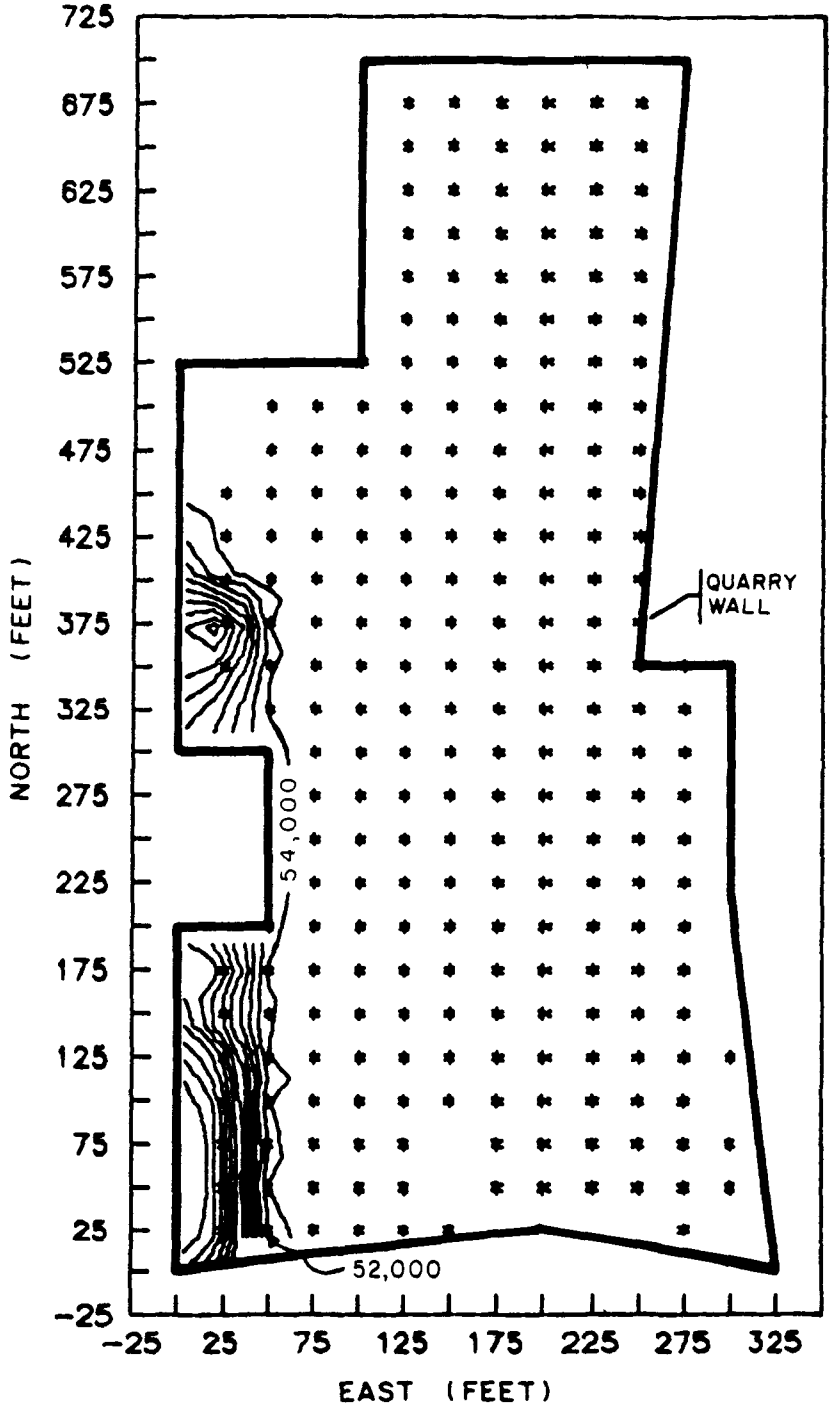


FIGURE 3-2
MAGNETIC GRADIENT READINGS
MAGNETOMETER SURVEY
REPUBLIC STEEL QUARRY RI



LEGEND

* DATA POINTS

ISOINTENSITY LINES
CONTOUR INTERVAL=2000 GAMMA

0 100 200
SCALE IN FEET
(APPROXIMATE)

FIGURE 3-3
TOTAL MAGNETIC FIELD READINGS
MAGNETOMETER SURVEY
REPUBLIC STEEL QUARRY RI

ft., N 150 ft. and hence are not reflected in the contour lines. It appears there are ferrous metallic objects located in the quarry along the bank from the southwest corner of the quarry to the first east-west quarry wall. The majority of the metallic mass is concentrated at or near the E 25 ft., N 150 ft. point.

There may be several tons of material at the E 25 ft., N 150 ft. point based on gradient anomaly and depth of water. The mass estimate was made using standard equations and calculation techniques for interpretation of portable magnetometer data. If this estimate is correct, the mass could not consist only of steel drums, but must include some other massive steel material. The total field values along this line are about 35,000 gammas, which compares to the normal background of the area of about 56,500 gammas, further indicating the presence of a large amount of ferrous metallic material. This background value for the area was obtained from Introduction to Geophysics: Mantle, Core and Crust, Figure 17-2, p. 223, written by G. D. Garland. LTV Steel personnel reported that a railroad car was left in the quarry bottom when the quarry was abandoned. LTV reported that, to the best of their knowledge, the railroad car was a locomotive used for transport of stone out of the quarry. The railroad car reported by LTV may be a source of one of the magnetic anomalies.

The point at E 25 ft., N 375 ft. is also a large anomaly. However, looking at the relative errors for each reading, which the magnetometer calculates and stores, the error for this location is much higher than all others. The reason for this error is not known, but may be due to a large local change in gradient at or near that survey point interfering with the measurement of the actual gradient there. Consequently, the validity of this gradient reading is questionable. Total field values at this point and others in the same line near it indicate the presence of metallic objects. Because the total field anomalies at E 25 ft., N 350 ft. and E 25 ft., N 375 ft. are less than those along the line through E 25 ft., N 25 ft. and E 25 ft., N 175 ft., it would seem that the mass of material near E 25 ft., N 375 ft. is less than that near E 25 ft., N 150 ft. Without a valid gradient value, however, a specific estimate of its mass cannot be made.

The remainder of the quarry appears to be free of metallic objects. All values for both gradient and total field reflect background. However, there may be a minor amount of metallic material in the northeastern-most corner of the quarry where a small gradient anomaly was located.

3.3.3 Summary

The results of the magnetometer survey indicate that it is unlikely that large quantities of metal drums are located on the quarry bottom. Only anomalies with masses of metal greater than or less than those representative of large numbers of drums were encountered during the survey.

3.4 SURVEYING AND PROPERTY BOUNDARY RESEARCH

A surveying subcontractor was procured to perform field surveying and property boundary research. The surveying contractor also researched a legal description of properties near the site in Lorain County records and verified the boundaries in the field. The research was performed to confirm boundaries so that subsequent remedial investigations and remedial measures do not carry into neighboring properties without appropriate permission. The property boundary map prepared is presented in Appendix C.

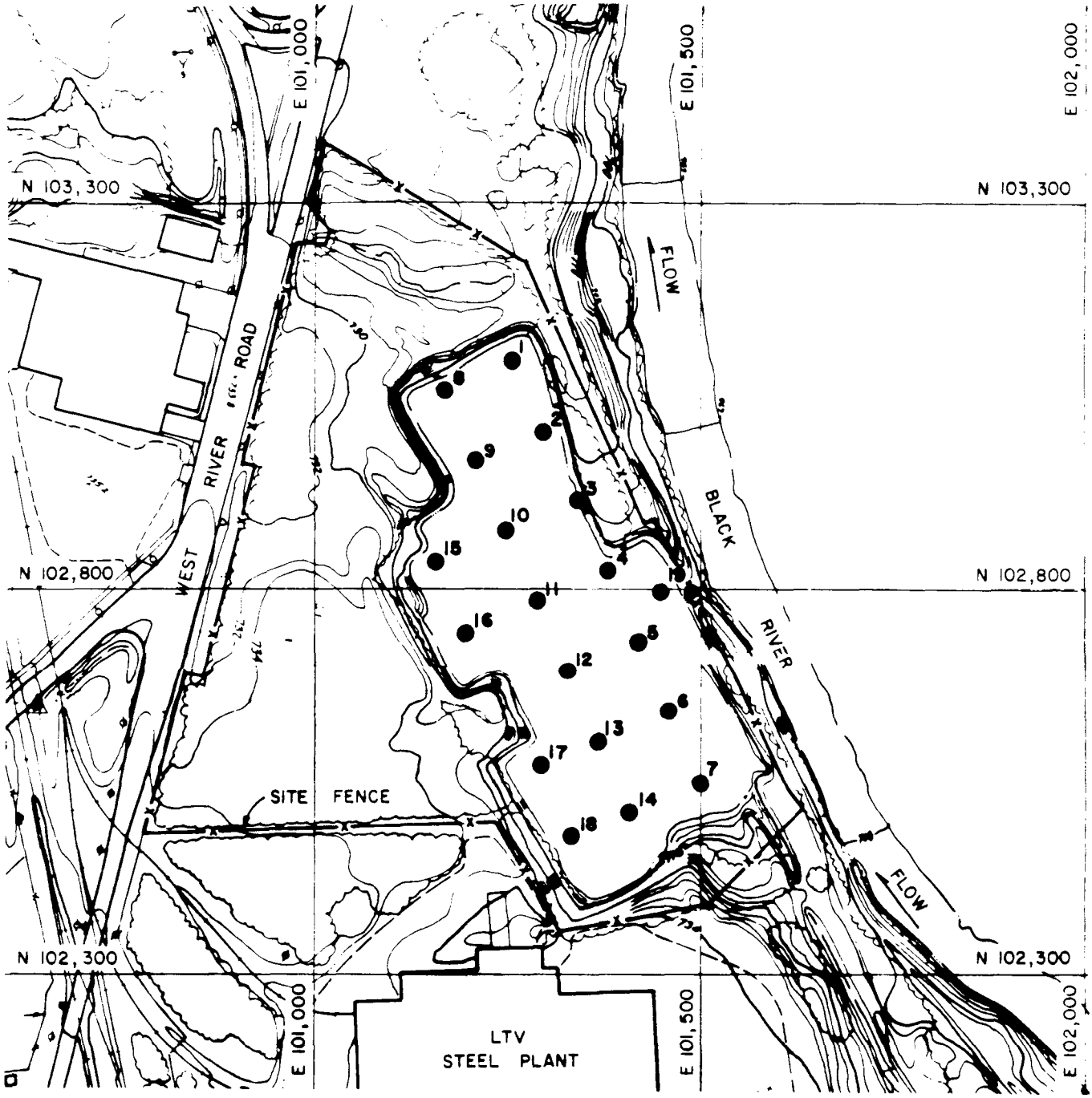
3.5 QUARRY WATER QUALITY PROFILING

On June 9 and 10, 1987, pH, temperature, conductivity, and dissolved oxygen measurements were obtained in the quarry at the 19 buoy locations shown on Figure 3-4 at five foot depth intervals. This profiling was performed to select the locations for quarry water sampling and to investigate quarry morphology. Profiling the quarry water enabled fewer samples to be collected at selected locations rather than using random sampling at arbitrary intervals.

Temperature, conductivity, and dissolved oxygen were measured using 50 foot cables that permitted measurement of these parameters to a depth of 48 feet. Because water entered a cable extension joint for the pH meter, pH measurements could not be obtained in-situ. A Kemmerer sampler was lowered to the depth to be measured and a "messenger" was dropped to close the Kemmerer and obtain a water sample from the specific depth. The Kemmerer was then raised to the surface and the top was opened just far enough to permit the pH probe to be inserted and measurements obtained. Appendix D presents the results of June 1987 water quality profiling.

Additional quarry profiling data were collected during March 14 through 16, 1988 when the quarry was resampled for semi-volatile organic analyses. Resampling was needed due to laboratory quality control problems during initial sampling as described in Section 4.2. Less data were collected during March 1988 profiling since measurements were obtained only at sampling locations rather than all 19 buoy locations. Water quality data were relatively uniform across the quarry during each separate quarry profile time period.

The analysis of this data as it relates to quarry morphology and the transfer of contaminants from the sediments to the soil is presented in Sections 3.6 and 3.7. Additionally, the results of the water quality profiling activities provided data which was used to select surface water sampling locations in the quarry as described in Section 4.2.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

● BUOY LOCATION NO. 8

N

0 200 400

SCALE IN FEET

FIGURE 3-4
BUOY LOCATIONS USED FOR WATER QUALITY PROFILING
REPUBLIC STEEL QUARRY RI

3.6 QUARRY MORPHOLOGY

The physical characteristics of the quarry were investigated through the performance of depth measurement and profiling to define and evaluate the depth, volume, area, and slope of the quarry. A total of 238 depth measurements were made on a 25 foot grid within the quarry. Measurements were made by sounding from a boat using a weighted tape measure. Depthfinder profiles were obtained between the discrete measurement points to identify any deeper zones within the quarry lying between discrete measurement points.

3.6.1 Surface Topography

The Republic Steel quarry lies in the flood plain of the Black River. Elevations range from about 734 msl to the west of the site to about 700 msl near the Black River. Near the Black River, elevations drop by about 20 feet due to the exposure of the Berea Sandstone. The natural topography of the area has been disrupted by sandstone removal during quarrying operations. Western quarry walls drop nearly vertically to the water surface resulting in elevation decreases of about 30 feet. Eastern quarry walls also drop vertical to the water surface resulting in elevation decreases of about 20 feet. Abrupt changes in elevations from the surrounding area results in a reduction of wind velocity and reduction in sunlight due to shading of the water surface by the quarry walls.

3.6.2 Water Surface Area

The water surface area of the quarry was estimated using aerial photographic mapping at a scale of 1 inch equals 100 feet provided by the Engineering Department of the City of Elyria, Ohio. Results indicate that the water surface area is about 164,300 square feet (about 3.8 acres).

3.6.3 Depth

Results of the interpretation of the depth measurement and profiling were illustrated on Figure 3-1. This contour map was prepared using a computerized inverse-square interpolation between discrete measurement locations. Results of the contouring were checked using the depthfinder profiles; agreement between the contouring and depthfinder profiles was acceptable and no depth anomalies were identified between the discrete measurement locations.

Results of the depth measurement and profiling activity indicate an irregular bottom due to surface quarrying. Depthfinder profiling suggests the bottom is somewhat undulatory, but may in fact be more angular due to the removal of sandstone in blocks during quarrying. Maximum depth of the quarry was estimated to be approximately 65 feet in the area of grid points E 225 feet, N. 200 feet lying along the east side of the quarry. Two other deep areas exist in the quarry: one at E 125 feet, N. 375 feet and the other at E 150 feet, N. 625 feet. A small island is located at grid points E 150 feet, N. 50 feet.

Interpretation of the depth measurement and profiling indicate the quarry bottom is irregular and has some very deep areas. The mean water depth is 33.6 feet calculated by dividing the quarry water volume by the water surface area. This value indicates considerable irregularity exists in bottom contours since the maximum depth is about 65 feet. The relative depth of the quarry is 13.3 percent which is defined as the ratio of the maximum depth to the surface area. This relative depth value indicates the quarry is very deep relative to its surface area. For example, Crater Lake, Oregon the deepest body of water in the United States (589 meters) was formed from a collapsed volcanic crater and has a relative depth of 7.5 percent.

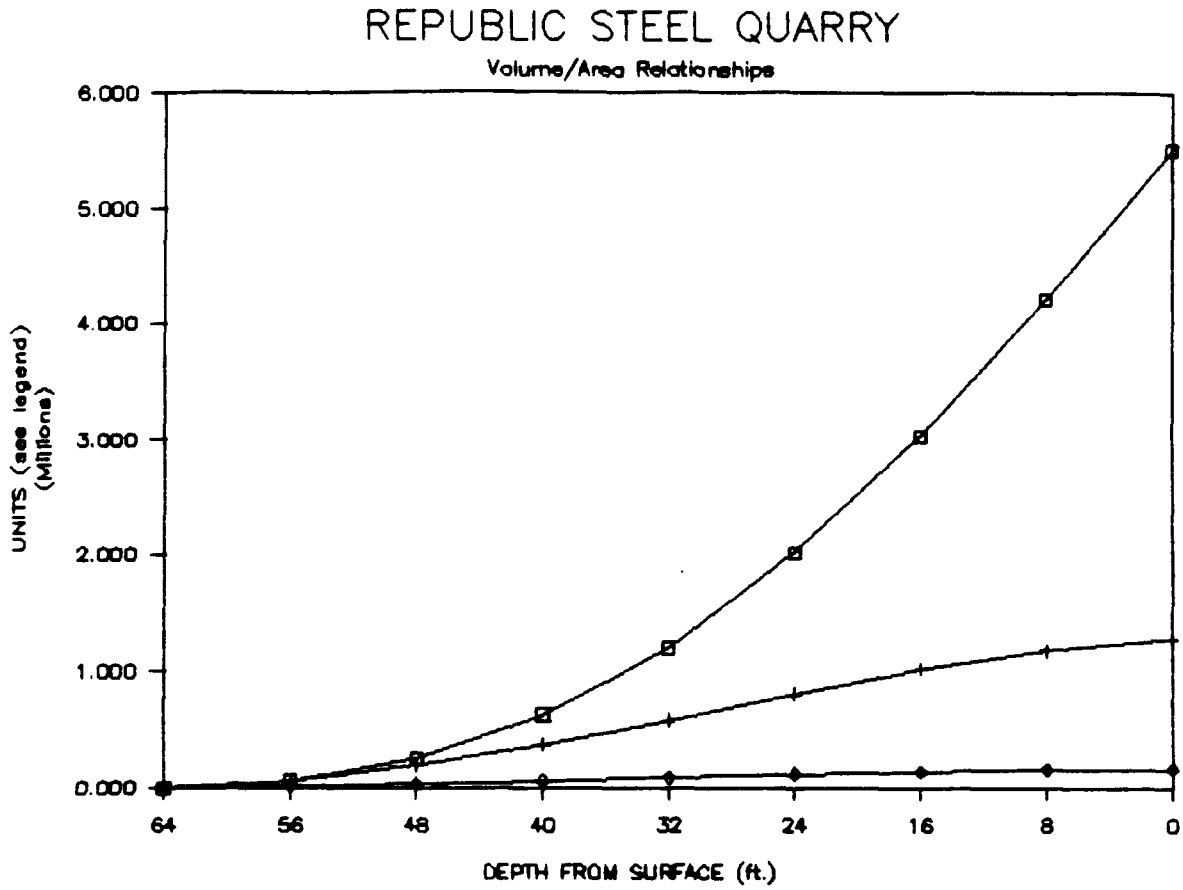
3.6.4 Volume and Area Relationships

Information from the depth measurement and profiling were used to calculate the volume of water contained in the quarry. The cumulative volume, incremental volume, and cumulative bottom surface area with depth for the Republic Steel quarry are shown in Figure 3-5. Information used to prepare the figure is presented on the figure.

Total quarry volume is estimated to be over 5.5 million cubic feet. The upper curve on Figure 3-5 indicates the cumulative volume with decreasing depth. As indicated by the steepest positive slope on the incremental volume curve (middle curve) on Figure 3-5, the 8 foot depth interval contributing the most to volume increase lies between 0 and 8 feet. Consideration of the incremental volume (middle) curve and the cumulative surface area (bottom) curve suggests a decrease in the contribution to total quarry volume above 24 feet due to the influence of the vertical quarry walls and the island. Figure 3-5 also indicates that 50 percent of the quarry volume is achieved at 18 feet from the water surface (47 feet from the deepest point).

3.7 QUARRY STRATIFICATION AND LIMNOLOGY

On June 9 and 10, 1987, pH, temperature, conductivity, and dissolved oxygen measurements were obtained at five foot depth intervals at 19 buoy locations in the quarry shown on Figure 3-4. A second set of measurements was obtained at selected locations in the quarry in March of 1988. The results of the two water quality profiling surveys indicate the presence of a zone of rapid temperature change (thermocline) existed between warm surface water and cold deeper water in the quarry during June 1987 as shown in Figure 3-6A. A similar effect was not observed during the March 1988 water quality profiling as shown in Figure 3-6B.



LEGEND:

□ CUMULATIVE VOLUME (CF)

\+ INCREMENTAL VOLUME (CF)

◇ AREA (SF)

REPUBLIC STEEL QUARRY
Quarry Volume/Area Relationships

DEPTH (ft.)	CUMULATIVE VOLUME (cu. ft.)	INCREMENT. VOLUME (cu. ft.)	% OF TOTAL VOLUME	AREA (sq. ft.)	% OF TOTAL AREA
64	0	0	0.0%	1,866	1.1%
56	60,184	60,184	1.1%	13,180	8.0%
48	252,408	192,224	4.6%	34,875	21.2%
40	627,992	375,584	11.4%	59,020	35.9%
32	1,208,392	580,400	21.9%	86,080	52.4%
24	2,021,608	813,216	36.6%	117,223	71.3%
16	3,046,176	1,024,568	55.2%	138,918	84.5%
8	4,230,776	1,184,600	76.7%	157,231	95.7%
0	5,517,088	1,286,312	100.0%	164,346	100.0%

FIGURE 3-5
QUARRY VOLUME/AREA RELATIONSHIPS
REPUBLIC STEEL QUARRY RI

The zone of rapid temperature change is due to the influences of solar heating, wind, and convection mixing in the upper water zones. As solar radiation passes downward through a water body, it is absorbed exponentially with the heating wavelengths absorbed most rapidly. The zone of rapid temperature change is established below the influence of solar heating and mixing by wind and convection currents. This transition zone separates warmer less dense water near the surface from colder denser water below the thermocline and reflects the lack of mixing between the layers above and below the thermocline. In effect, the thermocline is a zone of thermally induced density gradient within the water column. The depth and thickness of the thermocline depends on the resistance of the water to light penetration (clarity), the temperature differential between the overlying and underlying layers, and the amount of cooler ground water recharge to the water body below the thermocline.

The thermocline observed in the Republic Steel quarry during June of 1987 is delineated on Figure 3-6. The thermocline as defined by Birge (1897) identifies a region where temperature drops at least 1° C with each meter increase in depth. Using this definition, the thermocline in the quarry begins at a depth of 5 feet and continues to a depth of 18.5 feet. In addition, the planar thermocline (Hutchinson, 1957) is indicated on Figure 3-6A as the midpoint of the thermocline zone.

The upper warmer zone was shallow during June existing in only the first five feet below the water surface. Surface water temperature decreased by over 30 percent from 5 to 10 feet in depth within the thermocline. In contrast, water within the lower zone varied by less than 2° C below the thermocline.

Figure 3-6B indicates the temperature profile observed in the quarry during the March 1988 investigation. This profile does not indicate the existence of a thermocline barrier to mixing. With the onset of cooler temperatures, water at the surface loses heat to the atmosphere and becomes more dense. This density difference causes mixing within the upper zone until the temperature and density of the upper zone and the thermocline are similar. At this stage, the thermocline no longer exists and the barrier to circulation between the surface and bottom of the quarry are removed. With the onset of cooler temperatures, solar radiation becomes less effective in adding heat to the surface water causing density changes in the water. Thus during cooling periods, the water density differences which created the thermocline are gradually diminished, resulting in a more uniform temperature and density within the water column. The dissipation of the thermocline removes the barrier to mixing between the epiliminion and hypoliminion. During the transition period, mixing of the water column would be anticipated to occur. Based on the data collected, no evidence of sediment disturbance during this transition period was indicated. With the loss of solar-induced density changes during cooler periods, the major density force capable of mixing the water column is removed. Wind action on the water surface is then the major force causing mixing of water.

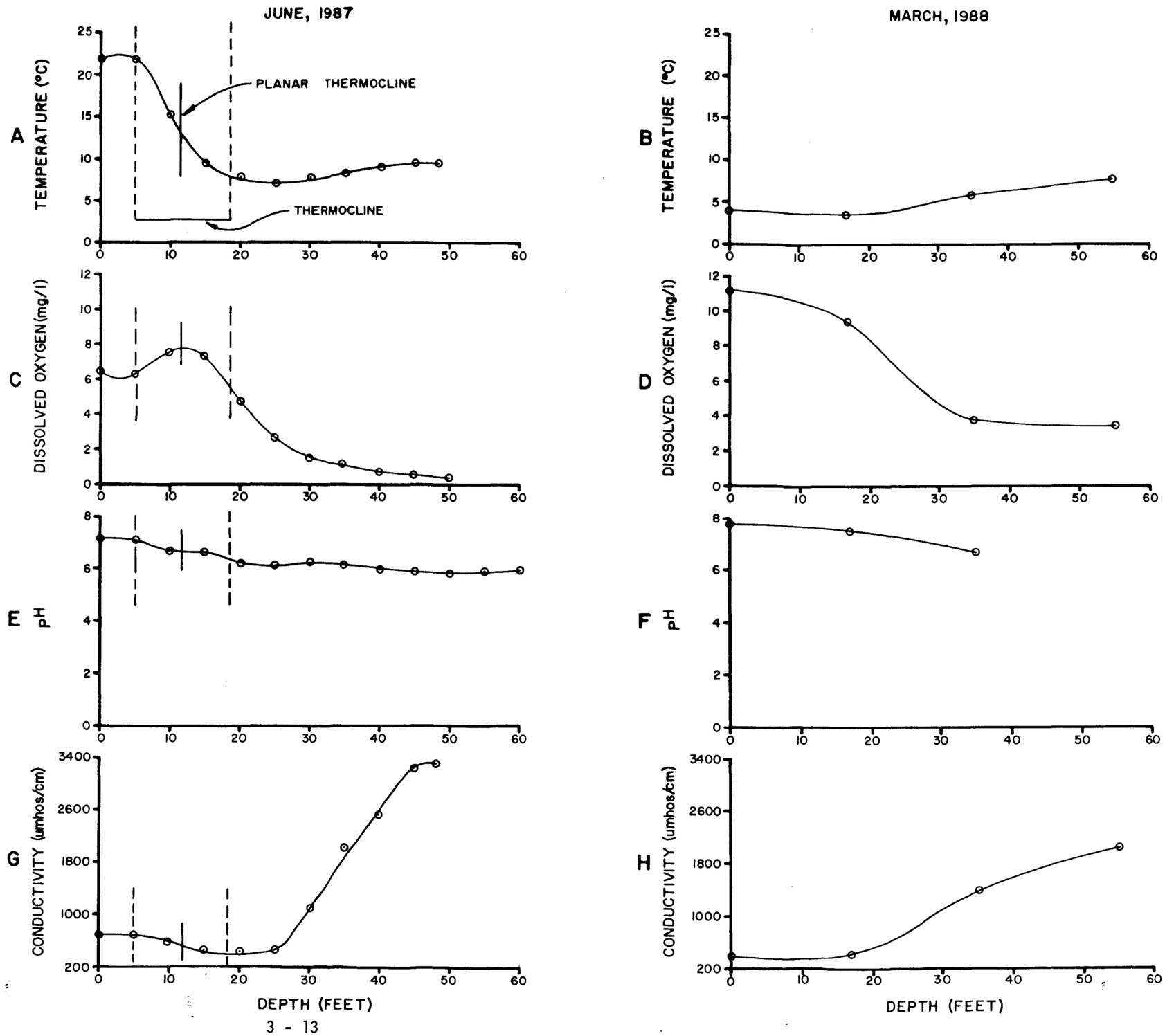


FIGURE 3-6
QUARRY WATER QUALITY
PROFILING RESULTS
FOR TEMPERATURE, DISSOLVED
OXYGEN, pH AND CONDUCTIVITY
REPUBLIC STEEL QUARRY RI

The temperature data on Figure 3-6 indicate significant cooling of the upper (<18.5 feet depth) zone occurred between June and March (22° C to 4° C) removing the thermocline mixing barrier which existed within the quarry. The temperature of this upper zone during March reflects the influence of the cold winter air and reduction in solar radiation. Only a 3° C temperature flux existed in the quarry compared to a 15° C temperature flux that existed during June. Based on water density differences, the potential for mixing in March was about 4 percent of that observed in June. Figure 3-6B indicates a 3° C increase in temperature between 20 and 30 feet depth mirroring a similar though damped 2° C increase in temperature between 25 and 40 feet depth observed during June. Average temperature below 20 feet in June was 8.3^{o} C versus 6.2^{o} C in March. This effect observed in both summer and winter temperature profiles may be due to entry of ground water into the quarry.

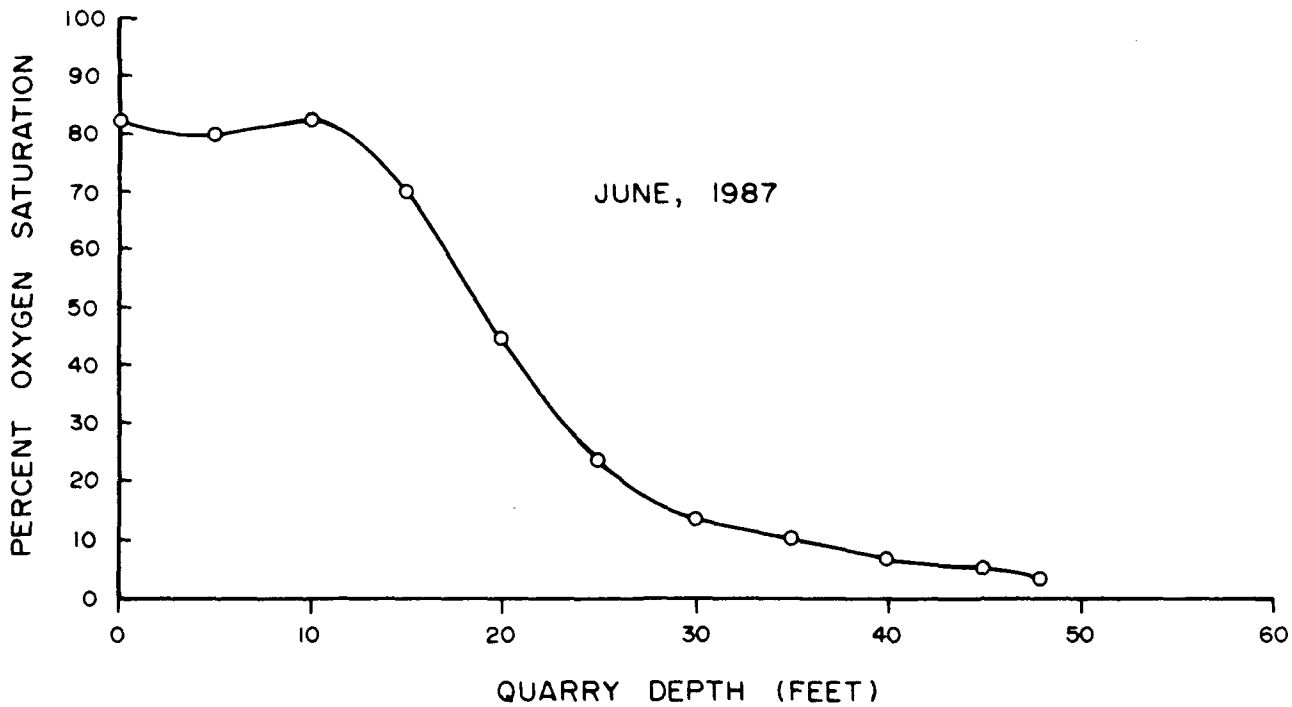
The upward increase in temperature with depth during March suggests that the quarry may not be completely mixed even when the thermocline is absent. The smaller the temperature differential between surface and bottom, the more important wind action becomes as a mixing force. The steep walls of the quarry and the recessed location of the water surface appear to reduce the effectiveness of wind mixing resulting in incomplete mixing.

3.7.1 Effects of Quarry Stratification on Water Chemistry

The existence of a thermocline observed during June prevents complete mixing of the water within the quarry. Because mixing is reduced, chemical reactions that occur at depth or at the surface of the quarry are separated by the thermocline and differences in chemical content become evident. Changes in dissolved oxygen, pH, and conductivity will be discussed.

Dissolved Oxygen: The amount of oxygen capable of dissolving in water is a function of the water temperature; more oxygen dissolves in cold water. The ratio of the actual dissolved oxygen concentration to the oxygen saturation concentration at a given temperature is termed percent oxygen saturation. Percent oxygen saturation versus quarry depth is presented on Figure 3-7. Changes in dissolved oxygen can be attributed to additions to the water system, to absorption from the atmosphere, and manufacture by aquatic plants and reductions by biological respiration and chemical oxidation. The changes in dissolved oxygen content of the water column with depth in June and March are plotted in Figures 3-6C and 3-6D, respectively.

Oxygen percent saturation in June was about 75 percent above the planar thermocline (0 to 11.5 feet depth) where direct absorption of oxygen from the atmosphere and light penetration can support the production of oxygen by aquatic plants. Variation in oxygen saturation was 3 percent indicating the zone was well mixed. Within this zone the additions of oxygen to the water predominated over processes reducing oxygen concentrations.



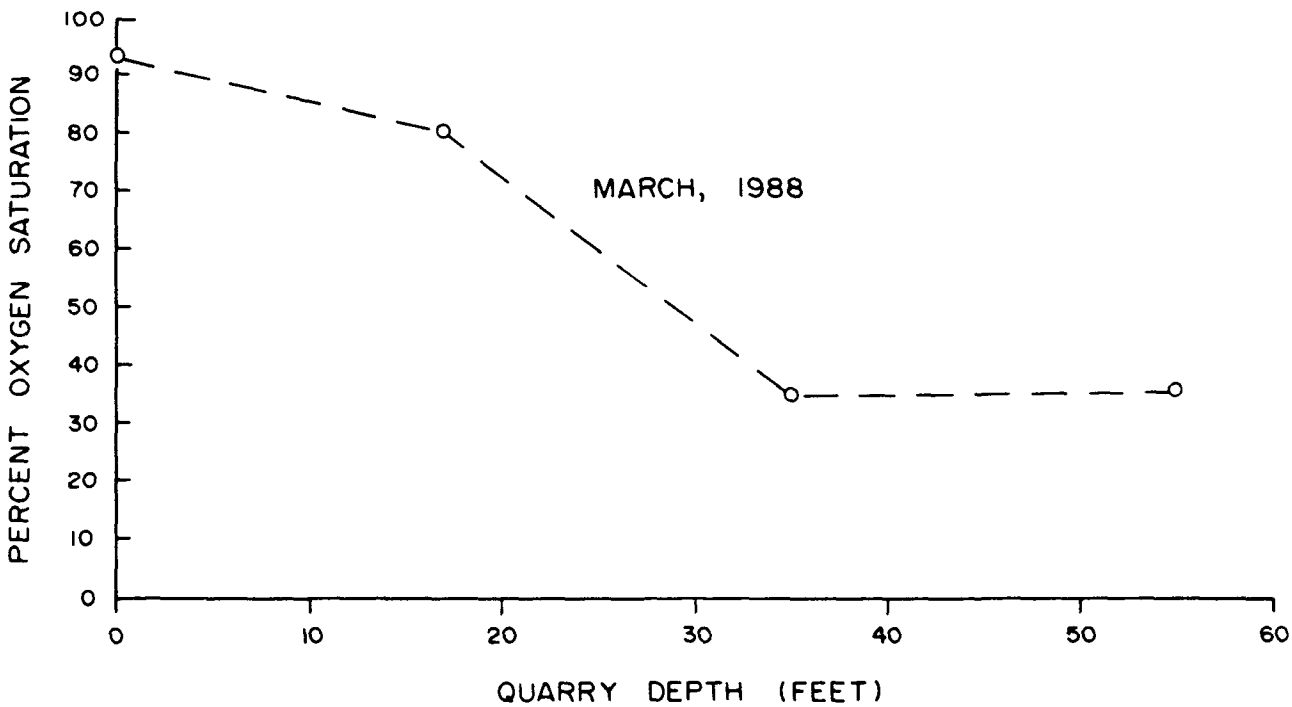


FIGURE 3-7
PERCENT OXYGEN SATURATION
VERSUS QUARRY DEPTH
REPUBLIC STEEL QUARRY RI

Below the planar thermocline, the oxygen concentration during June exhibited a marked decrease with depth. Percent oxygen saturation decreased from 67 percent below the planar thermocline (11.5 feet) to about 3 percent at 50 feet in depth. The reduction in percent saturation is due to the predominance of oxygen consuming processes (biological and chemical) over oxygen adding processes. The thermocline forms a thermo-density barrier to the circulation of oxygen rich surface water into the deeper zones. Variation in oxygen saturation was 63 percent indicating the zone was not well mixed. Percent oxygen saturation exhibited small changes (6 percent) below a depth of 36 feet. Poor mixing is probably due to the lack of a sufficient temperature differential within the zone to drive mixing.

During the March 1988 survey, no thermocline existed within the quarry; however, the data suggest that complete mixing was not occurring within the quarry. Percent oxygen saturation ranged from 85 percent near the surface to a low of 30 percent at about 35 feet in depth. As indicated in the discussion of March temperature profile, water temperatures do not vary significantly with depth and could be construed to indicate the occurrence of good mixing. However, based on the variation in both the dissolved oxygen concentrations and saturation values, it appears that in the absence of a temperature-density gradient wind induced mixing is not effective in producing complete mixing. In the March survey, complete mixing of the water column had not occurred. While percent oxygen saturation was between 85 and 30 percent, it varied by less than 13 percent below a depth of 35 feet.

Hydrogen ion concentration (pH): The pH profile for June is presented in Figure 3-6E and exhibits a slight decrease with depth from 7.18 at the surface to 5.95 at 60 feet. The pH profile for March (shown on Figure 3-6F) also exhibits a slight decrease from 7.78 at the surface to 6.81 at 35 feet (measurements were unavailable at 60 feet). The pH measurements are within expected values for surface waters, and are influenced more by the chemical composition of the water than the physical characteristics related to the processes causing the development of stratification within the quarry.

Conductivity: Conductivity reflects the ability of water to conduct an electric current. Indirectly conductivity is a measure of the dissolved ions in a water sample since water must contain ionized species (such as Na^+ and Cl^-) to conduct electricity. A higher conductivity indicates a greater number of ionized species are present in the samples. Conductivity is a function of temperature; all values reported have been adjusted for temperature effects. The changes in conductivity of the water column with depth in June and March are plotted in Figures 3-6G and 3-6H.

During the stratified period in June, conductivity was below about 700 umhos/cm. (micromhos per centimeter at 25° C) from the water surface to a depth of about 25 feet. Below 25 feet, conductivity increased rapidly reaching a peak of about 3400 umhos/cm. at a depth of 50 feet. This

increase is believed to be due to the increase in sulfate, calcium, hydrogen and iron ions noted in samples from below this depth. The chemical reactions producing these increases are probably associated with the consumption of oxygen noted below the planar thermocline. During the stratified period, the thermocline appears to isolate these concentration increases from the shallower portions (<25 feet depth) of the quarry.

During the March 1988 survey no thermocline existed within the quarry, however the data suggest that complete mixing was not occurring within the quarry. Conductivity values ranged from less than 500 umhos/cm. at the surface to greater than 2000 umhos/cm. at 55 feet in depth. This increase is similar to that observed during June in the quarry but is not as extreme. Based on the variation in conductivity observed, it appears that in the absence of a temperature-density gradient, wind induced mixing is not effective in producing complete mixing for movement of deeper water to the water surface, allowing discharge of chemicals present in deeper waters. Comparing the conductivity profiles obtained in June with those in March, an increase in conductivity is noted below a depth of 25 feet. Both temperature and dissolved oxygen saturation exhibited less variability (i.e. more stability) than conductivity, below this depth during June and March. These effects are attributed to incomplete mixing of the quarry primarily at depths below 25 feet.

A rough estimate of the amount of mixing in the quarry can be made by considering the difference in conductivity between the two survey periods. It is assumed for this analysis to get an approximation that the June survey represents maximum conductivity and March values represent minimum conductivity. A second assumption is that mixing of deeper waters is required for movement to the water surface for discharge through the quarry outfall. The ratio of the areas under the two conductivity curves may represent the differences bewteen the volumes of unmixed water during the two samplings. This value averages between 55 and 65 percent indicating an approximate mixing and removal estimate of between 35 and 45 percent.

3.7.2 Summary

When thermal stratification exists within the quarry, it limits the circulation of water within the quarry and results in changes in temperature, dissolved oxygen and conductivity versus quarry depth. Observations are interpreted as indicating that incomplete mixing occurs within the quarry with deeper zones being less subject to mixing than shallower depths. Mixing appears to be lowest at depths greater than 35 feet. Mixing appears to decrease with depth during stratification (June) due to the formation of a thermocline. During unstratified periods (March) mixing is incomplete due to a reduction in temperature differentials and sheltering of the quarry from wind action that forces mixing. Due to incomplete mixing of surface waters, suspension of quarry bottom sediments into the water column is not anticipated to occur. This limits the contaminant loading from quarry bottom sediments and their subsequent offsite transportation through the quarry discharge or contact with quarry fish or site trespassers.

3.8 AIR MONITORING PERFORMED DURING RI ACTIVITIES

Air monitoring was performed during the RI using an HNu photoionization detector (PID) to test for organic compounds in the air and an explosimeter/oxygen meter to check for buildup of combustible gases and ensure oxygen concentrations remained within acceptable levels. Air monitoring was performed during all RI activities, including drilling, monitoring well installation, monitoring well sampling, and quarry sampling activities. Based on previous investigations at the site and knowledge of the disposal activities which occurred, it was not anticipated that air contamination would be a problem. Air sampling was concluded to be unnecessary.

No readings greater than background were obtained on the HNu during the RI, indicating that organic compounds were not present in air at the site at detectable levels above background. Similarly, no combustible gases were found to be present in site air during the RI. Oxygen concentration of air at the site remained constant at 20.9 percent, indicating normal oxygen content. In summary, air monitoring results from the RI were as follows:

HNu:	0.0 ppm above background
Combustible Gas:	0.0 percent of lower explosive limit
Oxygen:	20.9 percent

Results of air monitoring performed at the site confirmed that air contamination was not a problem at this site.

4.0 SURFACE WATER INVESTIGATION

4.1 INTRODUCTION

The surface water investigation was conducted to obtain information on quarry water contamination and the effects water discharging from the quarry may have on Black River water quality. Investigation activities included sampling of the quarry and Black River and a hydrologic investigation. This section summarizes the results of the investigations, analyzes the data collected, and presents conclusions on site related contaminants.

4.2 HYDROLOGIC INVESTIGATION

A hydrologic investigation was performed at the Republic Steel Quarry site to characterize the quarry hydrologic water balance. As part of this investigation, staff gauges were installed in the quarry and Black River, a weir was constructed to determine flow volume from the quarry to the Black River, and a reconnaissance of surface drainage features near the site was performed. Some data were unable to be collected as a result of repeated acts of vandalism.

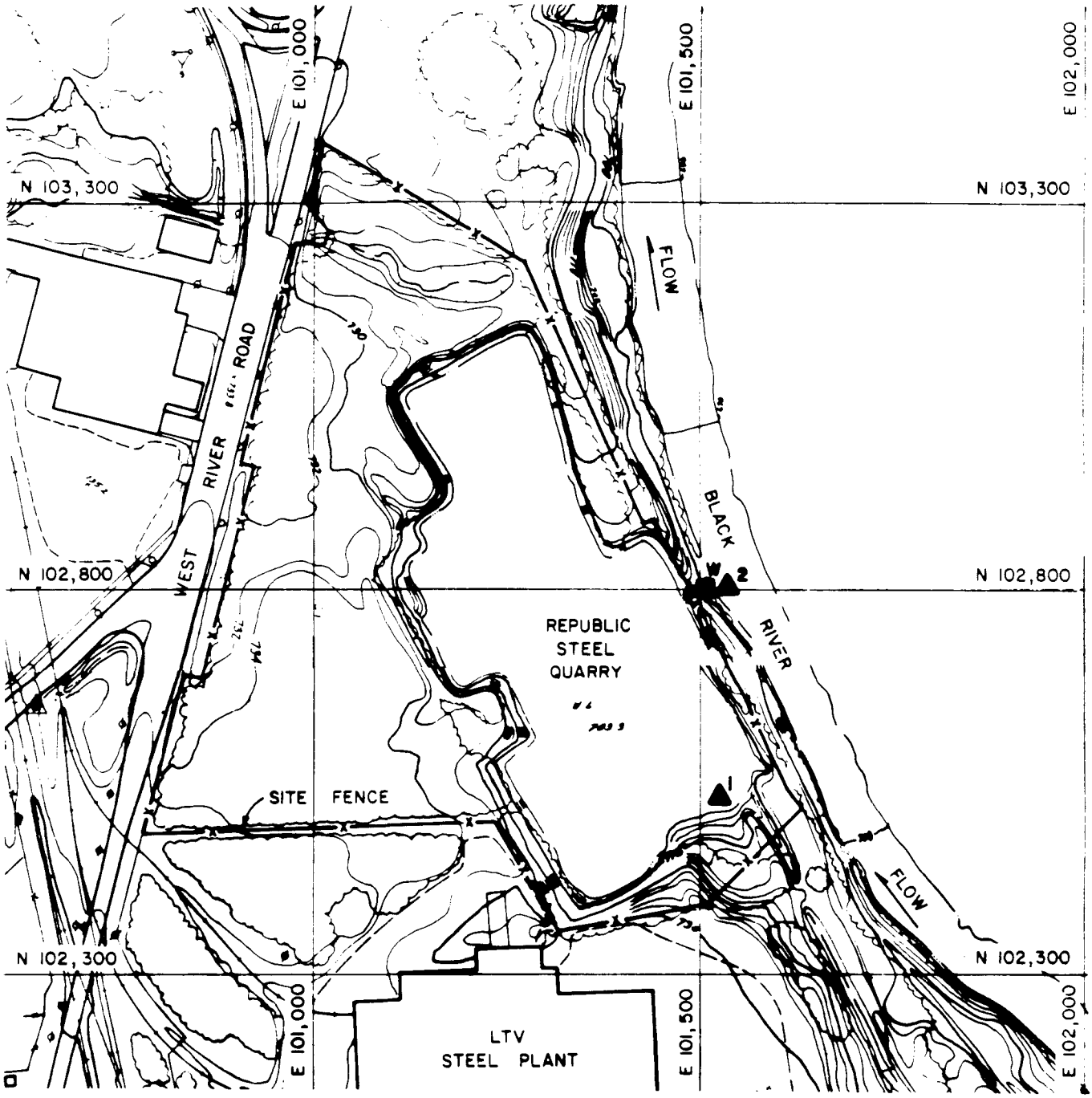
4.2.1 Staff Gauge Installation

Two staff gauges were installed at the site using aluminum angle sections with a steel tape riveted to one side to permit water level measurements. One staff gauge was installed in the Black River about 30 feet southeast of the quarry outlet works, and one staff gauge was installed near the bank at the southeast portion of the quarry. Locations of the staff gauges are shown as Figure 4-1. The staff gauges were driven into small fractures at these locations using a sledge hammer.

Water level readings from the two staff gauges were obtained periodically throughout the remedial investigation. However, prior to surveying the Black River staff gauge, the staff gauge was removed by vandals. Thus, the water level readings from this staff gauge cannot be related to any vertical datum and are unusable data. Water levels of the quarry and Black River near the discharge point were surveyed on September 24, 1987. The elevation of the quarry water was 702.15 ft. and the river elevation was 697.70 ft.

4.2.2 Weir Construction

A weir was constructed in the quarry discharge works during the week of June 15, 1987 to permit measurement of quarry discharge rates. The weir included the use of large amounts of bentonite clay and cement to secure the weir and prevent flow from traveling around or beneath the weir through the fractured sandstone. Despite the care taken to prevent flow



SOURCE: CITY OF ELYRIA ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

▲2 STAFF GAUGE LOCATION

■W WEIR LOCATION

N

0 200 400

SCALE IN FEET

FIGURE 4-1
STAFF GAUGE AND WEIR LOCATIONS
REPUBLIC STEEL QUARRY RI

around and beneath the weir, a small volume of water was observed to be flowing out from beneath the weir. Personnel constructing the weir estimated the flow rate at about 3 gpm, based on visual observations.

In addition to this flow beneath the weir, the weir itself was observed to be discharging at a rate of about 12 gpm. Total discharge from the quarry to the Black River was estimated to be about 15 gpm on June 18, 1987.

On June 22, 1987, the field team returned to the site to perform soil and sediment sampling. By this time the weir had been broken and a large steel gate and other debris had been thrown into the weir. The weir bentonite seal had been penetrated by the debris, and the weir was no longer damming up water to permit flow measurements. The weir was not repaired due to previous incidents of vandalism at the site that suggested that repairs would be short-lived.

4.2.3 Surface Drainage Features Reconnaissance

Surface drainage features near the site were identified and located on a map. There are no large areas that contribute surface water runoff to the quarry. All major ditches or surface water drainage features direct water around or away from the site.

4.3 SURFACE WATER SAMPLING LOCATIONS AND METHODS

4.3.1 Sampling Locations

On June 15 through 18, 1987, 27 surface water samples were collected and submitted for laboratory analyses. These included 19 samples from the quarry, six samples from the Black River, and two sampler rinsate samples. Additionally, one sample of quarry surface water between buoy locations 5 and 6 was collected during the groundwater investigation on August 18, 1987. This sample was oily and had an organic odor as a result of vigorous disturbance of bottom sediments at this location. Attempts were made to collect a sample of oily surface water during the surface water sampling in June; however, locations in the quarry where the sediments were disturbed failed to produce an oily sheen at the surface. The area of the quarry where the oily water sample could be produced by disturbing the sediments was not discovered until sediment sampling was performed. Since groundwater and surface water were analyzed for the same parameters, this sample was obtained during the groundwater investigation.

Quarry Samples: A total of 20 quarry water samples were collected at Buoys 8, 10, 12, 18, between Buoys 5 and 6, and the quarry discharge point to the Black River. Sampling depths and locations were selected based on the results of the water quality profiling to sample discrete zones of the quarry described in Section 3.5. Samples were collected at each buoy location at the surface to characterize the surface water and from a depth of 17 ft. to characterize the layer of reduced conductivity and lower temperature within the thermoclime. At Buoys 8, 10, 12 and between Buoys 5 and 6, samples were collected from a depth of 35 ft., to gain information on the layer where the conductivity begins to rise sharply and

dissolved oxygen starts to decrease. Samples were collected from the deepest portions of the quarry, at Buoy 12 at a depth of 56 ft. and between Buoys 5 and 6 at a depth of 60 ft., to characterize this bottom layer of high conductivity and low dissolved oxygen.

Black River: Seven samples were collected to investigate water quality in the Black River. Two samples were collected upstream of the quarry outlet (and upstream of any geologic lineaments that could permit quarry water to flow to the sample location) to establish background. One sample was collected immediately below the quarry discharge point to the Black River where mixing of quarry and river waters was occurring, and three samples were collected downstream of the quarry (two in standing pools and one of flowing water).

Resampling: As a result of laboratory quality control problems during analysis for semi-volatile organic compounds, most of the semi-volatile organic data from the June sampling event was rejected during data validation. The quarry and Black River were resampled during March 14 through 16, 1988 at the same locations and depths used during June 1987 where laboratory results were rejected. Nineteen quarry and six Black River samples were collected during the March 1988 episode.

Seven of the 27 surface water semivolatile organic analyses from the March 1988 sampling effort were again rejected due to laboratory quality control problems. The quality control problems were similar to the problems that occurred during analysis of June 1987 samples in that poor surrogate spike recoveries were obtained. The poor spike recovery may suggest that the laboratory had poor quality assurance procedures; however, since two independent laboratories had the same problems, quarry water chemistry may be responsible. Only the seven samples from the quarry at or below 35 ft. depth were rejected during the March 1988 sampling program. These deeper waters were determined to have a complex chemistry, with high conductivity, acidity, and metals concentrations, and low dissolved oxygen. The cause of the problems were either due to chemical, physical or matrix effects that interfered with spike recoveries.

Table 4-1 presents a summary of the sample numbers, locations, depths, sampling dates and times, pH, specific conductance, temperature, and dissolved oxygen at the time of sampling for the June 1987 and March, 1988 sampling programs, respectively. Buoy locations that are referenced are shown on Figure 4-2. Surface water sampling locations from June 1987 are shown on Figure 4-3. Surface water sampling locations from March 1988 are presented on Figure 4-4.

4.3.2 Sampling Methods

All water samples obtained at the surface were collected using a decontaminated nalgene beaker. The beaker was dipped into the water and the water was then poured into sample bottles.

TABLE 4-1
SURFACE WATER SAMPLE DESCRIPTIONS
REPUBLIC STEEL QUARRY RI

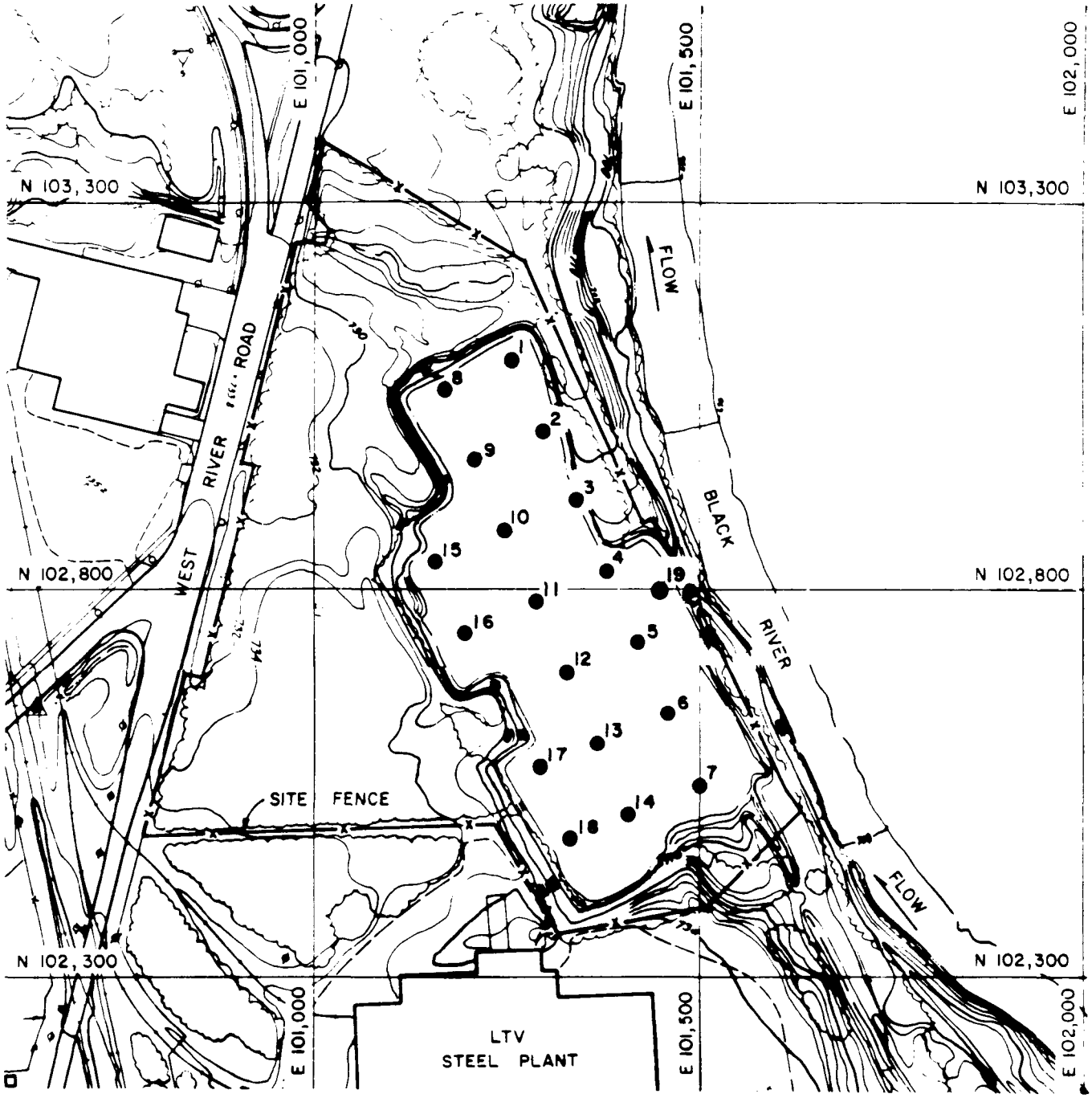
SAMPLE NUMBER	SAMPLE LOCATION	DEPTH (FEET)	SAMPLING DATE	SAMPLING TIME	pH	SPECIFIC CONDUCTANCE (UMHOS/CM.)	TEMPERATURE (C)	DISSOLVED OXYGEN (MG/L)
SW001/002	BOUY 8	0	06/15/87	0805	7.47	700	24.5	5.6
SW003/004	BOUY 8	17	06/15/87	0905	6.92	470	11.0	5.8
SW005/006	BOUY 8	35	06/15/87	0925	6.50	1100	10.0	4.6
SW007/008	BOUY 10	0	06/15/87	1045	7.51	700	25.0	5.3
SW009/010	BOUY 10	17	06/15/87	1055	6.80	480	10.0	5.3
SW011/012	BOUY 10	35	06/15/87	1115	6.47	1300	12.0	4.3
SW013/014	HOLE BETWEEN BOUYS 5 AND 6	0	06/15/87	1235	7.55	700	25.0	5.4
SW015/016	HOLE BETWEEN BOUYS 5 AND 6	17	06/15/87	1250	7.10	490	11.5	5.9
SW017/018	HOLE BETWEEN BOUYS 5 AND 6	35	06/15/87	1310	6.45	1600	11.0	3.2
SW019/020	HOLE BETWEEN BOUYS 5 AND 6	60	06/15/87	1330	6.19	3400	11.0	1.2
SW021/022	HOLE BETWEEN BOUYS 5 AND 6 (SPLIT)	60	06/15/87	1400	6.19	3400	11.0	1.2
SW023/024	QUARRY DISCHARGE WATER	0	06/16/87	0830	6.42	650	23.5	4.2
SW025/026	QUARRY/BLACK RIVER MIXED WATER	0	06/16/87	0840	7.14	530	22.0	5.4
SW027/028	BLACK RIVER DOWNSTREAM POOL	3	06/16/87	0950	7.29	530	22.5	4.8
SW029/030	BLACK RIVER UPSTREAM FLOWING	0	06/16/87	1040	7.68	600	24.0	4.2
SW031/032	BLACK RIVER UPSTREAM POOL	0	06/16/87	1300	7.62	590	25.5	5.2
SW033/034	BLACK RIVER DOWNSTREAM POOL	0	06/16/87	1200	7.57	600	27.0	5.0
SW035/036	BLACK RIVER DOWNSTREAM FLOWING	0	06/16/87	1220	7.52	510	26.0	5.4
SW037/038	KEMMERER SAMPLER RINSATE	N/A	06/16/87	0930	4.50	003	21.0	7.4
SW039/040	NALGENE BEAKER SAMPLER RINSATE	N/A	06/17/87	0800	6.05	005	23.0	5.0
SW041/042	BOUY 12	0	06/17/87	0845	7.59	700	24.5	6.0
SW043/044	BOUY 12	17	06/17/87	0905	7.04	600	15.5	6.4
SW045/046	BOUY 12	35	06/17/87	0920	6.53	1700	9.0	3.6
SW047/048	BOUY 12	56	06/17/87	1000	6.15	3100	11.5	2.8
SW049/050	BOUY 18	17	06/18/87	0915	6.80	520	12.0	4.9
SW051/052	BOUY 18	0	06/18/87	0815	7.54	650	24.0	6.1
SW053/054	BOUY 18 (SPLIT)	0	06/18/87	0815	7.54	650	24.0	6.1
GW005/006	HOLE BETWEEN BOUYS 5 AND 6	0	08/18/87	1130	7.67	610	27.0	3.8

NOTE: EVEN NUMBERED SAMPLES WERE COLLECTED AT THE SAME SAMPLE LOCATION AS THE PREVIOUS ODD
==== NUMBER, AND WERE FILTERED THROUGH A 0.45 MICRON FILTER PRIOR TO PRESERVATION AND SHIPMENT
FOR LABORATORY ANALYSES. (i.e., FOR SW001/002: SAMPLE SW002 REPRESENTS THE FILTERED PORTION OF SW001)

TABLE 4-1 (continued)
SURFACE WATER SAMPLE DESCRIPTIONS
REPUBLIC STEEL QUARRY RI

SAMPLE NUMBER	SAMPLE LOCATION	DEPTH (FEET)	SAMPLING DATE	SAMPLING TIME	pH	SPECIFIC CONDUCTANCE (UMHOS/CM.)	TEMPERATURE (C)	DISSOLVED OXYGEN (MG/L)
SW101	BUOY 8	0	03/14/88	1115	7.90	380	3	13.2
SW102	BUOY 8	17	03/14/88	1130	7.50	400	3	10.0
SW103	BUOY 8	35	03/14/88	1145	7.16	1200	5	4.0
SW104	BUOY 10	0	03/14/88	1215	7.65	410	4.5	11.0
SW105	BUOY 10	17	03/14/88	1225	7.46	420	4	9.0
SW106	BUOY 10	35	03/14/88	1245	6.47	1400	6	5.0
SW107	BOTTLE BLANK	N/A	03/14/88	1310	8.60	25	3	10.5
SW108	NALGENE BEAKER SAMPLER RINSATE	N/A	03/14/88	1315	8.60	25	3	10.5
SW109	KEMMERER SAMPLER RINSATE	N/A	03/14/88	1320	8.60	25	3	10.5
SW110	QUARRY DISCHARGE WATER	0	03/14/88	1520	7.20	300	10	12.0
SW111	QUARRY/BLACK RIVER MIXED WATER	0	03/14/88	1525	7.60	310	10	12.0
SW112	BLACK RIVER DOWNSTREAM FLOWING	0	03/15/88	0830	6.70	320	2	10.0
SW113	BLACK RIVER DOWNSTREAM FLOWING	0	03/15/88	0845	9.90	330	2	10.0
SW114	BLACK RIVER UPSTREAM FLOWING	0	03/15/88	0945	**	320	0.5	10.0
SW115	HOLE BETWEEN BUOYS 5 AND 6	17	03/15/88	1045	**	400	3	10.0
SW116	HOLE BETWEEN BUOYS 5 AND 6	35	03/15/88	1100	**	1400	7	3.0
SW117	HOLE BETWEEN BUOYS 5 AND 6	60	03/15/88	1130	**	650	6	6.5
SW118	HOLE BETWEEN BUOYS 5 AND 6 (SPLIT)	60	03/15/88	1138	**	650	6	6.5
SW119	HOLE BETWEEN BUOYS 5 AND 6	0	03/15/88	1200	**	360	4	10.1
SW120	HOLE BETWEEN BUOYS 5 AND 6 (SPLIT)	0	03/15/88	1215	**	360	4	10.1
SW121	HOLE BETWEEN BUOYS 5 AND 6	0	03/15/88	1230	**	360	4	10.1
SW122	BUOY 18	0	03/15/88	1300	**	400	5	10.0
SW123	BUOY 18	17	03/15/88	1315	**	430	5	9.0
SW124	BLACK RIVER DOWNSTREAM POOL	3	03/15/88	1400	**	320	2	12.0
SW125	BLACK RIVER UPSTREAM FLOWING	0	03/15/88	1420	**	300	2	10.0
SW126	BUOY 12	0	03/16/88	0820	**	380	3	11.0
SW127	BUOY 12	17	03/16/88	0850	**	410	3	9.0
SW128	BUOY 12	35	03/16/88	0900	**	1450	6	3.0
SW129	BUOY 12	55	03/16/88	0930	**	2000	8	3.5

NOTES: ** INDICATES THAT NO pH MEASUREMENT WAS OBTAINED FOR THIS SAMPLE DUE TO EQUIPMENT MALFUNCTION.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

●8 BUOY LOCATION NO. 8

0 200 400
SCALE IN FEET

FIGURE 4-2
BUOY LOCATIONS FOR
QUARRY WATER SAMPLING
REPUBLIC STEEL QUARRY RI

All water samples obtained below the surface were collected using a Kemmerer sampler to enable the collection of a sample from a discrete depth. The sampler consisted of a 4 in. diameter PVC tube with two retractable rubber end caps. Once the sampler had been lowered to the appropriate depth, a messenger was released which traveled down the rope supporting the sampler to trigger closing of the end caps.

4.3.3 Sample Numbering System and Laboratory Analyses Performed

June/August 1987 Samples: Two sample numbers were used to identify each sample location. Odd numbered samples were not filtered, and were analyzed for volatile organics, acid and base/neutral extractables, pesticides/PCB's, metals, cyanide, oil and grease, total suspended solids (TSS), total dissolved solids (TDS), acidity, alkalinity, sulfate, chloride and hexavalent chromium (hexachrome). Even numbered samples were filtered through a 0.45 micron filter and analyzed for metals and hexachrome. For example, sample SW001/002 is actually one sample, with 002 representing the filtered portion of sample 001 to be analyzed for metals and hexachrome.

The EPA Eastern District Office Laboratory, located in Westlake, Ohio, provided hexachrome analysis for the surface water samples. All other laboratory analyses were performed by Contract Laboratory Program (CLP) laboratories.

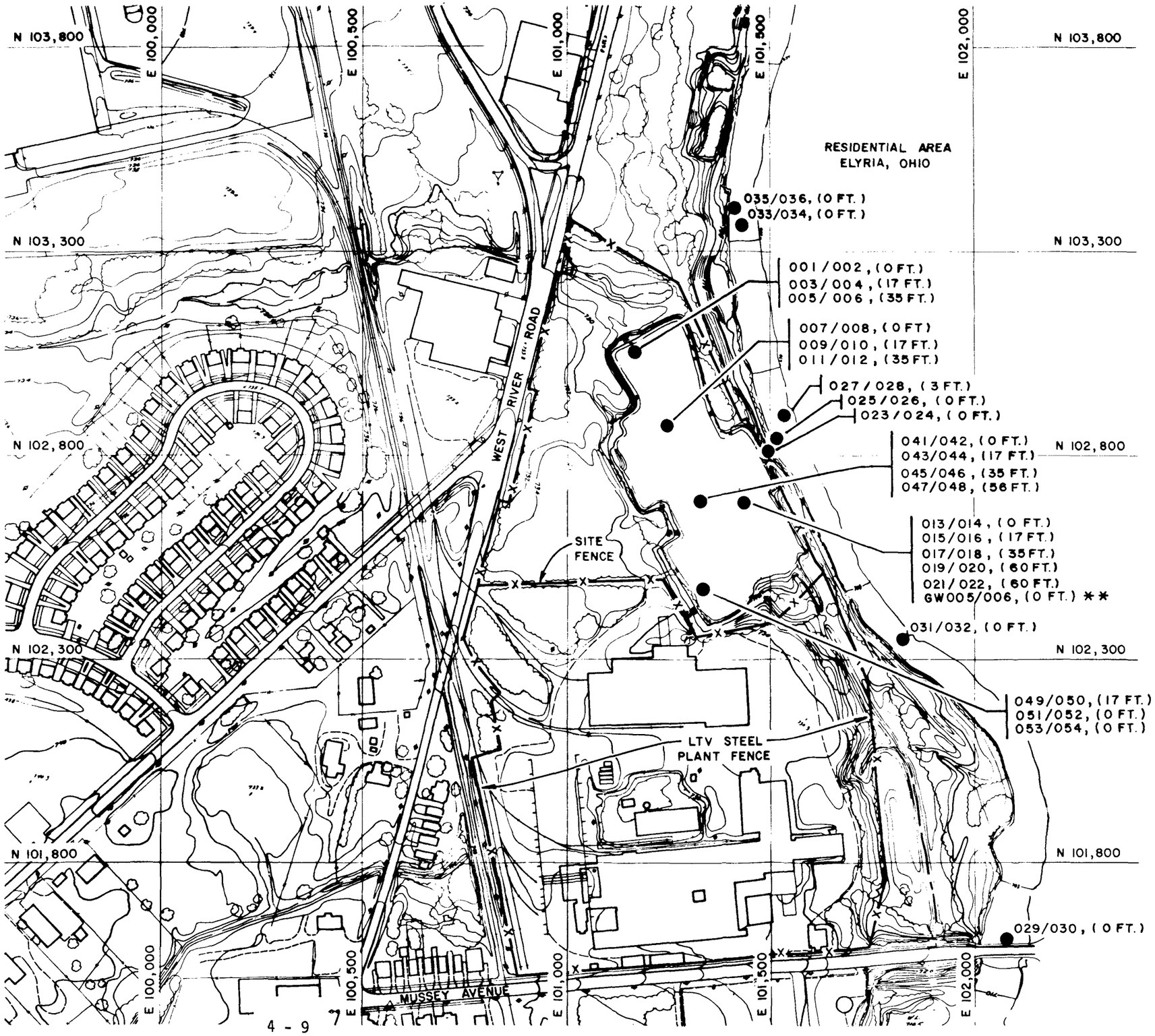
March 1988 Samples: One sample number was used to identify each sampling location. Samples were analyzed for acid and base/neutral extractables, and pesticides/PCBs except for sample number SW121 which was analyzed for volatile organics. All March 1988 laboratory analyses were performed by CLP laboratories.

4.4 LABORATORY ANALYSES RESULTS

Laboratory analytical results from surface water samples are presented in Appendix F. Laboratory analyses performed on each surface water sample are presented on tables in Appendix E. Summary tables presenting only "hits" where chemicals were detected in the samples are presented on Tables 4-2 through 4-4. Laboratory data problems for the surface water samples are presented in Appendix G, Data Considerations, and are noted on summary tables in this section.

4.5 NATURE AND EXTENT OF CONTAMINATION

The evaluation of the nature and extent of surface water contamination was performed in two stages. Initially, surface water in the quarry was compared to background groundwater samples to identify site related chemicals in the quarry water. Following the initial evaluation, the site related contaminants in the quarry water were compared to upstream and downstream Black River water samples to estimate the impact of the quarry on river water quality.



LEGEND:

● 027/028, (3 FT.)
SURFACE WATER SAMPLE NUMBER AND (SAMPLING DEPTH)

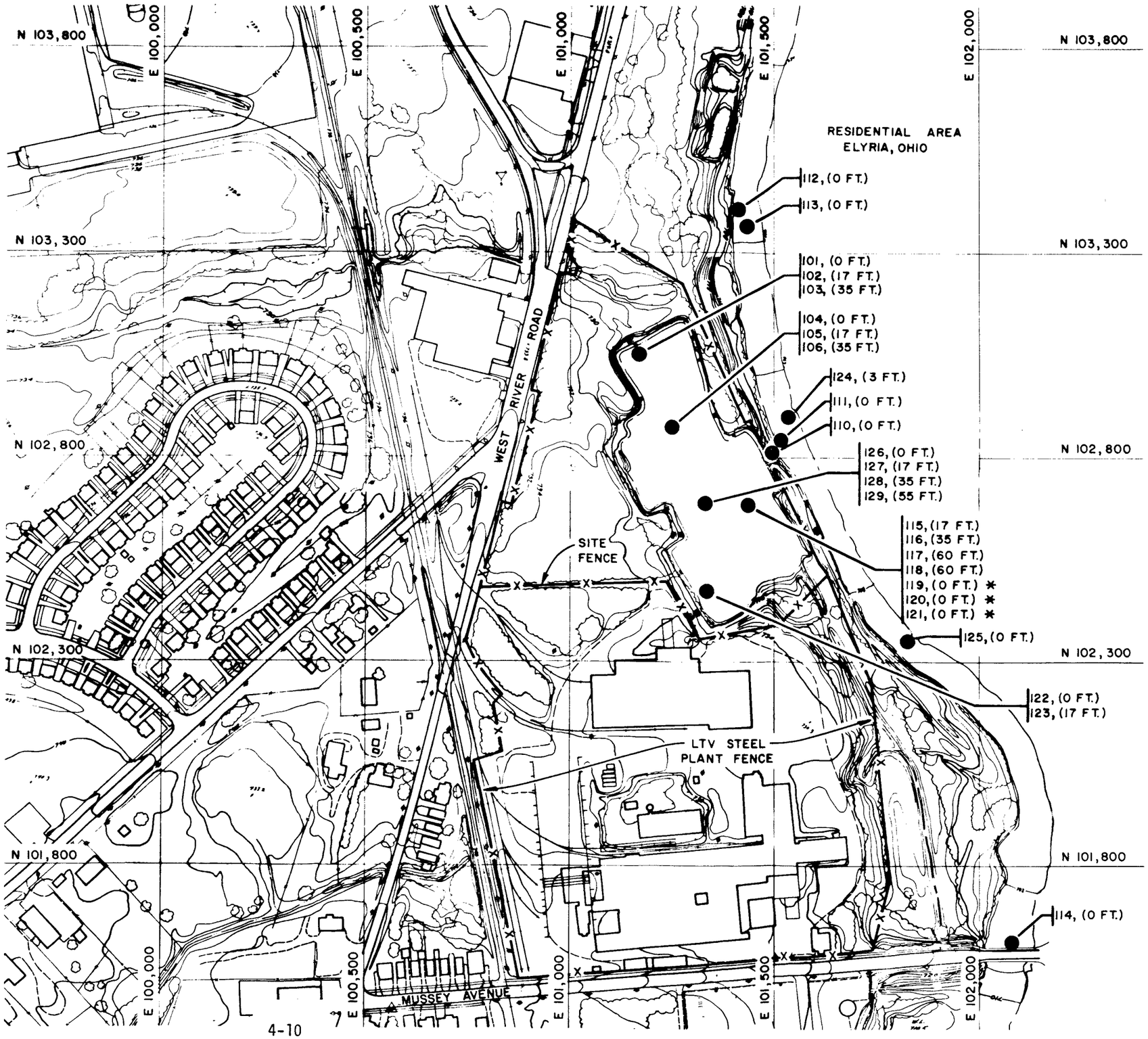
** GW005/006 WAS COLLECTED FROM THE QUARRY SURFACE AFTER VIGOROUSLY DISTURBING THE BOTTOM SEDIMENT. THIS SAMPLE WAS COLLECTED DURING THE GROUND-WATER SAMPLING AT THE SITE.

SOURCE: (1) City of Elyria Engineering Department, Scale: 1" = 100'.

N

0 250 500
SCALE IN FEET

FIGURE 4-3
JUNE 1987 SURFACE WATER SAMPLING LOCATIONS
REPUBLIC STEEL QUARRY RI



LEGEND:

● 110, (0 FT.)
SURFACE WATER SAMPLE NUMBER AND (SAMPLING DEPTH)

* 119, 120 AND 121 WERE COLLECTED FROM THE QUARRY SURFACE AFTER VIGOROUSLY DISTURBING THE BOTTOM SEDIMENT.

SOURCE: (1) City of Elyria Engineering Department, Scale: 1" = 100'.

N

0 250 500
SCALE IN FEET

FIGURE 4-4
MARCH 1988 SURFACE WATER SAMPLING LOCATIONS
REPUBLIC STEEL QUARRY RI

TABLE 4-2
VOLATILE ORGANIC DETECTED
SURFACE WATER
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	Acetone	Toluene	Trichloro-ethene	Benzene	Ethylbenzene	Methylene Chloride
SW017	Buoy 5/6	--	4 J	--	--	--	--
SW021	Buoy 5/6 Split	--	2 J	--	--	--	--
SW023	Quarry Discharge	27	4.3 J	--	--	--	--
SW025	Black Rvr Mix Water	--	5.4	--	--	--	--
SW027	Black Rvr Dwngradnt	--	1.9 J	--	--	--	--
SW031	Black Rvr Upgradnt	12 J	--	--	--	--	--
SW033	Black Rvr Downgradnt	13	--	1.2 J	1.1 J	--	--
SW035	Black Rvr Downgradnt	14	1.6 J	1.5 J	--	--	--
SW037	Sampler Blank	12	2.4 J	--	--	1.2 J	--
SW049	Buoy 18	--	2 J	--	--	--	--
SW051	Buoy 18	--	13	--	--	--	--
SW053	Buoy 18 Split	--	9	--	--	--	--
GW001	Bottle Blank	--	--	--	--	--	4 J
GW005	Buoy 5/6	--	--	--	--	--	9
GW101	Bottle Blank	--	1 J	--	--	--	--

NOTES: All concentrations are presented in micrograms per liter, ug/l.
J Indicates an estimated value.
-- Not Detected

SW001 series samples were collected during June 1987.
GW001 series samples were collected during August 1987.
GW101 series samples were collected during March 1988.

TABLE 4-3
SEMI-VOLATILE ORGANICS AND PESTICIDES/PCBs DETECTED
SURFACE WATER
REPUBLIC STEEL QUARRY RI

		Semi-Volatiles		SAS	Pesticides/PCBs	
Sample Number	Sample Location	bis(2-Ethylhexyl) Phthalate	di-n-Octyl Phthalate	Oil and Grease (x 10^3)	Gamma-BHC (Lindane)	Aroclor 1254
SW001	Buoy 8	14	2 J	--	--	--
SW005	Buoy 8	3 J	--	--	--	--
SW013	Buoy 5/6	8 J	--	--	--	--
SW035	Black Rvr Dwngradnt	4 J	--	--	--	--
SW037	Sampler Blank	--	--	12	--	--
SW039	Sampler Blank	--	--	11	--	--
SW041	Buoy 12	--	--	16	--	--
SW043	Buoy 12	--	--	9.5	--	--
SW049	Buoy 18	--	--	--	0.08	--
SW051	Buoy 18	--	--	--	0.08	--
SW053	Buoy 18 Split	--	--	8.4	0.09	--
GW005	Buoy 5/6	--	--	4250	--	2.9

NOTES: All concentrations are presented in micrograms per liter, ug/l.
J Indicates an estimated value.
-- Not Detected

SW001 Series samples were collected during June, 1987
GW001 Series samples were collected during August, 1987

TABLE 4-4
INORGANICS DETECTED
SURFACE WATER
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	SW001	SW002	SW003	SW004	SW005	SW006	SW007	SW008	SW009	SW010	SW011	SW012	SW013	SW014	SW015
SAMPLE DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Buoy 8	Buoy 8	Buoy 8	Buoy 8	Buoy 8	Buoy 8	Buoy 10	Buoy 10	Buoy 10	Buoy 10	Buoy 10	Buoy 10	Buoy 5/6	Buoy 5/6	Buoy5/6
SAMPLE DEPTH:	0 ft.	0 ft.	17 ft.	17 ft.	35 ft.	35 ft.	0 ft.	0 ft.	17 ft.	17 ft.	35 ft.	35 ft.	0 ft.	0 ft.	17 ft.
ALUMINUM	--	[40]	--	[30]	[101]	275	--	[52]	--	[47]	[60]	[101]	--	[30]	--
ARSENIC	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BARIUM	[21]	[21]	[25]	[26]	[90]	[76]	[22]	[22]	[28]	[25]	[42]	[36]	[22]	[21]	[27]
BERYLLIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CADMIUM	--	--	--	--	12	7.5	--	--	--	--	--	--	--	--	--
CALCIUM	69800	69700	73000	72200	167000	165000	72400	70400	80300	72000	116000	89000	73300	69800	79900
CHROMIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
COPPER	--	[7.9]	--	[4]	--	--	--	[9.6]	--	[8.9]	--	--	--	--	--
IRON	[57]	[25]	105	[20]	512000	472000	[70]	[94]	189	[32]	170000	92300	[83]	1030	118
LEAD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.5
MAGNESIUM	17400	18400	18500	19300	47600	51200	18300	18700	20600	19200	33200	24500	18400	18400	20300
MANGANESE	144	133	557	517	6760	6420	146	134	669	431	3170	2060	152	162	596
NICKEL	--	--	--	--	--	[16]	--	--	--	--	[9.4]	--	--	--	--
POTASSIUM	[4070]	[4480]	[4130]	[4520]	[7820]	8520	[4280]	[4610]	[4790]	[4570]	5720	5040	[4260]	[4420]	[4650]
SELENIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SILVER	--	[4.6]	--	--	--	--	--	--	--	--	--	--	--	--	--
SODIUM	39500	42700	39600	42800	43400	46100	41800	43600	44100	42200	42200	42800	41900	42400	43900
VANADIUM	--	--	--	--	[17]	[16]	--	--	--	--	[6.8]	[4.4]	--	--	--
ZINC	[6.6]	[13]	[5.8]	27	--	32	[3.5]	[12]	[7.7]	[9.7]	--	65	[7]	41	[6.6]
CYANIDE	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--
TOTAL SUSPENDED SOLIDS	--	NA	--	NA	296000	NA	--	NA	--	NA	136000	NA	--	NA	--
TOTAL DISSOLVED SOLIDS	511000	NA	513000	NA	2950000	NA	510000	NA	499000	NA	1330000	NA	453000	NA	529000
TOTAL ALKALINITY	74000	NA	74000	NA	235000	NA	75000	NA	71000	NA	62000	NA	75000	NA	71000
ACIDITY	--	NA	--	NA	686000	NA	--	NA	--	NA	247000	NA	--	NA	--
CHLORIDE	63000	NA	63000	NA	46000	NA	61000	NA	61000	NA	55000	NA	62000	NA	61000
SULFATE	165000	NA	170000	NA	1370000	NA	168000	NA	176000	NA	671000	NA	165000	NA	178000

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

-- Not Detected

TABLE 4-4 (Continued)
INORGANICS DETECTED
SURFACE WATER
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	SW016	SW017	SW018	SW019	SW020	SW021	SW022	SW023	SW024	SW025	SW026	SW027	SW028	SW029
SAMPLE DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87
SAMPLE LOCATION:	Buoy5/6	Buoy 5/6	Buoy 5/6	Buoy 5/6	Buoy 5/6	Buoy 5/6 Split	Buoy 5/6 Split	Quarry Discharge	Quarry Discharge	Black Rvr Mix Water	Black Rvr Mix Water	Black Rvr Downgrdnt	Black Rvr Downgrdnt	Black Rvr Upgradnt
SAMPLE DEPTH:	17 ft.	35 ft.	35 ft.	60 ft.	60 ft.	60 ft.	60 ft.	0 ft.	0 ft.	0 ft.	0 ft.	3 ft.	3 ft.	0 ft.
ALUMINUM	[55]	[133]	210	[155]	[743]	[195]	[777]	808	[55]	1460	[58]	983	[36]	1040
ARSENIC	--	--	--	--	--	15	--	--	--	--	--	--	--	--
BARIUM	[25]	[79]	[60]	[57]	[120]	[88]	[124]	[34]	[22]	[44]	[31]	[41]	[33]	[43]
BERYLLIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CADMIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CALCIUM	71700	138000	118000	149000	307000	251000	302000	73500	68100	70300	64400	70400	64700	71100
CHROMIUM	--	--	--	--	--	--	--	--	--	--	--	[4]	--	--
COPPER	[10]	--	--	--	--	--	--	[5.9]	[4]	[5]	[11]	[4.3]	[4.7]	[4.6]
IRON	[51]	413000	315000	485000	1600000	1150000	1590000	6800	[92]	1720	128	1550	[28]	1630
LEAD	8.6	--	--	--	--	--	6.2	19	9.7	7.8	--	--	--	--
MAGNESIUM	19200	37700	33600	39500	86200	67500	85800	18700	18000	19400	18500	19400	18500	19800
MANGANESE	486	6860	5240	7980	24800	18900	24500	915	277	77	34	71	26	88
NICKEL	--	[22]	[11]	[22]	--	--	--	--	[25]		100	[11]	--	--
POTASSIUM	[4540]	6050	5630	5920	[7450]	[7390]	[8020]	[4470]	[4400]	6010	5570	5820	5560	5960
SELENIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SILVER	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SODIUM	42200	43500	40600	44300	50700	44800	54100	41600	41500	24100	24500	24500	24100	24600
VANADIUM	--	[14]	[9.6]	[19]	[50]	[32]	[55]	--	--	--	--	--	--	--
ZINC	43	--	106	--		--	--	37	58	[9.9]	160	[9.9]	[4.9]	[12]
CYANIDE	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--
TOTAL SUSPENDED SOLIDS	NA	200000	NA	80000	NA	210000	NA	109000	NA	12000	NA	13000	NA	16000
TOTAL DISSOLVED SOLIDS	NA	2480000	NA	792000	NA	4850000	NA	510000	NA	461000	NA	459000	NA	448000
TOTAL ALKALINITY	NA	119000	NA	17000	NA	155000	NA	76000	NA	130000	NA	129000	NA	130000
ACIDITY	NA	646000	NA	39000	NA	1520000	NA		NA	--	NA	--	NA	--
CHLORIDE	NA	48000	NA	60000	NA	48000	NA	61000	NA	35000	NA	37000	NA	36000
SULFATE	NA	1180000	NA	346000	NA	2250000	NA	162000	NA	102000	NA	100000	NA	100000

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

-- Not Detected

TABLE 4-4 (Continued)
INORGANICS DETECTED
SURFACE WATER
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	SW030	SW031	SW032	SW033	SW034	SW035	SW036	SW037	SW038	SW039	SW040	SW041	SW042	SW043
SAMPLE DATE:	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87	06/17/87	06/17/87	06/17/87	06/17/87	06/17/87
SAMPLE LOCATION:	Black Rvr Upgradnt	Black Rvr Upgradnt	Black Rvr Upgradnt	Black Rvr Downgrdnt	Black Rvr Downgrdnt	Black Rvr Downgrdnt	Black Rvr Downgrdnt	Sampler Blank	Sampler Blank	Sampler Blank	Sampler Blank	Buoy 12	Buoy 12	Buoy 12
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	0 ft.	0 ft.	0 ft.	0 ft.	N/A	N/A	N/A	N/A	0 ft.	0 ft.	17 ft.
ALUMINUM	[42]	1030	[45]	642	[41]	754	[33]	--	--	[28]	[30]	--	[32]	[45]
ARSENIC	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BARIUM	[32]	[42]	[34]	[38]	[30]	[39]	[31]	--	--	--	--	[22]	[22]	[25]
BERYLLIUM	--	[1.9]	--	--	--	--	--	--	--	--	--	--	--	--
CADMIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CALCIUM	62800	69800	66100	70500	64200	68500	63600	[672]	[267]	[208]	[637]	70400	69100	74000
CHROMIUM	--	[4.3]	[4.2]	--	--	--	--	--	--	--	--	--	--	--
COPPER	[8.6]	[8.8]	[4.7]	[5.9]	[6.6]	[4.6]	[8.3]	[4.2]	[7.9]	[14]	[8.2]	[8.8]	[6.6]	[14]
IRON	[67]	1410	[63]	1020	[45]	1240	[50]	[94]	[23]	[44]	--	[69]	[43]	198
LEAD	19	--	7	--	6.4	6.3	5.8	6.8	8.2	--	--	--	--	--
MAGNESIUM	18100	19200	18900	19200	18200	18800	18200	[213]		[55]	[120]	19000	18600	20300
MANGANESE	36	76	32	56	17	60	21	--	--	--	--	146	133	681
NICKEL	--	[8.3]	--	[8.3]	--	--	--	--	--	--	--	--	--	--
POTASSIUM	5560	5920	5750	5780	5490	5720	5530	--	--	--	--	[4520]	[4400]	[4690]
SELENIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SILVER	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SODIUM	24000	24400	24900	24600	24000	23000	23800	--	[956]	--	[929]	43600	42700	43600
VANADIUM	--	[4.9]	--	--	--	--	--	--	--	--	--	--	--	--
ZINC	[14]	[15]	[6.9]	[9.1]	[4.4]	[11]	[6.7]	[7.7]	[12]	[12]	[12]	[12]	[12]	[11]
CYANIDE	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--
TOTAL SUSPENDED SOLIDS	NA	10000	NA	7000	NA	8000	NA	--	NA	--	NA	210000	NA	--
TOTAL DISSOLVED SOLIDS	NA	462000	NA	460000	NA	469000	NA	50000	NA	--	NA	6400000	NA	513000
TOTAL ALKALINITY	NA	130000	NA	130000	NA	130000	NA	--	NA	--	NA	74000	NA	67000
ACIDITY	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--
CHLORIDE	NA	37000	NA	36000	NA	37000	NA	--	NA	--	NA	62000	NA	62000
SULFATE	NA	99000	NA	109000	NA	105000	NA	--	NA	--	NA	182000	NA	192000

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

-- Not Detected

TABLE 4-4 (Continued)
INORGANICS DETECTED
SURFACE WATER
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	SW044	SW045	SW046	SW047	SW048	SW049	SW050	SW051	SW052	SW053	SW054	GW001	GW002	GW005	GW006
SAMPLE DATE:	06/17/87	06/17/87	06/17/87	06/17/87	06/17/87	06/18/87	06/18/87	06/18/87	06/18/87	06/18/87	06/18/87	08/18/87	08/18/87	08/18/87	08/18/87
SAMPLE LOCATION:	Buoy 12	Buoy 12	Buoy 12	Buoy 12	Buoy 12	Buoy 18	Buoy 18	Buoy 18	Buoy 18	Buoy 18 Split	Buoy 18 Split	Bottle Blank	Bottle Blank	Buoy 5/6 (Oily)	Buoy 5/6 (Oily)
SAMPLE DEPTH:	17 ft.	35 ft.	35 ft.	56 ft.	56 ft.	17 ft.	17 ft.	0 ft.	0 ft.	0 ft.	0 ft.	N/A	N/A	0 ft.	0 ft.
ALUMINUM	[43]	277	[333]	[771]	[731]	[36]	[38]	[37]	[39]	[31]	[35]	--	[18]	[37]	[21]
ARSENIC	--	--	--	--	21	--	--	--	--	--	--	--	--	--	--
BARIUM	[26]	[82]	[89]	[113]	[111]	[28]	[27]	[22]	[22]	[22]	[22]	--	--	[22]	[18]
BERYLLIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CADMIUM	--	--	10	--	--	--	--	--	--	--	--	--	--	--	--
CALCIUM	72100	147000	155000	315000	288000	75700	73700	71000	69000	70200	69000	--	[270]	63700	59600
CHROMIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
COPPER	[10]	--	--	--	--	[9.5]	[7.9]	[7.4]	[7.9]	[12]	[6.6]	--	--	--	--
IRON	[44]	472000	569000	1600000	1440000	404	[62]	[69]	[43]	105	[34]	--	[45]	564	--
LEAD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MAGNESIUM	19700	44100	46100	88900	82200	20600	20000	19200	18500	19100	18600	--	--	16800	16000
MANGANESE	603	6910	8550	25700	23200	776	600	149	117	129	116	--	--	28	[12]
NICKEL	--	[20]	[28]	[86]	--	--	--	--	--	--	--	--	--	--	--
POTASSIUM	[4520]	6700	[6560]	[8050]	[7970]	[4680]	[4630]	[4610]	[4500]	[4570]	[4360]	--	--	[4300]	[4250]
SELENIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SILVER	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SODIUM	42400	43500	44600	[49100]	57600	42600	42100	43300	43100	42900	43400	--	[1110]	37300	47200
VANADIUM	--	[15]	[17]	[60]	[50]	--	--	--	--	--	--	--	--	--	--
ZINC	[14]	--	[11]	--	[37]	26	[11]	[16]	[16]	[14]	[10]	[6.8]	[15]	[3.6]	[5.8]
CYANIDE	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA
TOTAL SUSPENDED SOLIDS	NA	--	NA	146000	NA	--	NA	--	NA	--	NA	--	NA	57000	NA
TOTAL DISSOLVED SOLIDS	NA	526000	NA	3260000	NA	544000	NA	510000	NA	526000	NA	--	NA	391000	NA
TOTAL ALKALINITY	NA	98000	NA	117000	NA	69000	NA	76000	NA	76000	NA	--	NA	81200	NA
ACIDITY	NA	945000	NA	2110000	NA	--	NA	--	NA	--	NA	--	NA	--	NA
CHLORIDE	NA	45000	NA	44000	NA	61000	NA	63000	NA	64000	NA	--	NA	52700	NA
SULFATE	NA	1590000	NA	3220000	NA	195000	NA	165000	NA	168000	NA	--	NA	149000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

-- Not Detected

The evaluation criteria used to identify potential site chemicals were as follows:

- Chemicals were considered to be potentially site related when either onsite or downstream samples detected concentrations two times the background concentration. The rationale for the selection of two times the background concentration as an evaluation criterion is presented in Appendix G, Data Considerations.

- Chemicals were considered to be potentially site related when they were detected in onsite or downstream samples at concentrations five times blank concentrations.

- Common laboratory chemicals (acetone, methylene chloride, toluene and phthalate esters) were considered to be potentially site related when detected ten times above blank concentrations.

- Chemicals were considered to be site related if they were encountered at more than one sampling location.

4.5.1 Comparison of Quarry Surface Water Against Upgradient Groundwater

Surface water quality in the quarry was compared to upgradient groundwater to identify potentially site related chemicals. Upgradient groundwater was selected as background since the majority of quarry recharge occurs by groundwater. The groundwater samples from Monitoring Wells B-2, B-3 and B-4 were used to establish upgradient water quality (see Section 7.0). Table 4-5 presents the chemicals, number of samples analyzed, number of times detected, percent detected, maximum and minimum concentrations detected, and evaluation of whether the chemical is site related and the location where the maximum concentration was observed. An analysis of the types of contaminants identified are included in the following items.

4.5.1.1 Volatile Organics

Three volatile organic compounds were detected in surface water samples from the quarry. Methylene chloride was found in similar concentrations onsite and in background samples and is not considered site related. Toluene and acetone, which are common laboratory contaminants, were also detected in quarry water samples. Toluene was detected frequently, but at concentrations approximately equal to the limits of the five times blank concentration criteria and much less than the ten times blank concentration used for laboratory contaminants. Acetone was detected in only one sample and was below both the five and ten times blank concentration criteria. Neither acetone or toluene are considered to be site related. No potentially site related volatile organic chemicals were identified in quarry water samples.

TABLE 4-5
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT GROUNDWATER
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM	DEPTH
VOLATILE ORGANIC ANALYSES									
Acetone	Site Related	21	1	5%	27	27	NO	Quarry Discharge	0 ft.
	Background GW	5	0	0%	BDL	BDL			
	Field QA SW	2	1	50%	12	12			
	Field QA GW	2	0	0	BDL	BDL			
Methylene Chloride	Site Related	21	1	5%	9	9	NO	Buoy 5/6	0 ft.
	Background GW	5	2	40%	6	3			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	2	1	50%	8	8			
Toluene	Site Related	21	6	29%	13	2	NO	Buoy 18	0 ft.
	Background GW	5	2	40%	4	1			
	Field QA SW	2	1	50%	2.4	2.4			
	Field QA GW	2	1	50%	3	3			
SEMI-VOLATILE ORGANIC ANALYSES									
bis(2-Ethylhexyl)Phthalate	Site Related	21	3	10%	14	3	NO	Buoy 8	0 ft.
	Background GW	4	1	25%	10	10			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	1	0	0	BDL	BDL			
di-n-Octyl Phthalate	Site Related	21	1	3%	2	2	NO	Buoy 8	0 ft.
	Background GW	4	0	0%	BDL	BDL			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	1	0	0	BDL	BDL			
PESTICIDE/PCBs ORGANIC ANALYSES									
Aroclor-1254	Site Related	39	1	5%	2.9	2.9	NO	Buoy 5/6 (Oily)	0 ft.
	Background GW	4	0	0%	BDL	BDL			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	1	0	0%	BDL	BDL			
Gamma-BHC (Lindane)	Site Related	39	3	8%	0.09	0.08	NO	Buoy 18	0 ft.
	Background GW	4	0	0%	BDL	BDL			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	1	0	0%	BDL	BDL			
Oil and Grease (X 10+3)	Site Related	24	4	17%	4250	8.4	YES	Buoy 5/6 (Oily)	0 ft.
	Background GW	4	0	0%	BDL	BDL			
	Field QA SW	2	2	100%	12	11			
	Field QA GW	1	0	0%	BDL	BDL			

TABLE 4-5 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT GROUNDWATER
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM	DEPTH
Aluminum	Site Related	40	33	83%	777	21	NO	Well B-4	N/A
	Background GW	8	6	75%	2180	24			
	Field QA SW	4	2	50%	30	28			
	Field QA GW	2	0	0	BDL	BDL			
Arsenic	Site Related	40	2	5%	21	15	NO	Well B-3	N/A
	Background GW	8	2	25%	26	21			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	2	0	0	BDL	BDL			
Barium	Site Related	40	40	100%	124	18	YES	Buoy 5/6	60 ft.
	Background GW	8	8	100%	38	8.2			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	2	0	0	BDL	BDL			
Cadmium	Site Related	40	3	8%	12	7.5	NO	Buoy 8	35 ft.
	Background GW	8	4	50%	6.8	4			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	2	0	0	BDL	BDL			
Calcium	Site Related	40	40	100%	315000	59600	YES	Buoy 12	56 ft.
	Background GW	8	8	100%	130000	30200			
	Field QA SW	4	4	100%	672	208			
	Field QA GW	2	1	50%	475	475			
Copper	Site Related	40	17	43%	14	4	NO	Buoy 12	17 ft.
	Background GW	8	2	25%	7.1	7			
	Field QA SW	4	4	100%	14	4.2			
	Field QA GW	2	0	0	BDL	BDL			
Iron	Site Related	40	39	98%	1600000	20	YES	Buoy 5/6	62 ft.
	Background GW	8	8	100%	2450	70		Buoy 12	56 ft.
	Field QA SW	4	3	75%	94	23			
	Field QA GW	2	0	0	BDL	BDL			
Lead	Site Related	40	5	13%	19	6.2	NO	Quarry Discharge	0 ft.
	Background GW	8	0	0%	BDL	BDL			
	Field QA SW	4	2	50%	8.2	6.8			
	Field QA GW	2	0	0	BDL	BDL			
Magnesium	Site Related	40	40	100%	88900	16000	YES	Buoy 12	56 ft.
	Background GW	8	8	100%	63300	15700			
	Field QA SW	4	3	75%	213	55			
	Field QA GW	2	0	0	BDL	BDL			

TABLE 4-5 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT GROUNDWATER
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED		
Manganese	Site Related	40	40	100%	25700	12	YES	Buoy 12	56 ft.
	Background GW	8	8	100%	661	6.2			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	2	1	50%	8.7	8.7			
Nickel	Site Related	40	9	23%	86	9.4	YES	Bouy 12	56 ft.
	Background GW	8	3	38%	15	8.5			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	2	0	0	BDL	BDL			
Potassium	Site Related	40	40	100%	8520	4070	NO	Buoy 8	35 ft.
	Background GW	8	8	100%	5360	3070			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	2	0	0	BDL	BDL			
Silver	Site Related	40	1	3%	4.6	4.6	NO	Buoy 8	0 ft.
	Background GW	8	0	0%	BDL	BDL			
	Field QA SW	4	0	0%	BDL	BDL			
	Field QA GW	2	0	0	BDL	BDL			
Sodium	Site Related	40	40	100%	57600	37300	NO	Well B-4	N/A
	Background GW	8	8	100%	143000	65800			
	Field QA SW	4	2	50%	956	929			
	Field QA GW	2	0	0	BDL	BDL			
Vanadium	Site Related	40	14	35%	60	4.4	YES	Buoy 12	56 ft.
	Background GW	8	1	13%	7	7			
	Field QA SW	4	0	0	BDL	BDL			
	Field QA GW	2	0	0	BDL	BDL			
Zinc	Site Related	40	31	78%	106	3.5	YES	Buoy 5/6	35 ft.
	Background GW	8	8	100%	26	7.7			
	Field QA SW	4	4	100%	12	7.7			
	Field QA GW	2	2	100%	18	8.7			
Total Suspended Solids	Site Related	20	9	16%	296000	57000	NO	Well B-2	N/A
	Background GW	4	0	0%	474000	13000			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	1	1	100%	3000	3000			
Total Dissolved Solids	Site Related	20	20	100%	6400000	391000	YES	Buoy 12	0 ft.
	Background GW	4	4	100%	2210000	733000			
	Field QA SW	2	1	50%	50000	50000			
	Field QA GW	1	0	0	BDL	BDL			

TABLE 4-5 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT GROUNDWATER
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED		
Total Alkalinity	Site Related	20	20	100%	235000	17000	NO	Well B-2	N/A
	Background GW	4	4	100%	425000	324000			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	1	0	0	BDL	BDL			
Acidity	Site Related	20	7	35%	2110000	39000	YES	Buoy 12	56 ft.
	Background GW	4	0	0%	BDL	BDL			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	1	0	0	BDL	BDL			
Chloride	Site Related	20	20	100%	64000	44000	NO	Well B-2	N/A
	Background GW	4	3	75%	808000	5500			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	1	0	0	BDL	BDL			
Sulfate	Site Related	20	20	100%	3220000	149000	YES	Buoy 12	56 ft.
	Background GW	4	4	100%	264000	27200			
	Field QA SW	2	0	0%	BDL	BDL			
	Field QA GW	1	0	0%	BDL	BDL			

NOTES: BDL = Below Detection Limit
Organic analyses maximum and minimum values are presented in micrograms per liter (ug/l).
Inorganic analyses maximum and minimum values are presented in milligrams per liter (ug/l).

4.5.1.2 Semi-Volatile Organics

Two semi-volatile organic compounds were detected in quarry water samples. Bis(2-ethylhexyl)phthalate is not considered site related because it was detected at similar concentrations in upgradient monitoring wells and onsite surface waters. Di-n-octyl phthalate is not considered site related since it was only detected in one sample and was found at concentrations below the contract required detection limits. No potentially site related semi-volatile chemicals were identified in quarry water samples.

4.5.1.3 Pesticides/PCBs and SAS Organics Analyses

Oil and grease was detected at greater concentrations in site samples than in background and field QA samples and is being treated as a potentially site related compound. Aroclor is not considered a potentially site related chemical since it was detected in only one sample which was produced by disturbing the quarry bottom. The condition during sampling does not represent normal quarry water conditions. Gamma-BHC (lindane) is not considered site related because it was only detected at one location (three samples) onsite at very low concentrations, and was not found in any other environmental media at the site. The concentrations at which it was detected were lower than normal detection limits and not by standard CLP techniques.

4.5.1.4 Inorganics

Twenty-three inorganic chemicals were detected in quarry surface water samples. Of these 23 chemicals, barium, calcium, iron, magnesium, manganese, nickel, vanadium, zinc, total dissolved solids, acidity and sulfate were measured at elevated concentrations in quarry water samples compared to upgradient wells and are concluded to be potentially site related. The maximum concentrations of all eight potentially site related metals identified were encountered at depths of 35 ft. or greater.

Aluminum, arsenic, cadmium, copper, lead, sodium, total dissolved solids, alkalinity and chloride were observed to be at similar or higher concentrations in upgradient groundwater samples compared to quarry surface water samples and are not concluded to be site related. Silver was detected in one surface water sample at approximately the contract required detection limit, and is not considered to be site related. Potassium was detected at similar concentrations in the background and quarry samples and is not considered site related.

4.5.1.5 Comparison of Past pH Data

Previous investigations (see Appendix A) indicated that the pH of the water near the bottom of the quarry ranged from 2 to 3 shortly after Republic Steel stopped discharging waste to the quarry. The pH near the quarry bottom during performance of RI activities was in the range of 6 to 7, as shown on Table 4-1. A pH of 6 to 7 is considered to be in the range

of naturally occurring values and it is concluded that the quarry has returned to approximately pre-disposal conditions with respect to pH.

4.5.1.6 Summary

There were no organic chemicals identified as being potentially site related except oil and grease. Several inorganic chemicals were detected in the quarry and are considered to be site related. These include barium, calcium, iron, magnesium, manganese, nickel, vanadium and zinc. All of these inorganic chemicals were detected at greatest concentrations near the quarry bottom.

4.5.2 Comparison of Quarry Surface Water Against Black River

The analytical results of quarry water samples were compared to both upstream and downstream Black River water quality results to estimate if the quarry was affecting river water quality. For volatile organic and inorganic analyses, sample SW025/206, 027/028, 033/034 and 035/036 were used to establish downstream quality and sample 029/030 and 031/032 were used to establish upstream water quality in the Black River. For semi-volatile analyses, downstream water quality was established using Samples SW035, SW111, 112, 113 and 124 while upstream water quality was established using samples SW031, SW114 and 125. Since pesticides/PCBs analyses were performed twice, both sets of samples were used to establish upstream and downstream concentrations. Table 4-6 presents the chemicals, number of samples analyzed, number of times detected, percent detected, maximum and minimum concentrations detected, and evaluation of whether the quarry discharge is affecting downstream Black River quality. Types of samples considered on the table were quarry samples, downstream Black River samples, upstream Black River samples (background) and field QA rinsates. This table summarizes analytical data presented on Table 4-2 and is used to estimate the impact of site surface water on the Black River.

4.5.2.1 Volatile Organics

None of the five volatile organic compounds detected in the quarry water samples appear to be affecting water quality in the Black River. As shown on Table 4-6, upstream Black River samples did not detect toluene, while downstream and quarry samples did contain very low concentrations of toluene. However, toluene was not concluded to be a potentially site related chemical in Section 4.5.1.1.

4.5.2.2 Semi-Volatile Organics

No semi-volatile compounds were concluded to be effecting Black River quality. The comparisons used to develop this conclusion are presented on Table 4-6.

TABLE 4-6
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT BLACK RIVER
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	AFFECTS RIVER	LOCATION OF MAXIMUM	DEPTH
VOLATILE ORGANIC ANALYSES									
Acetone	Quarry	21	1	5%	27	27	NO	Quarry	0 ft.
	Downstream	4	2	50%	14	13			
	Background	2	1	50%	12	12		Discharge	
	Field QA	2	1	50%	12	12			
Benzene	Quarry	21	0	0%	0	0	NO	Black River	0 ft.
	Downstream	4	1	25%	1.1	1			
	Background	2	0	0%	BDL	BDL		Downgradient	
	Field QA	2	0	0%	BDL	BDL			
Methylene Chloride	Quarry	21	1	5%	9	9	NO	Buoy 5/6	0 ft.
	Downstream	4	0	0%	BDL	BDL			
	Background	2	0	0%	BDL	BDL			
	Field QA	2	0	0%	BDL	BDL			
Toluene	Quarry	21	6	29%	13	2	NO	Buoy 18	0 ft.
	Downstream	4	3	75%	5.4	1.6			
	Background	2	0	0%	BDL	BDL			
	Field QA	2	1	50%	2.4	2.4			
Trichloroethene	Quarry	21	0	0%	1.5	1.2	NO	Black River	0 ft.
	Downstream	4	2	50%	0	0			
	Background	2	0	0%	BDL	BDL		Downgradient	
	Field QA	2	0	0%	BDL	BDL			
SEMI-VOLATILE ORGANIC ANALYSES									
bis(2-Ethylhexyl)Phthalate	Quarry	21	3	14%	14	3	NO	Buoy 8	0 ft.
	Downstream	5	1	20%	4	4			
	Background	3	0	0%	BDL	BDL			
	Field QA	2	0	0%	BDL	BDL			
di-n-Octyl Phthalate	Quarry	21	1	5%	2	BDL	NO	Buoy 8	0 ft.
	Downstream	5	0	0%	BDL	BDL			
	Background	3	0	0%	BDL	BDL			
	Field QA	2	0	0%	BDL	BDL			
PESTICIDE/PCBs ORGANIC ANALYSES									
Aroclor-1254	Quarry	39	1	3%	2.9	2.9	NO	Buoy 5/6	0 ft.
	Downstream	8	0	0%	BDL	BDL			
	Background	4	0	0%	BDL	BDL		(Oily)	
	Field QA	4	0	0%	BDL	BDL			

TABLE 4-6 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT BLACK RIVER
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	AFFECTS RIVER	LOCATION OF MAXIMUM	DEPTH
PESTICIDE/PCBs ORGANIC ANALYSES									
Gamma-BHC (Lindane)	Quarry	39	3	8%	0.09	0.08	NO	Buoy 18	0 ft.
	Downstream	8	0	0%	BDL	BDL			
	Background	4	0	0%	BDL	BDL			
	Field QA	4	0	0%	BDL	BDL			
Oil and Grease (X 10+3)	Quarry	20	4	20%	4250	8.4	NO	Buoy 5/6	0 ft.
	Downstream	4	0	0%	BDL	BDL			
	Background	2	0	0%	BDL	BDL		(Oily)	
	Field QA	2	2	100%	12	11			
INORGANIC ANALYSES									
Aluminum	Quarry	40	33	83%	777	21	NO	Black River	0 ft.
	Downstream	8	8	100%	1460	33			
	Background	4	4	100%	1040	42		Mix Water	
	Field QA	4	2	50%	30	28			
Arsenic	Quarry	40	2	5%	21	15	NO	Buoy 12	56 ft.
	Downstream	8	0	0%	BDL	BDL			
	Background	4	0	0%	BDL	BDL			
	Field QA	4	0	0%	BDL	BDL			
Barium	Quarry	40	40	100%	124	18	NO	Buoy 5/6	60 ft.
	Downstream	8	8	100%	44	30			
	Background	4	4	100%	43	32			
	Field QA	4	0	0%	BDL	BDL			
Beryllium	Quarry	40	0	0%	BDL	BDL	NO	Black River	0 ft.
	Downstream	8	0	0%	BDL	BDL			
	Background	4	1	25%	1.9	1.9		Upgradient	
	Field QA	4	0	0%	BDL	BDL			
Cadmium	Quarry	40	3	8%	12	7.5	NO	Buoy 8(only)	35 ft.
	Downstream	8	0	0%	BDL	BDL			
	Background	4	0	0%	BDL	BDL			
	Field QA	4	0	0%	BDL	BDL			
Calcium	Quarry	40	40	100%	315000	59600	NO	Buoy 12	56 ft.
	Downstream	8	8	100%	70500	64200			
	Background	4	4	100%	71100	62800			
	Field QA	4	4	100%	672	208			
Chromium	Quarry	40	0	0%	BDL	BDL	NO	Black River	0 ft.
	Downstream	8	1	13%	4	4			
	Background	4	2	50%	4.3	4.2		Upgradient	
	Field QA	4	0	0%	BDL	BDL			

TABLE 4-6 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT BLACK RIVER
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	AFFECTS RIVER	LOCATION OF MAXIMUM	DEPTH
Copper	Quarry	40	17	43%	14	4	NO	Buoy 12	17 ft.
	Downstream	8	8	100%	11	4.3			
	Background	4	4	100%	8.8	4.6			
	Field QA	4	4	100%	14	4.2			
Iron	Quarry	40	39	98%	1600000	20	NO	Buoy 5/6	62 ft.
	Downstream	8	8	100%	1720	28			
	Background	4	4	100%	1630	63		Buoy 12	56 ft.
	Field QA	4	3	75%	94	23			
Lead	Quarry	40	5	13%	19	6.2	NO	Quarry	0 ft.
	Downstream	8	4	50%	7.8	5.8			
	Background	4	2	50%	19	7		Discharge	
	Field QA	4	2	50%	8.2	6.8			
Magnesium	Quarry	40	40	100%	88900	16000	NO	Buoy 12	56 ft.
	Downstream	8	8	100%	19400	18200			
	Background	4	4	100%	19800	18100			
	Field QA	4	3	75%	213	55			
Manganese	Quarry	40	40	100%	25700	12	NO	Buoy 12	56 ft.
	Downstream	8	8	100%	77	21			
	Background	4	4	100%	88	32			
	Field QA	4	0	0%	BDL	BDL			
Nickel	Quarry	40	9	23%	86	9.4	YES	Black River	0 ft.
	Downstream	8	3	38%	100	8.3			
	Background	4	1	25%	8.3	8.3		Mix Water	
	Field QA	4	0	0%	BDL	BDL			
Potassium	Quarry	40	40	100%	8520	4070	NO	Buoy 8	35 ft.
	Downstream	8	8	100%	6010	5530			
	Background	4	4	100%	5960	5560			
	Field QA	4	0	0%	BDL	BDL			
Silver	Quarry	40	1	3%	4.6	4.6	NO	Buoy 8	0 ft.
	Downstream	8	0	0%	BDL	BDL			
	Background	4	0	0%	BDL	BDL			
	Field QA	4	0	0%	BDL	BDL			
Sodium	Quarry	40	40	100%	57600	23000	NO	Buoy 12	56 ft.
	Downstream	8	8	100%	24600	23800			
	Background	4	4	100%	24900	24000			
	Field QA	4	2	50%	956	929			

TABLE 4-6 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
QUARRY SURFACE WATER COMPARED TO UPGRADIENT BLACK RIVER
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	AFFECTS RIVER	LOCATION OF MAXIMUM	DEPTH
Vanadium	Quarry	40	14	35%	60	4.4	NO	Buoy 12	56 ft.
	Downstream	8	0	0%	BDL	BDL			
	Background	4	1	25%	4.9	4.9			
	Field QA	4	0	0%	BDL	BDL			
Zinc	Quarry	40	31	78%	106	3.5	YES	Black River	0 ft.
	Downstream	8	8	100%	160	4.4			
	Background	4	4	100%	15	6.9		Mix Water	
	Field QA	4	4	100%	12	7.7			
Total Suspended Solids	Quarry	20	9	45%	296000	57000	NO	Buoy 8	35 ft.
	Downstream	4	4	100%	13000	7000			
	Background	2	2	100%	16000	10000			
	Field QA	2	0	0%	BDL	BDL			
Total Dissolved Solids	Quarry	20	20	100%	6400000	391000	NO	Buoy 12	0 ft.
	Downstream	4	4	100%	469000	459000			
	Background	2	2	100%	462000	448000			
	Field QA	2	1	50%	50000	50000			
Total Alkalinity	Quarry	20	20	100%	235000	17000	NO	Buoy 8	35 ft.
	Downstream	4	4	100%	130000	129000			
	Background	2	2	100%	130000	130000			
	Field QA	2	0	0%	BDL	BDL			
Acidity	Quarry	20	7	35%	2110000	39000	NO	Buoy 12	56 ft.
	Downstream	4	0	0%	BDL	BDL			
	Background	2	0	0%	BDL	BDL			
	Field QA	2	0	0%	BDL	BDL			
Chloride	Quarry	20	20	100%	64000	44000	NO	Buoy 18	0 ft.
	Downstream	4	4	100%	37000	35000			
	Background	2	2	100%	37000	36000			
	Field QA	2	0	0%	BDL	BDL			
Sulfate	Quarry	20	20	100%	3220000	149000	NO	Buoy 12	56 ft.
	Downstream	4	4	100%	109000	100000			
	Background	2	2	100%	100000	99000			
	Field QA	2	0	0%	BDL	BDL			

NOTES: BDL = Below Detection Limits
Organic analyses maximum and minimum values are presented in micrograms per liter (ug/l).
Inorganic analyses maximum and minimum values are presented in milligrams per liter (ug/l)

4.5.2.3 Pesticides/PCBs and SAS Organic Analysis

No pesticides/PCBs or oil and grease were detected in the downstream water samples from the Black River. Some of these types of constituents detected in the quarry water samples do not appear to be affecting the Black River water quality.

4.5.2.4 Inorganics

Nickel and zinc concentrations are greater in the downstream Black River samples than in upstream samples. Since both of these chemicals were concluded as being potentially site related chemicals in Section 4.5.1, it is concluded that the elevated levels downstream of the quarry may be due to the site.

4.5.2.5 Mass Balance Analysis

Four upstream and two downstream Black River samples were collected on June 16, 1987 within a 5 hour period. A mass balance analysis was performed to estimate if the elevated levels of nickel and zinc detected in downstream surface water samples from the Black River could be attributed to discharges from the Republic Steel Quarry. To perform this analysis, the flow estimated during surface water sampling at the quarry discharge (15 gpm) was used as the quarry contribution to the river. The lowest flow recorded (2.6 cfs) for the West Branch of the Black River downstream of the site was used for the receiving stream. The concentration of chemicals used for the quarry contribution was the maximum concentration of nickel and zinc detected within the quarry regardless of depth. Maximum upstream and downstream concentrations were also used for Black River concentrations.

The results of the mass balance were as follows:

Chemical	Quarry Discharge Conc. (ug/l)	Upstream Conc. (ug/l)	Predicted Downstream Conc. (ug/l)	Actual Mixing Zone Conc. (ug/l)	Actual Downstream Conc. (ug/l)
Nickel	106	15	16	160	8.3
Zinc	86	8	9	100	11.0

The results of the mass balance indicate that the discharge from the quarry should not affect Black River water quality downstream of the site due to the enormous dilution which occurs as the quarry water enters the Black River. The elevated concentrations measured immediately downstream are estimated to be due to incomplete mixing of waters. These results are confirmed by further downstream sampling points SW033, SW034, SW035 and SW036, where the maximum nickel concentration was 8.3 ug/l and maximum zinc concentration was 11 ug/l. Thus, the high values are observed only immediately outside the quarry outlet prior to mixing of the waters. Following complete mixing, dilution is so great that downstream values are essentially identical to upstream locations.

Following complete mixing, dilution is so great that downstream values are essentially identical to upstream locations.

4.5.2.6 Summary

The results of the surface water sampling and mass balance indicate that surface water discharges from the quarry do not adversely affect Black River water quality. No organic chemicals were identified in downstream river samples that were attributable to the site. Concentrations of inorganic chemicals identified in downstream river samples are not attributable to site surface water discharges based on the results of the mass balance.

5.0 SEDIMENT INVESTIGATION

5.1 INTRODUCTION

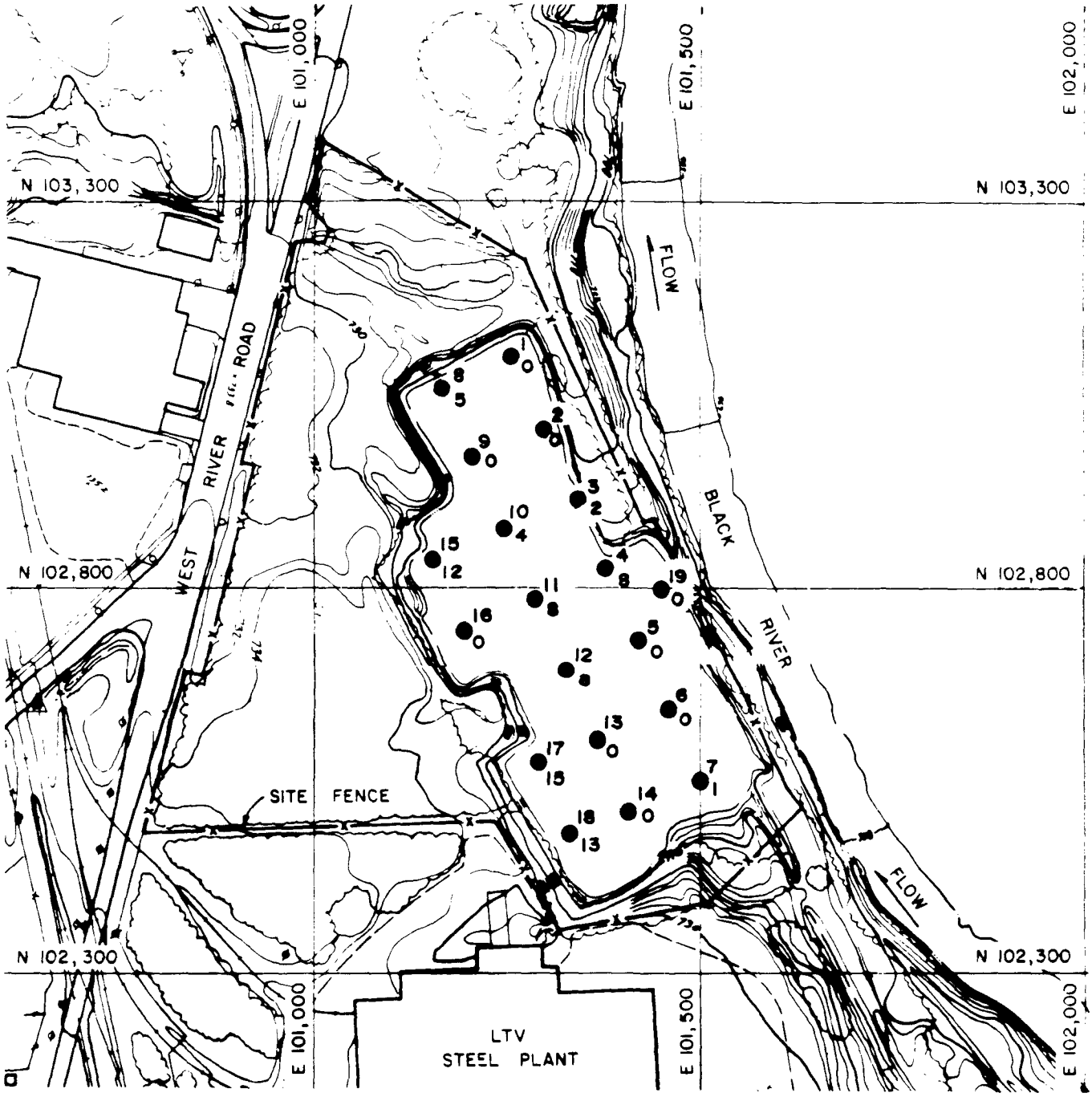
Sediment samples were collected from the quarry bottom and the Black River to investigate possible contamination. Quarry sediment thickness measurements were performed as a preliminary task to identify sampling locations. This section details activities performed during the sediment investigation at the Republic Steel Quarry site and the conclusions based on investigation results.

5.2 SEDIMENT THICKNESS MEASUREMENTS

On May 28 and 29, 1987, buoys were set in a grid pattern on the quarry, and quarry depth and sediment thickness were measured at the buoy locations. The grid that was established is shown on Figure 5-1. Sediment thickness measurements were performed using a one-half inch PVC pipe frame with webbing to measure the depth to the top of sediment. The PVC frame was lightweight and had a large base surface area so that it would not penetrate bottom sediments. Following estimation of the top of sediment, a one-inch diameter PVC pipe was pushed through the sediment to measure the depth to the bottom of the sediment. By subtracting the top of sediment measurement from the bottom measurement, an estimate of sediment thickness was obtained. Figure 5-1 also presents sediment thickness measured at the buoy locations.

Because of a highly irregular bottom surface, the field crew had difficulty measuring the top of sediment using the one-half inch PVC frame. The irregular bottom surface presented further problems because shifting winds within the quarry prevented the boat from being held in the same location during measurement of top and bottom of sediment. As a result, a second check on sediment thickness was performed using the one-inch diameter PVC pipe. The PVC pipe was gently lowered to the top of sediment and the depth recorded. Then the pipe was pushed down, to push through any bottom sediments. The second depth was recorded, and the difference was recorded as sediment thickness. Additionally, the bottom of the PVC pipe was examined to check for evidence of sediment (especially clayey or greasy sediment) that may have stuck to the side of the PVC pipe after it was withdrawn.

Sediment thickness measurements indicated that some areas of the quarry had little or no sediment; however, during sediment sampling, it was determined that the entire quarry had, at minimum, an approximately 1 inch thick, very soft, non-cohesive, silty sediment layer.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND
8 BOUY LOCATION NUMBER
5 SEDIMENT THICKNESS (Inches)

0 200 400
SCALE IN FEET

FIGURE 5-1
SEDIMENT THICKNESS
MEASUREMENTS
REPUBLIC STEEL QUARRY RI

5.3 SEDIMENT SAMPLING LOCATIONS AND METHODS

5.3.1 Sampling Locations

On June 23 through 25, 1987, 15 sediment samples were collected and submitted for laboratory analyses. These included eight samples from the quarry bottom, four samples from the Black River, and three quality assurance samples. Sediment sampling locations are shown on Figure 5-2 and are as follows:

Sample No.	Sample Location
SD001	Bottle Blank
SD002	Stainless Steel Dredge/Trowel/Bucket Sampling Blank
SD003	Buoy 18, Depth = 15 ft.
SD004	Near Buoy 7 at Pickle Liquor Discharge, Depth = 13 ft.
SD005	Buoy 10, Depth = 35 ft.
SD006	Buoy 8, Depth = 33 ft.
SD007	Buoy 10 (Split), Depth = 35 ft.
SD008	Buoy 12, Depth = 58 ft.
SD009	In Hole Between Buoys 5 and 6, Depth = 62 ft.
SD010	Outside Quarry at Outflow to Black River
SD011	In Hole Between Buoys 5 and 6 (Split)
SD012	Stainless Steel Dredge/Trowel/Bucket Sampling Blank
SD013	Upgradient - Black River By Mussey Avenue Bridge
SD014	Downgradient - Along Black River
SD015	Upgradient - Along Black River

Quarry Sediments: Sediment samples from the quarry bottom were collected at Buoys 8, 10, 12, 18, between Buoys 5 and 6, and near Buoy 7 by the outlet of the pickle liquor discharge ditch. Sediment sampling locations were chosen to permit comparison of sediment sampling data with the surface water sampling data collected the previous week and to permit evaluation of contamination as it relates to quarry depths and locations.

Black River: A total of four sediment samples were collected from the Black River. Two sediment samples were collected upstream from the quarry to establish background conditions, one sample was collected where the quarry discharges to the Black River, and one sample was collected downstream from the quarry discharge point.

5.3.2 Sampling Method

All samples collected from the quarry bottom were collected using a stainless-steel ponar dredge. The dredge was lowered to the quarry bottom, and a messenger was released which traveled down the rope supporting the dredge, triggering closing of the dredge and capturing

sediment inside. The sediment in the dredge was very soft, non-cohesive silt that mixed with water captured in the dredge; consequently, sediment samples resembled water samples with very high suspended solids content. As a result, the sample volume obtained only filled the sample jars from about 1/8 to 1/2 full with solids following settling. This volume of solids was insufficient to perform the laboratory analyses. Therefore, six sample jars were filled with the sediment/water slurry for each sample to be submitted to the laboratory. The sediment was permitted to settle overnight and was then composited by decanting supernatant liquid and pouring remaining sediments into one jar so that sufficient sample volume could be obtained. This procedure may have permitted volatile organics present in the sediment to escape.

Black River sediment samples were collected using a stainless steel trowel and stainless steel bucket. During sampling of the Black River sediments, water flow was higher than normal due to heavy rains during the weekend prior to sampling. The sampling team walked out into the river to locate sediments, and probed "pool" areas; however, the high flow rate scoured most sediments away. Additionally, water was sediment laden which made visibility of the river bottom difficult.

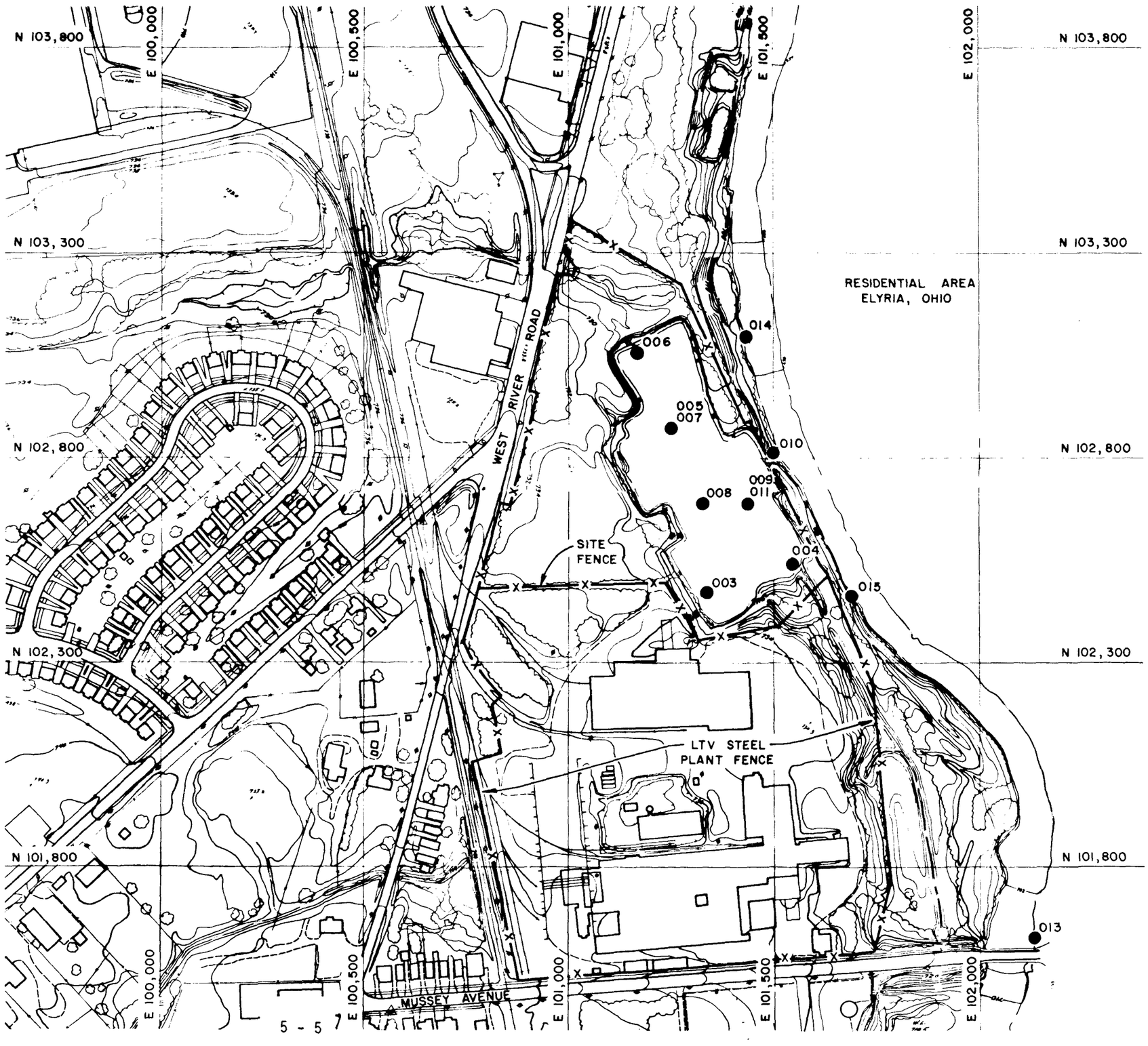
Sediment samples were collected at the edges of the Black River, along the river banks. Based on the ground surface profile near the sampling locations, sediment samples were believed to have been deposited by the river during other periods of high flow.

River sediment samples for volatile organic analysis were removed and placed directly into the volatile organic sample jars. Sediment for all other analyses was excavated and placed in a stainless steel bucket and thoroughly mixed. A representative sample of the sediment was then placed in the sample jars for analysis.

5.4 LABORATORY ANALYSES PERFORMED AND RESULTS

Fifteen sediment samples were submitted to the CLP for analysis for volatile organics, acid and base/neutral extractables, pesticides/PCBs, metals, cyanide, total organic carbon (TOC), and oil and grease. The 12 samples which were collected from the quarry and Black River were also submitted for particle size analysis. The three QA samples were not submitted for particle size analysis. Tables in Appendix E summarize the laboratory analyses performed on each sediment sample.

Laboratory analytical results from the sediment samples are presented in Appendix F. Particle size distribution plots are shown in Appendix H. Laboratory data QA problems are detailed in Appendix G. No significant QA problems were identified during the validation process. Summary tables presenting only "hits" where chemicals were above analytical detection limits are shown in Tables 5-1 through 5-4.



LEGEND:

003
● SEDIMENT SAMPLE LOCATION NO. 003

SOURCE: (1) City of Elyria Engineering Department, Scale: 1" = 100'.

N

0 250 500
SCALE IN FEET

FIGURE 5-2
SEDIMENT SAMPLING LOCATIONS
REPUBLIC STEEL QUARRY RI

TABLE 5-1
VOLATILE ORGANICS DETECTED
IN SEDIMENTS
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	Methylene Chloride	Acetone	Carbon Disulfide	2-Butanone	Benzene	Tetrachloro-ethene	Toluene	Chloro-Benzene	Ethyl-Benzene
SD005	Buoy 10	--	680 BJ	--	200 BJ	--	17J	520 BJ	--	--
SD006	Buoy 8	--	250 BJ	12	65 BJ	--	--	360 BJ	--	--
SD007	Buoy 10 Split	--	570 BJ	20	160 BJ	--	20J		--	--
SD008	Buoy 12	25 B	680 BJ	25	180 BJ	--	--	370 BJ	--	--
SD009	Between Buoy 5/6	--	870 BJ	20	230 BJ	--	33J	290 BJ	--	27 J
SD011	Buoy 5/6 Split	21 B	1400 BJ	36	490 BJ	7 J	42J	36 BJ	--	29 J
SD012	Sampler Blank	--	--	73	--	--	--	--	2 J	--
SD013	Black Rvr. Upgradnt	--	--	32	--	1 J	--	--	3 J	--
SD014	Black Rvr. Dwngradnt	--	--	42	--	--	--	--	--	--
SD015	Black Rvr. Upgradnt	--	--	53	--	--	--	--	--	--

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
-- Not Detected

TABLE 5-2
SEMI-VOLATILE ORGANICS DETECTED
IN SEDIMENTS
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	Phenol	Acena-phthene	Dibenzo-furan	Diethyl-phthalate	Fluorene	4-Methyl-phenol	Isophorone	Benzoic Acid	Naph-thalene	Pentachloro-phenol	Phenan-threne	Anthracene
SD001	Bottle Blank	--	--	--	--	--	--	--	280 J	42 J	76 J	40 J	--
SD002	Sampler Bottle	--	--	--	--	--	--	--	260 J	--	--	39 J	--
SD003	Buoy 18	--	--	--	--	--	--	--	--	--	--	1200 J	--
SD004	Buoy 7 @ Liq Ditch	--	--	--	3700 BJ	--	--	--	--	--	--	--	--
SD005	Buoy 10	--	--	--	9200 BJ	--	--	--	--	--	34,000	10,000	4800
SD006	Buoy 8	--	--	--	--	--	--	--	--	--	7100	940 J	--
SD007	Buoy 10 Split	--	--	--	--	--	--	--	--	--	--	15,000	--
SD008	Buoy 12	--	--	--	54,000 BJ	--	--	--	--	--	--	--	--
SD009	Buoy 5/6	--	--	--	47,000 BJ	--	--	--	--	--	--	--	--
SD010	Quarry Discharge	--	--	--		--	150 J	99 J	780 J			210 J	72 J
SD011	Buoy 5/6 Split	--	--	--	65,000 BJ	--	--	--	--	--	--	--	--
SD012	Sampler Blank	--	--	--	--	--	--	43 J	--	46 J	--	41 J	--
SD013	Black Rvr Upgradnt	48 J	140 J	190 J	--	230 J	--	74 J	--	240 J	--	2400	490
SD014	Black Rvr Dwngradnt	--	--	--	--	--	--	--	--	88 J	--	69 J	--
SD015	Black Rvr Upgradnt	--	--	--	--	--	--	--	--	--	--	650	590

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.

J Indicates an estimated value.

B Indicates the analyte was found in the laboratory blank as well as the sample.

= Not Detected

TABLE 5-2 (Continued)
SEMI-VOLATILE ORGANICS DETECTED
IN SEDIMENTS
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	Fluor-anthene	Pyrene	Benzo(a) Anthracene	Chrysene	Di-n-octyl Phthalate	Benzo(b) Fluoranthene	Benzo(k) Fluoranthene	Benzo(a) Pyrene	Indeno (1,2,3-cd) Pyrene	Benzo (g,h,i) Perylene	N-Nitrosodi-phenylamine(1)	Di-n-Butyl-phthalate
SD001	Bottle Blank	--	--	--	--	69 J	--	--	--	--	--	--	--
SD002	Sampler Bottle	--	--	--	--	530	--	--	--	--	--	--	--
SD003	Buoy 18	2000	3100	930 J	970 J	2600	1700	1700	1000 J	800 J	700 J	--	--
SD004	Buoy 7 a Liq Ditch	--	--	--	--	3400	--	--	--	--	--	--	--
SD005	Buoy 10	6100	8200	6000	5300	9200	11,000	11,000	7200	--	--	--	--
SD006	Buoy 8	1200 J	5900	--	880 J	--	1700	1700	940 J	--	--	1000 J	2400
SD007	Buoy 10 Split	6100 J	11,000	--	--	--	--	--	--	--	--	--	--
SD008	Buoy 12	17,000 J	--	--	--	--	--	--	--	--	--	--	29,000
SD009	Buoy 5/6	17,000 J	15,000 J										31,000
SD010	Quarry Discharge	450	310 J	210 J	160 J	--	300 J	300 J	130 J	170 J	190 J	--	--
SD011	Buoy 5/6 Split	--	--	--	--	--	--	--	--	--	--	--	--
SD012	Sampler Blank	--	--	--	--	63 J	--	--	--	--	--	--	--
SD013	Black Rvr Upgradnt	3300	2200	1600	1100	--	1900	1900	830	690 J	750 J	--	--
SD014	Black Rvr Dwngradnt	71 J	86 J	--	--	--	56 J	56 J	46 J	--	--	--	--
SD015	Black Rvr Upgradnt	2800	2900	4900	3400	--	4800	4800	2400	840 J	660 J	--	330 B

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
J Indicates an estimated value.

TABLE 5-2 (Continued)
SEMI-VOLATILE ORGANICS DETECTED
IN SEDIMENTS
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	Butylbenzyl-phthalate	bis (2-Ethylhexyl) Phthalate	2-Methylnaph-thalene	Acenaph-thylene	Dibenz(a,h) Anthracene
SD001	Bottle Blank	--	--	--	--	--
SD002	Sampler Bottle	--	--	--	--	--
SD003	Buoy 18	--	--	--	--	--
SD004	Buoy 7 @ Liq Ditch	--	--	--	--	--
SD005	Buoy 10	--	--	--	--	--
SD006	Buoy 8	--	--	--	--	--
SD007	Buoy 10 Split	--	--	--	--	--
SD008	Buoy 12	73,000	58000J	--	--	--
SD009	Buoy 5/6	130,000	68000J	--	--	--
SD010	Quarry Discharge	--	--	--	--	--
SD011	Buoy 5/6 Split	--	--	--	--	--
SD012	Sampler Blank	--	--	--	--	--
SD013	Black Rvr Upgradnt	690	--	230 J	59 J	--
SD014	Black Rvr Dwngradnt	--	--	74 J	--	--
SD015	Black Rvr Upgradnt	--	--	--	--	280 J

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
J Indicates an estimated value.

TABLE 5-3
PESTICIDES/PCBs DETECTED
IN SEDIMENTS
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	Oil and Grease (x 10^6)	Total Organic Carbon (x 10^6)	Aroclor-1248	Aroclor-1254
SD001	Bottle Blank	--	3.67	--	--
SD002	Sampler Blank	--	4.62	--	--
SD003	Buoy 18	18.2	75.0	--	--
SD004	Buoy 7 @ Liq Ditch	18.1	201.0	--	--
SD005	Buoy 10	85.7	148.0	--	--
SD006	Buoy 8	20.6	112.0	--	--
SD007	Buoy 10 Split	10.5	128.0	--	--
SD008	Buoy 12	99.8	161.0	--	--
SD009	Between Buoy 5/6	111.0	139.0	--	--
SD010	Quarry Discharge	1.3	29.3	1000	--
SD011	Buoy 5/6 Split	109.0	115.0	--	--
SD012	Sampler Blank	2.085	23.8	--	--
SD013	Black Rvr Upgradnt	0.89	13.7	1000	--
SD014	Black Rvr Dwngradnt	--	22.8	490	290
SD015	Black Rvr Upgradnt	--	3.52	3400	--

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
-- Not Detected

TABLE 5-4
INORGANICS DETECTED
IN SEDIMENTS
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	SD001	SD002	SD003	SD004	SD005	SD006	SD007	SD008	SD009	SD010	SD011	SD012	SD013	SD014	SD015
SAMPLE DATE:	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87	06/24/87	06/24/87	06/24/87	06/24/87	06/24/87	06/24/87	06/24/87	06/25/87
SAMPLE LOCATION:	Bottle Blank	Sampler Blank	Buoy 18	Buoy 7 at Liq Ditch	Buoy 10	Buoy 8	Buoy 10 Split	Buoy 12	Between Buoy 5/6	Quarry Discharge	Buoy 5/6 Split	Sampler Blank	Black Rvr Upgradnt	Black Rvr Dwngradnt	Black Rvr Upgradnt
ALUMINUM	9580	9320	10500	[949]	12300	9680	4280	17700	12200	3040	11300	16100	9340	6410	6380
ARSENIC	--	--	--	--	--	--	--	[42]	41	--	39	12	15	29	31
BARIUM	156	163	[112]	[35]	[93]	[53]	[26]	[97]	[94]	[25]	[84]	196	[81]	[85]	[52]
BERYLLIUM	[1.2]	[1.2]	[2.3]	--	--	--	--	--	--	--	--	[1.7]	[1.8]	[0.98]	[1.1]
CADMIUM	--	--	--	--	--	--	--	--	--	--	--	--	--	4.6	--
CALCIUM	12100	13100	73700	[2440]	[4080]	[2240]	[1600]	[6480]	[6010]	[2460]	[5640]	15100	59300	8440	4950
CHROMIUM	14	12	29	--	54	40	--	60	63	9.7	66	28	27	82	63
COBALT	[13]	[12]	--	--	--	--	--	--	--	[4.9]	--	[18]	[7]	[4.8]	[10]
COPPER	41	42	97	--	[88]	[58]	[23]	156	343	18	263	61	62	86	72
IRON	20600	20500	53900	145000	52500	31500	15100	79700	115000	19100	109000	39300	49900	170000	159000
LEAD	11	11	100	--	20	232 RJ	--	58	94	14	106	24	202	41	41
MAGNESIUM	3530	3540	20300	[699]	[2480]	[2080]	[1100]	[4740]	[3220]	[1580]	[3010]	4930	18900	[2430]	[2010]
MANGANESE	485	515	1060	255	372	201	141	454	1190	860	1100	628	1070	1570	1450
MERCURY	--	--	0.73	--	--	--	--	--	0.71	--	--	--	--	--	--
NICKEL	30	31	[18]	--	[54]	[26]	--	[103]	[61]	[12]	[61]	46	[40]	67	61
POTASSIUM	[1420]	[1410]	[947]	--	[1480]	[1040]	[721]	[2290]	[1700]	[477]	[1540]	[2500]	[940]	[886]	[513]
SODIUM	--	--	--	--	--	--	--	--	--	--	--	[981]	--	--	--
TIN	--	--	--	--	--	--	--	[79]	[59]	[10]	198	--	[18]	[16]	[15]
VANADIUM	[16]	[17]	[27]	--	[29]	[26]	--	[37]	[32]	[8.1]	[26]	37	[22]	[18]	[16]
ZINC	136	146	294	[81]	334	180	89	369	270	80	240	190	261	97	108
CYANIDE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

NOTE: All concentrations are presented in milligrams per kilogram, mg/kg.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

R The spike sample recovery is not within control limits.

J Indicates an estimated value.

5.5 NATURE AND EXTENT OF CONTAMINATION

Two analyses were performed to evaluate the nature and extent of the potential contamination of sediments due to the site. The first evaluation compared quarry sediments to background soils. This analysis was performed to separate disposal related chemicals from chemicals that were due to background concentrations. The second analysis was performed to evaluate the effects of the site on Black River sediment quality. For this evaluation, the laboratory analysis results of downstream sediments and quarry sediments were compared to upstream Black River sediment results.

5.5.1 Comparison of Sediments With Background Surface Soils

The quarry sediment analyses results were compared to the results of two background soil samples to identify potentially site related chemicals. Soil samples SS006 and SS007 were used to represent background soils that could be washed into the quarry and become sediments. The location and complete laboratory results for these two background soil samples are presented in Section 6. The results of the nature and extent evaluation are presented on Table 5-5. Table 5-5 presents the chemicals, number of samples analyzed, number of times detected, percent detected, maximum and minimum concentrations detected, an evaluation of whether the chemical is potentially site related and the location where the maximum concentration was observed.

Criteria were established during the nature and extent evaluation to determine if chemicals detected were potentially site related. The criteria for the chemicals to be considered potentially site related were as follows:

- Chemicals were considered to be site related if the chemical was detected at greater than or equal to twice the concentration observed in background soil samples. The rationale for the selection of two times the background concentration as an evaluation criterion is presented in Appendix G, Data Considerations.

- Chemicals were considered to be site related if the chemical was detected in greater than one onsite sediment sample.

- Chemicals were considered site related if they were found in one sediment sample, but were also found to be site related in other environmental media.

5.5.1.1 Volatile Organics

Eight volatile organic compounds were detected in onsite sediments. Following comparisons with background soils, only six of the eight were concluded to be potentially site related. Acetone, 2-butanone, ethylbenzene, methylene chloride, tetrachloroethene and toluene were detected at greater concentrations in onsite sediments than in background

TABLE 5-5
SUMMARY OF NATURE & EXTENT EVALUATION
QUARRY SEDIMENTS COMPARED TO SOIL BACKGROUND
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
VOLATILE ORGANIC ANALYSES								
Acetone	Site Related	9	6	67%	1400	250	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Benzene	Site Related	9	1	11%	7	7	NO	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
2-Butanone	Site Related	9	6	67%	490	65	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Carbon Disulfide	Site Related	9	5	56%	36	12	NO	Buoy 5/6
	Background	2	2	100%	18	7		
Ethylbenzene	Site Related	9	2	22%	29	27	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Methylene Chloride	Site Related	9	2	22%	25	21	YES	Buoy 12
	Background	2	0	0%	BDL	BDL		
Tetrachloroethene	Site Related	9	4	44%	42	17	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Toluene	Site Related	9	5	56%	520	36	YES	Buoy 10
	Background	2	1	50%	95	95		
SEMI-VOLATILE ORGANIC ANALYSES								
Anthracene	Site Related	9	2	22%	4800	72	YES	Buoy 10
	Background	2	0	0%	BDL	BDL		
Benzoic Acid	Site Related	9	1	11%	780	780	NO	Quarry Discharge
	Background	2	1	50%	630	630		
Benzo(a) pyrene	Site Related	9	4	44%	7200	130	YES	Buoy 10
	Background	2	2	100%	73	42		
Benzo(a)anthracene	Site Related	9	3	33%	6000	210	YES	Buoy 10
	Background	2	1	50%	70	70		
Benzo(b) fluoranthene	Site Related	9	4	44%	11000	300	YES	Buoy 10
	Background	2	1	50%	76	76		
Benzo(g,h,i) perylene	Site Related	9	2	22%	700	190	YES	Buoy 18
	Background	2	0	0%	BDL	BDL		

TABLE 5-5 (Continued)
SUMMARY OF NATURE & EXTENT EVALUATION
QUARRY SEDIMENTS COMPARED TO SOIL BACKGROUND
REPUBLIC STEEL QUARRY RI

SEMI-VOLATILE ORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	
Benzo(k) fluoranthene	Site Related	9	4	44%	11000	300	YES	Buoy 10
	Background	2	1	50%	76	76		
bis(2-ethylhexyl)phthalate	Site Related	9	2	22%	68000	58000	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Butylbenzyl-phthalate	Site Related	9	2	22%	130000	73000	YES	Buoy 5/6
	Background	2	1	50%	49	49		
Chrysene	Site Related	9	4	44%	5300	160	YES	Buoy 10
	Background	2	2	100%	65	56		
Diethylphthalate	Site Related	9	5	56%	65000	3700	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Di-n-butyl-phthalate	Site Related	9	3	33%	31000	2400	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Di-n-octyl phthalate	Site Related	9	3	33%	9200	2600	YES	Buoy 10
	Background	2	0	0%	BDL	BDL		
Fluoranthene	Site Related	9	7	78%	17000	450	YES	Buoy 5/6
	Background	2	2	100%	63	62		Buoy 12
Indeno (1,2,3-cd) pyrene	Site Related	9	2	22%	800	170	YES	Buoy 18
	Background	2	0	0%	BDL	BDL		
Isophorone	Site Related	9	1	11%	99	99	NO	Quarry
	Background	2	0	0%	BDL	BDL		Discharge
4-methylphenol	Site Related	9	1	11%	150	150	NO	Quarry
	Background	2	0	0%	BDL	BDL		Discharge
N-nitrosodi-phenylamine(l)	Site Related	9	1	11%	1000	1000	NO	Buoy 8
	Background	2	1	50%	58	58		
Pentachlorophenol	Site Related	9	2	22%	34000	71000	YES	Buoy 10
	Background	2	0	0%	BDL	BDL		
Phenanthrene	Site Related	9	5	56%	15000	210	YES	Buoy 10
	Background	2	1	50%	130	130		
Pyrene	Site Related	9	6	67%	15000	310	YES	Buoy 5/6
	Background	2	2	100%	60	57		

TABLE 5-5 (Continued)
SUMMARY OF NATURE & EXTENT EVALUATION
QUARRY SEDIMENTS COMPARED TO SOIL BACKGROUND
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	
PESTICIDE/PCBs ORGANIC ANALYSES								
Aroclor-1248	Site Related	9	1	11%	1000	1000	NO	Quarry
	Background	2	0	0%	BDL	BDL		Discharge
Oil and Grease (X 10+6)	Site Related	9	9	100%	111	1.3	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Tot. Org. Carbon (X 10+6)	Site Related	9	9	100%	201	29.3	YES	Buoy 7
	Background	0	0	NA	NA	NA		
INORGANIC ANALYSIS								
Aluminum	Site Related	9	9	100%	17700	949	NO	Buoy 12
	Background	2	2	100%	9860	7980		
Arsenic	Site Related	9	3	33%	42	39	YES	Buoy 12
	Background	2	0	0%	BDL	BDL		
Barium	Site Related	9	9	100%	112	25	NO	Buoy 18
	Background	2	2	100%	66	55		
Beryllium	Site Related	9	1	11%	2.3	2.3	NO	Buoy 18
	Background	2	2	100%	0.98	0.92		
Calcium	Site Related	9	9	100%	73700	1600	YES	Buoy 18
	Background	2	2	100%	1660	1250		
Chromium	Site Related	9	8	89%	66	9.7	YES	Buoy 5/6
	Background	2	2	100%	9.6	8.4		
Cobalt	Site Related	9	1	11%	4.9	4.9	NO	N. Offsite
	Background	2	2	100%	11	8		Background
Copper	Site Related	9	8	89%	343	18	YES	Buoy 5/6
	Background	2	2	100%	31	11		
Iron	Site Related	9	9	100%	145000	15100	YES	Buoy 7
	Background	2	2	100%	20900	19200		
Lead	Site Related	9	7	78%	232	14	YES	Buoy 8
	Background	2	2	100%	32	30		

TABLE 5-5 (Continued)
SUMMARY OF NATURE & EXTENT EVALUATION
QUARRY SEDIMENTS COMPARED TO SOIL BACKGROUND
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF
Magnesium	Site Related	9	9	100%	20300	699	YES	Buoy 18
	Background	2	2	100%	1990	1800		
Manganese	Site Related	9	9	100%	1190	141	NO	Buoy 5/6
	Background	2	2	100%	823	631		
Mercury	Site Related	9	2	22%	0.73	0.71	YES	Buoy 18
	Background	2	0	0%	BDL	BDL		
Nickel	Site Related	9	7	78%	103	12	YES	Buoy 12
	Background	2	2	100%	15	12		
Potassium	Site Related	9	9	100%	2290	477	NO	Buoy 12
	Background	2	2	100%	875	554		
Tin	Site Related	9	4	44%	198	10	YES	Buoy 5/6
	Background	2	0	0%	BDL	BDL		
Vanadium	Site Related	9	7	78%	37	8.1	NO	Buoy 12
	Background	2	2	100%	20	17		
Zinc	Site Related	9	9	100%	369	80	YES	Buoy 12
	Background	2	2	100%	84	62		

NOTES: BDL = Below Detection Limits
Organic analyses maximum and minimum values are presented in micrograms per kilogram (ug/kg).
Inorganic analyses maximum and minimum values are presented in milligrams per kilogram (mg/kg).

soils and are considered site related. The six volatile organic chemicals were detected only in the deep quarry sediments below a depth of 33 feet. The maximum concentration of four of the six chemicals were detected at the deepest portion of the quarry (62 ft.).

Benzene was detected at one location at a concentration slightly above the contract required detection limit, but was not found in other environmental media at the site and is not considered site related. Carbon disulfide in onsite sediment samples was at similar concentrations as background soil samples, and is not considered site related.

5.5.1.2 Semi-Volatile Organics

Twenty-one semi-volatile organics were detected in quarry sediment samples with 18 of those considered to be site related. Anthracene, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, butylbenzylphthalate, chrysene, diethylphthalate, di-n-butylphthalate, di-n-octylphthalate, fluoranthene, indeno(1,2,3-cd.)pyrene, pentachlorophenol, phenanthrene and pyrene were detected at greater concentration in onsite sediment samples than in background soil samples and are concluded to be potentially site related compounds. The semi-volatile compounds were detected throughout the quarry at various depths and at the quarry outlet.

Benzoic acid was found at similar concentration in background soils and onsite sediments and is not considered site related. Isophorone and 4 methylphenol were detected at the quarry discharge, but not in onsite sediments or other media at the site and are not believed to be site related compounds. N-nitrosodiphenylamine was detected at Buoy 8, but not at any other onsite locations, and is not considered site related.

5.5.1.3 Pesticide/PCBs and SAS Organics

Oil and grease and total organic carbon (TOC) are believed to be potentially site related parameters because high concentrations were detected in all onsite sediment samples. Aroclor-1248 is not concluded to be site related because it was detected at the quarry discharge, but not in any onsite sediments or any other media at the site. Additionally, Aroclor 1248 is present in upgradient Black River sediments.

5.5.1.4 Inorganic Analyses

Arsenic, calcium, chromium, copper, iron, lead, magnesium, mercury, nickel, tin and zinc were detected at elevated concentrations in onsite sediments compared to background soils and are considered potentially site related compounds. The range of concentrations for these contaminants are presented on Table 5-5. Aluminum, barium, beryllium, cobalt, manganese, potassium and vanadium were detected at similar levels in background soils and onsite sediments and are not thought to be site related.

5.5.1.5 Summary

The results of this analysis indicate quarry sediments contain concentrations of some chemicals in excess of those anticipated from erosion and deposition of background soils. Several volatile and semi-volatile organic and inorganic chemicals were identified as being potentially site related during the nature and extent evaluation. Potentially site related chemicals in onsite sediments are summarized below:

Volatile Organics	Semi-Volatile Organics	Inorganics
Acetone	Polycyclic Aromatic Hydrocarbons*	Arsenic
2-Butanone	Bis(2-ethylhexyl)phthalate	Calcium
Ethylbenzene	Butyl benzyl phthalate	Chromium
Methylene Chloride	Di-ethyl phthalate	Copper
Tetrachloroethene	Di-n-butylphthalate	Iron
Toluene	Di-n-octylphthalate	Lead
	Pentachlorophenol	Magnesium
		Mercury
		Nickel
		Tin
		Zinc

*Polycyclic Aromatic Hydrocarbons identified include anthracene, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno (1,2,3-cd)pyrene, phenanthrene and pyrene.

5.5.2 Comparison of Downstream and Quarry Sediments with Upstream Black River Sediments

Quarry and downstream sediment sample laboratory results were compared with analytical results from upstream Black River sediment samples. An evaluation was performed to estimate the effect that the site is having on Black River sediments. The upstream Black River sediment samples used for comparison were samples SD013 and SD015. Table 5-6 presents the chemicals, number of samples analyzed, number of times detected, percent detected, maximum and minimum concentrations detected, an evaluation of whether the chemical is impacting Black River sediments and the location where the maximum concentration was observed.

Criteria were developed to determine if potentially site related chemicals were affecting Black River sediments. Chemicals in downstream Black River sediments were considered to be site related when detected at greater than or equal to twice the concentration observed in upstream Black River sediments. The rationale for selection of two times the background concentration as an evaluation criterion is presented in Appendix G, Data Considerations.

TABLE 5-6
QUARRY AND DOWNSTREAM SEDIMENTS COMPARED TO UPSTREAM BLACK RIVER SEDIMENTS
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	RIVER IMPACTED	LOCATION OF MAXIMUM
VOLATILE ORGANICS ANALYSES								
Acetone	Quarry	9	6	67%	1400	250	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Benzene	Quarry	9	1	11%	7	7	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	1	50%	1	1		
2-Butanone	Quarry	9	6	67%	490	65	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Carbon Disulfide	Quarry	9	5	56%	36	12	NO	Black River
	Downstream	1	1	100%	42	42		Upgradient
	Background	2	2	100%	53	32		
Chlorobenzene	Quarry	9	0	0%	BDL	BDL	NO	Black River
	Downstream	1	0	0%	BDL	BDL		Upgradient
	Background	2	1	50%	3	3		
Ethylbenzene	Quarry	9	2	22%	29	27	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Methylene Chloride	Quarry	9	2	22%	25	21	NO	Buoy 12
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Tetrachloroethene	Quarry	9	4	44%	42	17	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Toluene	Quarry	9	5	56%	520	36	NO	Buoy 10
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
SEMI-VOLATILE ORGANICS ANALYSES								
Anthracene	Quarry	9	2	22%	4800	72	NO	Buoy 10
	Downstream	1	0	0%	BDL	BDL		
	Background	2	2	100%	590	490		
Benzoic Acid	Quarry	9	1	11%	780	780	NO	Quarry
	Downstream	1	0	0%	BDL	BDL		Discharge
	Background	2	0	0%	BDL	BDL		

TABLE 5-6 (continued)
QUARRY AND DOWNSTREAM SEDIMENTS COMPARED TO UPSTREAM BLACK RIVER SEDIMENTS
REPUBLIC STEEL QUARRY RI

SEMI-VOLATILE ORGANICS ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	RIVER IMPACTED	LOCATION OF MAXIMUM
Benzo(a) pyrene	Quarry	9	4	44%	7200	130	NO	Buoy 10
	Downstream	1	1	100%	46	46		
	Background	2	2	100%	2400	830		
Benzo(a)anthracene	Quarry	9	3	33%	6000	210	NO	Buoy 10
	Downstream	1	0	0%	BDL	BDL		
	Background	2	2	100%	4900	1600		
Benzo(b) fluoranthene	Quarry	9	4	44%	11000	300	NO	Buoy 10
	Downstream	1	1	100%	56	56		
	Background	2	2	100%	4800	1900		
Benzo(g,h,i) perylene	Quarry	9	2	22%	700	190	NO	Black River
	Downstream	1	0	0%	BDL	BDL		Upgradient
	Background	2	2	100%	750	660		
Benzo(k) fluoranthene	Quarry	9	4	44%	11000	300	NO	Buoy 10
	Downstream	1	1	100%	56	56		
	Background	2	2	100%	4800	1900		
bis(2-ethylhexyl)phthalate	Quarry	9	1	11%	68000	68000	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Butylbenzyl-phthalate	Quarry	9	2	22%	130000	73000	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	1	50%	690	690		
Chrysene	Quarry	9	4	44%	5300	160	NO	Buoy 10
	Downstream	1	0	0%	BDL	BDL		
	Background	2	2	100%	3400	1100		
Diethylphthalate	Quarry	9	5	56%	65000	3700	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Di-n-butyl-phthalate	Quarry	9	3	33%	31000	2400	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	1	50%	330	BDL		
Di-n-octyl phthalate	Quarry	9	3	33%	9200	2600	NO	Buoy 10
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Fluoranthene	Quarry	9	7	78%	17000	450	NO	Buoy 5/6
	Downstream	1	1	100%	71	71		Buoy 12
	Background	2	2	100%	3300	2800		

TABLE 5-6 (continued)
QUARRY AND DOWNSTREAM SEDIMENTS COMPARED TO UPSTREAM BLACK RIVER SEDIMENTS
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	RIVER IMPACTED	LOCATION OF MAXIMUM
SEMI-VOLATILE ORGANICS ANALYSES								
Indeno (1,2,3-cd) pyrene	Quarry	9	2	22%	800	170	NO	Black River
	Downstream	1	0	0%	BDL	BDL		Upgradient
	Background	2	2	100%	840	690		
Isophorone	Quarry	9	1	11%	99	99	NO	Quarry
	Downstream	1	0	0%	BDL	BDL		Discharge
	Background	2	1	50%	74	74		
2-Methylnaphthalene	Quarry	9	0	0%	BDL	BDL	NO	Black River
	Downstream	1	1	100%	74	74		Upgradient
	Background	2	1	50%	230	230		
4-methylphenol	Quarry	9	1	11%	150	150	NO	Quarry
	Downstream	1	0	0%	BDL	BDL		Discharge
	Background	2	0	0%	BDL	BDL		
Naphthalene	Quarry	9	0	0%	BDL	BDL	NO	Black River
	Downstream	1	1	100%	88	88		Upgradient
	Background	2	1	50%	240	240		
N-nitrosodi-phenylamine(l)	Quarry	9	1	11%	1000	1000	NO	Buoy 8
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Pentachlorophenol	Quarry	9	2	22%	34000	71000	NO	Buoy 10
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Phenanthrene	Quarry	9	5	56%	15000	210	NO	Buoy 10
	Downstream	1	1	100%	69	69		
	Background	2	2	100%	2400	650		
Pyrene	Quarry	9	6	67%	15000	310	NO	Buoy 5/6
	Downstream	1	1	100%	86	86		
	Background	2	2	100%	2900	2200		
PESTICIDES/PCBs AND SAS ORGANICS ANALYSES								
Aroclor-1248	Quarry	9	1	11%	1000	1000	NO	Black River
	Downstream	1	1	100%	490	490		Upgradient
	Background	2	2	100%	3400	1000		

TABLE 5-6 (continued)
QUARRY AND DOWNSTREAM SEDIMENTS COMPARED TO UPSTREAM BLACK RIVER SEDIMENTS
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	RIVER IMPACTED	LOCATION OF MAXIMUM
PESTICIDES/PCBs AND SAS ORGANICS ANALYSES								
Aroclor-1254	Quarry	9	0	0%	BDL	BDL	NO	Black River
	Downstream	1	1	100%	290	290		Downgradnt.
	Background	2	0	0%	BDL	BDL		
Oil and Grease (X 10+6)	Quarry	9	9	100%	111	1.3	NO	Buoy 5/6
	Downstream	1	0	0%	BDL	BDL		
	Background	2	1	50%	0.89	0.89		
Tot. Org. Carbon (X 10+6)	Quarry	9	9	100%	201	29.3	NO	Buoy 7
	Downstream	1	1	100%	22.8	22.8		
	Background	2	2	100%	13.7	3.52		
INORGANICS ANALYSES								
Aluminum	Quarry	9	9	100%	17700	949	NO	Buoy 12
	Downstream	1	1	100%	6410	6410		
	Background	2	2	100%	9340	6380		
Arsenic	Quarry	9	3	33%	42	41	NO	Buoy 12
	Downstream	1	1	100%	29	29		
	Background	2	2	100%	31	15		
Barium	Quarry	9	9	100%	112	25	NO	Buoy 18
	Downstream	1	1	100%	85	85		
	Background	2	2	100%	81	52		
Beryllium	Quarry	9	1	11%	2.3	2.3	NO	Buoy 18
	Downstream	1	1	100%	0.98	0.98		
	Background	2	2	100%	1.8	1.1		
Cadmium	Quarry	9	0	0%	BDL	BDL	NO	Black River
	Downstream	1	1	100%	4.6	4.6		Downgradnt.
	Background	2	0	0%	BDL	BDL		
Calcium	Quarry	9	9	100%	73700	1600	NO	Buoy 18
	Downstream	1	1	100%	8440	8440		
	Background	2	2	100%	59300	4950		
Chromium	Quarry	9	7	78%	66	9.7	NO	Black River
	Downstream	1	1	100%	82	82		Downgradnt.
	Background	2	2	100%	63	27		
Cobalt	Quarry	9	1	11%	4.9	4.9	NO	Black River
	Downstream	1	1	100%	4.8	4.8		Upgradient
	Background	2	2	100%	10	7		

TABLE 5-6 (continued)
QUARRY AND DOWNSTREAM SEDIMENTS COMPARED TO UPSTREAM BLACK RIVER SEDIMENTS
REPUBLIC STEEL QUARRY RI

INORGANICS ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	RIVER IMPACTED	LOCATION OF MAXIMUM
Copper	Quarry	9	8	89%	343	18	NO	Buoy 5/6
	Downstream	1	1	100%	86	86		
	Background	2	2	100%	72	62		
Iron	Quarry	9	9	100%	145000	15100	NO	Black River
	Downstream	1	1	100%	170000	170000		Downgradnt.
	Background	2	2	100%	159000	49900		
Lead	Quarry	9	7	78%	232	14	NO	Buoy 8
	Downstream	1	1	100%	41	41		
	Background	2	2	100%	202	41		
Magnesium	Quarry	9	9	100%	20300	699	NO	Buoy 18
	Downstream	1	1	100%	2430	2340		
	Background	2	2	100%	18900	2010		
Manganese	Quarry	9	9	100%	1190	141	NO	Black River
	Downstream	1	1	100%	1570	1570		Downgradnt.
	Background	2	2	100%	1450	1070		
Mercury	Quarry	9	2	22%	0.73	0.71	NO	Buoy 18
	Downstream	1	0	0%	BDL	BDL		
	Background	2	0	0%	BDL	BDL		
Nickel	Quarry	9	7	78%	103	12	NO	Buoy 12
	Downstream	1	1	100%	67	67		
	Background	2	2	100%	61	40		
Potassium	Quarry	9	8	89%	2290	477	NO	Buoy 12
	Downstream	1	1	100%	886	886		
	Background	2	2	100%	940	513		
Tin	Quarry	9	4	44%	198	10	NO	Buoy 5/6
	Downstream	1	1	100%	16	16		
	Background	2	2	100%	18	15		
Vanadium	Quarry	9	7	78%	37	8.1	NO	Buoy 12
	Downstream	1	1	100%	18	18		
	Background	2	2	100%	22	16		
Zinc	Quarry	9	9	100%	369	80	NO	Buoy 12
	Downstream	1	1	100%	97	97		
	Background	2	2	100%	261	108		

NOTES: BDL = Below Detection Limit
Organic analyses maximum and minimum values are presented in micrograms per kilogram (ug/kg)
Inorganics analyses maximum and minimum values are presented in milligrams per kilogram (mg/kg).

5.5.2.1 Volatile Organics

Only one volatile organic compound was detected in downstream sediments in the Black River. This compound, carbon disulfide was detected in the downstream sample at 42 ug/kg while carbon disulfide was detected at concentrations of 32 and 53 ug/kg in the upstream sediment samples. Since the downstream sediment concentration is similar in magnitude to the upstream concentrations, carbon disulfide in downstream sediment is not attributable to the site.

5.5.2.2 Semi-Volatile Organics

Eight semi-volatile organic compounds were detected in the Black River sediment sample downstream of the quarry. These compounds include benzo(a)pyrene, benzo naphthalene(b)fluoranthrene, benzo(k)fluoranthene, fluoranthene, 2-methylnapthalene, napthalene, phenanthrene and pyrene. All eight of these compounds were detected at greater concentrations in upstream sediment samples than in downstream samples. The site does not appear to increase semi-volatile organic contamination in Black River sediments.

5.5.2.3 Pesticide/PCBs and SAS Organics

Two pesticides were detected in the Black River sediment sample collected downstream of the site. The two pesticides detected were Aroclor-1248 and Aroclor-1254. Aroclor-1248 was detected at greater concentration in the upstream sediment samples than in the downstream samples and is not considered site related. Aroclor-1254 was not detected in any quarry sediment samples or other environmental media at the site. Aroclor 1254 was detected at 2.9 ug/l in an extremely biased surface water sample created by vigorous disturbance of bottom sediments. This sample was not representative of site conditions. Aroclor 1254 in downgradient sediments is not considered to be site related.

5.5.2.4 Inorganic Analyses

Eighteen inorganic chemicals were detected in the sediment sample downstream of the site. None of these eighteen samples were considered to indicate the site is affecting the quality of sediments in the Black River.

5.5.2.5 Summary

No organic or inorganic chemicals were identified in downstream Black River sediment samples in concentrations that would indicate that the site is affecting sediment quality.

6.0 SURFACE SOIL INVESTIGATION

6.1 INTRODUCTION

Surface soil samples were collected from seven locations near the Republic Steel Quarry to determine if surface soil contamination exists, and the types and extent of the contamination. This section describes surface soil investigation activities and presents conclusions on site related chemicals detected in the soils.

6.2 SURFACE SOIL SAMPLING LOCATIONS AND METHODS

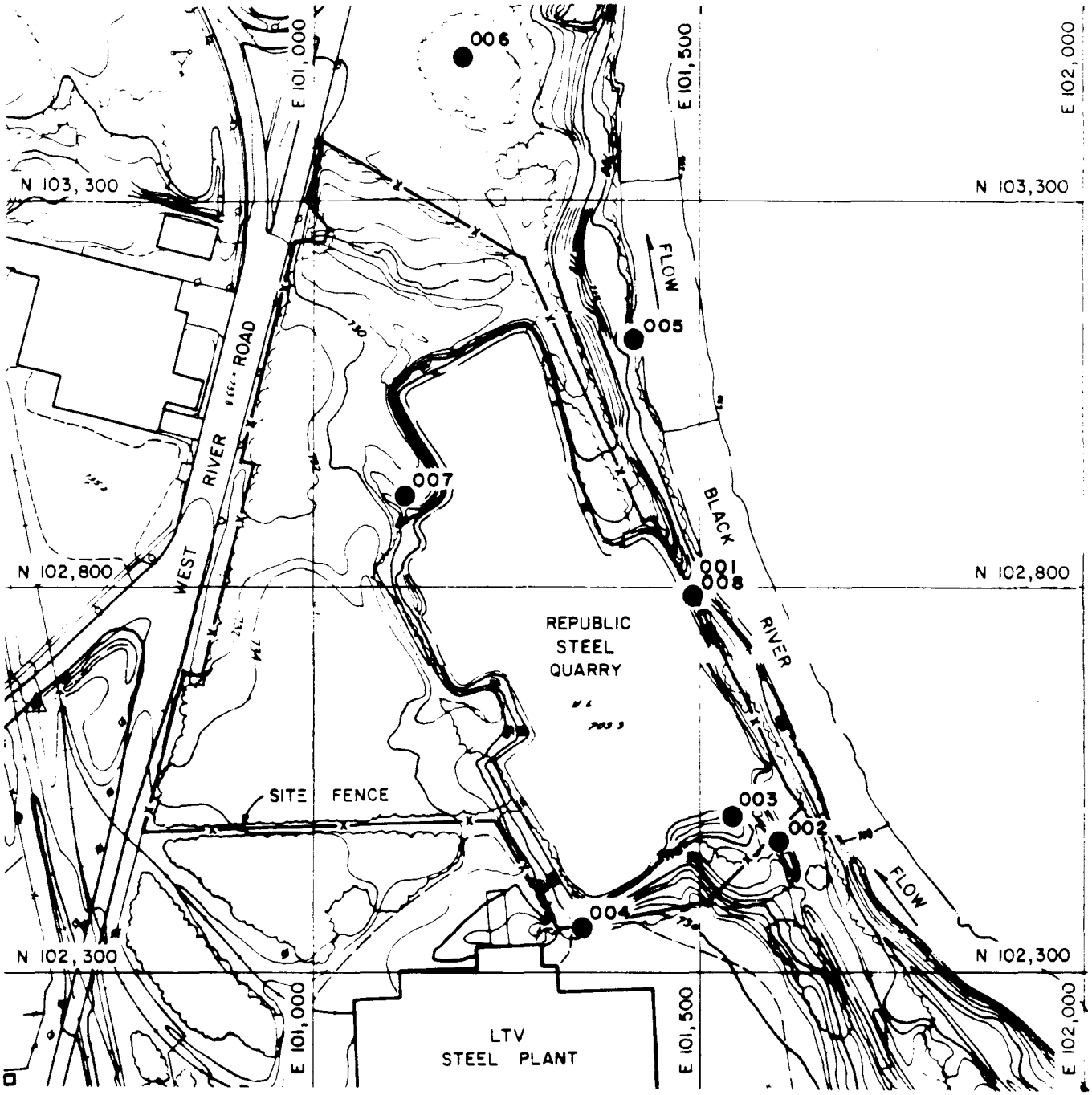
6.2.1 Sampling Locations

On June 22 and 23, 1987, ten surface soil samples were collected and submitted for laboratory analyses. Eight samples were collected from the site and surrounding areas; additionally, a bottle blank sample and a sampling procedure blank sample were also collected. Figure 6-1 illustrates surface soil sampling locations which are described as follows:

Sample No.	Sample Location/Description
SS001	Area where water discharges from the quarry into the Black River
SS002	Former waste pickle liquor discharge ditch from the Republic Steel plant (offsite)
SS003	Area at southeastern corner of quarry that would be periodically inundated by high quarry water
SS004	Area where material is sliding into the quarry from the Republic Steel plant yard (offsite)
SS005	The bank of the West Branch of Black River north of quarry discharge (offsite)
SS006	Area offsite north of site (background sample)
SS007	Area updrainage west of the site (background sample)
SS008	Duplicate sample of SS001
SS009	Bottle blank
SS010	Stainless steel trowel/stainless steel bucket sampling blank

6.2.2 Sampling Method

All surface soil samples were collected using decontaminated stainless-steel trowels, with the exception of the bottle blank, SS009. Soil for volatile organic analysis was excavated and placed directly into the sample containers following removal of vegetation on the ground surface, and following removal of rock fragments, roots, and worms that were visible in the sample. Soil for all analyses except volatile organics was excavated and placed in a decontaminated stainless steel



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

● 003 SURFACE SOIL SAMPLE LOCATION NO. 003

0 200 400
SCALE IN FEET

FIGURE 6-1
SURFACE SOIL SAMPLING LOCATIONS
REPUBLIC STEEL QUARRY RI

bucket and mixed thoroughly. A representative sample of the soil was then placed in the sample jars for analysis. The soils for volatile analysis of samples SS005 and SS006 were mixed in the stainless steel bucket prior to filling the volatile organic analysis (VOA) jars to remove excessive amounts of roots that were present in the soil.

Samples SS002 and SS003 were collected in a location where the Berea Sandstone was exposed, causing the sample to contain a large amount of large rock fragments. The sampling team leader determined that, in order to obtain a reasonable sample for analysis, large rock fragments would need to be removed. A large volume of soil had to be scraped from the ground surface using the stainless steel trowel at each of these locations and hand sifted. At sample locations SS002 and SS003, the sampling depth was from approximately 0.0 to 0.1 feet in depth due to the shallow bedrock, as opposed to the 0.5 ft. maximum depth for other samples.

6.3 LABORATORY ANALYSES PERFORMED AND RESULTS

Ten soil samples were submitted to the CLP for analysis for volatile organics, acid and base/neutral extractables, pesticides/PCBs, metals, cyanide, and oil and grease. The eight samples collected from the site were also submitted for particle size analysis. Tables in Appendix E summarize the laboratory analyses performed on each soil sample.

Laboratory analytical results from the surface soil samples are presented in Appendix F with laboratory QA problems that occurred during these analyses identified in Appendix G. No laboratory QA problems that resulted in the invalidation of data occurred during the analyses of the soil samples. Particle size distribution plots are shown in Appendix H. Tables 6-1 through 6-3 summarize chemical concentrations identified above analytical detection limits.

6.4 NATURE AND EXTENT OF CONTAMINATION

Chemicals detected in the soil samples were analyzed to develop conclusions on the nature and extent of site related contamination. This analysis was performed by dividing the eight environmental soil samples into two categories: site related and background. Site related samples were either obtained onsite or offsite in areas that could have been affected by waste disposal in the quarry. Six samples (SS001 through SS005 and SS008) were considered site related samples. Two samples, SS006 and SS007 were used to represent background soil conditions. The chemical concentrations of site related samples were compared to those found in background samples to evaluate soil contamination at the site. The results of this evaluation are presented on Table 6-4.

Table 6-4 presents the chemicals detected, number of samples analyzed, number of times detected, percent detected, maximum and minimum

TABLE 6-1
VOLATILE ORGANICS AND PESTICIDES/PCBs
DETECTED IN SOILS
REPUBLIC STEEL QUARRY RI

		Volatile Organics						Pesticides/PCBs		
Sample Number	Sample Location	Methylene Chloride	Acetone	2-Butanone	1,1,1-Trichlorethane	Toluene	Carbon Disulfide	4-4' DDT	Aroclor 1254	Oil and Grease
SS001	E. Quarry Discharge	29 B	--	--	--	--	--	450	--	9,480,000
SS002	S. Pickle Liq. Ditch	33 B	130 B	--	--	65 B	--	--	--	5,680,000
SS003	S. Boat Launch	--	150 B	78	--	--	--	--	--	4,850,000
SS0004	S. Steel Plant Yard	--	--	--	--	--	--	--	--	2,210,000
SS005	N. Black Rvr. Dwn Gradnt	--	--	--	9	--	14	--	280	--
SS006	N. Offsite Background	--	--	--	4 J	--	18	--	--	--
SS007	W. Updrainge Background	--	--	--	3 J	95 B	7	--	--	--
SS008	SS001 Split	--	--	--	--	--	--	390	--	8,780,000
SS009	Bottle Blank	--	--	--	--	--	--	--	--	--
SS010	Sampler Blank	--	--	--	--	--	--	--	--	--

NOTES: All concentrations are presented in micrograms per kilogram, (ug/kg)

J Indicates an estimated value
B Indicates the analyte was found in the laboratory blank sample as well as the sample
-- Not Detected

TABLE 6-2
SEMI-VOLATILE ORGANICS DETECTED IN SOILS
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	1,3-Dichloro-benzene	Benzoic Acid	N-Nitroso-diphenyl lamine(1)	Pentachlor-ophenol	Phenan-threne	Di-n-Butyl-phthalate	Fluor-anthene	Pyrene	Benzo(a) Anthracene
SS001	E. Quarry Discharge	--	--	--	--	--	--	--	--	--
SS002	S. Pickle Liq. Ditch	--	--	--	--	--	3100 J	--	4300 J	--
SS003	S. Boat Launch	--	--	--	--	--	1900	780 J	560 J	510 J
SS004	S. Steel Plant Yard	--	--	--	--	250 J	--	510 J	330 J	260 J
SS005	N. Black Rvr Dwn Gradnt	160 J	510 J	77 J	100 J	110 J	--	130 J	160 J	110 J
SS006	N. Offsite Background	--	--	--	--	--	--	62 J	57 J	70 J
SS007	W. Updrainge Background	--	630 J	58 J	--	130 J	--	63 J	60 J	--
SS008	SS001 Split	--	--	--	--	--	3400	--	--	--
SS009	Bottle Blank	--	560 J	--	380 J	39 J	--	--	42 J	--
SS010	Sampler Blank	--	450 J	--	160 J	--	--	--	--	--

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
-- Not Detected

TABLE 6-2 (Continued)
SEMI-VOLATILE ORGANICS DETECTED IN SOILS
REPUBLIC STEEL QUARRY RI

Sample Number	Sample Location	bis (2-Ethylhexyl) Phthalate	Chrysene	Di-n-Octyl Phthalate	Benzo(b) Fluoranthene	Benzo(k) Fluoranthene	Benzo(a) Pyrene	Naph-thalene	2-Methylnaph-thalene	Butyl-benzyl-phthalate	Dibenzo-furan
SS001	E. Quarry Discharge	--	--	--	--	--	--	--	--	--	--
SS002	S. Pickle Liq. Ditch	--	--	--	--	--	--	--	--	--	--
SS003	S. Boat Launch	7800 B	510 J	1900	780 J	780 J	--	--	--	--	--
SS004	S. Steel Plant Yard	--	250 J	--	--		--	--	--	--	--
SS005	N. Black Rvr Dwn Gradnt	--	140 J	--	260 J	260 J	130 J	--	--	--	--
SS006	N. Offsite Background	--	65 J	--	--		73 J	--	--	--	--
SS007	W. Updrainage Background	--	56 J	--	76 J	76 J	42 J	160 J	210 J	49 J	60 J
SS008	SS001 Split	--	--	--	--	--	--	40 J	49 J	--	--
SS009	Bottle Blank	--	--	--	--	--	--	44 J	--	--	--
SS010	Sampler Blank	--	--	58 J	--	--	--	--	--	--	--
		--	--	--	--	--	--	--	--	--	--

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
-- Not Detected

TABLE 6-3
INORGANICS DETECTED IN SOILS
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	SS001	SS002	SS003	SS004	SS005	SS006	SS007	SS008	SS009	SS010
SAMPLE DATE:	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87	06/23/87	06/23/87
SAMPLE LOCATION:	E. Quarry Discharge	S. Pickle Liq Ditch	S. Boat Launch	S. Steel Plant Yd	N. Black R Downgradnt	N. Offsite Background	W. Updrainge Background	SS001 Split	Bottle Blank	Sampler Blank
ALUMINUM	921	2400	2860	3620	3640	9860	7980	801	8810	9510
ARSENIC	--	--	--	--	8.3 RJ	--	--	23 RJ	--	--
BARIUM	[82]	[94]	[24]	[90]	[42]	[66]	[55]	[60]	146	153
BERYLLIUM	--	--	--	--	--	[0.98]	[0.92]	--	[1.3]	[1.3]
CADMIUM	--	--	--	--	--	--	--	5	--	--
CALCIUM	[651]	3780	[2710]	16000	[2650]	[1250]	[1660]	[355]	11800	12400
CHROMIUM	[16]	22	16	178	40	8.4	9.6	16	13	12
COBALT	--	[4]	[4]	--	[5]	[11]	[8]	--	[12]	[13]
COPPER	81	94	88	50	38	[11]	31	77	39	41
IRON	521000	51200	24800	380000	85800	20900	19200	377000	19400	21100
LEAD	27 RJ	63 RJ	47 RJ	26 RJ	24 RJ	30 RJ	32 RJ	21 RJ	11 RJ	11 RJ
MAGNESIUM	--	[1280]	[872]	[3020]	[1730]	[1800]	[1990]	--	3300	3520
MANGANESE	138	554	451	5990	903	823	631	98	470	500
MERCURY	--	0.32	0.34	--	--	--	--	--	--	--
NICKEL	--	[23]	[15]	73	34	[12]	[15]	--	29	30
POTASSIUM	[777]	[550]	[430]	[536]	[489]	[554]	[875]	[669]	[1350]	[1420]
TIN	--	--	--	--	98	--	--	--	--	--
VANADIUM	[34]	[7.5]	[6.7]	[32]	[12]	[20]	[17]	[26]	[16]	[17]
ZINC	[17]	79	46	84	62	62	84	24	122	135
CYANIDE	1.8 RJ	--	--	--	--	--	--	1 RJ	--	--

NOTES: All concentrations are presented in mg/kg.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

J Indicates an estimated value.

R The spike sample recovery is not within control limits.

-- Not Detected

TABLE 6-4
SUMMARY OF NATURE AND EXTENT EVALUATION
SOIL SAMPLES
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
VOLATILE ORGANIC ANALYSES								
Acetone	Site Related	6	2	33%	150	130	YES	S.Boat Launch
	Background	2	0	0%	BDL	BDL		
2-Butanone	Site Related	6	1	17%	78	78	YES	S.Boat Launch
	Background	2	0	0%	BDL	BDL		
Carbon Disulfide	Site Related	6	1	17%	14	14	NO	N. Offsite
	Background	2	2	100%	18	7		
Methylene Chloride	Site Related	6	2	33%	33	29	YES	S. Pickle Liq. Ditch
	Background	2	0	0%	BDL	BDL		
1,1,1-Trichloroethane	Site Related	6	1	17%	9	9	NO	N. Black Rvr. Dwn Gradnt.
	Background	2	2	100%	4	3		
Toluene	Site Related	6	1	17%	65	65	NO	West Updrainage
	Background	2	1	50%	95	95		
SEMI-VOLATILE ORGANIC ANALYSES								
1,3-Dichlorobenzene	Site Related	6	1	17%	160	160	NO	N. Black Rvr. Dwngradnt
	Background	2	0	0%	BDL	BDL		
2-Methylnaphthalene	Site Related	6	1	17%	49	49	NO	W. Updrainage
	Background	2	1	50%	210	210		
Benzoic Acid	Site Related	6	1	17%	510	510	NO	W. Updrainage
	Background	2	1	50%	630	630		
Benzo(a) pyrene	Site Related	6	1	17%	130	130	NO	N. Black Rvr. Dwngradnt
	Background	2	2	100%	73	42		
Benzo(a)anthracene	Site Related	6	3	50%	510	110	YES	S. Boat Launch
	Background	2	1	50%	70	70		
Benzo(b) fluoranthene	Site Related	6	2	33%	780	260	YES	S. Boat Launch
	Background	2	1	50%	76	76		
Benzo(k) fluoranthene	Site Related	6	2	33%	780	260	YES	S. Boat Launch
	Background	2	1	50%	76	76		
bis(2-ethylhexyl)phthalate	Site Related	6	1	17%	7800	7800	YES	S. Boat Launch
	Background	2	0	0%	BDL	BDL		

TABLE 6-4 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
SOIL SAMPLES
REPUBLIC STEEL QUARRY RI

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
SEMI-VOLATILE ORGANIC ANALYSES								
Chrysene	Site Related	6	3	50%	510	140	YES	S. Boat Launch
	Background	2	2	100%	65	56		
Di-n-butyl-phthalate	Site Related	6	2	33%	3100	1900	YES	S. Boat Launch
	Background	2	0	0%	BDL	BDL		
Di-n-octyl phthalate	Site Related	6	2	33%	3400	1900	YES	E. Quarry Discharge
	Background	2	0	0%	BDL	BDL		
Fluoranthene	Site Related	6	3	50%	780	130	YES	S. Boat Launch
	Background	2	2	100%	63	62		
Napthalene	Site Related	6	1	17%	40	40	NO	W. Updrainage
	Background	2	1	50%	160	160		
N-nitrosodi-phenylamine	Site Related	6	1	17%	77	77	NO	N. Black Rvr. Dwn Gr
	Background	2	1	50%	58	58		
Pentachlorophenol	Site Related	6	1	17%	100	100	NO	N. Black Rvr. Dwn Gr
	Background	2	0	0%	BDL	BDL		
Phenanthrene	Site Related	6	2	33%	250	110	NO	S. Steel Plant Yard
	Background	2	1	50%	130	130		
Pyrene	Site Related	6	4	67%	4300	160	YES	S. Pickle Liq. Ditch
	Background	2	2	100%	60	57		
PESTICIDE/PCBs ORGANIC ANALYSES								
Aroclor-1254	Site Related	6	1	17%	280	280	NO	N. Black Rvr. Dngradnt
	Background	2	0	0%	BDL	BDL		
4-4' DDT	Site Related	6	2(S)	0%	450	390	NO	E. Quarry Discharge
	Background	2	0	0%	BDL	BDL		
Oil and Grease	Site Related	6	5	83%	9480000	2210000	YES	E. Quarry Discharge
	Background	2	0	0%	BDL	BDL		

TABLE 6-4 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
SOIL SAMPLES
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	ANALYZED	DETECTED	DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
Aluminum	Site Related	6	6	100%	3640	801	NO	N. Black Rvr. Dwn Gr.
	Background	2	2	100%	9860	7980		
Arsenic	Site Related	6	2	33%	23	8.3	NO	E. Quarry Discharge
	Background	2	0	0%	BDL	BDL		
Barium	Site Related	6	6	100%	94	24	NO	S. Pickle Liq. Ditch
	Background	2	2	100%	66	55		
Cadmium	Site Related	6	1	17%	5	5	NO	E. Quarry Discharge
	Background	2	0	0%	BDL	BDL		
Calcium	Site Related	6	6	100%	16000	335	YES	S. Steel Plant Yd.
	Background	2	2	100%	1660	1250		
Chromium	Site Related	6	6	100%	178	16	YES	S. Steel Plant Yd.
	Background	2	2	100%	9.6	8.4		
Cobalt	Site Related	6	3	50%	5	4	NO	N. Black Rvr. Dwn Gr
	Background	2	2	100%	11	8		
Copper	Site Related	6	6	100%	94	38	YES	S. Pickle Liq. Ditch
	Background	2	2	100%	31	11		
Iron	Site Related	6	6	100%	521000	24800	YES	E. Quarry Discharge
	Background	2	2	100%	20900	19200		
Lead	Site Related	6	6	100%	63	21	NO	S. Pickle Liq. Ditch
	Background	2	2	100%	32	30		
Magnesium	Site Related	6	4	67%	3020	872	NO	S. Steel Plant Yard
	Background	2	2	100%	1990	1800		
Manganese	Site Related	6	6	100%	5990	98	NO	S. Steel Plant Yd.
	Background	2	2	100%	823	631		
Mercury	Site Related	6	2	33%	0.34	0.32	YES	S. Boat Launch
	Background	2	0	0%	BDL	BDL		
Nickel	Site Related	6	4	67%	73	15	YES	S. Steel Plant Yd.
	Background	2	2	100%	15	12		

TABLE 6-4 (Continued)
SUMMARY OF NATURE AND EXTENT EVALUATION
SOIL SAMPLES
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	ANALYZED	DETECTED	DETECTS	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
Potassium	Site Related	6	6	100%	777	430	NO	E. Quarry Discharge
	Background	2	2	100%	875	554		
Tin	Site Related	6	1	17%	98	98	NO	N. Black Rvr. Dwn Gr.
	Background	2	0	0%	BDL	BDL		
Vanadium	Site Related	6	6	100%	34	6.7	NO	E. Quarry Discharge
	Background	2	2	100%	20	17		
Zinc	Site Related	6	6	100%	84	17	NO	S. Steel Plant Yard
	Background	2	2	100%	84	62		W. Updrainage
Cyanide	Site Related	6	2(S)	0%	1.8	1	NO	E. Quarry Discharge
	Background	2	0	0%	BDL	BDL		

NOTES: BDL = Below Detection Limits
Organic analyses maximum and minimum values are presented in micrograms per kilogram (ug/kg).
Inorganic analyses maximum and minimum values are presented in milligrams per kilogram (mg/kg).
(S) Split samples collected from same location.

concentrations detected, an evaluation of whether the chemical is potentially site related and the location where the maximum concentration was observed. Criteria were established during the nature and extent evaluation to determine if chemicals detected were potentially site related. The following criteria were used in this evaluation:

- Chemicals were considered site related if onsite surface soils detected the chemical at greater than or equal to twice the concentration observed in background soil samples. The rationale for the selection of two times the background concentration as an evaluation criterion is presented in Appendix G, Data Considerations.

- Chemicals were considered site related if the chemical has been detected at greater than one onsite soil sampling location.

- Chemicals were considered site related if the chemical was detected at only one onsite location but was found to be potentially site related in other environmental media at the site.

Results of the nature and extent of contamination evaluations are presented in the following items.

6.4.1 Volatile Organics

Six volatile organic compounds were detected in the surface soil samples at locations considered to be site related. Based on comparison with background samples, only three of the six compounds should be considered potentially site related. Methylene chloride, acetone, and 2-butanone were detected onsite but not in background soil samples and are considered potentially site related. The chemicals were detected in areas that either currently or in past have been inundated by either quarry waters or discharges from the steel facility. Acetone was detected at concentrations of 130 to 150 ug/kg in the samples collected near the southern end of the quarry. Butanone was detected at the southern quarry bank at 788 ug/kg and methylene chloride was detected in the abandoned pickle liquor ditch and at the quarry discharge at concentrations of 33 and 29 ug/kg, respectively.

1,1,1-trichloroethane was found in two background samples and one downgradient sample, but not in onsite soils or sediments, and is not considered to be site related. Carbon disulfide and toluene were detected in surface soils onsite and also in background soil samples at similar concentrations. Because concentrations were detected at similar concentrations, these compounds are not considered site related.

6.4.2 Semi-Volatile Organics

Seventeen semi-volatile organic compounds were identified above analytical detection limits in the site related surface soil samples collected. Nine of these seventeen compounds are considered to be potentially site related based on comparison with background soil samples. Benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate,

chrysene, di-n-butyl-phthalate, di-n-octyl-phthalate, fluoranthene and pyrene are considered site related compounds since they were detected at greater concentrations in onsite and downgradient samples than in background surface soil samples. All of these compounds were detected in the soil sample obtained along the bank at the south end of the quarry that is periodically covered with water. The compounds were also detected in the samples obtained from the abandoned waste discharge ditch, the quarry discharge and the steel yard that is sliding into the quarry. The concentrations of these compounds ranged from several hundred to several thousand ug/kg.

These compounds were also detected in the soil sample obtained north of the site (down drainage) along the bank of the Black River. Detection of these compounds at this location is not considered site related since sediments obtained upstream of the site had greater concentrations of the same compounds. Since the soil sample was obtained in an area that is periodically covered with Black River waters, the sediments and the soil sample are presumably being affected by the Black River rather than by the site. See Section 5 for results of sediment sampling.

1,3-dichlorobenzene and pentachlorophenol, which were detected at only one sample station on the Black River downgradient of the site, were not found in onsite sediments and are not considered site related. 2-methylnapthalene, napthalene, and benzoic acid are not being treated as site related compounds because they are found at higher concentrations in background samples than in site related samples. Benzo(a)pyrene, n-nitrosodi-phenylamine, and phenanthrene are not considered site related as they have been detected in onsite samples at similar concentrations to background offsite samples.

6.4.3 Pesticides/PCB

Three chemical compounds in the pesticides/PCB group were detected in the surface soil samples collected at the site. Aroclor-1254 was detected at only one location downgradient of the site on the Black River and is not considered site related. 4-4′ DDT was detected twice at the same onsite location; however, it was not found in any other environmental media at the site, is not considered a product of disposal practices at the quarry, and is not considered site related. Oil and grease were detected in five out of six samples onsite in high concentrations and are related to disposal activities at the quarry. Concentrations of oil and grease ranged from 2,210,000 ug/kg to 9,480,000 ug/kg.

6.4.4 Inorganics

Nineteen inorganic chemicals were identified above analytical detection limits in site related surface soil samples collected. Six of these are considered to be site related. Mercury, calcium, chromium, copper, iron, and nickel were detected in higher concentrations in onsite samples than background samples and are considered potentially site related chemicals.

Cyanide was detected only in the soil from the quarry discharge area, was not observed in other environmental media at the site, is not considered a product of disposal practices at the quarry, and is not considered site related.

Aluminum, cobalt, and potassium were detected in background samples at higher concentrations than those found onsite and are not considered site related. Additionally, barium, lead, magnesium, manganese, vanadium, and zinc are not believed to be site related because these chemicals were found in onsite and background samples in similar concentrations. Arsenic is not considered to be site related since it was detected only in samples along the Black River that are periodically inundated by the river and upgradient sediment samples along the edge of the river detected arsenic at higher concentrations than those detected in the soil samples. Cadmium was found in one sample, but was not found in the sample split, was not determined to be potentially site related in other environmental media at the site, and is not estimated to be site related. Tin was found in a downdrainage soil sample, but not in any onsite samples and is not believed to be site related.

6.4.5 Summary

The results of this nature and extent of contamination analysis indicate that onsite surface soils contain elevated concentrations of some chemicals. Soils that were concluded to be affected by potentially site-related chemicals were located primarily in areas where periodic contact with waste discharges or quarry water had occurred. Several volatile and semi-volatile organic and inorganic chemicals were identified as being potentially site related during the nature and extent evaluation. Potentially site related chemicals are summarized below:

Volatile Organics	Semi-Volatile Organics	Inorganics
Acetone	Polycyclic Aromatic Hydrocarbons*	Calcium
2-Butanone	bis(2-ethylhexyl)phthalate	Chromium
Methylene Chloride	Di-n-butyl phthalate	Copper
	Di-n-octyl phthalate	Iron
		Mercury
		Nickel

*Polycyclic aromatic hydrocarbons identified include benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene and pyrene.

7.0 GROUNDWATER INVESTIGATION

7.1 INTRODUCTION

The purpose of the groundwater investigation at the Republic Steel Quarry Site was to characterize the site geology and groundwater system, and to determine if site related chemicals have moved into the groundwater system. The groundwater investigation program involved a geologic reconnaissance, test drilling, packer permeability testing, geophysical logging, and monitoring well installation. Groundwater samples were obtained from the monitoring wells on two occasions. This section documents the groundwater investigation methods, the data obtained, and the analysis and interpretation of the data.

7.2 GEOLOGIC RECONNAISSANCE

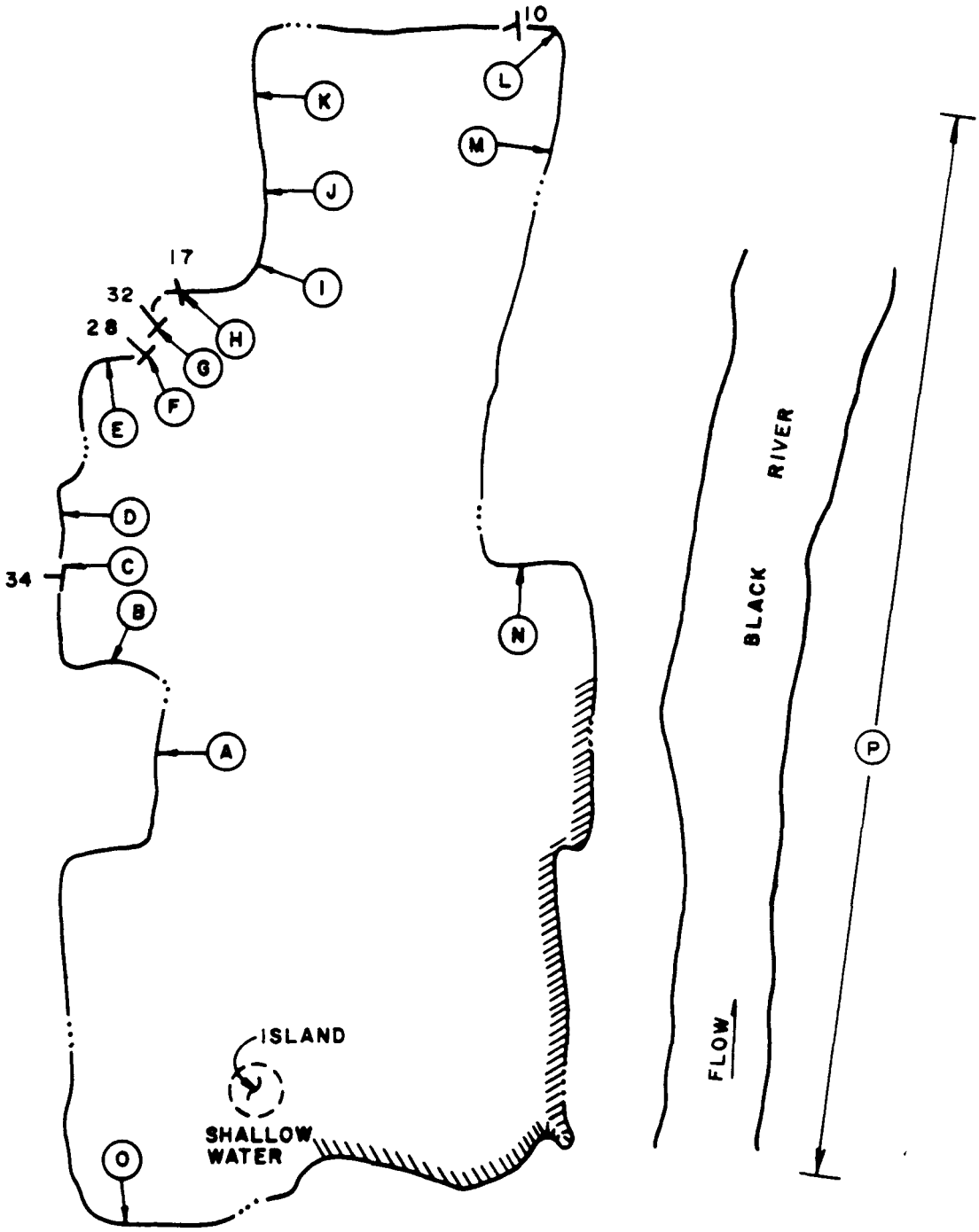
A geologic reconnaissance of the Republic Steel Quarry and immediate vicinity was performed on May 18 and 19, 1987. The reconnaissance included examination of the quarry walls from a boat and inspection of the West Branch of the Black River near the site by wading in the river. The reconnaissance was performed to support final planning of the surface water sampling and groundwater investigation programs by collecting data through a detailed examination of the bedrock fracture and joint orientations. These data were used to ensure that locations chosen for upgradient sampling points were upgradient of any geologic lineaments which would permit quarry water to flow to the sampling location.

7.2.1 Observations in Quarry

Intense iron staining of the rock (apparently caused by high water levels within the quarry) and boat instability impaired examination of exposed strata above the water level in the quarry. The rock face was smooth and relatively unweathered. As a result, there were not many good surfaces on which to measure strike and dip.

The rock was found to be intact, with relatively few natural fractures. Most of the fractures observed were small and closed. Only three large, open joints were exposed, at locations H, M and O (Figure 7-1). Bedding-plane separations were far more common than joints. Some discontinuities did show evidence of groundwater migration, such as staining and moss growth. Rain during the reconnaissance obscured surficial evidence of groundwater conditions. Subsequent RI activities, such as surface water and sediment sampling which were performed in the quarry during dry weather conditions, did not detect any surficial evidence of groundwater conditions.

A narrow bench is present around most of the quarry at less than one foot above the present water level. This bench does not appear to be related to any geologic feature.



LEGEND:

(A) GEOLOGIC FEATURE

34 ⊣ BEDDING PLANE ORIENTATION

AREA WHERE BEDROCK IS NOT EXPOSED

0 100 200

SCALE IN FEET (APPROXIMATE)

FIGURE 7-1

RESULTS OF GEOLOGIC RECONNAISSANCE

REPUBLIC STEEL QUARRY RI

One continuous bed of platy sandstone formed a concave upward structure on the western side of the quarry. Figure 7-1 illustrates the location of this feature. However, the bedding orientations appear to be sedimentary rather than structural in nature, and will therefore be specific to individual beds. Individual marker beds are probably not traceable over significant distances in this type of sandstone. Bedding surfaces were not truly planar, further complicating measurements.

Other observations included:

- Lenses of heavily weathered, very dark-gray shale at location D;
- Irregular bedding in the upper portion of the rock at location F;
- Atypical jointing at location I. This fracture pattern is different from any other location in the quarry. The fracture pattern may be related to blasting rather than rock structure;
- Crossbedding in upper strata at location H;
- Bedding plane separation at location J;
- Jointing and bedding plane separation at location K;
- Cross bedding at location N; and
- Intermittent, small oil films on the quarry water surface throughout the reconnaissance.

Table 7-1 summarizes individual orientations measured in the quarry.

7.2.2 Observations in Black River (Location P)

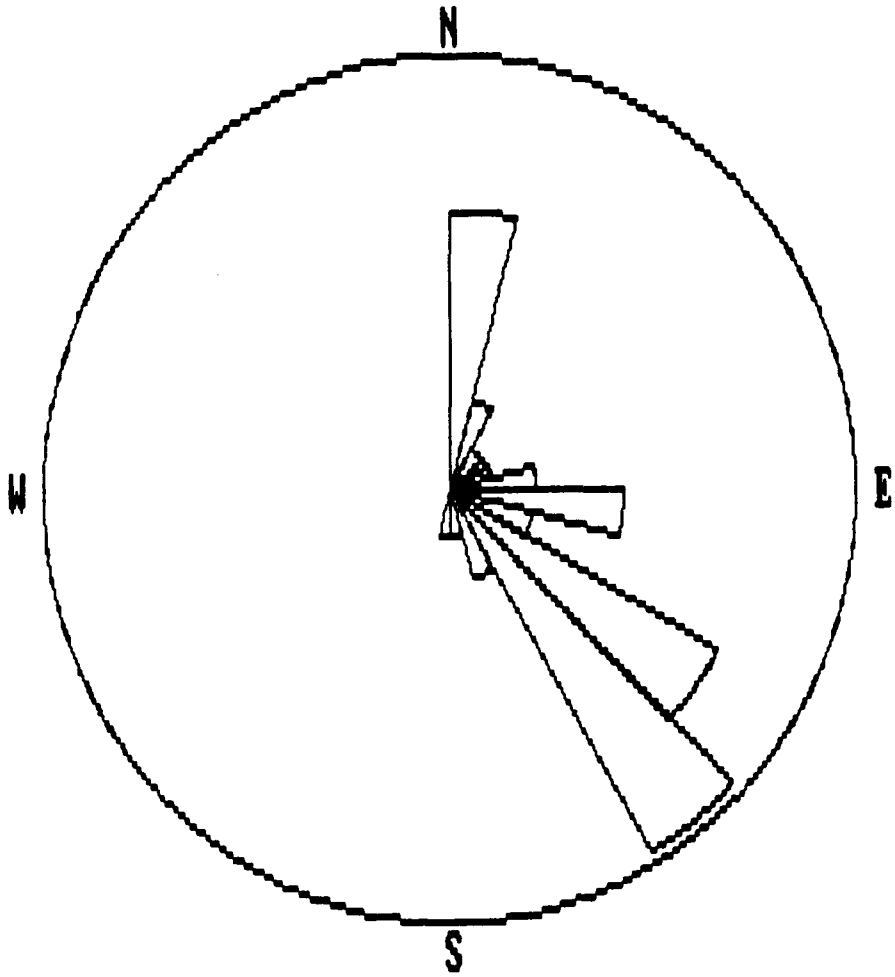
The depth of flow in the Black River was higher than it had been on previous site visits due to heavy rains; consequently, the measurement of joints was more difficult than originally anticipated. Beneath the river, joints were open and heavily eroded. Outside of the river, joints were closed, discontinuous, and not well developed. Figure 7-2 presents a rose diagram of joint orientations; Table 7-2 summarizes these orientations. Major joint orientations are 5 and 120 degrees.

Some crossbedding was noted in exposed bedrock along the river bank, but the base map was not of sufficient scale and detail to allow detailed mapping of the rock.

TABLE 7-1
BEDROCK ORIENTATION MEASUREMENTS WITHIN QUARRY
REPUBLIC STEEL QUARRY RI

Feature	Strike	Dip	Location
Joint	2° (A)		A
Joint	338° (A)	28° SE	A
Joint	236° (A)	12.5° NW	B
Joint	156°	31° NE	C
Joint	290°	47° SW	E
Bedding	156°	34° SW	C
Bedding	15°	28° NW	F
Bedding	195°	32° NW	G
Bedding	131°	17° SW	H
Bedding	7°	37° NW	G
Bedding	190°	33° NW	G
Bedding	14°	25° NW	G
Joint	65° (A)	37° NE	H
Bedding	150°	10° SW	L

(A) Denotes apparent orientation measured at intersection with quarry wall.



CLASS SIZE	=	15	DEGREES
MAX. RADIAL	=	9	ORIENTATIONS
MEDIAN	=	115	DEGREES
MEAN	=	98	DEGREES

FIGURE 7-2
JOINT ORIENTATIONS
AT BLACK RIVER
REPUBLIC STEEL QUARRY RI

TABLE 7-2
JOINT ORIENTATIONS MEASURED IN THE BLACK RIVER (AREA P)
REPUBLIC STEEL QUARRY RI

95° A	90° A
120° A	6° A
145° A	167° A
136° A	105° A
63° A	132° A
94° A	86° A
86° A	236° A
129°, 73° SW	146°, 90°
122° A	110°, 67° SW
146°, 80° SW	136°, 80° SW
151° A	6° A
33° A	18° A
127°, 76° SW	124° A
11° A	12° A
22° A	136° A
149° A	139° A
180°, 90°	149° A
94° A	152° A
128° A	182° A
7°, 78° SW	

"A" denotes apparent orientation measured at intersection with ground surface (relatively level)

7.2.3 Conclusions of Reconnaissance

Berea Sandstone at the Republic Steel Quarry fits the regional description of the rock unit as a stream-deposited, clean sandstone (Rau, 1969). Because the Berea is stream-deposited, traceable marker beds within the unit are unlikely to be present.

Although jointing appeared to be well developed in Black River, it was not conspicuous at any other locations. Discontinuities within the rock are believed to exist as microfractures only, and do not become open and obvious until the rock is subjected to intense weathering, which may explain the paucity of joints within the quarry.

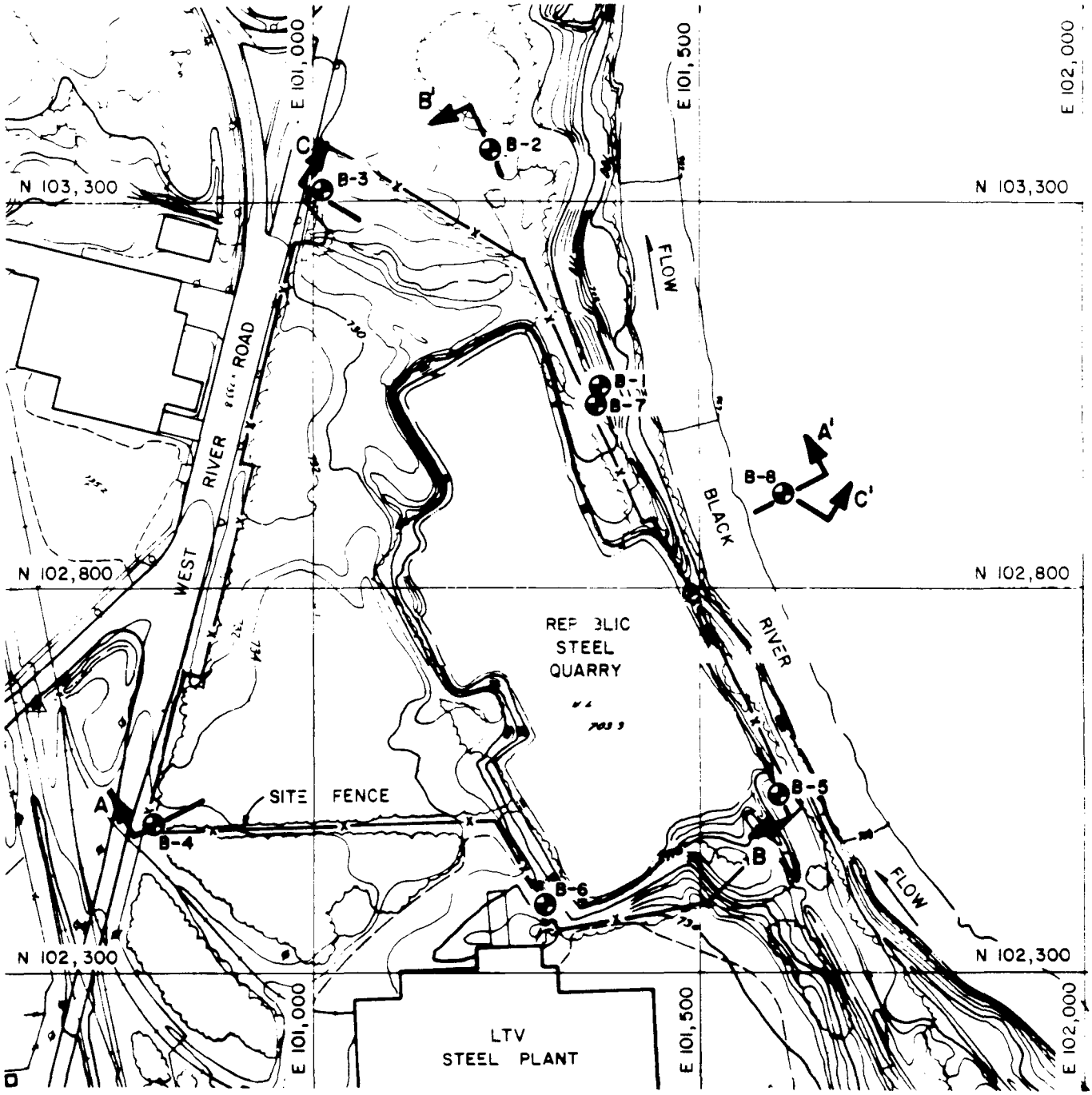
7.3 GEOLOGIC INVESTIGATION

7.3.1 Drilling Program

Eight test borings were drilled at the site during the period of June 29 to August 6, 1987. Three of the borings were planned to be drilled to deepen the pre-existing wells on site (B-1, B-2 and B-3), and five borings were drilled at new locations (B-4 through B-8). All borings were subsequently converted into monitoring wells. Locations of the borings are presented on Figure 7-3, and Table 7-3 summarizes the test boring and monitoring well data. Geologic logs and well completion logs are included in Appendix D.

It was anticipated prior to the initiation of drilling that no marker beds would be encountered to assist in well placement. To obtain data on rock structure, oriented rock coring methods were planned. This drilling technique involves using a compass, plumb bob and camera in the core barrel to record the orientation of the rock core. By stopping hole advancement at intervals and measuring the time and depth, a photographic record of the core orientation is made. The core itself then is oriented to its natural position on a goniometer, and bedding plane angles can be measured.

Boring (B-4) was the first hole drilled at the site and was used to develop the criteria for drilling the remaining borings. The hole was drilled to the top of bedrock using hollow stem augers with split-spoon samples obtained at 3 ft. centers. Below the top of bedrock, which was encountered at a depth of about 16 ft., the hole was advanced using oriented rock coring methods. The final bedrock core run in B-4, encountered the Bedford Shale underlying the Berea Sandstone. The decision was made to advance all remaining borings to the Bedford Shale. Results of the oriented coring for Boring B-4 are presented on the geologic log in Appendix I.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

B-2 TEST BORING/MONITORING WELL LOCATIONS

A A' LOCATION OF GEOLOGIC CROSS-SECTION

N

0 200 400

SCALE IN FEET

FIGURE 7-3
TEST BORING/MONITORING WELLS AND GEOLOGIC CROSS-SECTION LOCATIONS
REPUBLIC STEEL QUARRY RI

TABLE 7-3
TEST BORING AND MONITORING WELL SUMMARY
REPUBLIC STEEL QUARRY RI

Boring No.	Surface Elevation (ft.)	Depth to Top of Rock Berea Sandstone (ft.)	Depth to Top of Bedford Shale (ft.)	Total Boring Depth (ft).
B-1	721.45	24.5	60.0	80.0
B-2	723.78	8.0	74.2	82.0
B-3	725.67	13.0	71.9	77.5
B-4	734.35	18.0	109.0*	111.15
B-5	713.39	15.1	99.0	115.0
B-6	731.36	11.5	39.0	44.0
B-7	722.11	18.6	Below Total Depth	39.0
B-8	719.39	10.0	34.0	59.0

* Geophysical logs suggest that this contact may be located at a depth of 101 ft. The other contact depths are in close agreement with the geophysical logs.

The remaining borings were advanced through rock using standard rock coring methods. All holes, except B-7 were advanced to a depth where the Bedford Shale was encountered. B-7 was terminated within the upper 15 ft. of the Berea Sandstone to allow the estimation of vertical groundwater gradients.

The Work Plan proposed deepening existing Wells 1, 2 and 3 and converting them into cased monitoring wells. When the deepening of the first well (B-1) was attempted, however, the soil zone was found to be uncased and soil caved into the holes. This caused a number of drilling problems during the deepening and installation of the new well at B-1. For this reason, Borings 2 and 3 were not extended and new holes were drilled adjacent to the existing wells. This was done by drilling an air rotary hole to the depth of the existing well without sampling, then coring to the Bedford Shale. Existing wells B-2 and B-3 were not sampled and remain at the site. These borings were not grouted during the RI in the event they would be needed during some future work at the site.

Coring of the Berea Sandstone bedrock was difficult because fractures existed at some depths. The fractures prevented wash water from circulating drill cuttings to the surface. This situation led to core bit binding in the holes. To allow drilling to continue, oversized core casing was drilled into the bedrock across the fracture zone to maintain wash water circulation.

One hole, B-5, had to be abandoned because the oversized casing became bound in the hole due to loss of water and could not be removed. About 50 ft. of steel casing was left in the ground and the hole was grouted to the surface. Another hole was drilled adjacent to the original B-5 using air rotary methods without sampling, and the well was installed in the new hole.

7.3.2 Permeability Testing

In-situ packer permeability testing was performed in four borings to assist in the selection of well screen depths. Well screens were placed at depth intervals having relatively high hydraulic conductivities. B-4, B-5, B-6 and B-8 were packer tested at 10 ft. intervals, and the results are shown on Table 7-4. Hydraulic conductivities ranged between approximately 10^{-3} to 10^{-7} cm/sec., and generally decreased with depth. The permeability data is discussed further in Section 7.5 - Hydrogeology.

7.3.3 Borehole Geophysical Logging

Borehole geophysical logging was performed in three existing shallow wells (B-1, B-2 and B-3) and two newly installed deeper holes (B-4 and B-8). The logging was performed to obtain stratigraphy data and identify zones of porous or fractured rock where permeability might be high. The

TABLE 7-4
PACKER PERMEABILITY TESTING RESULTS
REPUBLIC STEEL QUARRY RI

Boring No.	Packer Interval Depth (ft.)	In-Situ Hydraulic Conductivity Measured (cm/s)	Strata Tested
B-4	104.5 - 114.5	2.24×10^{-7}	Bedford Shale/Berea Sandstone
	94.5 - 104.5	7.86×10^{-5}	Berea Sandstone
	84.5 - 94.5	4.37×10^{-6}	Berea Sandstone
	74.5 - 84.5	7.40×10^{-6}	Berea Sandstone
	64.5 - 74.5	1.05×10^{-5}	Berea Sandstone
	54.5 - 64.5	4.86×10^{-6}	Berea Sandstone
	44.5 - 54.5	2.77×10^{-5}	Berea Sandstone
	34.5 - 44.5	1.04×10^{-3}	Berea Sandstone
	24.5 - 34.5	1.02×10^{-3}	Berea Sandstone
	21.0 - 31.0	1.36×10^{-3}	Berea Sandstone
B-5	93.0 - 103.0	7.09×10^{-6}	Bedford Shale/Berea Sandstone
	83.0 - 93.0	3.66×10^{-5}	Berea Sandstone
	73.0 - 83.0	3.92×10^{-5}	Berea Sandstone
	63.0 - 73.0	4.05×10^{-5}	Berea Sandstone
	53.0 - 63.0	5.34×10^{-5}	Berea Sandstone
B-6	34.5 - 44.5	3.38×10^{-5}	Bedford Shale/Berea Sandstone
	24.5 - 34.5	8.12×10^{-5}	Berea Sandstone
	14.5 - 24.5	1.25×10^{-4}	Berea Sandstone
B-8	35.5 - 45.5	1.90×10^{-7}	Bedford Shale
	25.5 - 35.5	1.46×10^{-3}	Berea Sandstone
	15.5 - 25.5	4.47×10^{-5}	Berea Sandstone

following geophysical logging services were performed by Appalachian Coal Surveys on July 16 and 23, 1987:

- o Caliper
- o Natural Gamma
- o Density, High Resolution
- o Density, Gamma-Gamma
- o Neutron
- o Resistance
- o Temperature
- o Fluid Conductivity
- o Resistivity
- o Spontaneous Potential

A copy of the final report submitted by Appalachian Coal Surveys is included as Appendix J. The results are discussed in Section 7.4 Site Geology and Section 7.5 Site Hydrogeology.

7.3.4 Monitoring Well Installation

Following completion of coring, all holes were reamed to a 4 in. minimum diameter to permit well construction. Monitoring wells were constructed of 2 in. diameter teflon screens and risers below the water level, and 2 in. PVC risers above the water level. All screened zones were sand packed to a minimum height of 2 ft. above the top of the well screen. The sand pack was sealed with a minimum of 2 ft. of bentonite clay pellets placed above the sand pack and the remainder of the hole was grouted with a bentonite-cement slurry to the ground surface using a 3/4 in. diameter tremie pipe. Protective casings with locking caps were installed at each monitoring well.

Table 7-3 summarizes the surface elevation, depth to the top of rock, depth to the Bedford Shale, total depth, and well screen depth for all borings drilled at the site. Well completion logs are included as part of the geologic logs in Appendix C.

7.4 SITE GEOLOGY

7.4.1 Physiography

The site is located in the central lowland physiographic province, a region characterized by essentially undeformed bedrock and glaciated terrain. The topography is generally flat to mildly undulating. Most of the natural topographic relief at the site occurs at the stream banks of the Black River, which flows on bedrock about 30 ft. below the surrounding plain.

7.4.2 Bedrock Geology

Figure 7-4 presents geologic cross-sections for the Republic Steel Quarry Site. The cross-section locations are are shown on Figure 7-3.

The bedrock outcropping in the quarry and in the stream banks along the Black River is the Mississippian Age Berea Sandstone. The Berea Sandstone was deposited in channels and occurs locally as thick masses or stringers of sandstone interbedded with shale (Rau 1969). The average thickness where the sandstone was deposited in channels is 50 ft., but large lateral variations in thickness may occur in short distances (Rau 1969). This is confirmed by the test borings on site where the Berea Sandstone was found to vary in thickness from 27 ft. at B-8 to 94 ft. at B-4 (Figure 7-4). Because the upper surface of the Berea Sandstone (the top of rock) is relatively flat lying at this site, the sandstone thickness variations are due almost entirely to variations in the depth of the lower contact. The top of the Berea Sandstone varies from Elev. 720 at B-4 to Elev. 700 in borings along the Black River.

The geologic logs indicate that the Berea Sandstone is a light gray, medium to fine grained, massive quartz sandstone with occasional carbonaceous laminae. Pyritic nodules were identified in a thin layer near the base of the Berea in every boring that reached the base of the sandstone.

The Berea Sandstone was also characterized by Appalachian Coal Services based on the geophysical logging in boreholes B-1, B-2, B-3, B-4 and B-8 (Appendix I). The logs suggest that the Berea can be divided into three units: a lower unit, a thin shale unit, and an upper unit. The lowermost unit appears to be a thickly bedded channel sandstone based on the gamma and density logs. The base of the Berea Sandstone has a distinctive signature on the geophysical logs, and the depth to the base of this contact is shown on Table 7-3.

Above the base of the Berea in some of the borings is a 1 to 3 ft. thick, high gamma count zone indicative of shale. This shale zone is indicated on the geophysical logs for B-2 and B-3 at a location about 35 ft. above the base of the Berea, and in B-4 about 50 ft. above the base of the Berea, as shown on Figure 7-4. The shale occurs between elevations of approximately 685 to 690 ft. in the borings. The shale unit was confirmed in the geologic log for B-4 at 50.7 to 51.7 ft. and was also noted in the geologic log for B-3 at 38 to 42.5 ft. No drilling samples were taken in B-2 at the depth of the shale unit. The shale unit could not be found on the geologic logs for B-1, B-5, B-6 and B-7, although B-7 may be too shallow to be included. Immediately above the shale unit the geophysical logs indicate the presence of a massive sandstone unit similar to the basal unit.

The Mississippian-Devonian Age Bedford Shale underlies the Berea Sandstone. The contact between the two units is an erosional unconformity. The irregular upper contact of the shale represents an ancient erosional surface and not a structural feature. Figure 7-5, illustrates the estimated elevation contours for the top of the Bedford Shale. The shale contact is based on the test boring data and bottom elevation contours in the quarry (the assumption is made that the Bedford Shale is located at or below the bottom of the quarry). The figure also represents the estimated base of the Berea Sandstone, and as shown, the Berea reaches its greatest depth in B-5, located at the southeast corner of the quarry. It is possible that B-5 is located in a buried stream channel, but the orientation of the feature cannot be estimated based on the available data.

The Bedford Shale is described regionally as a gray siltstone and blue-gray clayshale (Rau, 1969). In test borings drilled at the site, however, the shale uniformly occurs as a dark red, fissile shale, but more gray in color near the upper contact. The Bedford Shale was penetrated in seven of the eight test borings drilled. The thickness of the shale is unknown.

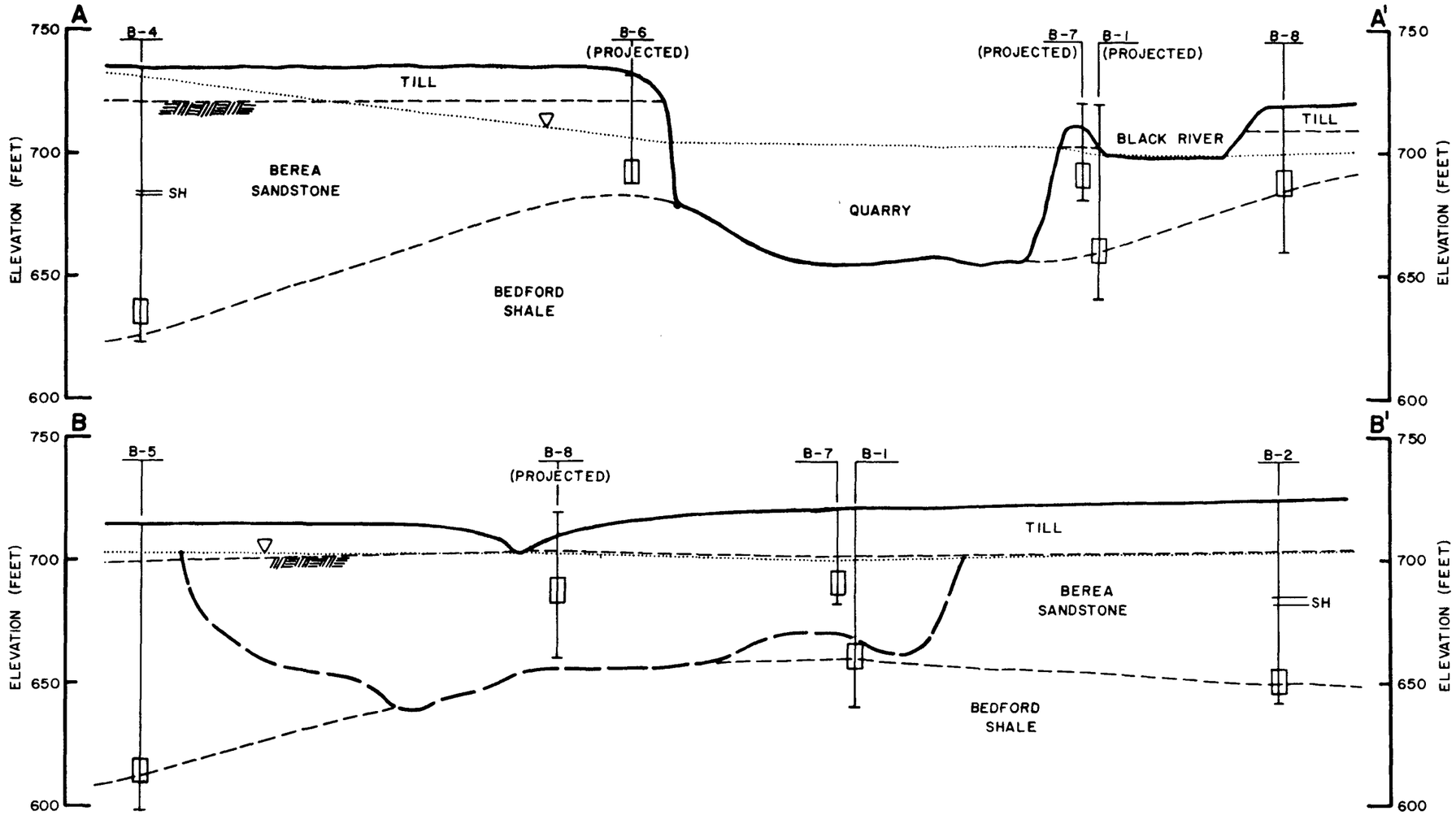
Underlying the Bedford Shale is the Devonian Age Cleveland Shale and Ohio Shale (Rau, 1969). These units were not reached by the site borings and the depth and thickness are unknown.

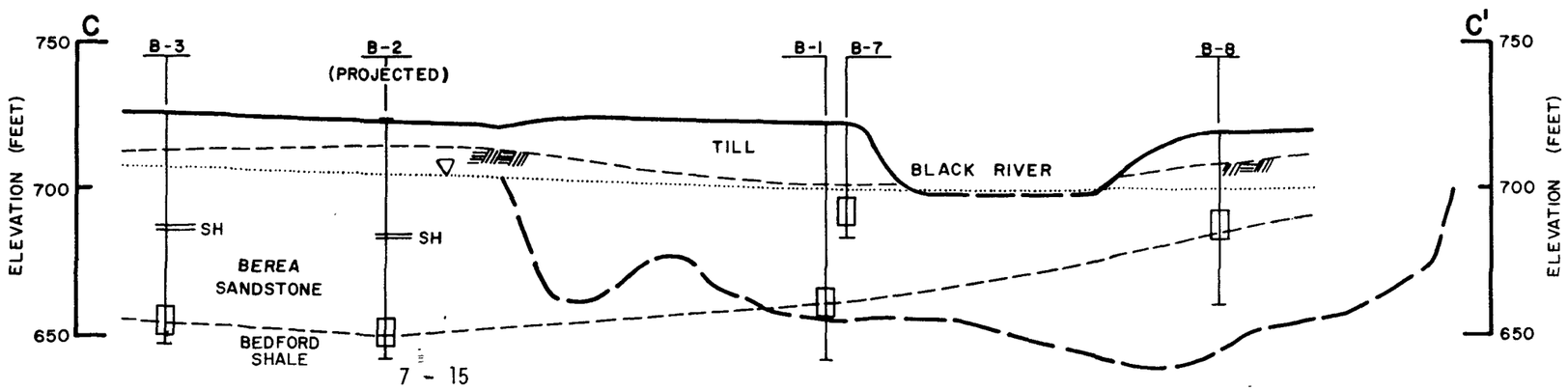
7.4.3 Structure

The bedrock structure in this area of Ohio is relatively featureless. The regional structure can be represented as a homocline that dips to the south-southwest at less than one degree. (Rau, 1969)

At the local scale, the most significant structural feature is the erosional unconformity that marks the top of the Bedford Shale. The test boring data suggests that this surface is very irregular, with relief of as much as 78 ft. over a distance of 320 ft. The surface may have been shaped by stream channels during depositional period of the Berea Sandstone.

The bedding orientations measured in borehole B-4 obtained by oriented coring indicated dip angles that ranged from 6 degrees to 32 degrees and dip directions that vary from South 32 degrees East to South 82 degrees East. Because the measurements were taken in a channel sandstone deposit, which characteristically has intricate cross-bedding and cut-and-fill structures, the measurements are representative of local bedding features and are not useful in area-wide stratigraphic correlations.





LEGEND:

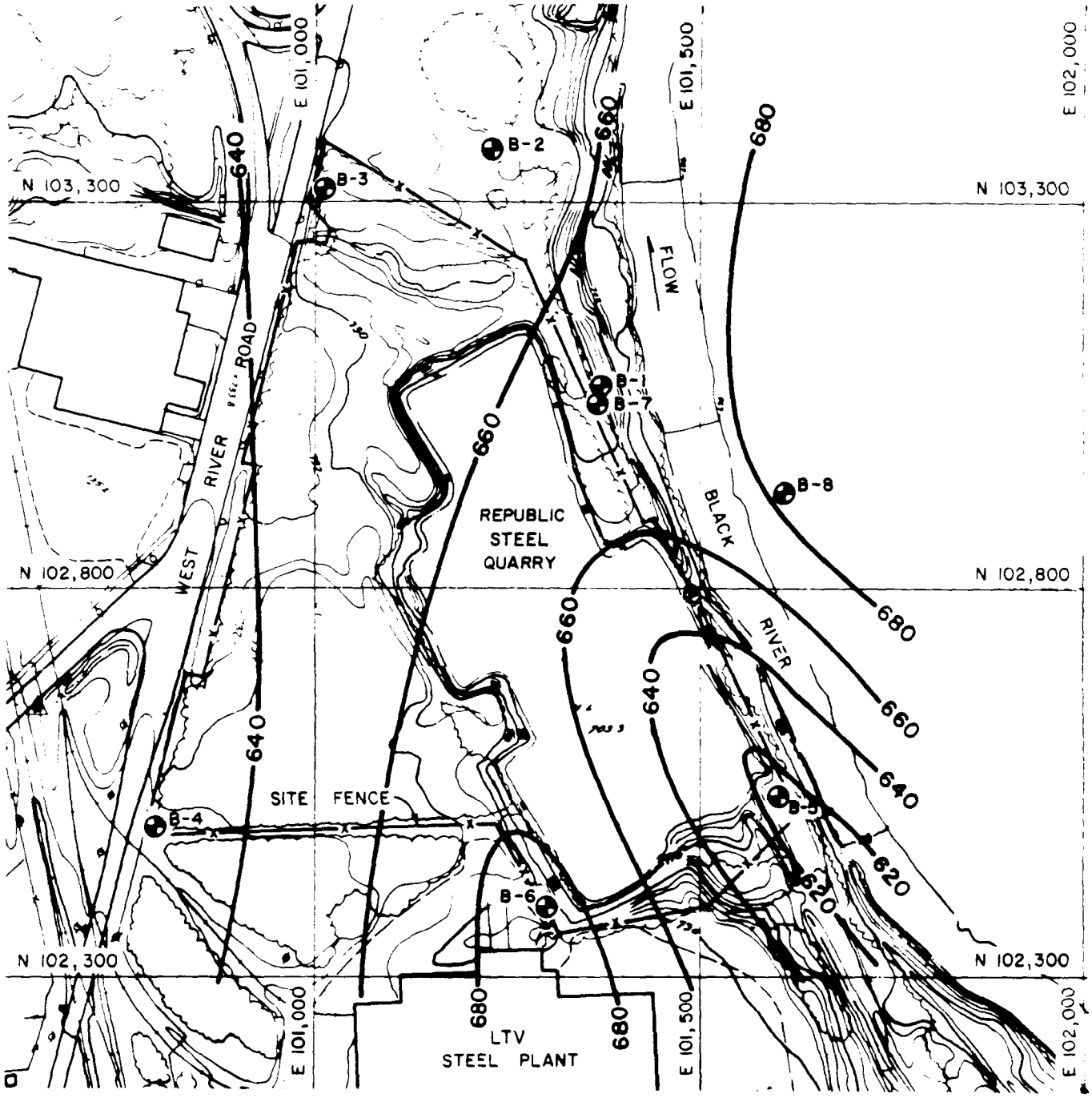
- GROUND SURFACE (APPROXIMATE)
- GEOLOGIC CONTACT (ESTIMATED)
- WELL SCREEN INTERVAL
- PROFILE ALONG THE DEEPEST QUARRY BOTTOM POINTS, PROJECTED TO CROSS-SECTION
- SH SHALE BED IN BEREA SANDSTONE
- WATER TABLE

NOTE: SEE FIGURE 7-3 FOR LOCATION OF GEOLOGIC CROSS-SECTIONS.

0 100 200
HORIZONTAL SCALE IN FEET

0 50 100
VERTICAL SCALE IN FEET

FIGURE 7-4
GEOLOGIC CROSS-SECTIONS
REPUBLIC STEEL QUARRY RI



SOURCE: CITY OF ELYRIA ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

B-2 TEST BORING LOCATION

—660— ELEVATION CONTOUR FOR THE UPPER CONTACT OF THE BEDFORD SHALE, IN FEET (ESTIMATED)

N

0 200 400
SCALE IN FEET

NOTE: CONTOURS ARE BASED ON THE GEOLOGIC LOGS AND THE ESTIMATED QUARRY DEPTH (FIGURE 2-2). THE TOP OF THE SHALE IS ASSUMED TO BE AT OR BELOW QUARRY BOTTOM.

FIGURE 7-5
ELEVATION CONTOURS ON THE BEDFORD SHALE
REPUBLIC STEEL QUARRY RI

The bedding orientations measured in the quarry wall during the geological reconnaissance are also representative of relatively small scale features typical of channel sandstone deposits. An example of this type of feature, visible on the western quarry wall, is a concave upward structure probably representative of a channel cut-and-fill.

Rock jointing in the quarry walls was largely absent. Few fractures were observed and most of those were closed. Only three large, open joints were exposed in the quarry. In the stream channel of Black River, joint patterns were more evident with the major joint orientations being 5 degrees and 120 degrees.

7.4.4 Soils

The soils at the Republic Steel Quarry Site are glacial in origin and vary in thickness from 8 to 25 ft. The soils are described in the literature as poorly drained silt loams developed in the Mahoning Till. The soils sampled at the test boring locations varied from stiff, silty clay with rock fragments at B-4 to loose, silty sand at B-7. The approximate depth of the till is illustrated on Figure 7-4.

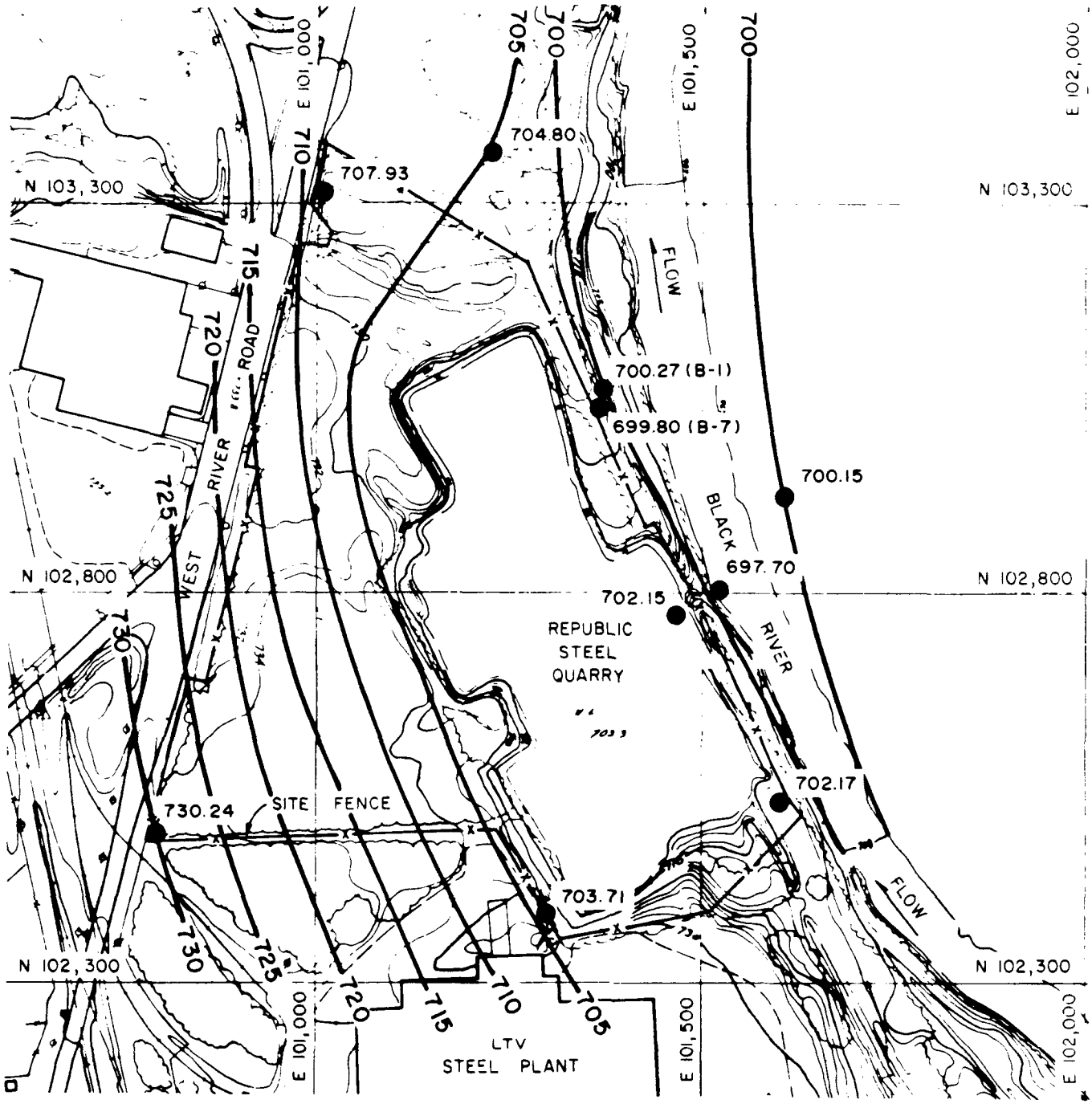
7.5 SITE HYDROGEOLOGY

The results of the geologic investigation indicate that the Berea Sandstone can be considered the water table aquifer, with the Bedford Shale forming a relatively impervious confining unit underlying the aquifer.

Figure 7-6 is a water table contour map based on water level readings in the monitoring wells obtained August 18 through 20, 1987, and on the approximate water levels in the quarry and Black River. The water table level is also illustrated on the geologic cross-sections, Figure 7-4. The quarry area is represented as having a constant head of approximately 703 ft. due to the outlet work at the eastern side adjacent to the Black River.

In general, the groundwater flow direction is from southwest to northeast. The water table contours suggest that the quarry area is a partial groundwater sink from which discharge is uniformly directed toward the Black River. The gradient west of the quarry is about 0.065 ft./ft. The gradient east of the quarry between the quarry and Black River varies from 0.04 to 0.12 ft./ft.

The in-situ packer permeability test results can be divided into three categories: 1) tests performed entirely within the Berea Sandstone; 2) tests performed in strata that spans both the Berea Sandstone and the Bedford Shale; and 3) tests performed entirely within the Bedford Shale.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE 1" = 100'

LEGEND:

— 720 — WATER TABLE ELEVATION CONTOUR (MSL)

● 702.19 WATER TABLE ELEVATION (MSL)

0 200 400
SCALE IN FEET

NOTE: CONTOURS ARE BASED ON WATER LEVELS TAKEN IN WELLS DURING THE PERIOD OF AUGUST 18-20, 1987.

FIGURE 7-6
WATER TABLE CONTOUR MAP
REPUBLIC STEEL QUARRY RI

Permeability tests performed entirely within the Berea Sandstone resulted in hydraulic conductivities in the range of 10^{-3} to 10^{-6} cm/sec. Tests performed in strata that includes both the Berea Sandstone and Bedford Shale resulted in hydraulic conductivities in the range of 10^{-5} to 10^{-7} cm/sec. At least one permeability test was performed entirely within the Bedford Shale (B-8, 35.5 to 45.5 ft.), and this test yielded a hydraulic conductivity of 2×10^{-7} cm/sec.

The permeability tests performed in Boring B-4 cover the most complete geologic section and include both the upper and lower units of the Berea Sandstone. The pattern of hydraulic conductivity measurements relative to the geologic units described earlier is as follows:

Test Depth Range (ft.)	Geologic Unit	Hydraulic Conductivity (cm/sec)
21 - 54	Berea Sandstone, Upper Unit	10^{-3} to 10^{-5}
54 - 104	Berea Sandstone, Lower Unit	10^{-5} to 4×10^{-6}
104 - 114	Bedford Shale*	2×10^{-7}

* The data conflict on the depth to the Bedford Shale in Boring B-4. Geophysical logs put the top of the shale at a depth of 101 ft.; but the geologic log identifies the top of the shale at 109 ft., with the Berea Sandstone described as shaly from 103 to 109 ft.

Wells B-1 and B-7 can be used to characterize the vertical groundwater gradient within the water table aquifer. Well B-1 is screened at the base of the sandstone and Well B-7, located 10 ft. east of B-1, is screened near the top rock. The water level in B-1 was approximately 0.4 ft. higher than in B-7 and this indicates a slight upward vertical gradient in the Berea Sandstone at this location. Upward gradients in the vicinity of streams are not uncommon, and these wells are located about 50 ft. west of the Black River. In addition, the two wells are screened above and below the elevation interval of the thin shale zone (refer to Section 7.3.2). This shale, where present, may act as a leaky, confining layer, or aquitard, and may be responsible for the slight, upward head differential between B-1 and B-7.

The geophysical logs suggest that the Berea Sandstone is hydrogeologically divided by the thin shale unit. The temperature logs generally showed temperature anomalies in a 10 to 12 ft. zone immediately above the shale parting and in an 8 to 10 ft. zone above the base of the sandstone. The anomalies are attributed to relatively high temperature water recharging the aquifer upgradient.

7.6 RESIDENTIAL WELL INVENTORY

A residential well inventory was performed to identify groundwater users near the site. Previous site investigations concluded only upgradient wells were in use. This residential well inventory was performed to confirm that no downgradient wells are being used as potable water sources.

7.6.1 Ohio Department of Natural Resources (ODNR) Well Records

As a preliminary task for the residential well inventory, the Ohio Department of Natural Resources (ODNR) was contacted to obtain well logs located within a one mile radius of the site. Twenty-one wells were registered with ODNR within the one mile radius from the site. The well records that were received from ODNR are presented as Appendix K. The approximate locations of the wells were plotted on a USGS quadrangle, presented as Figure L-1 in Appendix L. None of the well locations was estimated to be downgradient from the site.

7.6.2 Residential Well Inventory Summary

On June 4 and 5, 1987, a residential well inventory of homes located within a one-half mile radius of the site was performed. The residents were contacted to see if they presently, or have in the past, used groundwater from private wells as their source of potable water. The well inventory was performed by going door-to-door between homes. Seventy-one homeowners within the half mile radius were contacted. The well inventory record sheets that were completed by the field team are included as Appendix L to this Technical Report.

Based on the results of the well inventory, the following conclusions were made:

1. There are no known residential wells operating within a one-half mile radius of the site.

2. There are no known existing downgradient wells that were previously used to provide potable water, although a number of abandoned upgradient wells were identified.

7.7 GROUNDWATER SAMPLING

Two groundwater sampling efforts were conducted. The first groundwater sampling program involved sampling the eight wells and was performed during the week of August 17, 1987. Twelve groundwater samples consisting of eight well samples, a duplicate sample, a bottle blank, a bailer blank, and a sample of the water used by the drillers for coring and packer testing were collected and submitted for laboratory analyses.

A second groundwater sampling program was performed on March 14, 1988, to verify the presence of volatile organic compounds detected at well B-1

during the first groundwater sampling program. Four samples were collected, including a bottle blank, bailer bank, groundwater sample from monitoring well B-1 and a groundwater sample from well B-3.

Groundwater sampling locations are shown on Figure 7-7. The eight monitoring well/groundwater sampling locations were selected in a pattern that surrounded the site to provide groundwater quality data. Samples were collected from monitoring wells B-2, B-3 and B-4 to establish background levels. A groundwater sample was collected from Well B-8, installed on the east bank of the West Branch of the Black River across from the site, to determine if groundwater is flowing beneath the river. Additionally, Well B-7 is a shallow well installed beside Well B-1 to determine vertical hydraulic gradients in the groundwater. Sampling locations were selected to identify groundwater flow direction and determine if contaminants are migrating from the quarry. Table 7-5 presents the sample number, location, sampling data and time, pH, conductivity, temperature, and dissolved oxygen of the groundwater samples.

7.7.1 Sampling Method

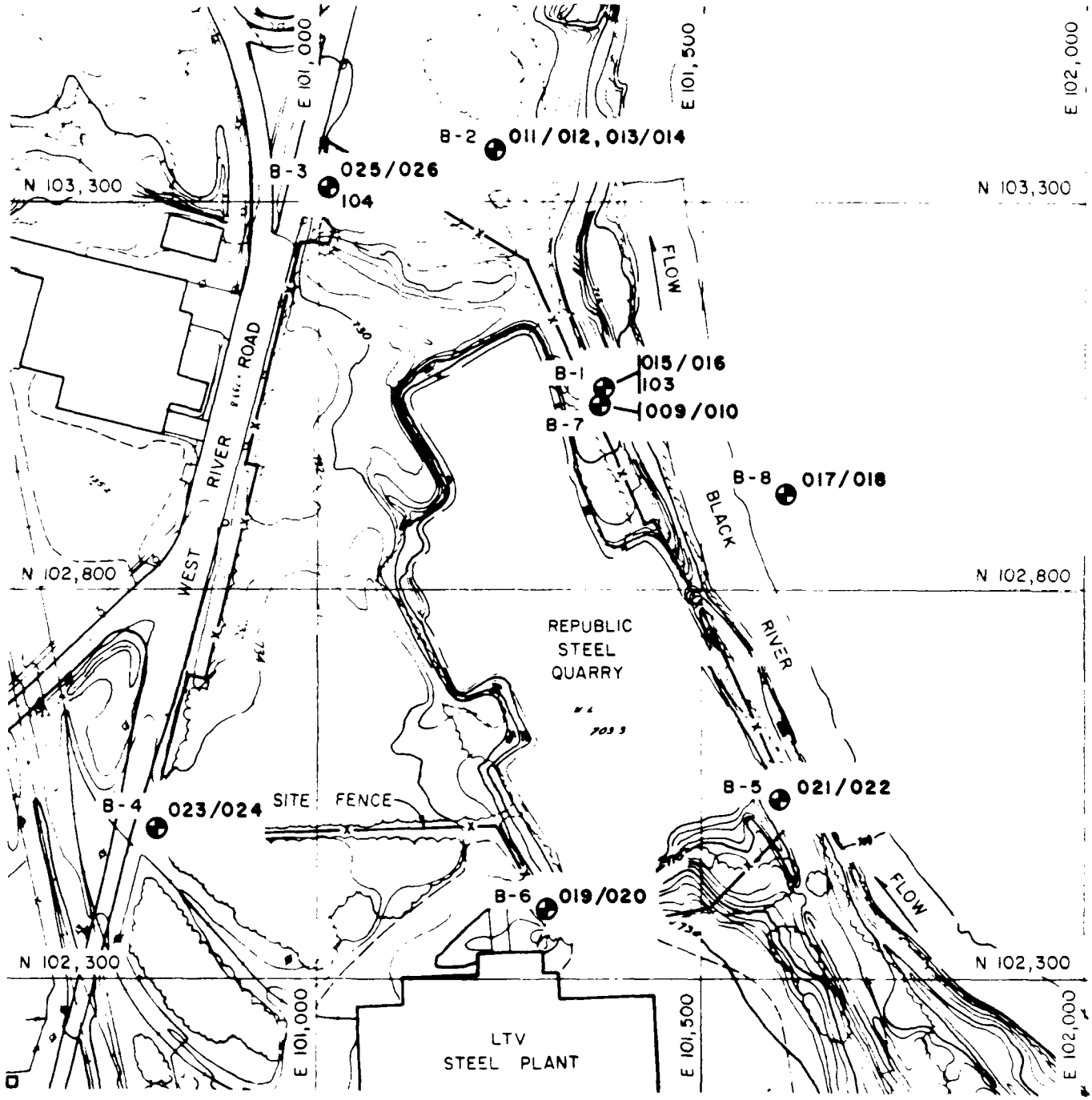
August, 1987, Samples: Prior to sampling the wells, a minimum of five well volumes were purged from the well using either a Fultz pump or by hand bailing. Dissolved oxygen, pH, conductivity, and temperature of the water were measured periodically during the purging. Dissolved oxygen, pH, temperature, and conductivity readings were taken at 5 minute intervals until three consecutive uniform values were obtained, indicating that the well had stabilized. Sampling of the wells was performed using decontaminated teflon bailers attached to nylon rope.

March, 1988, Samples: Prior to sampling the wells, a minimum of five well volumes were purged from the well by hand bailing. Dissolved oxygen, pH, conductivity, and temperature of the water were measured periodically during the purging. Dissolved oxygen, pH, temperature, and conductivity readings were taken at 5 minute intervals until three consecutive uniform values were obtained, indicating that the well had stabilized.

Sampling of the wells was performed using decontaminated teflon bailers attached to nylon rope.

7.7.2 Sample Numbering System and Laboratory Analyses

August, 1987, Program: Two sample numbers were used to identify each sample location. Odd numbered samples were not filtered, and were analyzed for volatile organics, acid and base/neutral extractables, pesticides/PCB's, metals, cyanide, oil and grease, total suspended solids(TSS), total dissolved solids (TDS), acidity, alkalinity, sulfate, chloride, and hexavalent chromium (hexachrome). Even numbered samples were filtered through a 0.45 micron filter and analyzed for metals and hexachrome. For example, sample GW001/002 is actually one sample, with 002 representing the filtered portion of sample 001 to be analyzed for metals and hexachrome.



SOURCE: CITY OF ELYRIA ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

B-3 025/026 — GROUNDWATER SAMPLE NUMBER 025/026 FROM AUGUST, 1987 GROUNDWATER SAMPLING PROGRAM

104 — GROUNDWATER SAMPLE NUMBER 104 FROM MARCH, 1988 GROUNDWATER SAMPLING PROGRAM

B-3 — MONITORING WELL B-3

N

0 200 400
SCALE IN FEET

FIGURE 7-7
GROUNDWATER SAMPLING LOCATIONS
REPUBLIC STEEL QUARRY RI

TABLE 7-5
GROUND WATER SAMPLE DESCRIPTIONS
REPUBLIC STEEL QUARRY RI

SAMPLE NUMBER	SAMPLE LOCATION	SAMPLING DATE	SAMPLING TIME	pH	SPECIFIC CONDUCTANCE (UMHOS/CM.)	TEMPERATURE (C)	DISSOLVED OXYGEN (MG/L)
GW001/002	BOTTLE BLANK	08/18/87	0800	5.16	002	23.5	4.2
GW003/004	TEFLON BAILER RINSATE	08/18/87	0900	5.09	002	26.0	3.6
GW007/008	CITY OF ELYRIA-DRILLING WATER USED	08/18/87	1000	6.15	218	24.5	3.1
GW009/010	MONITORING WELL B-7	08/19/87	0905	5.55	600	12.0	1.8
GW011/012	MONITORING WELL B-2	08/18/87	1600	7.04	800	15.0	9.3
GW013/014	MONITORING WELL B-2 (SPLIT)	08/18/87	1600	7.04	800	15.0	9.3
GW015/016	MONITORING WELL B-1	08/19/87	1000	5.70	1800	14.0	0.7
GW017/018	MONITORING WELL B-8	08/19/87	1215	6.79	1710	14.0	2.3
GW019/020	MONITORING WELL B-6	08/19/87	1445	7.30	800	13.0	2.4
GW021/022	MONITORING WELL B-5	08/20/87	1150	6.84	1200	11.0	2.2
GW023/024	MONITORING WELL B-4	08/20/87	1248	7.33	770	11.0	1.7
GW025/026	MONITORING WELL B-3	08/20/87	1110	6.83	810	12.0	1.5
GW101	BOTTLE BLANK	03/14/88	0730	8.60	25	3.0	10.5
GW102	TEFLON BAILER RINSATE	03/14/88	0740	8.60	25	3.0	10.5
GW103	MONITORING WELL B-1	03/14/88	0930	7.30	2030	1.0	2.5
GW104	MONITORING WELL B-3	03/14/88	1030	8.40	2010	13.0	1.0

NOTE: EVEN NUMBERED SAMPLES WERE COLLECTED AT THE SAME SAMPLE LOCATION AS THE PREVIOUS ODD
==== NUMBER, AND WERE FILTERED THROUGH A 0.45 MICRON FILTER PRIOR TO PRESERVATION AND SHIPMENT
FOR LABORATORY ANALYSES.

The EPA Eastern District Office laboratory, located in Westlake, Ohio, provided hexachrome analysis for the groundwater samples. All other laboratory analyses were performed by Contract Laboratory Program (CLP) labs.

March, 1988, Program: One sample number was used to identify each sample location since samples were submitted for only volatile organics analyses.

7.8 LABORATORY ANALYSES PERFORMED AND RESULTS

Laboratory analyses performed on each groundwater sample are summarized on tables in Appendix E. Laboratory analytical results from the groundwater samples are presented in Appendix F. Summary tables presenting only chemical concentrations identified above analytical detection limits are presented as Tables 7-6 and 7-7. Laboratory QA problems with groundwater analyses are presented in Appendix G. No significant QA problems were identified during review of laboratory methods and results.

7.9 NATURE AND EXTENT OF CONTAMINATION

Chemicals that were detected in the groundwater samples and presented on Tables 7-6 and 7-7 were analyzed to develop conclusions on the nature and extent of site related contamination. This analysis was performed by dividing the samples obtained into two groups: samples from upgradient wells (background) and samples from downgradient wells (site related). Upgradient wells included B-2, B-3 and B-4. Downgradient wells were B-1, B-5, B-6, B-7 and B-8. Downgradient concentrations of parameters were compared to upgradient concentrations to assess potentially site related contamination.

Criteria were developed to determine if chemicals identified in downgradient samples were potentially site related. Chemicals were labeled potentially site related if the following criteria were met:

- Chemicals were detected in downgradient monitoring wells at greater than or equal to twice the concentration observed in background groundwater samples. The rationale for the selection of two times the background concentration as an evaluation criterion is presented in Appendix G, Data Considerations.

- Chemicals were detected in greater than one downgradient monitoring well, or the chemical was found in only one onsite sample but was identified as potentially site related in other environmental media at the site.

TABLE 7-6
VOLATILE & SEMI-VOLATILE ORGANICS DETECTED IN GROUNDWATER
REPUBLIC STEEL QUARRY RI

		Volatile Organics					Semi-Volatile Organics					
Sample Number	Sample Location	Methylene Chloride	Chloroform	Bromodichloro-Methane	Toluene	Acetone	Pentachloro-phenol	Butylbenzyl-phthalate	Di-n-butyl-phthalate	bis(2-Ethylhexyl) phthalate	Phenol	Benzoic Acid
GW001	Bottle Blank	4 J	--	--	--	--	--	--	--	--	--	--
GW003	Bailer Blank	8	--	--	3 J	--	--	3 J	--	--	--	--
GW007	Elyria Water	11	74	19	2 J	--	--	--	--	--	--	--
GW009	Well B-7	--	--	--	--	--	5 J	--	--	--	--	--
GW011	Well B-2	6	--	--	1 J	--	--	--	--	--	--	--
GW013	Well B-2 Split	--	--	--	--	--	--	--	3 J	10	--	--
GW015	Well B-1	140	9	--	4 J	55	--	--	--	11 B	10	42 J
GW017	Well B-8	--	--	--	2 J	--	--	--	--	--	--	--
GW023	Well B-4	3 J	--	--			--	--	--	--	--	--
GW101	Bottle Blank	--	--	--	1 J	--	--	--	--	--	--	--
GW103	Well B-1	--	--	--	1 J	--	--	--	--	--	--	--
GW104	Well B-3	--	--	--	4 J	--	--	--	--	--	--	--

NOTES: All concentrations are presented in micrograms per liter, ug/l.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
-- Not Detected

GW001 series samples were collected during August 1987.
GW101 series samples were collected during March 1988.

TABLE 7-7
INORGANICS DETECTED IN GROUNDWATER
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	GW001	GW002	GW003	GW004	GW007	GW008	GW009	GW010	GW011	GW012	GW013	GW014
SAMPLE DATE:	08/18/87	08/18/87	08/18/87	08/18/87	08/18/87	08/18/87	08/19/87	08/19/87	08/18/87	08/18/87	08/18/87	08/18/87
SAMPLE LOCATION:	BOTTLE BLANK	BOTTLE BLANK	BAILER BLANK	BAILER BLANK	ELYRIA WATER	ELYRIA WATER	WELL B-7	WELL B-7	WELL B-2	WELL B-2	WELL B-2 SPLIT	WELL B-2 SPLIT
ALUMINUM	--	[18]	--	--	425	250	2030	[32]	[114]	--	292	[30]
ANTIMONY	--	--	[57]	--	--	--	--	--	--	--	--	--
ARSENIC	--	--	--	--	--	--	13	--	--	--	--	--
BARIUM	--	--	--	--	[20]	[15]	[35]	[21]	[20]	[19]	[22]	[20]
BERYLLIUM	--	--	--	--	--	--	--	--	--	--	--	--
CADMIUM	--	--	--	--	--	--	--	--	5.1	--	--	[4]
CALCIUM	--	[270]	--	[475]	36200	33500	69700	65600	120000	117000	124000	117000
CHROMIUM	--	--	--	--	--	--	--	--	--	--	--	--
COBALT	--	--	--	--	--	--	[9.4]	--	--	--	--	--
COPPER	--	--	--	--	[11]	--	--	--	--	--	[7.1]	--
IRON	--	[45]	--	--	--	--	153000	132000	426	120	616	130
LEAD	--	--	--	--	--	--	--	--	--	--	--	--
MAGNESIUM	--	--	--	--	7860	7540	23100	21800	55400	54100	55300	53800
MANGANESE	--	--	--	[8.7]	45	[8]	3340	3160	145	137	152	140
NICKEL	--	--	--	--	--	--	[30]	[21]	--	--	--	--
POTASSIUM	--	--	--	--	[1400]	[1420]	7480	6890	[3250]	[3280]	[3380]	[3300]
SILVER	--	--	--	--	--	--	[4.1]	--	--	--	--	--
SODIUM	--	[1110]	--	--	8920	19300	29700	31900	66000	72900	65800	73400
TIN	--	--	119	--	--	--	--	--	--	--	--	--
VANADIUM	--	--	--	--	--	--	[8.7]	--	--	--	--	--
ZINC	[6.8]	[15]	[8.7]	[18]	[6.5]	[5.9]	77	36	[7.7]	21	21	26
CYANIDE	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA
HEXACHROME	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL SUSPENDED SOLIDS	--	NA	3000	NA	1000	NA	20000	NA	31000	NA	474000	NA
TOTAL DISSOLVED SOLIDS	--	NA	--	NA	139000	NA	697000	NA	733000	NA	2210000	NA
TOTAL ALKALINITY	--	NA	--	NA	87300	NA	420000	NA	425000	NA	324000	NA
ACIDITY	--	NA	--	NA	--	NA	--	NA	--	NA	--	NA
CHLORIDE	--	NA	--	NA	19000	NA	--	NA	--	NA	808000	NA
SULFATE	--	NA	--	NA	34000	NA	242000	NA	242000	NA	120000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.
NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.
R The spike sample recovery is not within control limits.
-- Not Detected

TABLE 7-7 (Continued)
INORGANICS DETECTED IN GROUNDWATER
REPUBLIC STEEL QUARRY RI

SAMPLE NO:	GW015	GW016	GW017	GW018	GW019	GW020	GW021	GW022	GW023	GW024	GW025	GW026
SAMPLE DATE:	08/19/87	08/19/87	08/19/87	08/19/87	08/19/87	08/19/87	08/20/87	08/20/87	08/20/87	08/20/87	08/20/87	08/20/87
SAMPLE LOCATION:	WELL B-1	WELL B-1	WELL B-8	WELL B-8	WELL B-6	WELL B-6	WELL B-5	WELL B-5	WELL B-4	WELL B-4	WELL B-3	WELL B-3
ALUMINUM	11600	--	5840	--	10800	[17]	482	--	2180	[24]	[188]	--
ANTIMONY	--	--	--	--	--	--	--	--	--	82	--	--
ARSENIC	--	--	--	--	21	--	--	--	--	--	26	21 R
BARIUM	[104]	[70]	[114]	[88]	[48]	[15]	[20]	[18]	[16]	[8.2]	38	[38]
BERYLLIUM	[2.1]	--	[1]		[1.6]	--	--	--	--	--	--	--
CADMIUM	--	--	6.4	[4.6]	--	--	[4.1]	--	--	[4.5]	--	6.8
CALCIUM	348000	352000	238000	233000	170000	161000	477000	464000	31500	30200	130000	129000
CHROMIUM	[8.5]	--	[9.7]	--	20	--	--	--	[7]	--	--	--
COBALT	--	--	[13]	--	[18]	--	--	--	--	--	--	--
COPPER	--	--	[15]	--	28	--	--	--	[7.9]	--	--	--
IRON	571000	554000	15500	738	46900	[61]	17400	15800	2450 R	[70] R	647 R	186 R
LEAD	--	--	--	--	19	--	--	--	--	--	--	--
MAGNESIUM	88000	83300	50800	49300	53100	45400	33500	32300	16600	15700	63300	62700
MANGANESE	11600	11400	842	672	799	189	286	274	32	[6.2]	661	658
NICKEL	131	[96]	[24]		48	--	--	--	[8.5]	--	[14]	[15]
POTASSIUM	37200	31400	[4790]	[2780]	6580	[3700]	[4850]	[4600]	5360	[4720]	[3070]	[3070]
SILVER	--	--	--	--	--	--	--	--	--	--	--	--
SODIUM	91100	87200	324000	330000	62700	64400	55800	54000	143000	139000	75400	75500
TIN	[73]	--	--	--	--	--	--	--	--	115	--	--
VANADIUM	[57]	--	[14]	--	[33]	--	--	--	--	[7]	--	--
ZINC	99	[44]	35	[15]	106	[9.5]	[15]	[11]	[13]	[7.7]	[9.3]	[9.1]
CYANIDE	--	NA	--	NA	--	NA	--	NA	--	NA		NA
HEXACHROME	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL SUSPENDED SOLIDS	224000	NA	180000	NA	948000	NA	34000	NA	37000	NA	13000	NA
TOTAL DISSOLVED SOLIDS	3320000	NA	548000	NA	899000	NA	2220000	NA	744000	NA	952000	NA
TOTAL ALKALINITY	62500	NA	--	NA	209000	NA	280000	NA	417000	NA	414000	NA
ACIDITY	587000	NA	158000	NA	--	NA	--	NA	--	NA	--	NA
CHLORIDE	38100	NA	37900	NA	154000	NA	42500	NA	6500	NA	5500	NA
SULFATE	1760000	NA	360000	NA	270000	NA	935000	NA	27200	NA	264000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.
NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.
R The spike sample recovery is not within control limits.
-- Not Detected

Table 7-8 presents the chemicals, number of samples analyzed, number of times detected, percent detected, maximum and minimum concentrations detected, an evaluation of whether the chemical is potentially site related and the location where the maximum concentration was observed. The results of the evaluations are discussed in the following items.

7.9.1 Volatile Organics

Four volatile organic compounds were detected in groundwater samples collected from the monitoring wells at the Republic Steel Quarry Site. Acetone was detected in the June 1987 well sampling in Well B-1, but was not detected in later sampling. Acetone was identified as a site related chemical for soil and sediment, and is therefore being included as site related for groundwater since it was only detected at downgradient locations. Methylene chloride was also detected in Monitoring Well MW-1 during the first groundwater sampling effort and was also detected in background and field blank samples in much lower levels. Methylene chloride was not detected during the second groundwater sampling effort in March 1988. Nevertheless, methylene chloride is being considered a site related chemical.

Chloroform was detected in one downgradient sample and in a sample of water used to drill the monitoring wells. Chloroform is not considered to be a site related compound. Toluene was found in onsite, offsite and field blank samples at approximately equal concentrations. Toluene is not considered a site related chemical in groundwater.

7.9.2 Semi-Volatile Organics

Four semi-volatile organic compounds were detected in site related groundwater samples. Two of the four compounds are considered to be potentially site related. Pentachlorophenol and phenol were detected in downgradient monitoring wells but were not found in upgradient wells and are being considered site related chemicals in groundwater. The semi-volatile compounds were detected in either Well B-1 or B-7. These two wells form a nested system along the eastern bank of the quarry. Well B-1 was also the only downgradient well where volatile organic compounds were detected.

Bis(2-ethylhexyl)phthalate was detected in one upgradient and one downgradient monitoring well at approximately equal concentrations and is not considered a site related chemical for groundwater.

Benzoic acid was detected at one downgradient monitoring well, but not in any other environmental media at the site. Benzoic acid is not concluded to be potentially site related.

TABLE 7-8
SUMMARY OF NATURE & EXTENT EVALUATION
GROUNDWATER SAMPLES
REPUBLIC STEEL QUARRY RI

VOLATILE ORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
Acetone	Site Related	6	1	17%	55	55	YES	Well B-1
	Background	5	0	0%	BDL	BDL		
	Field QA	2	0	0%	BDL	BDL		
Chloroform	Site Related	6	1	17%	9	9	NO	Well B-1
	Background	5	0	0%	BDL	BDL		
	Field QA	2	0	0%	BDL	BDL		
Methylene Chloride	Site Related	6	1	17%	140	140	YES	Well B-1
	Background	5	2	40%	6	3		
	Field QA	2	1	50%	8	8		
Toluene	Site Related	6	3	50%	4	1	NO	Well B-1
	Background	5	2	40%	4	1		Well B-3
	Field QA	2	1	50%	3	3		

SEMI-VOLATILE ORGANIC ANLYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
Benzoic acid	Site Related	5	1	20%	42	42	NO	Well B-1
	Background	4	0	0%	BDL	BDL		
	Field QA	1	0	0%	BDL	BDL		
bis(2-ethylhexyl)phthalate	Site Related	5	1	20%	11	11	NO	Well B-1
	Background	4	1	25%	10	10		
	Field QA	1	0	0%	BDL	BDL		
Pentachlorophenol	Site Related	5	1	20%	5	5	YES	Well B-7
	Background	4	0	0%	BDL	BDL		
	Field QA	1	0	0%	BDL	BDL		
Phenol	Site Related	5	1	20%	10	10	YES	WELL B-1
	Background	4	0	0%	BDL	BDL		
	Field QA	1	0	0%	BDL	BDL		

PESTICIDE/PCBs ORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM

(PESTICIDES/PCBs WERE NOT DETECTED IN GROUNDWATER)

TABLE 7-8 (Continued)
SUMMARY OF NATURE & EXTENT EVALUATION
GROUNDWATER SAMPLES
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
Aluminum	Site Related	10	7	70%	11600	17	YES	Well B-1
	Background	8	6	75%	2180	24		
	Field QA	2	0	0%	BDL	BDL		
Arsenic	Site Related	10	2	20%	21	13	NO	Well B-3
	Background	8	2	25%	26	21		
	Field QA	2	0	0%	BDL	BDL		
Barium	Site Related	10	10	100%	114	15	YES	Well B-8
	Background	8	8	0%	38	8.2		
	Field QA	2	0	0%	BDL	BDL		
Beryllium	Site Related	10	3	30%	2.1	1	YES	Well B-1
	Background	8	0	0%	BDL	BDL		
	Field QA	2	0	0%	BDL	BDL		
Cadmium	Site Related	10	3	30%	6.4	4.1	NO	Well B-3
	Background	8	4	50%	6.8	4		
	Field QA	2	0	0%	BDL	BDL		
Calcium	Site Related	10	10	100%	477000	65600	YES	Well B-5
	Background	8	8	0%	130000	30200		
	Field QA	2	1	50%	475	475		
Chromium	Site Related	10	3	30%	20	8.5	YES	Well B-6
	Background	8	1	13%	7	7		
	Field QA	2	0	0%	BDL	BDL		
Cobalt	Site Related	10	3	30%	18	9.4	YES	Well B-6
	Background	8	0	0%	BDL	BDL		
	Field QA	2	0	0%	BDL	BDL		
Copper	Site Related	10	2	20%	28	15	YES	Well B-6
	Background	8	2	25%	7.1	7		
	Field QA	2	0	0%	BDL	BDL		
Iron	Site Related	10	10	100%	571000	61	YES	Well B-1
	Background	8	8	100%	2450	70		
	Field QA	2	0	0%	BDL	BDL		
Lead	Site Related	10	1	10%	19	19	YES	Well B-6
	Background	8	0	0%	BDL	BDL		
	Field QA	2	0	0%	BDL	BDL		

TABLE 7-8 (Continued)
SUMMARY OF NATURE & EXTENT EVALUATION
GROUNDWATER SAMPLES
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
Magnesium	Site Related	10	10	100%	88000	21800	NO	Well B-1
	Background	8	8	100%	63300	15700		
	Field QA	2	0	0%	BDL	BDL		
Manganese	Site Related	10	10	100%	11600	189	YES	Well B-1
	Background	8	8	100%	661	6.2		
	Field QA	2	1	50%	8.7	8.7		
Nickel	Site Related	10	6	60%	131	21	YES	Well B-1
	Background	8	3	38%	15	8.5		
	Field QA	2	0	0%	BDL	BDL		
Potassium	Site Related	10	10	100%	37200	2780	YES	Well B-1
	Background	8	8	100%	5360	3070		
	Field QA	2	0	0%	BDL	BDL		
Silver	Site Related	10	1	10%	4.1	4.1	NO	Well B-7
	Background	8	0	0%	BDL	BDL		
	Field QA	2	0	0%	BDL	BDL		
Sodium	Site Related	10	10	100%	330000	29700	NO	Well B-8
	Background	8	8	100%	143000	65800		
	Field QA	2	0	0%	BDL	BDL		
Tin	Site Related	10	1	10%	73	73	NO	Bailer Blank
	Background	8	1	13%	115	115		
	Field QA	2	1	50%	119	119		
Vanadium	Site Related	10	4	40%	57	8.7	YES	Well B-1
	Background	8	1	13%	7	7		
	Field QA	2	0	0%	BDL	BDL		
Zinc	Site Related	10	10	100%	106	9.5	YES	Well B-6
	Background	8	8	100%	26	7.7		
	Field QA	2	2	100%	18	8.7		
Tot. Suspended Solids	Site Related	5	5	100%	948000	20000	NO	Well B-6
	Background	4	4	100%	474000	13000		
	Field QA	1	1	100%	3000	3000		

TABLE 7-8 (Continued)
SUMMARY OF NATURE & EXTENT EVALUATION
GROUNDWATER SAMPLES
REPUBLIC STEEL QUARRY RI

INORGANIC ANALYSES

CHEMICAL	SAMPLE LOCATION	NO. SAMPLES ANALYZED	NO. TIMES DETECTED	PERCENT DETECTED	MAXIMUM VALUE	MINIMUM VALUE	SITE RELATED	LOCATION OF MAXIMUM
Tot. Dissolved Solids	Site Related	5	5	100%	3320000	548000	NO	Well B-1
	Background	4	4	100%	2210000	733000		
	Field QA	1	0	0%	BDL	BDL		
Tot. Alkalinity	Site Related	5	4	80%	420000	62500	NO	Well B-2
	Background	4	4	100%	425000	324000		
	Field QA	1	0	0%	BDL	BDL		
Acidity	Site Related	5	2	40%	587000	158000	YES	Well B-1
	Background	4	0	0%	BDL	BDL		
	Field QA	1	0	0%	BDL	BDL		
Chloride	Site Related	5	4	80%	154000	37900	NO	Well B-2
	Background	4	3	75%	808000	5500		
	Field QA	1	0	0%	BDL	BDL		
Sulfate	Site Related	5	5	100%	1760000	242000	YES	Well B-1
	Background	4	4	100%	264000	27200		
	Field QA	1	0	0%	BDL	BDL		

NOTES: Wells B-2, B-3, B-4 are considered upgradient, background.
BDL = Below Detection Limit
Organic analyses maximum and minimum values are presented in micrograms per liter (ug/l).
Inorganic analyses maximum and minimum values are presented in milligrams per liter (ug/l).

7.9.3 Pesticides/PCBs Organics

No pesticides, PCBs or oil and grease were detected in groundwater samples collected from the Republic Steel Quarry Site.

7.9.4 Inorganic Analyses

Numerous inorganic parameters were detected in groundwater samples collected from the site. Aluminum, barium, calcium, chromium, cobalt, copper, iron, lead, manganese, nickel, vanadium and zinc were detected in greater concentrations in downgradient wells than in upgradient wells, and are considered potentially site related chemicals for groundwater. Acidity and sulfate were also observed to be at elevated concentrations in downgradient monitoring wells and are considered potentially site related.

Arsenic, cadmium, magnesium, sodium, and tin were detected at similar concentrations in upgradient and downgradient wells and are not concluded to be site related elements for groundwater. Silver was detected at only one downgradient monitoring well and was not determined to be potentially site related in any other media; therefore, silver is not considered a site related contaminant in groundwater. Total suspended solids, total dissolved solids, total alkalinity and chloride were also at similar concentrations in upgradient and downgradient wells and were not concluded to be site related parameters.

Some inorganic chemicals were detected downgradient of the site and across the Black River in Well B-8. Based on the groundwater sampling results, it could be concluded that the groundwater from the quarry may be conveyed beneath the Black River in the vicinity of B-8. This groundwater movement could occur across a fracture that intercepts the quarry and the Well B-8 area. This, however, does not seem likely since the Black River appears to be a discharge point for groundwater on both sides of the Black River, based on available data. Groundwater would not be expected to move from the west to the east side of the river. There is not adequate data to attribute the elevated concentrations of inorganic chemicals in Well B-8 to the site.

7.9.5 Summary

The results of the groundwater sampling during the RI indicate that the quarry is affecting the chemistry of the water within the Berea Sandstone immediately adjacent to and downgradient of the site. Site related organic chemicals were detected only adjacent to the eastern quarry wall. Inorganic contaminants were detected downgradient and across the

Black River from the quarry in Well B-8. Chemicals identified as being potentially site related are summarized below:

Volatile Organics	Semi-Volatile Organics	Inorganics
Acetone	Pentachlorophenol	Aluminum
Methylene Chloride	Phenol	Barium
		Beryllium
		Calcium
		Chromium
		Cobalt
		Copper
		Iron
		Lead
		Manganese
		Nickel
		Potassium
		Vanadium
		Zinc

8.0 CHEMICAL FATE AND TRANSPORT

8.1 INTRODUCTION

During the remedial investigation, many chemicals were detected in surface soil, sediment, surface water, and groundwater at the Republic Steel Quarry Site. This section will focus on the environmental chemistry and the fate and transport of potentially site related chemicals identified in the previous four sections of this RI Report. Table 8-1 summarizes these chemicals in their associated media. As indicated in the table, only calcium, iron and nickel were considered potentially site related in all four environmental media.

Surface water and groundwater at the site appear to be less contaminated by organic chemicals than sediments and soils, based on Table 8-1 and a review of organic chemical concentrations detected in the environmental media. A number of inorganic parameters were detected at elevated concentrations at the site; however, many of the inorganic chemicals were found in only one media and may not be related to site disposal operations, (e.g., aluminum, arsenic, beryllium, cobalt, potassium, and tin).

To convert the list of potentially site related chemicals identified in the media by media analysis to a more representative list of chemicals that may have been disposed of in the quarry, chemicals that were determined to be potentially site related in only one media were eliminated. This basis for eliminating certain chemicals is reasonable since one would expect to find elevated concentrations in more than one media if a chemical is site related. For example, site related chemicals in surface water would likely be detected at elevated concentrations in groundwater, sediments and soils due to direct contact and periodic inundation. Nevertheless, for purposes of the endangerment assessment in Section 9.0, all site related chemicals were included for evaluation of risk.

Following application of the above criterion to establish chemicals which may be applicable to disposal activities for the site as a whole, the following list of chemicals is obtained.

Volatile Organics	Semi-Volatile Organics	Inorganics	SAS
Acetone	Benzo(a)anthracene	Barium	Oil/Grease
2-Butanone	Benzo(b)fluoranthene	Calcium	Acidity
Methylene Chloride	Benzo(k)fluoranthene	Chromium	Sulfate
	bis(2-ethylhexyl)phthalate	Copper	
	Chrysene	Iron	
	Di-n-butylphthalate	Lead	
	Di-n-octylphthalate	Magnesium	
	Fluoranthene	Manganese	
	Pentachlorophenol	Mercury	
	Pyrene	Nickel	
		Vanadium	
		Zinc	

TABLE 8-1
REPUBLIC STEEL QUARRY
POTENTIALLY SITE RELATED CHEMICALS IDENTIFIED

CHEMICALS	GROUND WATER	SURFACE WATER	SEDIMENT	SURFACE SOILS
VOLATILE ORGANICS:				
Acetone	X		X	X
2-Butanone			X	X
Ethylbenzene			X	
Methylene Chloride	X		X	X
Tetrachloroethene			X	
Toluene			X	
SEMI-VOLATILE ORGANICS:				
Anthracene			X	
Benzo(a)anthracene			X	X
Benzo(a)pyrene			X	
Benzo(b)fluoranthene			X	X
Benzo(k)fluoranthene			X	X
Benzo(g,h,i)perylene			X	
bis(2-ethylhexyl)Phthalate			X	X
Butylbenzylphthalate			X	
Chrysene			X	X
Diethylphthalate			X	
Di-n-butylphthalate			X	X
Di-n-octylphthalate			X	X
Fluoranthene			X	X
Indeno (1,2,3-cd) pyrene			X	
Pentachlorophenol	X		X	
Phenanthrene			X	
Phenol	X			
Pyrene			X	X
PESTICIDES/PCBs & SAS ORGANICS:				
Oil and Grease		X	X	X
Total Organic Carbon	NA	NA	X	NA

TABLE 8-1 (continued)
REPUBLIC STEEL QUARRY
POTENTIALLY SITE RELATED CHEMICALS IDENTIFIED

CHEMICALS	GROUND WATER	SURFACE WATER	SEDIMENT	SURFACE SOILS
INORGANICS and other SAS:				
Aluminum	X			
Arsenic			X	
Barium	X	X		
Beryllium	X			
Calcium	X	X	X	X
Chromium	X		X	X
Cobalt	X			
Copper	X		X	X
Iron	X	X	X	X
Lead	X		X	
Magnesium		X	X	
Manganese	X	X		
Mercury			X	X
Nickel	X	X	X	X
Potassium	X			
Tin			X	
Vanadium	X	X		
Zinc	X	X	X	
Total Suspended Solids			NA	NA
Total Dissolved Solids		X	NA	NA
Total Alkalinity			NA	NA
Acidity	X	X	NA	NA
Chloride			NA	NA
Sulfate	X	X	NA	NA

NA = Not Analyzed

8.2 FACTORS AFFECTING CONTAMINANT MIGRATION

Chemical migration consists of the following elements:

- o A source of contamination
- o A mechanism of chemical release to the environment
- o An environmental transport mechanism for the released chemical.

Factors that can affect the rate of release and transport include characteristics of the media of transport, physical/chemical characteristics of chemicals, and interactions between the media and associated chemicals. These factors, which have the potential to accelerate or hinder chemical migration, are discussed below. Appendix M summarizes the physical and chemical properties of the site related chemicals which are important determinants of their environmental behavior.

8.2.1 Release Mechanisms

An important parameter in describing the release potential and mobility of organic chemicals from soil or sediment to groundwater and surface water is the soil-water partition coefficient, K_D. Sediment appears to be the major source of chemicals in the Republic Steel Quarry Site. Organic compounds will adsorb preferentially to the organic carbon in the soil and sediment. The transport of chemicals from the sediment to groundwater and/or surface water is governed by the organic carbon partition coefficient (K_{OC}). K_{OC} multiplied by the fraction of organic carbon (f_{OC}) in the media results in the soil-water partition coefficient (K_D). Thus, the partitioning of organics between soil/sediment and groundwater (and surface water) is a function of the organic carbon content (f_{OC}) of the soil and the organic carbon partition coefficient (K_{OC}) of the chemical. The K_D is derived by the following:

$$K_D = (K_{OC})(f_{OC})$$

An example K_D calculation is included in Appendix O.

Thus, this term describes the partitioning of organics between sediment or soil and water. Analysis of the organic carbon content of sediment at the Republic Steel Quarry Site indicate a relatively high organic carbon content, approximately 135,000 mg/kg in certain sediment samples, compared to a typical value for sandy soils of about 1,000 mg/kg. Organic carbon results are presented in Table F-8 of Appendix F. Most of the chemicals detected in soils and sediments are of moderate relative solubility and K_{OC}; however, the high concentration of organic carbon in the sediments indicate that the chemicals of concern will have restricted mobility.

Factors affecting the release of inorganics vary with characteristics of the particular chemical. In general, most metals will only be released from soil to water at low pH. A condition that historically was a very important release mechanism for sediment bound metals of the quarry. The low pH bottom water, created by the addition of acidic pickle liquor into the quarry, presumably created a condition where metals were very mobile and able to

migrate freely through groundwater and surface water. Presently, the pH of the bottom water is around 6 and it is assumed that metal mobility has been reduced. The presence of clay minerals, other metal ions, hydrous metal oxides, and organic matter, may also inhibit the release and transport of inorganic chemicals. The primary exception is chromium VI which is mobile under most conditions. Chromium VI was not detected in any groundwater or surface water samples collected from the site.

Releases of chemicals may occur from the sediments to surface water in the quarry. Releases may then occur from the quarry water to the air via volatilization. In this case the partitioning of chemicals between the sediment and surface water is dependent not only on the organic carbon in the sediment and the organic carbon partition coefficient of the chemicals, but the depth of water in the pond, the depth of the sediment, the volatility of the chemical (as measured by its Henry's Law constant) and the prevailing wind speed and direction. These parameters describe the mass transfer relationships among the sediment, water, and soil.

Releases of chemicals to air from the quarry surface water are governed by the mass-transfer relationships which are dependent on chemical volatility, air temperature, water temperature, wind induced turbulence, water depth, and surface area of the pond through which the flux of chemicals may occur.

8.2.2 Transport and Fate Mechanisms

The following parameters provide a summary of information concerning the fate and transport of chemicals identified at the Republic Steel Quarry Site.

Physical Mechanisms: Once released, migration of chemicals in groundwater and surface water is controlled in large part by the geologic, hydrogeologic, and physical setting of the site. The hydrogeologic parameters governing groundwater flow (e.g., permeability and porosity) play a dominant role in establishing the level of advection and dispersion of chemicals in groundwater. Potential discharge points from an aquifer include wells, surface water bodies, seeps and springs, and other aquifers. The physical setting of the site controls migration of contaminants in the surface water by directing water to the Black River through the quarry discharge works.

As described in Section 7, the site is situated in the Berea Sandstone which has moderate hydraulic transmissivity. The less permeable Bedford Shale located beneath the Berea sandstone should tend to retard vertical migration of soluble chemicals. Lateral migration of chemicals through the Berea Sandstone, and particularly through fracture flow, may be a significant transport mechanism. West of the Black River, groundwater flow direction is to the east toward the Black River. Based on water level elevation readings from Well B-8 and the Black River, groundwater flow direction east of the Black River is west toward the Black River. As such, the Black River appears to be a regional discharge point for groundwater. Section 7 describes the geologic conditions at the Republic Steel Quarry in greater detail.

As described in Section 4, the quarry discharge to the Black River was approximated to be 15 gpm during the field investigation. Analyses outlined in Section 4 indicate that contaminants in the quarry surface water are not adversely affecting water quality in the river.

Solubility: The water solubility of a substance is a critical property affecting the environmental fate of organic chemicals. Highly soluble chemicals can be rapidly leached from sediments or soils and are generally mobile in groundwater. Solubilities of organic chemicals range from less than 1 ppb to greater than 100,000 ppm, with most common organic chemicals falling between 1 ppm and 100,000 ppm (EPA 1986a)). Solubility, along with several other factors, also affects volatilization from water. In general, high solubility is associated with lower volatilization rates. Vapor pressure and Henry's law constants are also measures of a chemical's volatility. Vapor pressure, a relative measure of the volatility of chemicals in their pure state, ranges from 0.001 to 760 mm Hg for liquids (EPA 1986a). Henry's law constant, which combines vapor pressure with solubility and molecular weight, is more appropriate for estimating releases to air from water. Chemicals with Henry's law constants in the range of 10^{-3} to 10^{-5} are associated with possibly significant but not rapid volatilization, while chemicals with values less than 10^{-5} will only volatilize slowly from water (Lyman 1982).

The VOCs detected at the site are relatively soluble in water and are likely to be leached out of the contaminated soil and sediment and transported into the groundwater and surface water. However, VOCs are still detected in soil and sediment 20 years after disposal operations ceased at the quarry which may indicate that the high TOC and sorption kinetics (discussed below) are a more significant parameter of mobility than solubility. However, VOCs were not expected to be a waste product of prior disposal operations. Moreover, even though high concentrations of TOCs were detected in soils and sediments at the site, the likelihood of the sediment acting as a VOC sink is unlikely and it is likely that the VOCs are laboratory artifacts and are not present at the Republic Steel Quarry Site.

Volatilization: Volatilization of organic chemicals from surface water to the atmosphere can be an important pathway for chemicals with high vapor pressures or low solubilities. The importance of volatilization is indicated by the magnitude of the Henry's Law constant. Volatilization is not anticipated to be a major pathway at the site.

Sorption: Sorption of chemicals to suspended sediments and bottom sediment can be an important process in aquatic environments. The term sorption is used since other commonly used terms of adsorption and absorption have mechanistic connotations which cannot be identified in most experiments. In general, the more hydrophobic a chemical is the more likely it is to be sorbed to sediment. The importance of sorption is indicated by the magnitude of the K_D. Sorption of site related chemicals is anticipated to be one of the most significant processes occurring at the site.

Photolysis: Photolysis of chemicals dissolved in aquatic systems may occur at wavelengths greater than 290 nm since ozone in the stratosphere filters out light of shorter (higher energy) wavelengths. Photochemical transformations may occur by one or more processes depending on the chemical structure of substances in the environment. Photolysis is not believed to be a major fate process at this site.

Oxidation: Oxidation may occur as a result of reducing agents formed during photochemical processes in natural water. Oxidation of certain inorganic chemicals can result in precipitation of the chemical from solution, and a lowering of dissolved chemical concentration. Organic chemicals may also be oxidized resulting in altered properties for the organic chemical. Oxidation of certain site related chemicals at this site may be an important fate process in the quarry. For example, iron at high concentrations in the bottom water may move up in the water column and be oxidized to form ferrous or ferric oxide. This newly formed metal oxide may then precipitate, reducing the mobility of the metal.

Bioaccumulation: Bioaccumulation of chemicals in various living species has been shown to result in significant ecological effects, and is especially important for hydrophobic chemicals which can be partitioned into fat and lipid tissues. Bioaccumulation also occurs with inorganic chemicals being partitioned into various tissues. Lead, mercury, and chromium are examples of chemicals having significant bioaccumulation potential. Bioaccumulation may be an important fate process for some of the site related chemicals identified.

Biotransformation and biodegradation: Biodegradation results from enzyme-catalyzed transformation of chemicals. Organisms require energy, carbon, and other fundamental inputs from the environment for their growth and maintenance. In the process, they manufacture enzymes to transform many chemicals introduced into the environment. Because biodegradation processes in aquatic and soil environments are carried out primarily by microbes, the effects of macrobiota are usually considered insignificant in studying biotransformation and biodegradation.

The biodegradation rate is the function of a microbial biomass and a chemical's concentration under given environmental conditions. When microorganisms utilize chemical substrates, there are increases in biomass, and biodegradation rates will then be a function of cell growth rate. When an organic compound is utilized by microorganisms as a sole carbon source, the specific growth rate of organisms is a function of chemical concentration. The significance of biotransformation and biodegradation as fate processes at this site are unknown. Additional investigations, such as treatability studies, would be required to ascertain this information.

Reduction: In anaerobic environments, reduction of chemicals by both biological and non-biological processes can occur. Examples for these reactions are organochlorine chemicals, where a chlorine atom is replaced by a hydrogen atom. The role of reduction as a fate process for the chemicals at the site is not indicated from available data.

Air Transport: Releases of chemicals from the sediments to surface water in the quarry may then be released to the air via volatilization. Important parameters here are not only the partitioning of chemicals between the sediment and surface water, but also the depth of water in the pond, the depth of the sediment, the volatility of the chemical (as measured by its Henry's Law constant) and the prevailing wind speed and direction. These parameters describe the mass transfer relationships among the sediment, water, and soil. Because of the physical-chemical properties of the chemicals in the quarry and the environmental chemistry of the quarry, transport of chemicals through the air pathway is not expected to be significant.

8.3 POTENTIAL ROUTES OF MIGRATION

Primary routes of migration of chemicals in the environment can include migration through groundwater, surface water, and air. At the Republic Steel Quarry site, the transport media of concern are groundwater and surface water. Quarry surface water discharges directly to the West Branch of the Black River adjacent to the site. Quarry surface waters, probably from a sediment source, are affecting groundwater chemical concentrations at the site, but are not affecting the quality of the Black River at downgradient locations. Both surface water discharge and groundwater migration are demonstrated pathways for chemical transport at the Republic Steel Quarry site. The potential for offsite migration of surface soils due to wind or water erosion is unlikely at the site due to a dense vegetation and a surrounding ground surface which slopes toward the quarry. However, during periods of flooding, it is possible soils along the quarry perimeter could be released. The potential for offsite migration of sediments in the quarry is also low because water turnover in the quarry is unlikely to transport quarry bottom sediments into the upper water column. Additionally, due to the high total organic carbon content of the sediments, it is unlikely that significant releases of organic contaminants from the quarry sediments to groundwater or surface water will occur. Volatilization of organic compounds for chemical migration through air is not anticipated to be a significant pathway at the site due to high total organic carbon content of sediments, relatively deep depth of contaminated sediments, and relatively low concentration (<1 ppm) of volatile contaminants in environmental media at the site.

The previous discussion suggests that the following potential routes of contaminant migration are important at the Republic Steel Quarry site:

(1) Release of contaminants in quarry surface water to downgradient groundwater.

(2) Release of contaminants in quarry surface water to Black River.

(3) Release of contaminants in quarry surface soils during periods of quarry flooding.

Transport and exposure models for quantifying these releases and estimating concentrations of contaminants at exposure points are discussed in Section 9.0. Some conservative estimates of releases from quarry sediments and

surface soils into quarry surface water and groundwater are also performed within Section 9.0.

8.4 CONTAMINANT PERSISTENCE AND CHEMISTRY

Properties of the major groups of site related chemicals detected at the Republic Steel Quarry site and their environmental fate are presented in Appendix M.

8.5 CONTAMINANT TRANSPORT ANALYSIS

All models and equations used for estimating transport and contaminant concentrations in performing the Endangerment Assessment in the next chapter of this report are detailed in Appendix O of this report.

9.0 ENDANGERMENT ASSESSMENT

9.1 INTRODUCTION

The Republic Steel Quarry site is currently the subject of a CERCLA Remedial Investigation/Feasibility Study (RI/FS) being conducted by the REM IV team under contract to USEPA. The site is classified as an enforcement site, indicating the possibility of cost recovery measures against potentially responsible parties. In cases where enforcement actions may be taken under Section 106(a) of CERCLA, USEPA is required by the National Contingency Plan to undertake an Endangerment Assessment (EA) to properly document and justify its assertion that an imminent and substantial endangerment to public health, welfare, or the environment may exist. This endangerment assessment provides the information for any such justification. It is important to note at this juncture that "imminent" does not mean immediate harm; rather, it means an impending risk of harm. Sufficient justification for determination of an imminent endangerment may exist if harm is threatened; no actual injury need have occurred or be occurring. Similarly, "endangerment" means something less than actual harm (USEPA 1985).

This endangerment assessment addresses the potential human health and environmental impacts associated with the Republic Steel quarry site under the no-action alternative--that is, in the absence of remedial (corrective) action. Evaluation of the no-action alternative is required under Section 300.68(f)(v) of the National Contingency Plan.

The methodologies used in this EA are designed to be consistent with guidelines from the Office of Emergency and Remedial Response (Public Health Evaluation Manual 1986a) and federal guidelines for risk assessment (EPA 1986b, c, d, e).

It should be noted that this EA has been conducted using generally conservative assumptions according to the general guidelines outlined by USEPA. The purpose of using conservative assumptions is to explore the potential for adverse health effects using conditions that tend to overestimate risk so that the final estimates will usually be near or higher than the upper end of the range of actual exposures and risks. As a result, this risk assessment should not be construed as presenting an absolute estimate of risk to human or environmental populations. Rather, it is a conservative analysis intended to indicate the potential for adverse impact for Superfund sites in particular (EPAa, b, c, d).

This EA is organized as follows:

SECTION 9.2 SELECTION OF CHEMICALS OF CONCERN. In this section, the analytical data are reviewed to identify site-related chemicals based on their frequency of occurrence, concentrations in environmental media, their relative toxicity, and their association with the source of contamination.

The next four sections, 9.3, 9.4, 9.5, and 9.6 constitute the components of the human health risk assessment.

SECTION 9.3 TOXICITY CHARACTERIZATION. In this section, potential health effects associated with exposure to the chemicals of concern are discussed and the quantitative health criteria used in the EA are presented.

SECTION 9.4 HUMAN EXPOSURE ASSESSMENT. Potential pathways by which populations may be exposed under current or potential future land use conditions are evaluated. In addition, concentration of chemicals in environmental media at potential exposure points are identified for all complete pathways. Concentration estimates are derived using available concentration data, and/or chemical-specific physical and chemical properties, and models to describe the movement of chemicals in and between media.

SECTION 9.5 ESTIMATION OF EXPOSURE POINT CONCENTRATIONS. In this section, concentrations of chemicals of concern in various exposure media will be estimated. This may be accomplished by using the RI data to calculate direct exposure or by utilizing models to predict potential concentrations.

SECTION 9.6 HUMAN RISK CHARACTERIZATION. As one measure of risk, concentrations of site-related chemicals at exposure points are compared with applicable or relevant and appropriate requirements (ARARs). Since ARARs are not available for all chemicals in all media, quantitative risk estimates are also developed, where necessary, by combining the estimated intakes of potentially exposed populations (derived using conservative assumptions regarding exposure duration, route, frequency, and absorption of chemicals) with health effects criteria.

SECTION 9.7 ENVIRONMENTAL ASSESSMENT. In this section, potential impacts on aquatic life will be evaluated by comparison of surface water concentrations to available aquatic life criteria.

SECTION 9.8 UNCERTAINTIES. The uncertainties and limitations of this risk assessment are discussed.

SECTION 9.9 CONCLUSIONS. The main conclusions of the risk assessment are summarized.

This assessment is principally based on CERCLA Contract Laboratory Program data generated during the remedial investigation (RI). Some assumptions have been made about site conditions (i.e., soil characteristics) where such data were not available from the RI. These assumptions and others derived from the USEPA Superfund Public Health Evaluation Manual (USEPA 1986a) are referenced and documented as appropriate.

9.2 SELECTION OF CHEMICALS OF CONCERN

The earlier sections of the RI report have discussed in detail the site background information and the results of the investigations that have taken place at the Republic Steel site. The results of sampling performed during the RI in August, 1987 and March, 1988 are summarized in this section to identify site related chemicals to be evaluated in this risk assessment. Sampling results are discussed below by environmental medium (soil, ground water, surface water, sediments, and air).

The following guidelines were used in evaluating data:

- Data are summarized for each medium by presenting frequencies of detection, geometric means[1] and maximum detected values of each chemical.

- Sample concentrations of certain inorganic chemicals in various media were compared with those levels considered to be naturally occurring in the region of the Republic Steel site in order to determine if the detected levels were elevated above 2 times the background concentration. The factor of 2 is chosen to compensate for the lack of a sufficient number of background samples to determine statistical significance and due to the highly variable nature of environmental sampling. The rationale for the selection of two times the background concentration as an evaluation criterion is presented in Appendix G, Data Considerations. Table 9-1 presents available background data in soil and ground water. While background samples were not available to compare sediment and surface water data from the quarry, since inorganics are naturally occurring constituents in this media, they will be compared to off site sediment and surface water samples.

- Surface water chemical concentrations will also be compared to chemical concentrations in background groundwater to eliminate chemicals from the risk assessment. The quarry is below the groundwater level and is fed by groundwater. Therefore, this comparison is considered appropriate and will eliminate chemicals in surface water that are below 2 times the chemical concentrations detected in the background groundwater wells.

- Concentrations reported for duplicate samples of a given sampling point were first averaged by calculating a geometric mean of the sample and its associated duplicate. If this geometric mean was below the sample detection limit, the sample was treated as a non-detect.

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[1]Geometric means rather than arithmetic means were calculated since most collections of measurements of environmental contaminants are log-normally distributed (Dean 1981, Ott 1988)

TABLE 9-1
CONCENTRATIONS OF INORGANICS DETECTED AROUND THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Groundwater (ug/l)	Soil (mg/kg)
Aluminum	2,180	3,640
Antimony	254	7.5
Arsenic	26	8.3
Barium	38	90
Beryllium	0.5	0.6
Cadmium	2	3.1
Calcium	130,000	16,000
Chromium	7	178
Cobalt	4.5	5
Copper	8	50
Iron	2,450	380,000
Lead	2.5	26
Magnesium	63,300	3,020
Manganese	661	5,990
Mercury	0.1	0.12
Nickel	14	73
Potassium	5,360	536
Selenium	25	3.1
Silver	2	2.5
Sodium	143,000	560
Thallium	5	6.5
Tin	11	98
Vanadium	3.5	32
Zinc	13	84
Cyanide	5	0.32

- For chemicals detected in samples and blanks the common laboratory chemicals (i.e., acetone, methylene chloride, toluene, and phthalate esters) will be included as chemicals of concern when they are detected above 10 times the level detected in blanks. Carbon disulfide may also be considered a common laboratory contaminant and will be included as a chemical of concern when detected above 10 times the level detected in blanks. The remaining chemicals on the USEPA's target compound list will be included as chemicals of concern when they are detected above 5 times the level detected in blanks. This criteria is used much like data rejection in QA/QC data validation. For data validation purposes the laboratory rejects data when samples are less than 10 times the concentration observed in the QA/QC blank.

- Data that were approximated (flagged with a J) by data validation, and data that were below the contract required detection limits were used in this assessment. For data below the detection limit (flagged with a U), half of the detection limit was used.

- In evaluating risk, potentially carcinogenic polynuclear aromatic hydrocarbons (PNAs) are considered separately from noncarcinogenic PNAs. Therefore, data summary tables will list carcinogenic PNAs separately from noncarcinogenic PNAs. Details concerning this classification of PNAs are given in Section 9.5.

- Phthalate esters may be considered contaminants in the samples at the Republic Steel site because certain samples have concentrations more than 10 times the blank samples. However, phthalate esters have been qualified in many instances indicating that the chemical was found in the laboratory blank as well as in the site related sample. Therefore, the possibility of these chemicals entering the sample in the laboratory is very real. If the contaminant enters a concentrated sample in the laboratory it will be multiplied by the dilution factor required by the experimental method. If the samples have a very high organic content, as is seen in sediment samples, this dilution can be substantial. Though it is assumed that phthalate esters are present in the samples because of laboratory contamination, due to their very high concentrations, phthalate esters will be included in the assessment where they exceed 10 times the blank level.

Chemicals of concern are discussed below by medium.

9.2.1 Soil

Surface soils were analyzed at four areas of the site: the quarry discharge, the pickle liquor ditch, at the south boat launch, and at the southern end of the steel plant yard. At the southern end of the steel plant yard slag material was being deposited onto the site from an off-site area of the steel plant yard. This is a good indication that the site will reflect the

chemicals associated with the steel plant yard and not chemicals that are associated with the historic activity of the site. Nonetheless, the area is included in the site assessment. Background samples included a sample north of the site, and a sample west of the site. A sample was also obtained north of the site, next to the Black River. Table 9-1 lists concentrations of inorganic chemicals in background samples.

Table 9-2 lists the mean and the range of inorganic and organic chemical concentrations detected in soil at above naturally occurring levels. Copper, mercury, chromium, manganese, calcium, iron and nickel were the inorganic chemicals observed at the site at more than 2 times the background concentrations near the site.

Carbon disulfide and toluene had concentrations in the samples at less than 10 times the blank concentration, respectively and will thus be removed from consideration. Acetone and methylene chloride are detected in soil at greater than 10 times concentrations detected in background, and will be treated conservatively as chemicals of concern. DDT was detected only in soil at one location of the site. Because of this low frequency of occurrence, and because DDT is not attributable to site activity, DDT will not be included as a chemical of concern. Benzoic acid was seen in samples from the site at concentrations less than 10 times the blank concentration and will not be included as a chemical of concern. Polynuclear Aromatic Hydrocarbons (PNAs) were detected in soils with the highest frequency at the South boat launch area. A discussion of PNAs will be included in the next section.

9.2.2 Sediment

Table 9-3 lists concentrations of inorganic and organic chemicals in quarry sediment at above naturally occurring levels. Three inorganic chemicals, mercury, tin, and copper were considered as a chemicals of concern based on comparison to naturally occurring levels.

Methylene chloride and acetone were common laboratory contaminants observed at above 10 times the blank concentrations. They will therefore be considered as chemicals of concern. Pentachlorophenol is observed at a very high level compared to the rest of the sampling at one location of the Republic Steel site. Pentachlorophenol is not thought to be associated with operations at the site and possible breakdown products of pentachlorophenol (i.e., 2-chlorophenol) were not observed at the site. Due to the high concentration of penachlorphenol detected from the one location, it will be considered as a chemical of concern.

Polynuclear Aromatic Hydrocarbons (PNAs) were observed at relatively high concentrations along with the solvents ethylbenzene, 2-butanone, and tetrachloroethene and have been included as chemicals of concern. PNAs were detected only in sediment samples and soil samples.

TABLE 9-2
SURFACE SOIL DATA FROM AREAS AT AND NEAR THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

CHEMICAL	FREQUENCY OF DETECTION	NO. OF EST. VALUES	RANGE max	RANGE min	BACKGROUND CONCENTRATIONS		BLANK CONCENTRATIONS
VOLATILE ORGANIC ANALYSES (in ug/kg)							
Methylene chloride	2 /4	0	33	29			
Acetone	2 /4	0	150	130			
2-Butanone	1 /4	0	78				
Toluene	1 /4	0	65		95		
SEMIVOLATILE ORGANIC ANALYSES (in ug/kg)							
Phenanthrene	1 /4	1	250		130		
Di-n-butylphthalate	3 /4	2	5400	1900			
Fluoranthene	2 /4	2	780	510	63	130*	
Pyrene	3 /4	3	4300	330	60	160*	
Benzo[a]anthracene	2 /4	2	510	260	70	110*	
bis(2-Ethylhexyl)phthalate	1 /4	0	7800				
Chrysene	2 /4	2	510	250	65	140*	
Di-n-octyl phthalate	1 /4	0	1900				58
Benzo[b]fluoranthene	1 /4	1	780		76	260*	
Benzo[k]fluoranthene	1 /4	1	780		76	260*	
INORGANIC AND NON-ORGANIC SAS ANALYSES (in mg/kg)							
Aluminum	4 /4	0	3620	860	9860		
Barium	4 /4	0	90	70	66		153
Cadmium	1 /4	0	2.2				
Calcium	4 /4	0	16000	480	1660	2650*	12400
Chromium	4 /4	0	178	16	9.6	40*	13
Cobalt	2 /4	0	4	4	11		13
Copper	4 /4	0	94	50	31	38*	41
Iron	4 /4	0	443000	24800	20900	85800*	21100
Magnesium	3 /4	0	3020	872	1990		3520
Manganese	4 /4	0	5990	116	823	903*	
Mercury	2 /4	0	0.34	0.32			
Nickel	3 /4	0	73	15	15	34*	30
Potassium	4 /4	0	721	430	875		1420
Vanadium	4 /4	0	32	6.7	20		
Zinc	4 /4	0	84	20	84		135

Table 9-2 (cont'd)
Page 2

CHEMICAL	FREQUENCY OF DETECTION	NO. OF EST. VALUES	RANGE max	RANGE min	BACKGROUND CONCENTRATIONS	BLANK CONCENTRATIONS
PESTICIDE/PCBs AND SAS ORGANICS ANALYSES (in ug/kg)						
4,4'-DDT	1 /4	0	419			

* Concentration from N. Black River downgradient. Not used in comparison purposes for elimination of chemicals.

TABLE 9-3
QUARRY SEDIMENT DATA FROM THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

CHEMICAL	FREQUENCY OF DETECTION	NO. OF EST. VALUES	RANGE max	RANGE min	COMPARISON CONCENTRATIONS	BLANK CONCENTRATIONS
VOLATILE ORGANIC ANALYSES (in ug/kg)						
Methylene chloride	2 /7	0	25	14.5		
Acetone	4 /7	4	1100	250		
Carbon disulfide	4 /7	0	27	1.6	53	73
2-Butanone	4 /7	4	336	65		
Benzene	1 /7	1	3.7		1	
Tetrachloroethane	2 /7	0	37	18		
Toluene	4 /7	4	370	72		
Ethylbenzene	1 /7	1	28			
SEMIVOLATILE ORGANIC ANALYSES (in ug/kg)						
Benzoic acid	1 /7	1	780			280
Diethylphthalate	4 /7	0	55300	2800		46
Isophorone	1 /7	1	99			43
Pentachlorophenol	2 /7	0	23300	7100		76
Phenanthrene	4 /7	3	12200	210	2400	40
Anthracene	2 /7	1	4000	72	590	
Di-n-butylphthalate	3 /7	0	29000	2400	330	
Fluoranthene	5 /7	4	17000	1200	3300	
Pyrene	4 /7	1	12200	3100	2900	
Butylbenzylphthalate	2 /7	0	73000	36000	690	
Benzo[a]anthracene	3 /7	2	4450	210	4900	
bis(2-Ethylhexyl)phthalate	1 /7	0	26000		3400	
Chrysene	4 /7	3	4200	160		
Di-n-octyl phthalate	3 /7	0	5500	2600		
Benzo[b]fluoranthene	3 /7	1	6000	300	4800	
Benzo[k]fluoranthene	3 /7	1	6000	300	4800	
Benzo[a]pyrene	4 /7	3	4900	130	2400	
Indeno(1,2,3-cd)pyrene	2 /7	2	800	170	840	
Benzo[g,h,i]perylene	2 /7	2	700	190	750	
PESTICIDES/PCBs AND SAS ORGANICS ANALYSES (in ug/kg)						
Aroclor 1248	1 /7	0	1000		3400	

Table 9-3 (cont'd)
Page 2

CHEMICAL	FREQUENCY OF DETECTION	NO. OF EST. VALUES	RANGE max	RANGE min	COMPARISON CONCENTRATIONS	BLANK CONCENTRATIONS
INORGANIC AND NON-ORGANIC SAS ANALYSES (in mg/kg)						
Aluminum	7 /7	0	17700	949	9340	16100
Arsenic	2 /7	0	42	40	31	12
Barium	7 /7	0	112	25	81	196
Beryllium	1 /7	0	2.3		1.8	
Calcium	7 /7	3	73700	2440	59300	
Chromium	6 /7	0	64	9.7	63	
Cobalt	1 /7	0	4.9		10	18
Copper	6 /7	0	300	18	72	86*
Iron	7 /7	0	112000	19100	159000	
Lead	3 /7	0	100	14	202	
Magnesium	7 /7	0	20300	699	18900	
Manganese	7 /7	0	1140	201	1450	1570*
Mercury	2 /7	0	0.73	0.45		
Nickel	6 /7	0	103	12	61	67*
Potassium	6 /7	0	2290	477	940	2500
Tin	3 /7	0	108	10	18	
Vanadium	6 /7	0	29	8.1	22	37
Zinc	7 /7	0	369	80	261	

* Concentration from N. Black River downgradient. Not used in comparison purposes for elimination of chemicals.

the method used for lindane determination and the possibilities of laboratory contamination due to the very low concentrations detected, lindane was eliminated as a chemical of concern.

Aroclor 1254 was also detected in surface water, however, the sampling procedure used was to capture oil that emanated from disturbed sediments. The chemical was not detected in sediment samples. Thus, due to the bias of the sampling procedure and the low frequency of detection Aroclor 1254 was eliminated as a chemical of concern. The common laboratory contaminants detected in the samples below ten times laboratory blank concentrations will not be further evaluated.

9.2.4 Groundwater

Table 9-5 lists concentrations of inorganic and organic chemicals in groundwater detected at the Republic Steel site at above naturally occurring levels. Fifteen metals were detected at 2 times above the background concentrations. These were aluminum, beryllium, silver, vanadium, calcium, cobalt, iron, manganese, potassium, chromium, copper, lead, zinc and nickel. These metals have been included as chemicals of concern. The metals chromium, copper, lead, nickel, cobalt, silver, tin, and vanadium were seen in only one or two wells at the site. Concentrations of pentachlorophenol and phenol were detected very close to the detection limit. However, these organic contaminants have been conservatively included as chemicals of concern. Common laboratory contaminants were below or near ten times the field blank concentrations except for acetone and methylene chloride which were detected in one well during the first sampling of the site. Methylene chloride and acetone were not identified as chemicals of concern in surface water, were only found in one downgradient monitoring well, and were not confirmed to be present during a subsequent sampling effort. Nevertheless, these compounds will be conservatively included as chemicals of concern. Benzoic acid was detected at greater than 10 times blank concentrations and will be included as a chemical of concern.

9.2.5 Summary

The chemicals presented in Table 9-6 were present in one or more media at the Republic Steel site above levels considered to be naturally occurring and are therefore included in this EA. Carcinogenic and noncarcinogenic PNAs detected in soil and sediments at this site are presented in Table 9-7.

9.3 TOXICITY CHARACTERIZATION

The general methodology for the classification of health effects and the development of health effects criteria is described in Section 9.3.1 in order to provide the analytical framework for the characterization of human health impacts in Section 9.5. In section 9.3.2, the concept of chemical-specific ARARs is introduced, and the types of standards, criteria, or guidance that may be classified as potential ARARs for the Republic Steel site are described. In addition, potential ARARs and the numerical values of health

TABLE 9-5
GROUNDWATER DATA FROM WELLS AT OR NEAR THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

CHEMICAL	FREQUENCY OF DETECTION	NO. OF EST. VALUES	RANGE max	RANGE min	COMPARISON CONCENTRATIONS	BLANK CONCENTRATIONS
VOLATILE ORGANIC ANALYSES (in ug/L)						
Methylene chloride	3 /7		140	3	11	8
Acetone	1 /7		55			
Chloroform	1 /7		9		74	
Toluene	4 /7	4	4	1	2	3
SEMIVOLATILE ORGANIC ANALYSES (in ug/L)						
Phenol	1 /7		10			
Benzoic acid	1 /7	1	42			
Pentachlorophenol	1 /7	1	5			
Di-n-butylphthalate	1 /7	1	3.9			
bis(2-Ethylhexyl)phthalate	2 /7		11	7.1		
INORGANIC AND NON-ORGANIC SAS ANALYSES (in ug/L)						
Aluminum	6 /6		11600	94	2180	18
Arsenic	2 /6		21	13	26	
Barium	6 /6		114	20	38	
Beryllium	3 /6		2.1	1		
Cadmium	4 /6		6.4	2.8		
Calcium	6 /6		477000	69700	130000	
Chromium	3 /6		20	8.5	7	
Cobalt	3 /6		18	9.4		
Copper	3 /6		28	6.5	11	
Iron	6 /6		571000	283	2450	45
Lead	1 /6		19			
Magnesium	6 /6		88000	16900	63300	
Manganese	6 /6		11600	145	661	
Nickel	4 /6		131	24	14	
Potassium	6 /6		37200	3250	5360	
Silver	1 /6		4.1			
Sodium	6 /6		324000	29700	143000	
Tin	2 /6		73		119	
Vanadium	4 /6		57	8.7		
Zinc	6 /6		106	7.7	13	

These contaminants may derive from cutting oils used in steel manufacturing as the PNA concentrations correspond to oil and grease concentrations in these sediments.

It should be noted that PNAs are ubiquitous in the environment, and background levels may be relatively high. PNAs are produced by virtually every combustion process, from forest fires to refuse burning. They are also released from internal combustion engine emissions. PNAs in soil result principally from the deposition of airborne PNAs. Based on data compiled from IARC (1973), White and Vanderslice (1980), and EPA (1982), total carcinogenic PNA concentrations in forest soils can range from 0.02 to 0.26 mg/kg. In urban soils, higher concentrations are found, with total carcinogenic PNA concentrations ranging from 100 to 175 mg/kg. This area of Ohio and specifically the Black River has a historical record of high ambient PNA levels due to the type and magnitude of industries such as steel plants and coking facilities (West et al. 1986; West et al. 1988). These high ambient concentrations could have an impact on the concentrations at the Republic Steel site. Because no data on background concentrations of this ubiquitous class of compounds are available for the Republic Steel site, PNAs are considered site-related and evaluated in this assessment.

While no background concentration data is available for quarry sediments a comparison is made to inorganic concentrations in the upriver areas of the Black River. This comparison appears appropriate since inorganics are common constituents of even pristine soils and detectable concentrations of inorganics do not necessarily represent an anthropogenic source. Since the sampled areas of the Black River are close to the quarry we expect concentrations less than two times these comparison concentrations to represent ambient concentrations in the area and not to be attributable to the Republic Steel quarry site.

9.2.3 Surface water

Table 9-4 lists concentrations of inorganic and organic chemicals detected in surface water at the Republic Steel site at above the naturally occurring levels. For the inorganic chemicals, calcium, iron, magnesium, manganese, nickel, vanadium, and cadmium had concentrations above 2 times the comparison concentration. These inorganic chemicals will be considered chemicals of concern. Comparison to groundwater inorganic concentrations from background wells was used for comparison, as was comparison to area surface water inorganic concentrations.

No organic chemicals in the surface water were considered for the risk assessment. The pesticide lindane was detected at very low concentrations in one surface water area at the Republic Steel site and does not appear to be associated with the facility. Reported concentrations of lindane were below a level discernable by mass spectrometer techniques. Due to the uncertainty of

TABLE 9-4
QUARRY SURFACE WATER DATA FROM THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

CHEMICAL	FREQUENCY OF DETECTION	NO. OF EST. VALUES	RANGE max	RANGE min	COMPARISON CONCENTRATIONS	BLANK CONCENTRATIONS
VOLATILE ORGANIC ANALYSES (in ug/L)						
Acetone	1 /17	0	27			12
Toluene	3 /17	0	4.3	2		2.4
SEMIVOLATILE ORGANIC ANALYSES (in ug/L)						
Bis(2-ethylhexyl)phthalate	3 /17	0	14	3		
PESTICIDE/PCBs AND SAS ORGANIC ANALYSES (in ug/L)						
Lindane	2 /35	0	0.09	0.08		
INORGANIC AND NON-ORGANIC SAS ANALYSES (in ug/L)						
Aluminum	13 /20	0	808	33	1040	
Arsenic	1 /20	0	8.7			
Barium	20 /20	0	105	21	43	
Cadmium	1 /20	0	12			
Calcium	20 /20	0	315000	63700	71100	
Copper	6 /20	0	14	5.9	8.8	14
Iron	20 /20	0	1600000	57	1630	
Lead	3 /20	0	19	3.9		8.2
Magnesium	20 /20	0	88900	16800	19800	
Manganese	20 /20	0	25700	28	88	
Nickel	5 /20	0	86	9.4	8.3	
Potassium	20 /20	0	8050	4070	5960	
Sodium	20 /20	0	49200	37300	47200	
Vanadium	7 /20	0	60	6.8	4.9	
Zinc	13 /20	0	37	3.5	15	

TABLE 9-6
CHEMICALS OF CONCERN SELECTED AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Medium	Chemical	
Groundwater	ALUMINUM	NICKEL
	BARIUM	PENTACHLOROPHENOL
	BENZOIC ACID	PHENOL
	BERYLLIUM	POTASSIUM
	CALCIUM	SILVER
	CHROMIUM	TIN
	COBALT	VANADIUM
	COPPER	ZINC
	IRON	ACETONE
	LEAD	METHYLENE CHLORIDE
Surface Water	BARIUM	NICKEL
	CALCIUM	VANADIUM
	IRON	
	MAGNESIUM	
	MANGANESE	
Sediment	ACETONE	BUTYLBENZYLPHTHALATE
	2-BUTANONE	DIETHYLPHTHALATE
	COPPER	DI-N-BUTYLPHTHALATE
	ETHYLBENZENE	DI-N-OCTYLPHTHALATE
	MERCURY	TIN
	METHYLENE CHLORIDE	TETRACHLOROETHENE
	PENTACHLOROPHENOL	TOLUENE
	ncPNA[a]	
	cPNA[b]	
	BIS(2-ETHYLHEXYL)	
	PHTHALATE	
Soil	2-BUTANONE	cPNA[b]
	CHROMIUM	BIS(2-ETHYLHEXYL)
	COPPER	PHTHALATE
	MANGANESE	DI-N-BUTYLPHTHALATE
	MERCURY	DI-N-OCTYLPHTHALATE
	METHYLENE CHLORIDE	CALCIUM
	ncPNA[a]	IRON
	ACETONE	NICKEL

[a] = non-carcinogenic by IARC 1983 criteria

[b] = carcinogenic by IARC 1983 criteria

TABLE 9-7
IDENTIFICATION OF NON-CARCINOGENIC PNAs AND CARCINOGENIC PNAs
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Sediment:		
	nc PNA[a]:	Phenanthene Fluoranthene Pyrene Anthacene
	c PNA[b]:	Benzo[b]fluoranthene Benzo[k]fluoranthene Benzo[a]pyrene
Soil:		
	nc PNA[a]:	Fluoranthene Pyrene
	c PNA[b]:	Benzo[a]anthracene Chrysene Benzo[b]fluoranthene Benzo[k]fluoranthene

[a] = non-carcinogenic by IARC 1983 criteria.

[b] = carcinogenic by IARC 1983 criteria.

effects criteria that will be used in the quantitative risk assessment are presented in tabular form.

9.3.1 Health Effects Classification and Criteria Development

For risk assessment purposes, individual pollutants are separated into two categories of chemical toxicity depending on whether they exhibit noncarcinogenic or carcinogenic effects. This distinction relates to the currently held scientific opinion that the mechanism of action for each category is different. EPA has adopted, for the purpose of assessing risks associated with potential carcinogens, the scientific position that a small number of molecular events can cause changes in a single cell or a small number of cells that can lead to tumor formation. This is described as a no-threshold mechanism, since there is essentially no level of exposure (i.e., a threshold) to a carcinogen which will not result in some finite possibility of causing the disease. In the case of chemicals exhibiting noncarcinogenic effects, however, it is believed that organisms have protective mechanisms that must be overcome before the toxic endpoint is manifested. For example, if a large number of cells performs the same or similar functions, it would be necessary for significant damage or depletion of these cells to occur before an effect could be seen. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without appreciable risk of causing the disease (EPA 1987a).

9.3.1.1 Health Effects Criteria for Noncarcinogens

Health criteria for chemicals exhibiting noncarcinogenic effects are generally developed using risk reference doses (RfDs) developed by the USEPA RfD Work Group, or RfDs obtained from Health Effects Assessments (HEAs). The RfD, expressed in units of mg/kg/day, is an estimate of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. These RfDs are usually derived either from human studies involving workplace exposures or from animal studies, and are adjusted using uncertainty factors. The RfD provides a benchmark to which chemical intakes by other routes (e.g., via exposure to contaminated environmental media) may be compared.

9.3.1.2 Health Effects Criteria for Potential Carcinogens

Cancer potency factors, developed by EPA's Carcinogen Assessment Group (CAG) for potentially carcinogenic chemicals and expressed in units of $(mg/kg/day)^{-1}$, are derived from the results of human epidemiological studies or chronic animal bioassays. The animal studies must usually be conducted using relatively high doses in order to detect possible adverse effects. Since humans are expected to be exposed at lower doses than those used in the animal studies, the data are adjusted by using mathematical models. The data from animal studies are fitted to the linearized multistage model to obtain a dose-response curve. The 95th percentile upper confidence limit slope of the

dose-response curve is subjected to various adjustments and an interspecies scaling factor is applied to derive the cancer potency factor for humans. Thus, the actual risks associated with exposure to a potential carcinogen quantitatively evaluated based on animal data are not likely to exceed the risks estimated using these cancer potency factors, but they may be much lower. Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on an ad hoc basis. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. Cancer potency factors based on human epidemiological data are also derived using very conservative assumptions and, as such, they too are unlikely to underestimate risks. Therefore, while the actual risks associated with exposures to potential carcinogens are unlikely to be higher than the risks calculated using a cancer potency factor, they could be considerably lower.

EPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A chemicals (human carcinogens) are agents for which there is sufficient evidence to support the causal association between exposure to the agents in humans and cancer. Groups B1 and B2 chemicals (probable human carcinogens) are agents for which there is limited (B1) or inadequate (B2) evidence of carcinogenicity from human studies but for which there is sufficient evidence of carcinogenicity from animal studies. Group C chemicals (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals, and Group D chemicals (not classified as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available. Group E chemicals (evidence on non-carcinogenicity in humans) are agents for which there is no evidence of carcinogenicity in adequate human or animal studies.

9.3.2 Applicable or Relevant and Appropriate Requirements (ARARs)

The Superfund Amendments and Reauthorization Act (SARA) and concurrent EPA interpretation provide guidance on selecting health-based applicable or relevant and appropriate requirements (ARARs) (EPA 1987) to be met at Superfund sites. ARARs are selected by EPA on a site-by-site basis taking into consideration such factors as groundwater classification. Potential ARARs are defined below and may include drinking water Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs), Federal Ambient Water Quality Criteria, National Ambient Air Quality Standards (NAAQS), and state environmental standards.

The USEPA's interim guidance on ARARs (EPA 1987b) defines ARARs as follows:

Applicable Requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a

hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Relevant and appropriate requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

Only those ARARs or advisories or guidance that are ambient or chemical-specific requirements (i.e., those requirements which "set health or risk-based concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants" (EPA 1987b) as opposed to ARARs which are classified as action-specific or locational requirements) are used in risk assessment. The classes of ambient or chemical-specific ARARs or guidance which are considered pertinent to the risk assessment for the Republic Steel site are discussed below by environmental medium.

9.3.2.1 Surface Water

State Water Quality Standards. States may promulgate their own water quality standards, either by adopting Federal water quality standards or by setting criteria which are more restrictive than the Federal standards.
The state of Ohio will be changing and adding to present water quality guidance and standards by mid-July 1988 (letter from Susan MacMillan, Ohio EPA to Paul Tomiczek, ICF/SRW, June 3, 1988). For this risk assessment, all state standards and guidance to be enacted by this time are considered as potential ARARs for the Republic Steel site. Ohio State ARARs were available for two chemicals of potential concern at the Republic Steel site. These potential ARARs are presented in Table 9-8.

Federal Water Quality Standards. Federal Water Quality Standards are available for fish consumption and for acute and chronic toxicity of aquatic life. Of the 20 chemicals of potential concern at the Republic Steel Site, 8 have available criteria for consumption of fish and 11 have available criteria for acute and chronic toxicity. These criteria are available along with State of Ohio Criteria in Table 9-8.

9.3.2.2 Groundwater

Primary and Secondary Maximum Contaminant Limits (MCLs and SMCLs). Primary MCLs are Federal drinking water standards promulgated under the Safe Drinking Water Act (SDWA). Generally an MCL for a toxic chemical represents the allowable lifetime exposure to the contaminant for a 70-kg adult who is assumed to ingest two liters of water per day. In addition to health factors,

TABLE 9-8
SURFACE WATER QUALITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Ohio State ARARs Aquatic Life (ug/L)	Federal Water Quality Criteria ug/L Consumption of Fish	Federal Water Quality Criteria (ug/L) Aquatic Life	
			Acute	Chronic
ncPNA	--	--	2,300[a]	620[a]
Benzene	--	40[e]	5,300[a]	--
cPNA[f]	--	0(0.031[e])	--	--
Pentachlorophenol	--	--	20[c]	13[c]
Diethylphthalate	--	1,800,000	940[ad]	3[ad]
Acetone	--	--	--	--
Tetrachloroethene	--	0(8.85)	5,280	840
Ethylbenzene	--	3,280	--	--
2-Butanone	--	--	--	--
Di-n-butylphthalate	--	154,000	940[ad]	3[ad]
bis(2-ethylhexyl)	--	--	--	--
phthalate	--	--	940[ad]	3[ad]
Iron	--	--	--	1,000
Magnesium	--	--	--	--
Nickel	--	100	1,400[b]	160[b]
Vanadium	--	--	--	--
Tin	--	--	--	--
Calcium	--	--	--	--
Copper	1,000[b]	--	18[b]	12[b]
Mercury	--	0.146	2.4	0.012
Barium	--	--	--	--
Manganese	--	100[b]	--	--
Methylene Chloride	--	--	--	--
Butylbenzylphthalate	--	--	940[ad]	3[ad]
Di-n-octylphthalate	--	--	940[ad]	3[ad]
Toluene	--	424,000	17,500	--

a Insufficient data to develop criteria. Value presented in L.O.E.L. - Lowest Observed Effect Level.

b Hardness dependent criteria (100 mg/L used).

c pH dependent criteria (7.8 pH used).

d Criteria for phthalate esters.

e Human health criteria for carcinogens reported for the risk levels. Value presented in parenthesis is the 10^{-6} risk level.

f cPNA considered as benzo(a)pyrene

an MCL is required by law to reflect the technological and economic feasibility of removing the contaminant from the water supply. The limit set must be feasible given the best available technology and treatment techniques (EPA 1986a).

Secondary MCLs are Federal standards promulgated under the SDWA to control contaminants that primarily affect the aesthetic qualities (such as taste and odor) that would relate to the public acceptance of drinking water. Secondary MCLs are not federally enforceable standards (40 CFR 143).

According to EPA guidance on the use of MCLs as ARARs (EPA 1987b), MCLs are applicable at the tap where the water will be provided directly to 25 or more people or will be supplied to 15 or more service connections, but in addition are relevant and appropriate requirements against which to evaluate groundwater quality.

Maximum Contaminant Level Goals (MCLG). MCLGs are promulgated under the SDWA as chemical-specific health criteria used in setting MCLs and other enforceable drinking water standards. An MCLG for a toxic chemical is based only on health considerations (i.e., technological and economic considerations are not included) and represents a level at which no adverse effects occur (EPA 1987b). Since MCLs are set as close to MCLGs as possible, EPA does not consider MCLGs to represent a separate class of ARARs.

For chemicals of potential concern in groundwater, drinking water ARARs are available for 10 of the 18 chemicals at the Republic Steel site. These ARARs are presented along with Ohio State ARARs for Public Water Supply in Table 9-9.

9.3.2.3 Soil and Sediment

No Federal or State standards, criteria or guidelines have been identified for chemicals in soil or sediment.

9.3.2.4 Numerical Values of ARARs and Toxicity Criteria

Tables 9-9 and 9-10 presents the numerical values of ARARs and other guidance identified for site-related chemicals of concern in surface water and groundwater at the Republic Steel site. Health effects criteria values are presented in Table 9-10. It should be noted that health criteria appropriate for use in a quantitative risk assessment have not been developed for some of the selected chemicals of concern; therefore, they are not listed in Table 9-10. Among this group of chemicals, calcium, cobalt, iron, magnesium, and potassium are not especially toxic following oral exposure and are essential human nutrients and thus will not be discussed further in this EA. In addition, aluminum will not be discussed further in the EA since it has a low acute toxicity following oral exposure, and there are inadequate dose-response data from which to estimate an acceptable daily intake level for

TABLE 9-9
DRINKING WATER ARARs FOR CHEMICALS OF POTENTIAL CONCERN
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Ohio State Public Water Supply (ug/L)	Federal (ug/L)
Pentachlorophenol	1	220 MCLG
Phenol	--	3,500 WQC
Chromium	--	50 MCL
Copper	1,000	--
Lead	--	50 MCL
Nickel	--	15.4 WQC
Zinc	--	5,000 WQC (organoleptic)
Silver	--	50 WQC
Aluminum	--	--
Barium	--	1,000 MCL
Beryllium	--	0 (3.9 ng/l)
Calcium	--	--
Cobalt	--	--
Iron	--	--
Manganese	--	--
Potassium	--	--
Tin	--	--
Vanadium	--	--

TABLE 9-10
TOXICITY CRITERIA FOR SITE-RELATED CHEMICALS OF CONCERN
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Reference Dose (RfD) Oral (mg/kg/day)	Source	Carcinogenic Potency Factor Oral $(mg/kg/day)^{-1}$	Weight of Evidence
Barium	5.0×10^{-2}	IRIS	--	--
Beryllium	5.0×10^{-3}	IRIS	--	--
Bis(2-ethylhexyl) phthalate	2.0×10^{-2}	IRIS	8.3×10^{-3}	B2
Butylbenzyl-phthalate	NA	--	--	--
Diethylphthalate	8.0×10^{-1}	IRIS	--	--
Di-n-butylphthalate	1.0×10^{-1}	IRIS	--	--
Di-n-octylphthalate	NA	--	NA	--
Tetrachloroethene	1.0×10^{-2}	IRIS	5.1×10^{-2}	B2
Toluene	3.0×10^{-1}	IRIS	--	--
Nickel	0.02	IRIS	--	--
Pentachlorophenol	0.03	IRIS	--	--
Ethylbenzene	0.1	IRIS	--	--
2-Butanone (MEK)	0.05	IRIS	--	--
ncPNA	0.41	HEA[a]	--	--
cPNA	--	--	11.5[b]	B2
Copper	3.7E-2	HEA	--	--
Mercury (inorganic)	1.4E-3	--	--	--
Methylene Chloride	0.06	RfD	7.5E-3	B2
Acetone	0.1	IRIS	--	--
Silver	0.003	RfD	--	--
Tin	0.64	HEA	--	--
Vanadium	0.02	RfD[c]	--	--
Chromium	0.005[d]	HEA	--	--
Lead	0.0014	HEA	--	--
Phenol	0.04	IRIS	--	--
Zinc	0.21	HEA	--	--
Manganese	0.22	HEA	--	--
DDT	5E-4	RfD	0.34	B2

HEA = Health Effects Assessment
IRIS = Integrated Risk Information System

a Based on toxicity of naphthalene.
b Based on potency of benzo(a)pyrene. This potency factor is being reevaluated by EPA; nevertheless, it will be used in EA for quantitative assessment.
c Based on vanadium pentoxide.
d Based on chromium (VI).

ionic aluminum in drinking water (EPA 1985b). Detailed information on the toxicity of the chemicals of concern to be included in the EA is provided in the Toxicity Profiles (Appendix N).

9.4 POTENTIALLY EXPOSED POPULATIONS AND EXPOSURE PATHWAYS

An exposure pathway (the link between the source and the receptors) is defined by the following four elements:

- A source and mechanism of chemical release to the environment;
- An environmental transport medium for the released chemical;
- A point of potential exposure by the receptor with the medium; and
- A route of exposure (i.e., inhalation, ingestion, dermal contact).

An exposure pathway is considered "complete" if all these elements are present. The first two elements of an exposure pathway, a source and transport of a chemical have been addressed to some extent above and fully in previous sections of this report. This subsection addresses the last two elements and identifies populations exposed to site-related contaminants onsite under current and possible future land-use conditions and also identifies the routes through which these populations may be exposed.

9.4.1 Site and Surrounding Area Under Current-Use Conditions

The Republic Steel Quarry is located in an area of mixed industrial, commercial and residential land use. The quarry occupies approximately 4 acres. Although the quarry is fenced, it is accessible through a large hole in the fence. There is known to be some use of the site by local populations. During the period of data collection for the RI, children were observed swimming in the quarry on several occasions and numerous incidents of vandalism occurred.

Taking into account the above factors, potential pathways of exposure to contaminants at the Republic Steel Quarry site under current land-use conditions have been identified and are discussed below by exposure medium (soil, air, groundwater, surface water and sediment). These potential exposure pathways also are summarized in Table 9-11 along with an indication of whether the pathway is complete.

Exposures to Soil. Under current conditions at the site, trespassers on the site may potentially come into dermal contact with contaminants. However, almost all of the area surrounding the quarry is heavily vegetated, limiting areas for exposure to occur. The area of the south boat launch as well as a steep area where slag material is sliding onto quarry property from the adjacent steel plant yard are the two areas where contact of individuals with

TABLE 9-11
POTENTIAL PATHWAYS OF EXPOSURE TO CONTAMINANTS ORIGINATING AT THE REPUBLIC STEEL QUARRY
UNDER CURRENT-USE CONDITIONS
REPUBLIC STEEL QUARRY

Medium	Potential Routes of Exposure	Potential Receptors	Pathway Complete?
Soil (surface)	Dermal absorption, incidental ingestion	Trespassers	Yes. However, the majority of the site is densely vegetated.
Air	Inhalation of volatile organics and/or fugitive dust	Trespassers, nearby residents	No. Dense vegetation cover prohibits soils from becoming airborne.
Surface water/ Sediment	Dermal absorption, incidential ingestion	Trespassers swimming in quarry	Yes. Trespassers have been observed swimming in the quarry. Quarry depth precludes exposure to sediment.
	Uptake by fish with subsequent ingestion by humans	Trespassers fishing in quarry	Yes. Large fish were observed in the quarry.
		People fishing in nearby surface water bodies.	No. No site related contaminants have been detected in Black River downgradient of the quarry.
Groundwater	Ingestion, inhalation, dermal absorption	Local residents	No. Groundwater is not currently being used for a potable supply in the vicinity of the site.

surface soil is most likely to occur. Therefore, direct contact with soils associated with dermal absorption and incidental ingestion of contaminants in surface soils by trespassers is considered to be a complete exposure pathway. No samples were collected from subsurface soils at the site; there are currently no ways in which subsurface soils are likely to be contacted although they may act as sources of contaminants to groundwater.

Exposures to Air. Site trespassers potentially could be exposed to contaminants present in the air through inhalation of volatile organics and/or fugitive dust emitted from soils or surface waters. As discussed above, most areas of the site surrounding the quarry are heavily vegetated, making the generation of dust by wind erosion highly unlikely. In addition, because the volatile chemicals detected in soils and quarry water were generally present at very low concentrations, the likelihood of significant vapors being generated is low. Therefore, exposures of trespassers or downwind receptors to site contaminants through inhalation of volatile chemicals or fugitive dust are not considered likely to be significant under current-use conditions of the site, and will not be evaluated as a current exposure pathway.

Exposures to Surface Water/Sediment. Site trespassers potentially may be exposed to surface water or sediments on the site while swimming in the quarry. As mentioned previously, children were observed swimming in the quarry on several occasions during RI field work. Therefore, exposure of trespassers to chemicals in surface water through dermal absorption and incidental ingestion is considered to be a complete pathway. However, given the depth of the quarry (range of 8 to 60 feet with most areas 40 feet) it is unlikely that site trespassers swimming in the quarry would come into contact with bottom sediment. In the rare instance when contact with sediment was made, swimming activities would likely rinse off any sediment from skin surfaces. Therefore, the potential for exposure of trespassers to quarry sediment primarily through dermal absorption is considered to be negligible and this pathway will not be evaluated.

Site observations confirm that the quarry supports aquatic life. Exposure of aquatic life to contaminants through uptake of chemicals from the surface water and/or sediments is considered to be a complete pathway. Additionally, human exposure to contaminants in surface water and sediment may occur indirectly through ingestion of fish. This pathway is considered to be complete and it will be addressed in the following section.

Exposure to Groundwater. The groundwater at or near the site is not currently used as a potable water supply. A residential well survey was conducted by ICF/SRW to identify groundwater uses near the site. This survey confirmed that there is no groundwater use within a one-half mile radius of the site. Therefore, exposure of individuals to chemicals in groundwater through ingestion, inhalation or dermal absorption is not considered to be a complete exposure pathway under current-use conditions of the site.

9.4.2 Site and Surrounding Area Under Future-Use Conditions

In evaluating the no-action alternative, possible future uses of the site must be considered because different land-use conditions may lead to exposures which do not currently occur. It was reported that a potential future use of the site was for a city park. Another possible future use of the site includes residential development as is commonly done around quarries in Ohio. Additional exposure pathways that might result from such uses are discussed below and summarized in Table 9-12.

Future use of the site as either a recreational park area or a residential area could result in exposure of park patrons or residents to chemicals of concern in soil through direct contact resulting in dermal absorption and incidental ingestion of these contaminants from hand-to-mouth contact, smoking, or eating food. For future residents, these exposures could occur on a fairly regular basis, and in both cases, these exposures would involve children, who are generally more likely to come into contact with soil and who would potentially be more affected by any soil contaminants. Exposure via this pathway will be quantitatively evaluated for future residents and for future recreational users. Soil exposures to future residents will be the worst-case exposure because exposure to recreational users will be less frequent and for shorter durations.

In the event of future development of the site, the potential exists for workers involved in the construction activities to be exposed through direct contact with contaminated soils, as well as dust generated from these materials. In addition, workers may be exposed to contaminants that have volatilized from the soil. However, significant inhalation exposure to chemicals during soil disturbance is not expected because the concentration of volatile chemicals in the surface soil is low. Although no subsurface soil samples were collected, site history and available data do not indicate wastes have been buried in the subsurface soil at the site.

With respect to future uses of groundwater, as discussed previously, local residents do not currently use private groundwater wells for drinking water. However, future use of the site could require a potable water supply and groundwater could be used for this purpose. Therefore, this exposure pathway is considered to be complete and it will be evaluated further. Inhalation of volatilized chemicals and dermal absorption of chemicals of concern in ground water while showering, washing dishes, etcetera, are not evaluated in this EA; however, they could be associated with health risks within an order of magnitude of those posed by ingestion of groundwater.

9.5 ESTIMATION OF EXPOSURE POINT CONCENTRATIONS

In order to assess risk, concentrations of chemicals of concern in various media at points of potential exposure (i.e., exposure point concentrations) must be estimated. Estimating exposure point concentrations may generally be

TABLE 9-12
POTENTIAL PATHWAYS OF EXPOSURE TO CONTAMINANTS ORIGINATING AT THE REPUBLIC STEEL QUARRY UNDER FUTURE-USE CONDITIONS
REPUBLIC STEEL QUARRY RI

Medium	Potential Routes of Exposure	Potential Receptors	Pathway Complete?
Soil	Dermal absorption, incidental ingestion	Future users of the site (residents)	Yes.
Groundwater	Ingestion, inhalation, dermal absorption	Future users of the site	Yes.

accomplished in two ways: (1) by using the RI data to calculate direct exposure, and (2) by utilizing models in conjunction with RI data to predict the potential concentrations of chemicals which migrate through various environmental media prior to reaching the exposure points.

Exposure point concentrations of chemicals of concern in soil are presented in Table 9-13. As stated in Section 9.4.1, under current conditions trespassers are the most likely group to contact these soils. For the future exposures to soils discussed in Section 9.4.2, the concentrations of the chemicals of concern currently detected in site surface soil are conservatively assumed to remain the same in the future. This assumption is based on historical evidence. Site activities were stopped 20 years ago; thus, since chemicals have remained on site for 20 years they are expected to be present in the future. Therefore, the exposure point concentrations for future residents and park patrons are also those concentrations presented in Table 9-13.

For trespassers swimming in the quarry, concentrations of chemicals of potential concern currently detected in the surface water (Table 9-14) are considered to be exposure point concentrations. As noted in Section 9.2, several chemicals were detected in sediments (Table 9-15) which were not detected in surface water. Although considered unlikely, these contaminants may desorb from the sediments into surface water. Therefore, exposure point concentrations of chemicals in the surface water will be estimated based on a conservative sediment-water partitioning model. This model is discussed in detail below.

As discussed in Section 9.4, humans may be indirectly exposed to contaminants in surface water and sediments through the ingestion of fish which take up chemicals from the surface water and sediments. Sampling and analysis of fish or a fish species survey in the quarry were not done; therefore, a conservative sediment/surface water exposure model (described in detail in Appendix O) was utilized to predict the concentrations of the chemicals of concern in fish tissue. For chemicals of concern currently detected in the surface water, this model predicts concentrations in fish tissue based on partitioning of chemicals of concern between surface water and fish tissue. For chemicals of concern currently detected only in the sediments, a two part bioconcentration model was derived. In part one, the contaminant concentration in the water was determined by assuming an equilibrium partitioning between the sediment and water to yield sediment pore water concentrations. Then, the pore water concentrations were assumed to be diluted by the depth of water in which the fish are considered to reside. This depth was considered to be the upper 30 feet of the quarry. Below 30 feet, dissolved oxygen concentrations drop to below one ppm. A fish in the low-oxygenated water for any period of time would be under metabolic stress and would move to more oxygenated water. Also, lower foodchain organisms such as the invertebrates often have lower dissolved oxygen threshold than fish and benthic invertebrates normally require a hard substrate which is lacking at the Republic Steel site. Thus, it is not expected that fish will go below the

TABLE 9-13
CONCENTRATIONS OF CHEMICALS OF CONCERN IN SOIL
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Mean Concentration (ug/kg)	Maximum Concentration (ug/kg)	Frequency of Detection
Methylene Chloride	15	33	2/4
Acetone	37	150	2/4
2-Butanone	NR	78	1/4
ncPNA	3,210	5,640	3/4
cPNA	NA	1,800	3/4
Copper	85,000	94,000	3/4
Mercury	NA	340	2/4
bis(2-ethylhexyl) phthalate	NR	7,800	1/4
Di-n-butylphthalate	NA	2,400	2/4
Di-n-octylphthalate	NA	1,900	1/4
Chromium	32	178	3/4
Manganese	842	5,990	4/4

NR = Not relevant. Only 1 sample contained detectable concentrations; therefore a geometric mean was not calculated.

NA = The mean value was below detection.

TABLE 9-14
CONCENTRATIONS OF CHEMICALS OF CONCERN IN SURFACE WATER
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Mean Concentration (ug/l)	Maximum Concentration (ug/l)	Frequency of Detection
Barium	46	113	19/19
Calcium	56,700	315,000	19/19
Iron	3,070	1,600,000	19/19
Magnesium	23,600	67,500	19/19
Manganese	940	25,700	11/19
Nickel	NA	86	5/19
Vanadium	4.4	55	8/19

NA - The mean concentration is below the detection level and is considered as a nondetect.

TABLE 9-15
CONCENTRATIONS OF CHEMICALS OF CONCERN IN SEDIMENT
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Mean Concentration (ug/kg)	Maximum Concentration (ug/kg)	Frequency of Detection
Butylbenzylphthalate	72,300	73,000	2/6
Di-n-octylphthalate	5,000	9,200	3/6
Diethylphthalate	30,250	65,000	4/6
Toluene	340	520	2/4
Methylene Chloride	NA	25	2/4
Acetone	670	1,400	4/4
Tetrachloroethene	5	42	4/9
Ethylbenzene	3.4	29	2/9
2-Butanone	45	360	2/9
ncPNA	8,430	33,200	6/9
cPNA	3,000	17,500	4/6
Pentachlorophenol	34,000	1,600	2/6
Copper	58	300	6/7
Mercury	0.40	0.73	2/7
Tin	NA	108	4/7
Diethylphthalate	4,200	54,000	3/7
Di-n-butylphthalate	8,700	51,300	2/7
bis(2-ethylhexyl) phthalate	NR	26,000	1/7

NA = The mean concentration is below the detection limit.

NR = Not relevant. Only 1 sample contained detected concentrations; therefore a geometric mean was not calculated.

30-foot depth to feed. The model therefore uses the water layer where the fish are expected to reside (the upper 30 feet) to estimate dilution of the estimated sediment pore water concentrations. During warmer weather when a thermocline is present, it is expected that very little mixing between the two water layers occurs. Thus, there is a physical water barrier between the bottom layer where the contaminated sediments are located and the upper layer where the fish are expected to spend the majority of the time. During winter months when a thermocline is not expected, mixing is more likely to occur in the entire water column. Thus, in considering year round mixing over a shallow depth, the model is considered to be conservative. Also, preliminary RI data shows that most of the chemicals of concern identified in the sediments were not identified in the surface water at depth.

In the second part of the model, concentrations in fish (whole body) in the quarry were estimated by multiplying the bioconcentration factor for a chemical by the estimated water concentration of that chemical. The model assumes that no metabolism of contaminants by fish occurs. The chemical concentrations in fish have been estimated based on the assumption that water is the major source of residues. Although chemicals may also be taken up indirectly through the food web and directly from ingested sediments, at the present time insufficient experimental information is available to quantitatively include these residue sources in exposure assessments. This may result in underestimation of concentrations in fish tissue.

The model requires initial source concentrations as input. Average and maximum values of chemicals in surface water and sediment (given in Tables 9-14 and 9-15) were used to provide average and plausible maximum case estimates. Table 9-16 lists the predicted concentrations in surface water and in fish based on the model described above. It should be noted that the predicted concentrations of chemicals of potential concern in surface water will also be used as exposure point concentrations for the swimming scenario.

As discussed in Section 9.4, the groundwater at the site may potentially be used in the future as a potable water source. Exposure point concentrations for future users of this site groundwater are assumed to be the same as those measured in the groundwater during the RI and are presented in Table 9-17.

9.6 HUMAN RISK CHARACTERIZATION

According to guidelines for preparing risk assessments as part of the RI/FS process (EPA 1986a, PRC 1985), the potential adverse effects on human health should be assessed where possible by comparing chemical concentrations found at or near the site with applicable or relevant and appropriate requirements (ARARs) or other guidance that has been developed for the protection of human health or the environment. If ARARs are available for all chemicals in all environmental media, then a comparison to ARARs constitutes the risk assessment. If not, quantitative risk estimates must be developed in addition to the comparison to ARARs. As noted previously in Section 9.3, a complete

TABLE 9-16
ESTIMATED CONCENTRATIONS OF CHEMICALS OF CONCERN IN FISH TISSUE AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical of Concern	K_d	Concentration in Water (ug/L)		BCF	Concentration in Fish (mg/kg)	
		Average	Maximum		Average	Maximum
Barium[a]	60	NC(46)	NC(113)	NA	--	--
Tetrachloroethane[bg]	44	0.00126	0.011	31	0.00004	0.00034
Ethylbenzene[bh]	130	0.00029	0.0025	37.5	0.000011	0.000091
2-Butanone[ci]	0.5	1.0	8.0	0.9	0.00090	0.0072
ncPNA[bj]	660,000	0.00014	0.00060	920	0.00013	0.00051
cPNA[bj]	660,000	0.00005	0.00058	920	0.000046	0.00053
Copper[fk]	35	18	96	290	5.1	28
Mercury[al]	10	0.44	0.81	5,000	2.2	4.0
Pentachlorophenol[bm]	6,400	0.0028	0.059	7.3	0.00002	0.00043
Acetone[cg]	0.3	24	52	0.4	0.0098	0.021
Methylene Chloride[bg]	1.0	NA	0.28	5	NA	0.0017
bis(2-ethylhexyl) phthalate[dq]	10,500	NR	0.028	1.2×10^{-7}	NR	336
Di-n-octylphthalate[dq]	NA	--	--	--	--	--
Di-n-butylphthalate[bq]	20,400	0.0047	0.028	9.8×10^{3}	0.046	0.274
Diethylphthalate[dq]	NA	40	87	117	4.7	10
Butylbenzylphthalate[dq]	2,000	0.406	0.405	9.8×10^{3}	3.9	4
Toluene[bg]	36	0.105	0.16	10.7	0.0011	0.0017
Tin	NA	--	--	--	--	--
Vanadium[a]	1,000	NC(4.4)	NC(55)	NA	--	--
Manganese[ao]	65	NC (940)	NC (25,700)	25	24	640
Nickel[ep]	40	NA	NC (86)	1.1	NA	0.09

NC = Not calculated. Concentration in surface water presented in parentheses.
NA = The mean value was below detection.
NR = Not relevant. Chemical was detected at only one location.
a = Baes, et al., 1984
b = Mabey, et al.
c = K_{oc} estimated from log K_{oc} = -0.55 log Sol + 3.64 where Sol = solubility
d = Russell, D.J., et al., 1986
e = Tyler, L.D. and McBride, M.B. 1982. Mobility and Extractability of Cadmium, Copper, Nickel and Zinc in Organic and Mineral Soil Columns. Soil Sci. 134: 198-205.
f = Benoit, D.A., 1975
g = OWRS, USEPA 1980. Ambient Water Quality Criteria Documents for [Specific Chemical].
h = EPA 1980 AWQC ethyl benzene EPA 440/5-80-048
i = Dawson, G.W. et al., 1980.
j = Gerhart, E.H. and Carlson, R.M. 1978
k = Lind, D. et al. Regional Copper-Nickel Study Aquatic Toxicology Progress Report (Manuscript) (as cited in EPA 1980b)
l = Perry and Chilton, 1973.
m = EPA, 1986 AWQC PCP February 18, 1986 Draft.
o = Chapman, W.H. et al., 1968.
p = Calamari, D., et al, 1982.
q = Bysshe, D.L., 1981.

TABLE 9-17
CONCENTRATIONS OF CHEMICALS OF CONCERN IN GROUNDWATER
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Mean Concentration (ug/L)	Maximum Concentration (ug/L)	Frequency of Detection
Chromium	NA	20	2/5
Copper	NR	28	1/5
Lead	NR	19	1/5
Nickel	NA	131	3/5
Zinc	43	106	5/5
Pentachlorophenol	NR	5[a]	1/8
Phenol	NR	10[b]	1/8
Barium	64	114	5/5
Beryllium	1	2.1	3/5
Chromium	8.4	20	3/5
Copper	11	28	2/5
Lead	NR	19	1/5
Manganese	1,490	11,600	5/5
Nickel	117	131	4/5
Pentachlorophenol	NR	5	1/5
Phenol	NR	10	1/5
Silver	NR	4.1	1/5
Vanadium	29	57	4/5
Zinc	66	106	5/5
Methylene Chloride	7	140	2/5
Acetone	8	55	1/5

NA = The mean concentration is below the detection limit.
NR = Not relevant. Only 1 sample contained detected concentrations; therefore, a geometric mean was not calculated.
[a] The value is estimated in the data base and is one half the detection limit.
[b] The detection limit of phenol is 10 ug/L.

set of suitable ARARs or other guidance are not available for the site, therefore, a quantitative risk characterization was completed for soil, groundwater, surface water, and sediment exposure pathways. A comparison with ARARs and a quantitative risk characterization are presented below.

9.6.1 Comparison With Applicable or Relevant and Appropriate Requirements (ARARs) or Other Criteria

For the chemicals of concern at the Republic Steel site, the concentrations of those chemicals found in groundwater are compared to standards and criteria developed under the Safe Drinking Water Act and Clean Water Act. This comparison will be applied to the appropriate chemicals for drinking water in Table 9-18. Table 9-19 provides standards for surface water. The table shows that the concentrations at the Republic Steel site in groundwater and surface water are below applicable standards in most cases.

Phenol does not have an applicable standard in water. Thus, even though phenol is detected infrequently (1/13) and at a low concentration (at the detection limit) phenol will be included in the quantitative risk assessment.

Available ARARs and other guidance for this assessment have been presented in Tables 9-18 and 9-19.

9.6.1.1 Groundwater

Potential ARARs which have been identified for groundwater are presented in Table 9-18. Guidance issued by USEPA (EPA 1987b) states that "The actual or potential uses of water, and the manner in which it is used, will determine what kinds of requirements may be applicable or relevant and appropriate." Other considerations that EPA note are that (1) drinking water standards are neither applicable nor relevant and appropriate for groundwater that is not suitable for drinking and that does not affect drinkable groundwater, and (2) that MCLs are generally the applicable or relevant and appropriate standard for water that is or may be used for drinking, being applicable at the tap where the water will be provided directly to 25 or more people or will be supplied to 15 or more service connections. Otherwise, where groundwater is to be used for drinking, MCLs are relevant and appropriate requirements. As part of this same guidance, USEPA notes that where there are no specific ARARs for a chemical or where such ARARs are not sufficient to be protective, pertinent health advisories should be identified and used.

In addition, the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that promulgated State environmental standards be included as potential ARARs. Ohio may adopt the federal MCLs and SMCLs as State drinking water standards when federal standards are more stringent than Ohio standards (Susan MacMillan, Ohio EPA, personal communication). However, there is inevitably a time-lag before the States can adopt new Federal MCLs.

TABLE 9-18
COMPARISON OF GROUNDWATER CONCENTRATIONS AT
THE REPUBLIC STEEL SITE WITH ARARs
REPUBLIC STEEL QUARRY RI

Chemical	Concentration in Groundwater ug/L		Water Quality Criteria	
	Average	Maximum	Ohio	Federal
Barium	64	114	--	1,000 MCL
Beryllium	1	2.1	--	0(3.9 ng/l)
Manganese	1,490	11,600	--	--
Chromium	8.4	20	--	50 MCL
Copper	11	28	1,000	--
Lead	NR	19	--	50 MCL
Nickel	47	131	--	15.4 WQC[a]
Zinc	66	106	--	5,000 WQC[b] (organoleptic)
Pentachlorophenol	NR	5	1	--
Phenol	NR	10	--	3,500 WQC[a]
Aluminum	2,600	11,600	--	--
Calcium	190,000	348,000	--	--
Cobalt	NR	18	--	--
Silver	NR	4.1	--	50 WQC[a]
Vanadium	29	57	--	--
Methylene Chloride	7	140	--	--
Acetone	8	55	--	--

NR = Not relevant. Chemical was detected at only 1 location.

a These adjusted criteria, for drinking water ingestion only, were derived from published EPA ambient water quality criteria (45 FR 79318-79379, November 28, 1980) for combined fish and drinking water ingestion and for fish ingestion alone. The adjusted values are not official EPA ambient water quality criteria, but may be appropriate for Superfund sites with contaminated groundwater.

b Criteria designated as organoleptic are based on taste and odor effects, not human health effects. Health-based water quality criteria is not available for this chemical.

TABLE 9-19
COMPARISON OF SURFACE WATER CONCENTRATIONS AT THE REPUBLIC STEEL SITE
WITH AWQC TOXICITY VALUES
REPUBLIC STEEL QUARRY RI

Chemical	Concentration in Surface Water ug/L Average	Maximum	Federal Water Quality Criteria (ug/L) for Consumption of Fish
Nickel	NA	86	100
Vanadium	4.4	55	--
Barium	46	113	--
Manganese	9,210	75,700	100 ug/l
ncPNA[a]	0.00014	0.00060	--
cPNA[a]	0.000050	0.00058	0.031
Pentachlorophenol[a]	0.0028	0.0059	--
Acetone[a]	24	52	--
Tetrachloroethene[a]	0.0026	0.011	--
Ethylbenzene[a]	0.00029	0.00024	3,280
2-Butanone[a]	1.0	8.0	--
bis(2-ethylhexyl) phthalate[a]	NR	14	--
Copper[a]	18	96	--
Mercury[a]	0.44	0.81	0.146
Methylene Chloride[a]	NR	0.28	--
Butylbenzylphthalate[a]	0.400	0.405	--
Di-n-butylphthalate[a]	0.0047	0.0280	--
Di-n-octylphthalate[a]	0.0053	0.0094	--
Toluene[a]	0.105	0.16	424,000

NR = Not relevant. Chemical was detected at only 1 location.

NA = Not applicable. The mean value was below detection.

[a] = calculated concentration

In the following discussion, in which concentrations of site-related chemicals in groundwater in monitoring wells are compared with potential ARARs, the most appropriate of available ARARs or guidance for the aquifer and its use will be identified and used for the comparison. Concentrations detected in the wells during the current sampling effort were used in the comparison.

As indicated in Table 9-18, concentrations of chemicals of potential concern of the Republic Steel site are generally below Water Quality Criteria. Pentachlorophenol exceeds the State of Ohio Criteria for drinking water, a Federal MCL is not available for the chemical.

9.6.1.2 Surface Water.

Potential ARARs for surface water are presented in Table 9-19. Concentrations of site-related chemicals will be compared to ARARs in this section. The results of this comparison are discussed below.

Table 9-19 shows that for concentrations of chemicals of potential concern at the Republic Steel site only mercury exceeds the Federal Water Quality Criteria for consumption of fish and for chronic toxicity to aquatic organisms. While both the average and maximum concentrations of mercury exceed these Water Quality Criteria it should be noted that mercury was not observed in detectable concentrations in surface water but rather was calculated by the sediment/water partitioning model.

Concentrations in the water column are expected to be lower than those predicted by this conservative model.

9.6.2 Quantitative Risk Characterization

9.6.2.1 Quantitative Risk Assessment Methodology

To quantitatively assess the potential risks to human health associated with the current-use and future-use exposure scenarios considered in this assessment, the concentrations of chemicals in relevant environmental media at points of potential exposure (exposure point concentrations) developed in Section 9.4.3 are converted to chronic daily intakes (CDIs). CDIs are expressed as the amount of a substance taken into the body per unit body weight per unit time, or mg/kg/day. A CDI is averaged over a lifetime for carcinogens (EPA 1986b) and over the exposure period for noncarcinogens (EPA 1986c).

For potential carcinogens, excess lifetime cancer risks are obtained by multiplying the daily intake of the contaminant under consideration by its cancer potency factor. EPA recommends that the total cancer risk to individuals resulting from exposure at a Superfund site be reduced to zero where possible. EPA has implemented actions under Superfund associated with

total cancer risks ranging from 10^{-4} to 10^{-7} (i.e., one excess cancer in every 10,000 or 10,000,000 individuals, respectively, exposed throughout their lifetime) (EPA 1986a). A risk level of 10^{-6}, representing an upperbound probability that one excess cancer case in 1,000,000 individuals might result from exposure to the potential carcinogen, is often used as a benchmark by regulatory agencies. Accordingly, 10^{-6} will be the benchmark risk level used in this report.

Potential risks for noncarcinogens are presented as the ratio of the chronic daily intake exposure to the reference dose (CDI:RfD). The sum of all of the ratios of chemicals under consideration is called the hazard index. The hazard index is useful as a reference point for gauging the potential effects of environmental exposures to complex mixtures. In general, hazard indices which are less than one are not likely to be associated with any health risks, and are therefore less likely to be of regulatory concern than hazard indices greater than one. A conclusion should not be categorically drawn, however, that all hazard indices less than one are "acceptable" or that hazard indices of greater than one are "unacceptable". This is a consequence of the perhaps one order of magnitude or greater uncertainty inherent in estimates of the RfD and CDI in addition to the fact that the uncertainties associated with the individual terms in the hazard index calculation are additive.

In accordance with EPA's guidelines for evaluating the potential toxicity of complex mixtures (EPA 1986d), it was assumed that the toxic effects of the site-related chemicals would be additive. Thus, lifetime excess cancer risks and the CDI:RfD ratios were summed to indicate the potential risks associated with mixtures of potential carcinogens and noncarcinogens, respectively. In the absence of specific information on the toxicity of the mixture to be assessed or on similar mixtures, EPA guidelines generally recommend assuming that the effects of different components on the mixtures are additive when affecting a particular organ or system. Synergistic or antagonistic interactions may be taken into account if there is specific information on particular combinations of chemicals. In this risk assessment, it was assumed that the potential effects of the site-related chemicals would be additive. Equations used to estimate contaminant intakes, carcinogenic risks, and noncarcinogenic risks are presented in Appendix P.

To determine the rates of contaminant intake for the populations likely to be at risk of exposure, scenarios depicting the activities of trespassers (current), park patrons (future), and residents (future) have been constructed. For each scenario, two cases were considered - an average case and a plausible maximum case. The average case assumes average estimates of exposure parameters (e.g., average frequency and duration of exposure and quantity of contaminated media contacted) and uses the geometric mean concentrations of the contaminants found in relevant environmental media. On the other hand, the plausible maximum case assumes the highest estimates of the exposure parameters and considers the maximum concentrations of the contaminants found in the media. Exposure characteristic of the plausible maximum case are possible; however, they are likely to apply to only a small fraction of the population.

9.6.2.2 Current-Use Scenario: Intermittent Exposure of Trespassers to Contaminated Soils

Under this scenario, it is assumed that trespassers may enter the property and come into contact with contaminated soils. Contaminants may then be absorbed through the skin or be inadvertently ingested by smoking or eating, or in the case of children, by placing soiled objects in the mouth.

To calculate the amount of soil taken in by trespassers several assumptions are made. These assumptions are summarized in Table 9-20. The trespassers are assumed to be youths between the ages of 13 and 18 having an average body weight of 60 kg. They are expected to visit the site an average of 24 and a maximum of 40 times per year over a period of about 5 years under the average and plausible maximum exposure scenarios, respectively.

Based on LaGoy (1987), it was assumed that these youths will incidentally ingest approximately 50 mg and possibly up to 100 mg of contaminated soil per visit. However, depending on the compounds, only a fraction of the contamination in the soil that is ingested will be absorbed. These more recently generated values have replaced values provided in the Superfund Public Health Evaluation by Kimbrough et al. (1984). In calculating the intake of contaminants from ingestion of contaminated soil from the Republic Steel site, the following percentages of gastrointestinal absorption for the different chemicals are assumed: 15-45 percent of the carcinogenic PNAs are absorbed; 50-100 percent of the noncarcinogenic PNAs are absorbed; and 100 percent of all other chemicals are absorbed. (Estimated from Poiger & Schlatter, 1980; McConnel et al., 1984; Lucier et al., 1986; VandenBerg, et al., 1985, 1986; and Galey et al. 1976).

In addition to inadvertently ingesting soils, trespassers may be exposed to soil contaminants by direct dermal contact and subsequent absorption. Based on the work of Schaum (1984), daily soil contact rates of 0.5 mg/cm^2 to 1.5 mg/cm^2 have been assumed for the average and maximum exposure scenarios, respectively. An area of exposed skin surface of 1,980 cm^2 has been estimated for the hands and forearms (EPA 1985). Dermal absorption of PNAs is based on Feldman and Maibach (1970) with consideration for soil matrix effects. One percent of the remaining organic chemicals in the soil is assumed to be absorbed through the skin in the average case, and 4 percent of the remaining organic chemicals is absorbed in the plausible maximum case (based on Feldman and Maibach 1970).

Chronic daily intakes and noncarcinogenic risks calculated using the above assumptions and the equations presented in Appendix P are presented in Table 9-21. CDIs and associated excess lifetime cancer risks for this scenario are presented in Table 9-22. As indicated in Table 9-21, the estimated intakes of

TABLE 9-20
ASSUMPTIONS USED TO ESTIMATE EXPOSURE TO TRESPASSERS VIA CONTACT WITH SOIL UNDER CURRENT-USE CONDITIONS AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Parameter	Average Case	Plausible Maximum Case
Ages Exposed	13-18 years	13-18 years
Frequency of Exposure	24 days/yr	40 days/yr
Period of Exposure	5 years	5 years
Incidental Ingestion[a]	50 mg/day	100 mg/day
Oral absorption factor[b]		
Metals	1	1
cPNAs	0.15	0.45
ncPNAs	0.50	1
Other organic chemicals	1	1
Daily Soil Contact Rate[c]	0.5 $mg/cm^2/day$	1.5 $mg/cm^2/day$
Area of Exposed Skin[d]	1,980 cm^2	1,980 cm^2
Dermal Absorption Factor[e]		
Metals	0	0
PNAs	0.003	0.03
Other organic chemicals	0.01	0.04
Average Body Weight	60 kg	60 kg
Exposure Point Concentrations[f]	Mean	Maximum

a Based on the work of LaGoy 1987.
b This factor represents the percentage of contaminants absorbed from ingested soil.
c Based on the work of Schaum 1984.
d EPA 1985.
e This factor represents the percentage of contaminants absorbed through the skin.
f These concentrations are shown in Table 9-13.

TABLE 9-21
CHRONIC DAILY INTAKE AND NONCARCINOGENIC RISKS TO TRESPASSERS
VIA DIRECT CONTACT WITH SOIL UNDER CURRENT-USE CONDITIONS
AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	RfD (mg/kg/d)	Chronic Daily Intake (mg/kd/day)		CDI:RfD Ratio	
		Average	Plausible Maximum	Average	Plausible Maximum
Acetone	$1.0x10^{-1}$	$2.4x10^{-9}$	$6.0x10^{-8}$	$2x10^{-8}$	$6x10^{-7}$
Copper	$3.7x10^{-2}$	$4.7x10^{-6}$	$1.7x10^{-8}$	$1x10^{-4}$	$5x10^{-7}$
ncPNA	$4.1x10^{-1}$	$9.8x10^{-8}$	$1.9x10^{-6}$	$2x10^{-7}$	$5x10^{-6}$
Methylene Chloride	$6.0x10^{-2}$	$1.4x10^{-9}$	$1.3x10^{-8}$	$2x10^{-8}$	$2x10^{-7}$
2-Butanone	$5.0x10^{-2}$	$5.1x10^{-9}$	$3.1x10^{-8}$	$1x10^{-7}$	$6x10^{-7}$
Di-n-octyl-phthalate	NA	$8.9x10^{-9}$	$5.4x10^{-8}$	NA	NA
Di-n-butyl-phthalate	$1.0x10^{-1}$	$1.1x10^{-8}$	$6.8x10^{-8}$	$1x10^{-7}$	$7x10^{-7}$
bis(2-ethylhexyl) phthlate	$2.0x10^{-2}$	$5.1x10^{-7}$	$3.1x10^{-6}$	$2x10^{-5}$	$2x10^{-4}$
Mercury	$1.4x10^{-3}$	$1.9x10^{-8}$[b]	$6.2x10^{-8}$	$1x10^{-5}$	$4x10^{-5}$
Chromium	$5.0x10^{-3}$	$1.8x10^{-9}$	$3.3x10^{-8}$	$4x10^{-7}$	$7x10^{-6}$
Manganese	$2.2x10^{-1}$	$4.6x10^{-8}$	$1.1x10^{-6}$	$2x10^{-7}$	$5x10^{-6}$
Total Hazard Index				$1x10^{-4}$	$3x10^{-4}$

a The assumptions made in developing the average and plausible maximum exposure cases are shown in Table 9-20. Exposure point concentrations are presented in Table 9-13.

b Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate average CDI.

TABLE 9-22
CHRONIC DAILY INTAKES AND POTENTIAL EXCESS LIFETIME CANCER RISKS TO TRESPASSERS VIA DIRECT CONTACT WITH SOIL UNDER CURRENT-USE CONDITIONS AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	Potency Factor $(mg/kg/d)^{-1}$	Chronic Daily Intake (mg/kd/d)		Excess Lifetime Cancer Risk	
		Average	Plausible Maximum	Average	Plausible Maximum
cPNA	$1.5x10^{1}$	$1.5x10^{-9}$[b]	$3.1x10^{-8}$	$2x10^{-8}$	$4x10^{-7}$
Methylene Chloride	$7.5x10^{-3}$	$7.1x10^{-11}$	$9.4x10^{-10}$	$5x10^{-13}$	$7x10^{-12}$
bis(2-ethylhexyl) phthlate	$6.8x10^{-4}$	$3.7x10^{-8}$[b]	$2.2x10^{-7}$	$2x10^{-11}$	$2x10^{-10}$
Total	--	--	--	$2x10^{-8}$	$4x10^{-7}$

-- = Not relevant.

[a] The assumptions made in developing the average and plausible maximum exposure cases are shown in Table 9-20.

[b] Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate CDI. Exposure point concentrations are presented in Table 9-13.

the chemicals of potential concern are less than the available criteria for protection against noncarcinogenic effects and the hazard index for both the average and plausible maximum exposure scenarios is less than one. Thus, noncarcinogenic health risks are not likely to result from exposure to the chemicals evaluated. Table 9-22 indicates that under the average and plausible maximum exposure assumptions, the upperbound excess lifetime cancer risks are less than 10^{-6}.

9.6.2.3 Current-Use Scenario: Intermittent Exposure of Trespassers to Contaminated Surface Water While Swimming.

Under this exposure scenario, it is assumed that older children trespass onto the site and swim in the quarry. These individuals may be exposed to chemicals of concern in the quarry water through dermal absorption and incidental ingestion. To evaluate this exposure scenario, it is assumed that individuals would use these lakes for swimming between the ages of 13 to 18 years. It also is assumed that individuals swim two times a week during the warmest 4 months of the year for the average case and four times a week during the same months for the plausible maximum case. These and other assumptions used to calculate exposures while swimming are summarized in Table 9-23.

Significant dermal absorption of the metals detected in the quarry is not expected because the concentrations are low, and because the permeability of even hydrated skin to metal ions is low. Further, the episodic nature and short-duration of swimming events also minimizes the potential for significant exposure. As a result, intakes from dermal absorption of metals while swimming is not evaluated. However, dermal absorption of organic chemicals will be evaluated. A simplified approach presented in the Superfund Exposure Assessment Manual (EPA 1987) is used to estimate exposures while swimming via dermal absorption. This approach assumes that a contaminant is carried through the skin as a solute in water (rather than being preferentially absorbed independently of the water).

The flux rate of water across the skin boundary is assumed to be the factor controlling the contaminant absorption rate. Although the Exposure Assessment Manual suggest using a flux rate of 0.5 $mg/cm^2/hr$, more recent data suggest this value may be closer to 1 $mg/cm^2/hr$ (Brown et al. 1984). In this assessment, 0.5 $mg/cm^2/hr$ will be used to evaluate the average exposure scenario, and 1 $mg/cm^2/hr$ will be used to evaluate the plausible maximum exposure scenario. It is assumed that the dermal absorption of the organic chemicals is 100%.

In addition to dermal contact, it is possible that a person may accidentally swallow water while swimming. For the purpose of evaluating this potential exposure, it is assumed that an individual will ingest approximately 100 milliliters (about 3.5 fluid ounces) of water during each swimming event. All of the chemicals of concern in the quarry water will be assessed in this exposure pathway.

TABLE 9-23
ASSUMPTIONS USED FOR CALCULATING CHEMICAL INTAKES
DUE TO SWIMMING IN THE REPUBLIC STEEL QUARRY
REPUBLIC STEEL QUARRY RI

Parameter	Plausible Average Exposure	Maximum Exposure
Age of exposed individual	13-18 years	13-18 years
Frequency of swimming	32 events/year	64 events/year
Duration of exposure event	1 hr	1 hr
Years of exposure	5	5
Average weight over period of exposure	60 kg	60 kg
Amount of water ingested while swimming	100 ml/event	100 ml/event
Skin surface area[a]	15,300 cm^2	15,300 cm^2
Flux rate of water (and chemical) across skin	0.5 $mg/cm^2/hr$	1.0 $mg/cm^2/hr$

[a] Corresponding to the 50th percentile among 12-15 year old males (EPA 1985d).

Chronic daily intakes and risks, calculated using the above assumptions and equations presented in Appendix P, are presented in Tables 9-24 and 9-25, for noncarcinogens and carcinogens respectively. Subchronic daily intakes are not calculated, as proposed in the Superfund PHE, because concentrations at Superfund sites are most often at a level to potentially promote chronic effects. If levels of contaminants were high enough to promote subchronic effects, it is assumed that these effects would have been observed at the site. The endangerment assessment uses average and plausible maximum concentrations to calculate average and upper bound risk. As indicated in Table 9-24, the hazard index for both the average and plausible maximum exposure scenarios is less than one. Thus, noncarcinogenic health risks are not likely to result from exposure through swimming.

Additionally, as indicated in Table 9-25, the upperbound excess lifetime cancer risks are less than 10^{-6} for the average and maximum scenarios.

9.6.2.4 Current-Use Scenario: Intermittent Exposure of Trespassers to Contaminated Fish.

For the purposes of this assessment, it is assumed that fishing occurs during 4 months of the year for 10 years as an average case and 20 years as a maximum case, and that enough fish is assumed to be caught to occasionally feed a family. Under this scenario, it is assumed that fish are caught and consumed once a week for 4 months for a total of 16 meals each year. The average quantity of fish consumed per meal is 113 g (corresponding to the 50th percentile among fish eaters, as reported by Pao et al. 1982) and the plausible maximum amount ingested is 340 g (corresponding to the 95th percentile). The average exposed family member is assumed to weigh 60 kg. The exposure assumptions are summarized in Table 9-26. CDIs and calculated risk estimates (calculated using the equations in Appendix P) for noncarcinogens and carcinogens are presented in Tables 9-27 and 9-28, respectively.

As indicated in Table 9-27, under the average exposure conditions, the hazard index is less than one, indicating that noncarcinogenic health risks are not likely to result. However, for the maximum exposure scenarios the estimated intake of mercury is greater than available criteria for protection against noncarcinogenic effects, thus making the overall hazard index greater than one. It should be noted that mercury was only detected in 2 out of 7 sediment samples and that it was not detected in the surface water.

As shown in Table 9-28 the upperbound excess lifetime cancer risks associated with ingestion of fish are $3x10^{-8}$ and $4x10^{-6}$ under the average and maximum exposure scenarios. For the maximum exposure scenario the risk is primarily due to exposure to carcinogenic PNAs.

TABLE 9-24
CHRONIC DAILY INTAKES AND NONCARCINOGENIC RISKS TO INDIVIDUALS
SWIMMING IN THE QUARRY UNDER CURRENT-USE CONDITIONS
AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	RfD (mg/kg/d)	Chronic Daily Intake (mg/kd/day) Average	Chronic Daily Intake (mg/kd/day) Plausible Maximum	CDI:RfD Ratio Average	CDI:RfD Ratio Plausible Maximum
Barium	$5.0x10^{-2}$	$6.7x10^{-6}$	$3.3x10^{-5}$	$1x10^{-4}$	$7x10^{-4}$
Butylbenzyl-phthalate[c]	NA	$6.3x10^{-8}$	$1.4x10^{-7}$	NA	NA
Diethylphthalate[c]	$8.0x10^{-1}$	$6.3x10^{-6}$	$2.9x10^{-5}$	$8x10^{-6}$	$4x10^{-5}$
Di-n-butylphthalate[c]	$1.0x10^{-1}$	$7.4x10^{-10}$	$9.4x10^{-9}$	$7x10^{-9}$	$9x10^{-8}$
Di-n-octylphthalate[c]	NA	$8.3x10^{-10}$	$3.3x10^{-9}$	NA	NA
Tin[c]	$6.4x10^{-1}$	NA	NA	NA	NA
Toluene[c]	$3.0x10^{-1}$	$1.7x10^{-8}$	$5.4x10^{-8}$	$5x10^{-8}$	$2x10^{-7}$
Ethylbenzene	$1.0x10^{-1}$	$4.6x10^{-11}$	$3.7x10^{-9}$	$5x10^{-10}$	$4x10^{-8}$
2-Butanone	$5.0x10^{-2}$	$1.6x10^{-7}$	$2.7x10^{-6}$	$3x10^{-6}$	$5x10^{-5}$
ncPNA	$4.1x10^{-1}$	$2.2x10^{-11}$	$2.0x10^{-10}$	$5x10^{-11}$	$5x10^{-10}$
Copper	$3.7x10^{-2}$	$2.6x10^{-6}$	$2.8x10^{-5}$	$7x10^{-5}$	$8x10^{-4}$
Mercury	$1.4x10^{-3}$	$6.4x10^{-8}$	$2.4x10^{-7}$	$5x10^{-8}$	$2x10^{-4}$
Methylene Chloride	$6.0x10^{-2}$	$4.4x10^{-9}$[b]	$9.4x10^{-9}$	$7x10^{-8}$	$2x10^{-7}$
Acetone	$1.0x10^{-1}$	$3.8x10^{-6}$	$1.8x10^{-5}$	$4x10^{-5}$	$2x10^{-4}$
Pentachlorophenol	$3.0x10^{-2}$	$4.4x10^{-10}$	$2.0x10^{-8}$	$1x10^{-8}$	$7x10^{-7}$
Manganese	$2.2x10^{-1}$	$1.4x10^{-4}$	$7.9x10^{-4}$	$6x10^{-4}$	$4x10^{-3}$
Nickel	$2.0x10^{-2}$	$1.3x10^{-5}$[b]	$2.5x10^{-5}$	$6x10^{-4}$	$1x10^{-3}$
Vanadium	$2.0x10^{-2}$	$6.4x10^{-7}$	$1.6x10^{-5}$	$3x10^{-5}$	$8x10^{-4}$
bis(2-ethylhexyl) phthalate	$2.0x10^{-2}$	$2.2x10^{-6}$	$4.7x10^{-6}$	$1x10^{-4}$	$2x10^{-4}$
Total Hazard Index	--	--	--	$2x10^{-3}$	$8x10^{-3}$

-- = Not relevant.

[a] The assumptions used in calculating the average and maximum intakes are presented in Table 9-23.

[b] Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate CDI.

[c] Chemicals were not detected in surface water. Water concentrations were calculated from sediment concentrations.

TABLE 9-25
CHRONIC DAILY INTAKES AND POTENTIAL EXCESS LIFETIME CANCER RISKS TO INDIVIDUALS SWIMMING IN THE QUARRY UNDER CURRENT-USE CONDITIONS AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	Potency Factor $(mg/kg/d)^{-1}$	Chronic Daily Intake (mg/kg/day)		Excess Lifetime Cancer Risk	
		Average	Plausible Maximum	Average	Plausible Maximum
Tetrachloroethene	$5.1x10^{-2}$	$4.9x10^{-11}$	$7.9x10^{-10}$	$2x10^{-12}$	$4x10^{-11}$
cPNA	$1.15x10^{1}$	$5.6x10^{-13}$	$1.4x10^{-11}$	$6x10^{-12}$	$2x10^{-10}$
Methylene Chloride	$7.5x10^{-3}$	$3.1x10^{-9}$[b]	$6.7x10^{-9}$	$2x10^{-11}$	$5x10^{-11}$
bis(2-ethylhexyl) phthalate	$6.84x10^{-4}$	$1.6x10^{-7}$[b]	$3.3x10^{-7}$	$1x10^{-10}$	$2x10^{-10}$
Total	--	--	--	$1x10^{-10}$	$4x10^{-10}$

[a] The assumptions used in calculating the average and maximum intakes are presented in Table 9-23.

b Mean concentration was not available. Therefore, maximum concentration was used in conjunction with average exposure conditions to obtain average CDIs.

TABLE 9-26
ASSUMPTIONS USED TO ESTIMATE EXPOSURE TO EATING FISH
FROM THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Parameter	Average Case	Plausible Maximum Case
Frequency of Fish Meals	16 meals/year	16 meals/year
Years of Exposure	10 years	20 years
Quantity of Fish Ingested Per Meal[a]	113 g	340 g
Average Body Weight of Individual	70 kg	70 kg

[a] Average and maximum values correspond to the 50th and 95th percentile of the amount of fish consumed by fish eaters, Pao et al. 1982.

TABLE 9-27
CHRONIC DAILY INTAKES AND NONCARCINOGENIC RISKS TO INDIVIDUALS
VIA CONSUMPTION OF FISH UNDER CURRENT-USE CONDITIONS
AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	RfD (mg/kg/d)	Chronic Daily Intake (mg/kd/day) Average	Chronic Daily Intake (mg/kd/day) Plausible Maximum	CDI:RfD Ratio Average	CDI:RfD Ratio Plausible Maximum
Ethylbenzene	$1x10^{-1}$	$9.1x10^{-10}$	$2.3x10^{-8}$	$9x10^{-9}$	$2x10^{-7}$
2-Butanone	$5x10^{-2}$	$7.5x10^{-8}$	$1.8x10^{-6}$	$1x10^{-6}$	$4x10^{-5}$
ncPNA	$4.1x10^{-1}$	$1.1x10^{-8}$	$1.3x10^{-7}$	$3x10^{-8}$	$3x10^{-7}$
Copper	$3.7x10^{-2}$	$4.4x10^{-4}$	$7.0x10^{-4}$	$1x10^{-2}$	$2x10^{-2}$
Mercury	$3.0x10^{-4}$	$1.8x10^{-4}$	$1.0x10^{-3}$	$6x10^{-1}$	$3x10^{0}$
Methylene Chloride	$6.0x10^{-2}$	$1.4x10^{-7}$[b]	$4.3x10^{-7}$	$2x10^{-6}$	$7x10^{-6}$
Acetone	$1.0x10^{-1}$	$8.1x10^{-7}$	$5.3x10^{-6}$	$8x10^{-6}$	$5x10^{-5}$
Pentachlorophenol	$3.0x10^{-2}$	$1.7x10^{-9}$	$1.1x10^{-7}$	$6x10^{-8}$	$4x10^{-6}$
Manganese	$2.2x10^{-1}$	$2.0x10^{-3}$	$1.6x10^{-1}$	$9x10^{-3}$	$7x10^{-1}$
Nickel	$2.0x10^{-2}$	$3.3x10^{-4}$[b]	$1.0x10^{-3}$	$2x10^{-2}$	$5x10^{-2}$
bis(2-ethylhexyl) phthalate	$2.0x10^{-2}$	$1.8x10^{-4}$[b]	$5.5x10^{-4}$	$9x10^{-3}$	$3x10^{-2}$
Butylbenzyl-phthalate	NA	$3.2x10^{-7}$	$9.9x10^{-7}$	NA	NA
Diethylphthalate	$8.0x10^{-1}$	$3.9x10^{-7}$	$2.5x10^{-6}$	$5x10^{-7}$	$3x10^{-6}$
Di-n-butyl-phthalate	$1.0x10^{-1}$	$3.8x10^{-9}$	$6.8x10^{-8}$	$4x10^{-8}$	$7x10^{-7}$
Di-n-octyl-phthalate	NA	$8.3x10^{-6}$	$4.6x10^{-5}$	NA	NA
Tin	$6.4x10^{-1}$	NA	NA	NA	NA
Toluene	$3.0x10^{-1}$	$9x10^{-11}$	$4.2x10^{-10}$	$3x10^{-10}$	$1x10^{-9}$
Barium	$5.0x10^{-2}$	NA	NA	NA	NA
Vanadium	$2.0x10^{-2}$	NA	NA	NA	NA
Total Hazard Index				$7x10^{-1}$	4

[a] The assumptions used in calculating the average and maximum intakes are presented in Table 9-26.

[b] Mean concentrations was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate CDI.

TABLE 9-28
CHRONIC DAILY INTAKE AND POTENTIAL CANCER RISKS TO INDIVIDUALS
VIA CONSUMPTION OF FISH UNDER CURRENT-USE CONDITIONS
AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	Potency Factor $(mg/kg/d)^{-1}$	Chronic Daily Intake (mg/kg/day)		Excess Lifetime Cancer Risk	
		Average	Plausible Maximum	Average	Plausible Maximum
Tetrachloroethene	$1.0x10^{-2}$	$2.2x10^{-9}$	$9.9x10^{-8}$	$2x10^{-11}$	$1x10^{-9}$
cPNA	$1.15x10^{1}$	$5.4x10^{-10}$	$3.8x10^{-7}$	$6x10^{-9}$	$4x10^{-6}$
Methylene Chloride	$7.5x10^{-3}$	$2.0x10^{-8}$	$1.2x10^{-7}$	$2x10^{-10}$	$9x10^{-10}$
bis(2-ethylhexyl) phthalate	$6.84x10^{-4}$	$2.6x10^{-5}$[b]	$1.7x10^{-4}$	$2x10^{-8}$	$1x10^{-7}$
Total	--	--	--	$3x10^{-8}$	$4x10^{-6}$

[a] The assumptions used in calculating the average and maximum intakes are presented in Table 9-26.

[b] Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate CDI.

9.6.2.5 Future-Use Scenario: Lifetime Exposure of Residents to Contaminated Soils

Residential development of the Republic Steel site may allow future residents to be exposed to contaminated soils. Children are the most likely population at risk because their daily intake of soil may be high as a result of playing or crawling on their hands and subsequently placing their hands in their mouths. Some children also directly eat soil in a behavior known as habitual pica (this extreme behavior would result in a greater potential risk than what is calculated). This behavior, however, is primarily associated with medical disorders such as malnutrition and is thus not evaluated in this EA. Adults also come into contact with and may inadvertently ingest contaminated soil.

The amounts of soil ingested by individuals differs with age. Estimates of intakes by different age groups has been discussed by LaGoy (1987). Children from 1-6 years old may ingest 100 to 500 mg per day; and children from 6 to 12 years old may ingest 50 to 250 mg per day. Adults and children over the age of 12 are assumed to ingest 25 to 100 mg of soil per day. Over a lifetime, a person is assumed to ingest 30 to 140 mg per day. These values represent time-weighted averages of the values present for each age group.

The length of time the residents spend outdoors also differs with age. Based on EPA (1984) for the average and maximum scenarios, children are assumed to spend an average of 125 days and a maximum of 250 days per year outdoors. The average adult is assumed to spend one day a week outdoors on yard work from May to October (25 days/year); while the avid gardener is assumed to spend up to four days a week outdoors from May to October (100 days/year). Based on these values, time-weighted averages of lifetime frequencies of exposure were calculated to be 40 and 125 days/year for the average and assumed maximum scenarios, respectively.

Residents directly contacting contaminated soils will be exposed not only by ingestion, but through dermal absorption of chemicals. The average lifetime soil contact rates are assumed to be 0.5 mg/cm^2 and 1.5 mg/cm^2 under average and plausible maximum exposure conditions respectively (Schaum 1984). The surface area exposed for children in different age groups was derived from information provided by EPA (1985) and involved summing the percentages of total body surface area contributed by the hands, lower arms (40 percent of the arms), and the lower legs (40 percent of the legs) for each age group and multiplying the value by 90 percent of the total body surface area for male children. The adult values for surface area exposed included the area of the hand and forearms only (EPA 1985) since these areas are most likely to be exposed to soil contaminants. To calculate the exposure parameters for a lifetime resident, the values for the different age groups were averaged taking into consideration the length of time the person spends in that age group (i.e., the lifetime values represent time weighted-average values). Table 9-29 summarizes these assumptions. Tables 9-30 and 9-31 present CDIs

TABLE 9-29
ASSUMPTIONS USED TO ESTIMATE EXPOSURE TO RESIDENTS VIA DIRECT CONTACT WITH SOIL--FUTURE-USE SCENARIO AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Parameter	Average Case	Plausible Maximum Case
Frequency of Exposure		
Children (1-12 years)	125 days/year	250 days/year
Adults (12-70 years)	25 days/year	100 days/year
Lifetime (0-70 years)	40 days/year	125 days/year
Period of Exposure		
Children aged 1-6 years	5 years	5 years
Children aged 6-12 years	6 years	6 years
Ages 12 and older	59 years	59 years
Lifetime (0-70 years)	70 years	70 years
Incidental Ingestion Rate[a]		
Children aged 1-6 years	100 mg/day	500 mg/day
Children aged 6-12 years	50 mg/day	250 mg/day
Ages 12 and older	25 mg/day	100 mg/day
Lifetime (0-70 years)	50 mg/day	140 mg/day
Oral Absorption factor[b]		
cPNAs	0.15	0.45
ncPNAs	0.50	1.00
Other organic chemicals & metals	1.00	1.00
Daily Soil Contact Rate[c]	0.5 mg/cm^2	1.5 mg/cm^2
Area of Exposed Skin[d]		
Children ages 1-6 years	1730 cm^2	1730 cm^2
Children aged 6-12 years	2920 cm^2	2920 cm^2
Ages 12 and older	1980 cm^2	1980 cm^2
Lifetime (0-70 years)	2040 cm^2	2040 cm^2
Dermal Absorption Factor[e]	0.01	0.04
Metals	0	0
PNAs	0.003	0.03
Other organic chemicals	0.01	0.04
Average Body Weight		
Children aged 1-6 years	15 kg	15 kg
Children aged 6-12 years	30 kg	30 kg
Ages 12 and older	70 kg	70 kg
Lifetime (0-70 years)	60 kg	60 kg
Exposure Point Concentrations[f]	Geometric Mean	Maximum

[a] Based on the work of LaGoy 1987.
[b] This factor represents the percentage of contaminants absorbed from ingested soil.
[c] Based on the work of Schaum 1984.
[d] EPA 1985. Adult values were calculated based on the exposure of the hands and forearms. Children's values were calculated based on the exposure of the hands, lower legs and lower arms.
[e] This factor represents the percentage of contaminants absorbed through the skin.
[f] These concentrations are shown in Table 9-13.
[g] Lifetime values are weighted averages of values for different age groups.

TABLE 9-30
CHRONIC DAILY INTAKES AND NONCARCINOGENIC RISKS TO RESIDENTS
VIA DIRECT CONTACT WITH SOILS UNDER FUTURE-USE CONDITIONS
AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	RfD (mg/kg/d)	Chronic Daily Intake (mg/kd/day)		CDI:RfD Ratio	
		Average	Plausible Maximum	Average	Plausible Maximum
Copper	$3.7x10^{-2}$	$4.9x10^{-6}$	$7.5x10^{-5}$	$1x10^{-4}$	$2x10^{-3}$
ncPNA	$4.1x10^{-1}$	$1.1x10^{-7}$[b]	$7.3x10^{-6}$	$3x10^{-7}$	$2x10^{-5}$
Acetone	$1.0x10^{-1}$	$2.8x10^{-9}$	$2.2x10^{-7}$	$3x10^{-8}$	$2x10^{-6}$
Methylene Chloride	$6.0x10^{-2}$	$1.1x10^{-9}$	$5.0x10^{-8}$	$2x10^{-8}$	$8x10^{-7}$
Di-n-butylphthalate	$1.0x10^{-1}$	$1.9x10^{-7}$	$3.7x10^{-6}$	$2x10^{-6}$	$4x10^{-5}$
Di-n-octylphthalate	NA	$1.5x10^{-7}$	$2.9x10^{-6}$	NA	NA
bis(2-ethylhexyl) phthalate	$2.0x10^{-2}$	$6.0x10^{-7}$[b]	$1.2x10^{-5}$	$3x10^{-5}$	$6x10^{-4}$
Mercury	$1.4x10^{-3}$	$2.0x10^{-8}$[b]	$2.7x10^{-7}$	$1x10^{-5}$	$2x10^{-4}$
Chromium	$5.0x10^{-3}$	$1.9x10^{-9}$	$1.4x10^{-7}$	$4x10^{-7}$	$3x10^{-5}$
Manganese	$2.2x10^{-1}$	$4.9x10^{-8}$	$4.8x10^{-6}$	$2x10^{-7}$	$2x10^{-5}$
Total Hazard Index	--	--	--	$1x10^{-4}$	$3x10^{-3}$

-- = Not relevant.

[a] The assumptions made in developing the average and maximum exposure cases are shown in Table 9-29.

[b] Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate the CDI.

TABLE 9-31
CHRONIC DAILY INTAKES AND POTENTIAL EXCESS LIFETIME CANCER RISKS TO RESIDENTS VIA DIRECT CONTACT WITH SOILS UNDER FUTURE USE CONDITIONS AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	Potency Factor $(mg/kg/d)^{-1}$	Chronic Daily Intake (mg/kg/day)		Excess Lifetime Cancer Risk	
		Average	Plausible Maximum	Average	Plausible Maximum
bis(2-ethylhexyl) phthalate	6.84×10^{-4}	6.0×10^{-7}[b]	1.2×10^{-5}	4×10^{-10}	8×10^{-9}
cPNA	1.15×10^{1}	2.5×10^{-8}[b]	1.6×10^{-6}	3×10^{-7}	2×10^{-5}
Methylene Chloride	7.5×10^{-3}	1.1×10^{-9}	5.0×10^{-8}	9×10^{-12}	4×10^{-10}
Total	--	--	--	3×10^{-7}	2×10^{-5}

-- = Not relevant

[a] The assumptions made in developing the average and assumed maximum exposure cases are shown in Table 9-29.

[b] Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate CDI.

and calculated risk estimates for noncarcinogens and carcinogens, respectively.

As indicated in Table 9-30 the hazard index for both the average and plausible maximum case is less than one indicating that noncarcinogenic health risks will not result from future residential exposure to soils. For carcinogens, Table 9-31 illustrates that the potential upperbound excess lifetime cancer risk is less than 10^{-6} under the average case and equal to $2x10^{-5}$ under the plausible maximum exposure scenario. The maximum risk is primarily due to exposure to cPNAs, which were detected at higher concentrations at one area of the site (the south boat launch) and which are ubiquitous in the environment.

9.6.2.6 Future-Use Scenario: Exposure of Park Patrons to Contaminated Soils

The assumptions for exposure of park patrons to contaminated soils in the event that the site is converted into a park are similar to the assumptions for exposure of current trespassers, except that the frequency of exposure in the average case is assumed to be 16 times per year and in the plausible maximum case 40 times per year. The period of exposure will be 20 years for both the average case and plausible maximum cases. All other assumptions (e.g., soil ingestion rates, absorption factors etc.) other than the ones described will be identical to those present Table 9-20 for trespassers. Table 9-32 lists these assumptions for park patrons. CDIs and calculated risk estimates for noncarcinogens and carcinogens are given in Tables 9-33 and 9-34, respectively.

Table 9-33 shows that the hazard index for both the average and plausible maximum scenarios is less than one indicating that noncarcinogenic health risks will not result under the conditions evaluated. Table 9-34 illustrates that the upperbound excess lifetime cancer risk is less than and equal to 10^{-6} under the average and plausible maximum exposure conditions evaluated. The maximum risk is primarily due to cPNA which, as discussed before, are present mainly at the south boat launch.

9.6.2.7 Future-Use Scenario: Lifetime Exposure of Residents to Contaminated Groundwater

As discussed in Section 9.4, the Republic Steel site could potentially be converted to a housing development in the future with groundwater on the site being used as a potable water supply. Potential health risks associated with exposure of residents to the chemicals of concern in groundwater through ingestion of groundwater was estimated by assuming that a 70-kg individual ingests two liters of groundwater a day for a 70-year lifetime. These assumptions are summarized in Table 9-35. Table 9-36 contains noncarcinogenic risk estimates for this exposure scenario, while Table 9-37 contains carcinogenic risk estimates.

TABLE 9-32
ASSUMPTIONS USED TO ESTIMATE EXPOSURE TO PARK PATRONS VIA CONTACT WITH SOIL - FUTURE USE SCENARIO AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Parameter	Average Case	Plausible Maximum Case
Frequency of Exposure	16 days/yr	40 days/yr
Period of Exposure	20 years	20 years
Incidental Ingestion[a]	50 mg/day	100 mg/day
Oral absorption factor[b]		
Metals	1	1
cPNAs	0.15	0.45
ncPNAs	0.50	1
Other organic chemicals	1	1
Daily Soil Contact Rate[c]	0.5 mg/cm^2	1.5 mg/cm^2
Area of Exposed Skin[d]	2,040 cm^2	2,040 cm^2
Dermal Absorption Factor[e]		
Metals	0	0
PNAs	0.003	0.03
Other organic chemicals	0.01	0.04
Average Body Weight	70 kg	70 kg
Exposure Point Concentrations[f]	Mean	Maximum

[a] Based on the work of LaGoy 1987.
[b] This factor represents the percentage of contaminants absorbed from ingested soil. Factor for metals and organic chemicals is default value assuming 100% absorption. Factors for cPNAs and ncPNAs based on .
[c] Based on the work of Schaum 1984.
[d] EPA 1985.
[e] This factor represents the percentage of contaminants absorbed through the skin.
[f] These concentrations are shown in Table 9-1.

TABLE 9-33
CHRONIC DAILY INTAKES AND NONCARCINOGENIC RISKS TO PARK PATRONS
VIA DIRECT CONTACT WITH SOIL UNDER FUTURE-USE CONDITIONS
AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	RfD (mg/kg/d)	Chronic Daily Intake (mg/kd/day)		CDI:RfD Ratio	
		Average	Plausible Maximum	Average	Plausible Maximum
Copper	$3.7x10^{-2}$	$3.1x10^{-6}$	$1.7x10^{-6}$	$8x10^{-5}$	$5x10^{-5}$
ncPNA	$4.1x10^{-1}$	$6.4x10^{-8}$[a]	$1.9x10^{-6}$	$2x10^{-7}$	$5x10^{-6}$
Acetone	$1.0x10^{-1}$	$1.6x10^{-9}$	$6.0x10^{-8}$	$2x10^{-8}$	$6x10^{-7}$
Methylene Chloride	$6.0x10^{-2}$	$6.6x10^{-10}$	$1.3x10^{-8}$	$1x10^{-8}$	$2x10^{-7}$
2-Butanone	$5.0x10^{-2}$	$3.4x10^{-9}$[b]	$3.1x10^{-8}$	$7x10^{-8}$	$6x10^{-7}$
bis(2-ethylhexyl) phthlate	$2.0x10^{-2}$	$3.4x10^{-7}$	$3.1x10^{-6}$	$2x10^{-5}$	$2x10^{-4}$
Di-n-octyl-phthalate	NA	$8.3x10^{-8}$	$7.6x10^{-7}$	NA	NA
Di-n-butyl-phthalate	$1.0x10^{-1}$	$1.1x10^{-7}$	$9.6x10^{-7}$	$1x10^{-6}$	$1x10^{-5}$
Mercury	$1.4x10^{-3}$	$6.2x10^{-8}$[b]	$3.1x10^{-8}$	$4x10^{-5}$	$2x10^{-5}$
Chromium	$5.0x10^{-3}$	$1.2x10^{-8}$	$3.2x10^{-8}$	$2x10^{-6}$	$7x10^{-6}$
Manganese	$2.2x10^{-1}$	$3.1x10^{-8}$	$1.1x10^{-6}$	$1x10^{-7}$	$5x10^{-6}$
Total Hazard Index				$1x10^{-4}$	$3x10^{-4}$

[a] The assumptions made in developing the average and plausible maximum exposure cases are shown in Table 9-32.

[b] Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate average CDI.

TABLE 9-34
CHRONIC DAILY INTAKE AND POTENTIAL EXCESS LIFETIME CANCER RISKS TO PARK PATRONS[a]
VIA DIRECT CONTACT WITH SOIL UNDER FUTURE-USE CONDITIONS
AT THE REPUBLIC STEEL SITE[a]
REPUBLIC STEEL QUARRY RI

Chemical	Potency Factor $(mg/kg/d)^{-1}$	Chronic Daily Intake (mg/kg/day)		Excess Lifetime Cancer Risk	
		Average	Plausible Maximum	Average	Plausible Maximum
cPNA	1.15×10^{1}	4.0×10^{-9} [b]	1.3×10^{-7}	4×10^{-8}	1×10^{-6}
Methylene Chloride	7.5×10^{-3}	1.8×10^{-10}	3.8×10^{-9}	1×10^{-12}	3×10^{-11}
bis(2-ethylhexyl) phthalate	6.8×10^{-4}	9.8×10^{-8} [b]	8.9×10^{-7}	7×10^{-11}	6×10^{-10}
Total	--	--	--	4×10^{-8}	1×10^{-6}

[a] The assumptions made in developing the average and plausible maximum exposure cases are shown in Table 9-32.

[b] Mean concentration was not available. Therefore, maximum concentrations were used in conjunction with average exposure conditions to calculate CDI.

TABLE 9-35
ASSUMPTIONS USED TO ESTIMATE EXPOSURE TO RESIDENTS VIA INGESTION OF DRINKING WATER -- FUTURE USE SCENARIO
AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Parameter	Average Case	Plausible Maximum Case
Frequency of Exposure	365 days/yr	365 days/yr
Period of Exposure	70 years	70 years
Ingestion	2 liters/day	2 liters/day
Oral Absorption Factor Metals	1	1
Average Body Weight	70 kg	70 kg
Exposure Point Concentration	Mean	Maximum

TABLE 9-36
CHRONIC DAILY INTAKES AND NONCARCINOGENIC RISKS TO INDIVIDUALS VIA LIFETIME INGESTION OF GROUNDWATER AS DRINKING WATER UNDER FUTURE-USE CONDITIONS AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	RfD (mg/kg/d)	Chronic Daily Intake (mg/kg/day)		CDI:RfD Ratio	
		Average	Plausible Maximum	Average	Plausible Maximum
Chromium	$5.0x10^{-3}$	NA	$5.7x10^{-4}$	--	$1x10^{-1}$
Copper	$3.7x10^{-2}$	NA	$8.0x10^{-4}$	--	$2x10^{-2}$
Lead	$1.4x10^{-3}$	NA	$5.4x10^{-4}$	--	$4x10^{-1}$
Nickel	$1.0x10^{-2}$	NA	$3.7x10^{-3}$	--	$4x10^{-1}$
Zinc	$2.1x10^{-1}$	$1.2x10^{-3}$	$3.0x10^{-3}$	$6x10^{-3}$	$1x10^{-2}$
Pentachlorophenol	$3.0x10^{-2}$	NA	$1.4x10^{-4}$	--	$5x10^{-3}$
Phenol	$4.0x10^{-2}$	NA	$2.8x10^{-4}$	--	$7x10^{-3}$
Barium	$5.0x10^{-2}$	$1.8x10^{-3}$	$3.3x10^{-3}$	$4x10^{-2}$	$7x10^{-2}$
Beryllium	$5.0x10^{-3}$	$2.9x10^{-5}$	$6.0x10^{-5}$	$6x10^{-3}$	$1x10^{-2}$
Manganese	$2.2x10^{-1}$	$4.0x10^{-2}$	$3.3x10^{-1}$	$2x10^{-1}$	1.5
Silver	$3.0x10^{-3}$	NA	$1.2x10^{-4}$	--	$4x10^{-2}$
Vanadium	$2.0x10^{-2}$	$3.7x10^{-4}$	$1.6x10^{-3}$	$2x10^{-2}$	$8x10^{-2}$
Acetone	$1.0x10^{-1}$	$2.3x10^{-4}$	$1.6x10^{-3}$	$2x10^{-3}$	$2x10^{-2}$
Methylene Chloride	$6.0x10^{-2}$	$2.0x10^{-4}$	$4.0x10^{-3}$	$3x10^{-3}$	$7x10^{-2}$
Total Hazard Index	--	--	--	$3x10^{-1}$	3

NA = The mean concentration is below the detection limit.

-- = Not relevant.

TABLE 9-37
CHRONIC DAILY INTAKES AND POTENTIAL EXCESS LIFETIME CANCER RISKS TO RESIDENTS VIA LIFETIME INGESTION OF GROUNDWATER AS DRINKING WATER UNDER FUTURE-USE CONDITIONS AT THE REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Chemical	Potency Factor $(mg/kg/d)^{-1}$	Chronic Daily Intake (mg/kg/day)		Excess Lifetime Cancer Risk	
		Average	Plausible Maximum	Average	Plausible Maximum
Methylene Chloride	7.5×10^{-3}	2.0×10^{-4}	4.0×10^{-3}	2×10^{-6}	3×10^{-5}

As Table 9-36 indicates, under average exposure, the hazard index is less than one. However, under maximum exposure conditions, the hazard index is greater than one; although no individual CDI:RfD ratio exceeds one. However, since the three metals that contribute significantly to the hazard index (manganese, lead, and nickel) each have different end points of toxicity, summing by end point is appropriate. By this method, manganese is the only chemical whose individual hazard index is greater than one.

Methylene chloride was the only carcinogen detected in groundwater above background concentrations. Potential lifetime cancer risks to residents drinking contaminated groundwater is 2×10^{-6} for the average case and 3×10^{-5} for the plausible maximum scenario. Though methylene chloride was chosen as a chemical of concern in groundwater, there is the potential as mentioned in Section 9.2 that this solvent is nothing more than a laboratory artifact and does not represent risk to this population.

9.7 ECOLOGICAL RISK ASSESSMENT

In addition to potential exposure of the human population discussed in earlier sections of this report, aquatic life may also be exposed to contamination at the Republic Steel site. The quarry is the aquatic life habitat of potential concern since no evidence of chemicals being transported from the quarry to the Black River has been noted. Therefore only exposures of aquatic life to chemicals of concern in the quarry will be assessed. The quarry water is a potential habitat for both invertebrate and vertebrate species. The fish and other animals existing at the Republic Steel site have not yet been inventoried.

The chemicals that will be evaluated in this assessment of effects on aquatic life are the same chemicals evaluated for potential impacts to human health as these were not selected based on human health considerations; the chemicals of concern were selected on the basis of their presence at the site at concentrations above background. Thus, the chemicals of potential concern for the environmental assessment are barium, calcium, iron, magnesium, manganese, nickel, vanadium, copper, mercury, tin, tetrachloroethene, ethylbenzene, 2-butanone, polynuclear aromatic hydrocarbons, pentachlorophenol, methylene chloride, acetone, toluene, diethylphthalate, di-n-butylphthalate, butylbenzylphthalate, bis(2-ethylhexyl)phthalate, and di-n-octylphthalate.

Fish can be exposed to the chemicals of concern at the Republic Steel site through direct contact with or ingestion of contaminated water in the quarry. Concentrations in the quarry water are available from the preliminary RI results and from using a model estimating steady state partitioning of the chemicals from sediment into the water column as described in the sediment/water partitioning model in Section 9-6. In addition to exposure to water fish and other aquatic life may also be exposed to chemical contaminants at the Republic Steel site via contact with contaminated sediments and ingestion of contaminated food. However, toxicity data are not available to

assess exposure via sediment and ingestion of contaminated food, and therefore this exposure assessment is limited to an assessment of exposure to contaminated surface water.

In order to determine potential impacts on aquatic life a comparison is made between surface water concentrations in the quarry and State and Federal and ambient water quality criteria (AWQC). Table 9-38 presents a comparison between maximum surface water concentrations and the acute ambient water quality criteria (AWQC), and between average surface water concentrations and the chronic AWQC. With respect to potential impacts on aquatic life in the quarry, of the 11 chemicals with acute AWQC values, only copper exceeds the acute criteria. Tetrachloroethene, nickel, toluene, ncPNA, mercury, pentachlorophenol, and the phthalates are all below the acute level. Ten of the chemicals have chronic AWQC values. Of these, surface water concentrations are below chronic AWQC for tetrachloroethene, butylbenzylphthalate, di-n-butylphthalate, di-no-octylphthalate, ncPNA, and pentachlorophenol. Copper, mercury and di-ethylphthalate were the chemicals that exceeded the AWQC.

It should be noted that all chemicals except barium, vanadium, manganese and nickel were calculated using the sediment/water partitioning model. The model is conservative and chemical concentrations in the water are not expected to be as large as those predicted by the model.

EPA (Zarba 1988) is currently in the process of establishing sediment criteria for the protection of aquatic benthic organisms. Although EPA's Office of Water notes that these criteria are interim in nature, they have been recommended for use at Superfund sites. Of the chemicals found at Republic Steel, EPA has developed interim criteria values for the PNAs. With Zarba assuming 1% organic carbon in the sediment, the mean interim sediment quality criteria values range from 1.39 mg/kg for phenanthrene to 18.8 ug/kg for fluoranthene. The upper confidence levels range from 6.05 mg/kg for phenanthrene to 83.8 for fluoranthene. EPA considers sediments with concentrations higher than the upper confidence levels to be hazardous to benthic fauna. These levels are comparable to the measured concentrations in the quarry sediments; thus, it is likely that a viable benthic community could not be supported based on chemical evidence alone.

9.8 RISK ASSESSMENT UNCERTAINTIES

The procedures and inputs used to assess risks in this EA, as in all such assessments, are subject to a wide variety of uncertainties. In general, sources of uncertainty include: environmental chemistry sampling and analysis; environmental parameter measurement; fate and transport modeling; exposure parameter estimation; and toxicological data. Uncertainties are summarized on Table 9-39.

TABLE 9-38
COMPARISON OF SURFACE WATER CONCENTRATIONS AT THE REPUBLIC STEEL SITE
WITH AWQC TOXICITY VALUES
REPUBLIC STEEL QUARRY RI

Chemical	Concentration in Water (ug/L)		State Water Quality Criteria Aquatic Life (ug/L)		Federal Water Quality Criteria	
	Average	Maximum	Average	Maximum	Chronic	Acute
Tetrachloroethene	0.0044	0.033	--	--	--	--
Ethylbenzene	0.00029	0.0024	--	--	--	--
2-Butanone	1.0	8.0	--	--	--	--
ncPNA	0.00014	0.00060	--	--	620[a]	2,300[a]
cPNA	0.000050	0.00058	--	--	--	--
Copper	18	96	14[b]	--	12	18
Mercury	0.44	0.81	0.2	2.2	0.012	2.4
Pentachlorophenol	0.0028	0.059	1	--	13	20
Acetone	24	52	--	--	--	--
Methylene Chloride	NC	0.28	--	--	--	--
bis(2-ethylhexyl) phthalate	NR	14	--	--	--	--
Diethylphthalate	40	87	--	--	3[c]	--
Magnesium	23,600	67,500	--	--	--	--
Nickel	NA	86	341	--	160	1,400
Vanadium	4.4	55	--	--	--	--
Calcium	56,700	315,000	--	--	--	--
Methylene Chloride	NR	0.28	--	--	--	--
Tin	--	--	--	--	--	--
Barium	46	113	--	--	--	--
Manganese	940	25,700	--	--	--	
Butylbenzylphthalate	0.400	0.405	--	--	3[c]	940
Di-n-butylphthalate	0.0047	0.038	--	--	3[c]	940
Di-n-octylphthalate	0.0053	0.0047	--	--	3[c]	940
Toluene	0.105	0.16	--	--	--	17,500[b]

NC = Not calculated.
NA = The mean value was below detection.
NR = Not relevant. Chemical was detected at only one location.

[a] For naphthalene.

[b] Hardness dependent parameter

TABLE 9-39
UNCERTAINTIES IN THE RISK ASSESSMENT REPUBLIC STEEL SITE
REPUBLIC STEEL QUARRY RI

Assumption	Magnitude of Effect on Risk	Direction of Effect on Risk
Environmental Sampling and Analysis		
Sufficient samples may not have been taken to characterize the matrices being evaluated.	Moderate	May over- or under-estimate risk
Systematic or random errors in the chemical analyses may yield erroneous data.	Low	May over- or under-estimate risk
Chemical concentrations reported as "below method detection limit" are included as one-half the CLP required detection limit.	Moderate	May over- or under-estimate risk
The endangerment assessment is based on the chemicals of concern, rather than the complete data set.	Moderate	May underestimate risk
Fate and Transport Modelling		
The models used to estimate water concentrations assume simple steady-state partitioning.	Moderate	May over- or under-estimate risk
Toxicological Data		
Some of the cancer potencies used are upper 95 percent confidence limits derived from the linearized multi-stage model.	High	May overestimate risk
Risks are assumed to be additive. Risks may not be additive because of synergistic or antagonistic actions of other chemicals.	Moderate	May over- or under-estimate risk

TABLE 9-39 (Continued)

Assumption	Magnitude of Effect on Risk	Direction of Effect on Risk
Exposure Parameter Estimation		
The standard assumptions regarding body weight, period exposed, life expectancy, population characteristics, and lifestyle may not be representative for any actual exposure situation.	Moderate	May overestimate risk
The amount of media intake is assumed to be constant and representative of the exposed population.	Moderate	May overestimate risk
Exposure to contaminants remains constant over exposure period.	Moderate	May over- or under-estimate risk
Concentration of contaminants remains constant over exposure period.	Moderate	May over- or under-estimate risk
Dermal absorption of inorganic chemicals from soil is negligible.	Low	May underestimate risk
For most contaminants all intake is assumed to come from the medium being evaluated. This does not take into account other contaminant sources such as diet, exposures occurring at locations other than the exposure point being evaluated, or other environmental media which may contribute to the intake of the chemical (i.e., relative source contribution is not accounted for).	Moderate	May underestimate risk

Uncertainty in environmental sampling arises in part from the potentially uneven distribution of chemicals in the media samples. Typically, this problem is encountered more frequently in soil than water. A problem specific to the Republic Steel Quarry is that no background surface water or sediment samples could be collected; samples from the Black River were used for comparison purposes only since the Black River does not flow into the quarry.

Chemicals that are not on EPA's Target Compound List (TCL) may contribute to risk, especially if they are present at a high concentration. Cutting oils are insoluble lubricants and coolants in cutting, threading, and similar metal working operations. Cutting oils are a fraction of crude oil distillate that is a complex mixture of several hundred organic compounds, these are mostly straight-run refined, medium-viscosity oils from paraffinic, mixed-base, and naphthenic crudes (Kirk-Othmer 1982). While a large number of these compounds are straight-chained, low toxicity hydrocarbons, many are polynuclear aromatic hydrocarbons. When released to the environment, the components of cutting oils are subject to differential chemical fate and transport processes.

The concept of food-chain transport of PNAs poses many questions. Although there is evidence that aquatic organisms can rapidly assimilate PNAs (Eisler 1987), there is also evidence that these compounds are rapidly metabolized and eliminated (Eisler 1987). In one laboratory ecosystem study (Lu 1977) in mosquito fish, BaP was 93% metabolized within 33 days of exposure. The tendency of fish to metabolize BaP and related compounds may explain why BaP is often not detected or detected in only low amounts in environmental situations where predictions based on BCFs would indicate higher levels. It is not known if the metabolites, some of which are potentially carcinogenic, can be absorbed in biologically active forms from food. The strong and rapid tendency for these metabolites to form DNA adducts (Williams and Weisburger 1986) indicates that they are not persistent in a biological environment.

Another potential source of uncertainty in this risk assessment is from modeling of sediment concentrations into fish. As discussed, a conservative mixing model was used to calculate surface water exposure point concentrations for chemicals of concern in sediment. Thus risks via ingestion of fish from the quarry are likely to be an overestimate.

With respect to the exposure scenarios evaluated in this risk assessment, there are several uncertainties in determining the exposure parameters that go into the scenario that will ultimately be combined with toxicological information to assess risk. For example, there are a number of uncertainties regarding estimates of how often, if at all, an individual would come into contact with the chemicals of concern and the period of time over which such exposures would occur. Risks for certain individuals within an exposed population will be higher or lower than the risks shown depending on actual intakes, body weights, etc. Table 9-39 summarizes the uncertainties of the risk assessment.

Toxicological data extrapolation is probably the largest source of error in risk assessments. As EPA noted in its Guidelines for Carcinogenic Risk Assessment (EPA 1986d):

> There are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to genetic constitution, diet, occupational and home environment, activity patterns, and other cultural factors.

A particular problem is also presented by the necessity to perform risk assessments for PNA. PNAs occur in the environment as complex mixtures of many components with widely varying toxic potencies. Only a few components of these mixtures have been characterized adequately, and only limited information is available on potential synergistic or antagonistic effects of the PNAs mixture. Most evidence on PNAs carcinogenic potency indicates that BaP is more potent than most of the other carcinogenic PNAs or even a mixture of carcinogenic PNAs (Schmahl et al. 1977, Pfeiffer 1977); therefore, the technique used in this assessment will probably overestimate risk. A further uncertainty presented by the PNAs is the absence of research data and health effects criteria for the noncarcinogenic PNAs.

9.9 CONCLUSIONS

In this endangerment assessment, the potential risks to human health attributed to chemicals present at the Republic Steel Quarry site were evaluated under a number of exposure scenarios. Potential pathways of exposure to chemicals originating at the site under both current-use and hypothetical future-use conditions were examined. Table 9-40 presents a summary of the risks associated with the various scenarios evaluated. Additionally, combined risks are presented for those exposure pathways that could potentially apply to the same receptors.

Under current-use conditions the only exposure scenario resulting in a greater than 10^{-6} risk is the maximum case for ingestion of fish. However, this risk is primarily due to carcinogenic PNAs which were very conservatively estimated using the sediment/surface water exposure model. Also, fish metabolize PNA to some extent, further reducing the dose contamination. Additionally, for the noncarcinogens, the maximum exposure scenario results in a hazard index greater than one because the estimated chronic daily intake for mercury is greater than available criteria for protection against noncarcinogenic effects. However, mercury was only

TABLE 9-40
SUMMARY OF POTENTIAL RISKS ASSOCIATED WITH THE REPUBLIC STEEL QUARRY
REPUBLIC STEEL QUARRY RI

Exposure Scenario	Total Cancer Risks		Noncarcinogenic Hazard Index	
	Average	Maximum	Average	Maximum
Current-Use (Trespassers)				
Direct Contact with Soil	$2x10^{-8}$	$4x10^{-7}$	<1	<1
Swimming in the Quarry	$1x10^{-10}$	$4x10^{-10}$	<1	<1
Consumption of Fish	$3x10^{-8}$	$4x10^{-6}$	<1	>1
Combined Risk to Trespassers	$5x10^{-8}$	$4x10^{-6}$	<1	>1
Future-Use				
Park Patron - Direct Contact with Soil	$4x10^{-8}$	$1x10^{-6}$	<1	<1
Residential Use - Direct Contact with Soil	$3x10^{-7}$	$2x10^{-5}$	<1	<1
Residential Use - Ingestion of Groundwater	$2x10^{-6}$	$3x10^{-5}$	<1	<1
Combined Residential Risk	$2x10^{-6}$	$5x10^{-5}$	<1	>1

detected in 2 out of 7 sediment samples and this risk is based on modeling the concentration of mercury from the sediment to fish tissue using very conservative assumptions. Combined risks to trespassers, assuming the same person would be exposed to soil through direct contact and incidental ingestion, quarry water through swimming, and fish through ingestion were estimated. As indicated in Table 9-40 the combined upperbound excess lifetime cancer risks are $5x10^{-8}$ to $4x10^{-6}$ under average and maximum exposure conditions. The combined hazard index is less than one under the average scenario and greater than one under the maximum scenario.

Under future-use conditions the exposure scenarios evaluated that resulted in a greater than 10^{-6} upperbound excess lifetime cancer risk are maximum exposure to future residents through direct contact and incidental ingestion of soil, and average and maximum exposure via ingestion of groundwater. Consequently the combined potential residential risk is $2x10^{-6}$ to $5x10^{-5}$ under average and maximum exposure scenarios. It should be noted that the risk from exposure to contaminants in soil is primarily due to exposure to cPNA's, which were detected primarily at one area of the site (the south boat launch) and which are ubiquitous in the environment. In evaluating the combined noncarcinogenic risk, the hazard index is greater than one under the maximum exposure scenarios. However, none of these noncarcinogenic chemicals in groundwater, have chronic daily intakes that exceed available criteria. In addition, each of the chemicals of potential concern with the highest CDI:RfD ratios have different end points of toxicity. Therefore, impacts from ingestion of noncarcinogenic chemicals are not expected.

With respect to potential impacts on aquatic life in the quarry, of the 11 chemicals with acute AWQC values, only copper exceeds the acute criteria. Tetrachloroethene, nickel, toluene, ncPNA, mercury, pentachlorophenol, and the phthalates are all below the acute level. Ten of the chemicals have chronic AWQC values. Of these, surface water concentrations are below chronic AWQC for tetrachloroethene, ncPNA, pentachlorophenol, butylbenzylphthalate, di-n-butylphthalate, and di-n-octylphthalate. Copper, mercury, and diethylphthalate were the chemicals that exceeded the AWQC.

It should be noted for the surface water concentrations that all chemicals except barium, vanadium, manganese and nickel were calculated using the sediment/water partitioning model. The model is conservative and chemical concentrations in the water are not expected to be as large as those predicted by the model.

10.0 REMEDIAL INVESTIGATION SUMMARY

10.1 NATURE AND EXTENT OF CONTAMINATION SUMMARY

Samples of surface water, sediments, surface soils and groundwater were collected and analyzed to estimate the types and extent of contamination due to the site. The conclusions with respect to the contamination of each media are included in the following items.

10.1.1 Surface Water

Surface water samples were collected from the quarry and Black River adjacent to the site during June 1987. Resampling was performed during March 1988 for semi-volatile organic analyses due to laboratory quality control problems during the initial analyses. During the June 1987 sampling, 19 quarry and 6 river samples were obtained and analyzed for a complete range of organic and inorganic chemicals. Due to laboratory QA problems, resampling for semi-volatile chemicals was necessary. The second sampling performed during March 1988 collected water from approximately the same locations originally sampled and the samples were analyzed for only semi-volatile organic chemicals.

To estimate the extent and nature of contamination, two analyses were performed. Initially, the quarry water samples were compared to upgradient groundwater samples to identify potentially site related chemicals in the quarry. No organic chemicals were identified in the quarry water as being potentially site related. Several inorganic chemicals were identified as being potentially site related. These chemicals include barium, calcium, iron, magnesium, manganese, nickel, vanadium and zinc. All of these chemicals were detected at elevated concentrations compared to upgradient groundwater, with the greatest concentrations observed near the quarry bottom.

The downstream Black River samples were compared to upstream river samples and quarry samples to estimate if the site was affecting river water quality. The results of this comparison indicated that the site was not adversely impacting Black River water quality.

10.1.2 Sediments

Sediment samples from the quarry and the Black River were collected in June 1987 and analyzed for organic and inorganic chemicals. Eight samples of quarry sediments and four samples of Black River sediments were collected. The nature and extent evaluation for sediments was performed in two phases to determine if the quarry sediments were contaminated and to estimate if the quarry had adversely impacted the quality of Black River sediments.

Initially, quarry sediments were compared to background soils to identify potentially site related chemicals. This analysis concluded that sediments within the quarry contained elevated levels of volatile and semi-volatile organic and inorganic chemicals. Volatile organic compounds

were detected only in the deep quarry sediment samples (greater than 35 ft.) while semi-volatile organics and inorganics were detected in both deep and shallow samples. Concentrations of the inorganic and semi-volatile contaminants of the sediments obtained from deeper portions of the quarry were greater than those from the shallow sediments. Past activities at the site have affected the quarry sediment quality.

Potentially site related chemicals in onsite sediments are summarized below:

Volatile Organics	Semi-Volatile Organics	Inorganics
Acetone	Polycyclic Aromatic Hydrocarbons*	Arsenic
2-Butanone	Bis(2-ethylhexyl)phthalate	Calcium
Ethylbenzene	Butylbenzylphthalate	Chromium
Methylene Chloride	Di-ethylphthalate	Copper
Tetrachloroethene	Di-n-butylphthalate	Iron
Toluene	Di-n-octylphthalate	Lead
	Pentachlorophenol	Magnesium
		Mercury
		Nickel
		Tin
		Zinc

*Polycyclic Aromatic Hydrocarbons identified include anthracene, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno (1,2,3-cd)pyrene, phenanthrene and pyrene.

A comparison of downstream Black River sediments to upstream river and quarry sediments was performed to estimate if the site is adversely impacting Black River sediments. The analysis indicated that no potentially site related organic or inorganic chemicals were detected in the sediments downstream. The site is not affecting sediments in the Black River.

10.1.3 Surface Soils

Eight surface soil samples were collected in June 1987. Two samples were collected from background locations while six samples were collected in an effort to identify potential site contamination. Analyses performed on surface soils obtained from areas of the site that are periodically inundated by quarry water or that were exposed to waste discharges in the past detected contaminants above background concentrations. Contaminants detected included volatile and semi-volatile organic and inorganic chemicals. Past disposal activities have affected surface soils at the site.

Semi-volatile and inorganic chemicals were also detected in a sample of the steel yard soils that are sliding into the quarry.

Potentially site related chemicals identified in surface soil samples are summarized below:

Volatile Organics	Semi-Volatile Organics	Inorganics
Acetone	Polycyclic Aromatic Hydrocarbons*	Calcium
2-Butanone	bis(2-ethylhexyl)phthalate	Chromium
Methylene Chloride	Di-n-butylphthalate	Copper
	Di-n-octylphthalate	Iron
		Mercury
		Nickel

*Polycyclic aromatic hydrocarbons identified include benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene and pyrene.

10.1.4 Groundwater

Eight monitoring wells were installed at or near the Republic Steel Quarry Site. All of these wells were sampled in August 1987 and two wells were resampled and analyzed for volatile organics in March 1988.

Volatile and semi-volatile organic and inorganic chemicals were detected in groundwater samples downgradient from the quarry. Volatile and semi-volatile organics were detected at low concentrations in monitoring wells adjacent to the site, but were not detected in the monitoring well across the Black River east of the site. Inorganic chemicals were detected in all downgradient wells adjacent to the site and in the well across the Black River; however, a direct connection to the site cannot be made to the inorganics in well B-8. It is unlikely that contaminants from the quarry are passing beneath the Black River within groundwater since well B-8 is hydraulically upgradient from the site.

Chemicals identified as being potentially site related are summarized below:

Volatile Organics	Semi-Volatile Organics	Inorganics
Acetone	Pentachlorophenol	Aluminum
Methylene Chloride	Phenol	Barium
		Beryllium
		Calcium
		Chromium
		Cobalt
		Copper
		Iron
		Lead
		Manganese
		Nickel
		Potassium
		Vanadium
		Zinc

10.2 FATE AND TRANSPORT SUMMARY

At the Republic Steel Quarry Site, the transport media of concern are groundwater and surface water. Quarry surface water discharges directly to the West Branch of the Black River adjacent to the site. Quarry surface waters are affecting groundwater chemical concentrations at the site, but are not affecting the quality of the Black River at downgradient locations. Both surface water discharge and groundwater migration are demonstrated pathways for chemical transport at the Republic Steel Quarry site. The potential for offsite migration of surface soils due to wind or water erosion is unlikely at the site due to a dense vegetation and a surrounding ground surface which slopes toward the quarry. However, during periods of flooding, it is possible soils along the quarry perimeter could be released. The potential of offsite migration of sediments in the quarry is also low because water turnover in the quarry is unlikely to transport quarry bottom sediments into the upper water column. Additionally, due to the high total organic carbon content of the sediments, it is unlikely that significant releases of organic contaminants from the quarry sediments to groundwater or surface water will occur. Volatilization of organic compounds for chemical migration through air is not anticipated to be a significant pathway at the site due to high total organic carbon content of sediments, relatively deep depth of contaminated sediments, and relatively low concentration (<1 ppm) of volatile contaminants in environmental media at the site. Therefore, the following potential routes of contaminant migration are important at the Republic Steel Quarry Site:

(1) Release of contaminants in quarry surface water to downgradient groundwater.

(2) Release of contaminants in quarry surface water to Black River

(3) Release of contaminants in quarry perimeter surface soils during periods of quarry flooding.

Fate and transport processes expected to play a major role at the site include sorption, bioaccumulation and oxidation; whereas volatilization, photolysis, biodegradation and reduction are anticipated to have less significant effects.

10.3 ENDANGERMENT ASSESSMENT SUMMARY

The potential risks to human health attributed to chemicals present at the Republic Steel Quarry Site were evaluated under a number of exposure scenarios. Potential pathways of exposure to chemicals originating at the site under both current-use and hypothetical future-use conditions were examined. Table 10-1 presents a summary of the risks associated with the various scenarios evaluated. Additionally, combined risks are presented for those exposure pathways that could potentially apply to the same receptors.

Under current-use conditions, the only exposure scenario resulting in a greater than 10^{-6} risk is the maximum case for ingestion of fish. However, this risk is primarily due to carcinogenic PNAs which were conservatively estimated using the sediment/surface water exposure model. Also, fish metabolize PNA to some extent, further reducing the dose concentration. Additionally, this maximum exposure scenario results in a hazard index greater than one because the estimated chronic daily intake for mercury is greater than available criteria for protection against noncarcinogenic effects. However, mercury was only detected in 2 out of 7 sediment samples and this risk is based on modeling the concentration of mercury from the sediment to water and then to fish tissue using very conservative assumptions. Combined risks to trespassers, assuming the same person would be exposed to soil through direct contact and incidental ingestion, quarry water through swimming, and fish through ingestion were estimated. As indicated in Table 10-1, the combined upperbound excess lifetime cancer risks are 5×10^{-8} to 4×10^{-6} under average and maximum exposure conditions. The combined hazard index is less than one under the average scenario and greater than one under the maximum scenario.

Under future-use conditions, the exposure scenarios evaluated that resulted in a greater than 10^{-6} upperbound excess lifetime cancer risk are maximum exposure to future residents through direct contact and incidental ingestion of soil, and average and maximum exposure from the ingestion of groundwater, primarily as the result of high concentrations of methylene chloride, a potential laboratory contaminant. Consequently the combined potential residential risk is 2×10^{-6} to 5×10^{-5} under average and maximum exposure scenarios. It should be noted that the risk from exposure to contaminants in soil is primarily due to exposure to cPNAs, which were detected primarily at one area of the site (the south boat launch) and which are ubiquitous in the environment. In evaluating the combined noncarcinogenic risk, the hazard index is greater than one under the maximum exposure scenarios. However, none of these noncarcinogenic chemicals in groundwater have chronic daily intakes that exceed available criteria. In addition, each of the chemicals of potential concern with the highest CDI:RfD ratios have different end points of toxicity. Therefore, impacts from ingestion of noncarcinogenic chemicals are not expected.

With respect to potential impacts on aquatic life in the quarry, of the 11 chemicals with acute AWQC values, only copper exceeds the acute criteria. Tetrachloroethene, nickel, toluene, ncPNA, mercury, pentachlorophenol, and the phthalates are all below the acute level. Ten of the chemicals have chronic AWQC values. Of these, surface water concentrations are below chronic AWQC for ncPNA, tetrachloroethene, butylbenzylphthalate, di-n-butylphthalate, di-n-octylphthalate, and pentachlorophenol. Copper, mercury and diethylphthalate were chemicals that exceeded the AWQC.

It should be noted that all chemicals except barium, vanadium, manganese and nickel were calculated using the sediment/water partitioning model. The model is conservative and chemical concentrations in the water are not expected to be as large as those predicted by the model.

TABLE 10-1
SUMMARY OF POTENTIAL RISKS ASSOCIATED WITH THE REPUBLIC STEEL QUARRY
REPUBLIC STEEL QUARRY RI

Exposure Scenario	Total Cancer Risks		Noncarcinogenic Hazard Index	
	Average	Maximum	Average	Maximum
Current-Use (Trespassers)				
Direct Contact with Soil	$2x10^{-8}$	$4x10^{-7}$	<1	<1
Swimming in the Quarry	$1x10^{-10}$	$4x10^{-10}$	<1	<1
Consumption of Fish	$3x10^{-8}$	$4x10^{-6}$	<1	>1
Combined Risk to Trespassers	$5x10^{-8}$	$4x10^{-6}$	<1	>1
Future-Use				
Park Patron - Direct Contact with Soil	$4x10^{-8}$	$1x10^{-6}$	<1	<1
Residential Use - Direct Contact with Soil	$3x10^{-7}$	$2x10^{-5}$	<1	<1
Ingestion of Ground Water	$2x10^{-6}$	$3x10^{-5}$	<1	>1
Combined Residential Risk	$2x10^{-6}$	$5x10^{-5}$	<1	>1

10.4 UNRESOLVED DATA NEEDS

The only risk identified that may exceed acceptable criteria at the site under current-use scenarios was associated with the ingestion of fish. Since the risk was estimated using conservative contaminant uptake models and not actual fish samples, it has been decided that fish sampling and analysis will be performed to confirm the presence of the risks due to fish ingestion. This work will be performed in the near future and is outside the scope of this RI.

Under future-use scenarios, ingestion of groundwater by residents at the site was calculated to have a greater than 10^{-6} upperbound excess lifetime cancer risk, primarily due to methylene chloride detected at one downgradient monitoring well during one groundwater sampling program. Resampling failed to confirm the presence of methylene chloride in the monitoring well. USEPA and Ohio EPA have decided that resampling groundwater an additional time is appropriate to confirm or refute the presence of methylene chloride in the downgradient monitoring well. This work will be performed in the near future and is outside the scope of this RI.

10.5 CONCLUSION OF RI

It is concluded that the site, as it exists today, presents a limited health risk to the public, with ingestion of fish posing the greatest risk at the site. Under future-use scenarios, the combined residential risks are calculated to pose a greater than 10^{-6} upperbound excess lifetime cancer risk. Based on the results of this study, USEPA and Ohio EPA have determined that a limited remedial action is warranted at the Republic Steel Quarry Site.

10.6 REMEDIAL TECHNOLOGY SCREENING

The EPA and State may select to implement some remedial actions at the site to further reduce current or future risks. This remedial technology screening was performed to identify a preliminary set of technologies that could be implemented at the Republic Steel Quarry Site to address these risks.

10.6.1 Remedial Action Goals

The risks identified in the endangerment assessment (EA) form the basis for identifying remedial action goals. Based on the EA, the following media and pathways of exposure may require remediation:

Media	Pathway
Quarry Surface Water	Fish Ingestion
Quarry Sediments	Fish Ingestion
Surface Soil	Direct Contact

The preliminary remedial action goals for these media are as follows:

- o Quarry Surface Water: Protect public from ingestion of contaminated fish.
- o Sediment: Protect public from ingestion of contaminated fish.
- o Surface Soil: Protect public from dermal absorption or incidental ingestion of contaminated soils.

10.6.2 General Response Actions

General response actions are broad classes of responses or remedies intended to meet the remedial action goals at the site. Several response actions have been identified for each of the following operable units: soil, sediment, and surface water. Although some response actions may be capable of meeting the remedial objectives alone, combinations of response actions may later prove to be more effective in meeting all of the remedial goals and objectives. Combinations of response actions will be considered in the feasibility study, if one is performed. Table 10-2 presents the general response actions for each of the operable units.

10.6.3 Potentially Applicable Technologies

Remedial technologies and corresponding process options were screened to identify applicable technologies to be further evaluated, screened, and assembled into alternatives in a feasibility study, if one is performed. The screening includes consideration of five criteria:

- o Site conditions
- o Contamination characteristics
- o Ability to meet objectives of NCP
- o Implementation of technology
- o Demonstrated performance of technology

Table 10-3 summarizes the potentially applicable technologies identified during the screening. Tables Q-1 through Q-3 present the details of the technologies and process options screened and those remaining after screening for the general response actions within each operable unit. A brief discussion of process options and screening results is included in the tables. Those process options and technologies that are screened out at this stage will not be carried forward for detailed analysis.

TABLE 10-2
GENERAL RESPONSE ACTIONS
REPUBLIC STEEL QUARRY RI

Operable Unit	General Response Actions
Soil	No Action Access Restrictions Containment Removal Treatment Disposal Other Management Options
Sediment	No Action Access Restrictions Containment Removal Treatment Disposal Other Management Options
Surface Water	No Action Access Restrictions Collection Treatment Disposal Other Management Options

TABLE 10-3
SUMMARY OF POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES
REPUBLIC STEEL QUARRY RI

Potentially Applicable Remedial Technology	Quarry Surface Water	Quarry Sediment	Surface Soil
NO ACTION	X	X	X
ACCESS RESTRICTIONS			
Deed Restrictions	X	X	X
Site Fencing	X	X	X
CONTAINMENT			
Surface Controls			
Soil Cover			X
Capping			
Single Layer			X
Multi-Layer			X
Horizontal Barriers		X	
REMOVAL			
Excavation/Demolition		X	X
COLLECTION			
Bulk Liquid Removal	X		
TREATMENT			
Physical Treatment			
Activated Carbon Adsorption	X		
Solvent Leaching			X
Vitrification			X
Chemical Treatment			
Chemical Modifications		X	
Biological Treatment			
Aerobic	X		
New Biotechnologies	X	X	
Thermal Treatment			
Incineration		X	X

Table 10-3 (cont'd)
Page 2

Potentially Applicable Remedial Technology	Quarry Surface Water	Quarry Sediment	Surface Soil
DISPOSAL			
Onsite Disposal			
RCRA Landfill		X	X
Vault		X	X
Unlined Landfill		X	X
Offsite Disposal			
RCRA Landfill			X
Wastewater Discharge			
POTW	X		
Deep Injection Wells	X		
Discharge to Surface Water	X		
RCRA Facility	X		

11.0 REFERENCES

Baes, C.F., III, Sharp, R.D., 1983. A Proposal for Estimation of Soil Leaching and Leaching Constants for Use in Assessment Models. J. Environ. Qual. 12: 17-28.

Benoit, D.A., 1975. Chronic Effects of Copper on Survival, Growth and Reproduction of the Bluegill (Lepomis macrochirus). Trans Am. Fish Soc. 104:353 (as cited in EPA 1984f).

Birge, E.A., 1897. Plankton Studies on Lake Mendota: II. The Crustacea from the Plankton from July, 1894 to December, 1896. Trans. Wisconsin Acad. Sci. Arts Lett. 11:274-448.

Brown, H.S., Bishop, D.R., and Rowan, C.A., 1984. The Role of Skin Absorption as a Route of Exposure for Volatile Organic Compounds (VOCs) in Drinking Water. Am. J. Public Health. 74:479-484.

Bysshe, S.E., 1981. Biocencentration Factors in Aquatic Organisms. In Lyman, W.J., Reehl, W.F., and Rosenblatt, D.H., eds. Handbook of Chemical Property Estimation Methods. McGraw-Hill, New York. pp. 5-1 to 5-30.

Calamari, O., Gaggins, G.F., and Paccletti, G., 1982. Toxicokinetics of Low Levels of Cd, Cr, Ni and Their Mixtures in Long-Term Treatment of Samo Goirdiniri. Chemosphere. 11:59-70.

Chapman, W.H., Fisher, H.L., and Pratt, M.W., 1968. Concentration Factors of Chemical Elements in Edible Aquatic Organisms. Lawrence Radiation Laboratory, University of California, Livermore.

Dawson, G.W., English, C.J., and Petty, S.E., 1980. Physical/Chemical Properties of Hazardous Waste Constituents. Prepared by Southeast Environmental Research Laboratory. Prepared for U.S. Environmental Protection Agency.

Davis, Jerry M., 1976. "Climate" section of Soil Survey of Lorain County, Ohio, National Weather Service, U.S. Department of Commerce.

Eisler, R., 1987. Polycyclic Aromatic Hydrocarbons Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service, Bio. Report 85 (1.11).

Feldman, R.J. and Maibach, H.I., 1970. Absorption of Some Organic Compounds Through the Skin in Man. J. Investigative Dermatology. 54:399-404.

Fraser, J.L. and Lum, K.R., 1983. Availability of Elements of Environmental Importance in Incinerated Sludge Ash. Environ. Sci. Technol. 17: 52-54.

Galey, W.R., Lansdale, H.R. and Nacht, S., 1976. The Invitro Permeability of Skin and Buccal Mucosa to Selected Drugs and Tritiated Water. J. Invest. Dermatol. 67:713-717.

Gallagher, M., 1984. Memorandum from Michael Gallagher, Ecology and Environment, Inc. to Gene Wong, EPA, Subject: Republic Steel Quarry, Elyria, Ohio, #OHO308.

Garland, George D., 1971. Introduction to Geophysics Mantle Core and Crust. W.B. Saunders Co., Philadelphia, PA.

Gerhart, E.H. and Carlson, R.M. 1978. Hepatic Mixed Function Oxidase Activity in Rainbow Trout Exposed to Several Polycyclic Aromatic Hydrocarbons. Environ. Res. 17: 184-195.

Gubane, D., July 11, 1984. Telephone Conversation Between Dave Gubane, Chemical Waste Management and Gene Wong, USEPA Region V.

Hutchinson, G.E., 1957. A Treatise on Limnology: Vol I: Geography, Physics and Chemistry. John Wiley & Sons, Inc., New York. 1015 pp.

International Agency for Research on Cancer (IARC), 1985. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Volume 35: Polynuclear Aromatic Compounds, Part 4, Bitumens, Coal-Tar and Derived Products, Shale-Oils, and Soots. World Health Organization, Lyon, France.

Kimbrough, R.D., Falk, H., Stehr, P., and Fries, G., 1984. Health Implications of 2,3,7,8-Tetrachlorodibenzodioxin (TCDD) Contamination of Residential Soil. J. Tox. Environ. Health 14:47-93.

Kirk-Othmer, 1980. Encyclopedia of Chemical Technology. Volume 12, John Wiley and Sons, New York.

LaGoy, P.K. 1987. Estimated Soil Ingestion Rates for Use in Risk Assessment. Risk Analysis 7: 355-360.

Lind, D., et. al. Regional Copper-Nickel Study. Aquatic Toxicology Progress Report (Manuscript) (as cited in EPA 1980b).

LTV, July 1987 through August 1988. Telephone Conversations Between Various LTV Personnel and Paul W. Tomiczek III, ICF Technology.

Lu, P.Y., Metcalf, R.L., Plummner, N. and Mandel, P. 1977. The Environmental Fate of Three Carcinogens: benzo(a)pyrene, benzidine, and vinyl chloride Evaluated in Laboratory Model Ecosystems. Arch. Environ. Contam. Toxicol. 6:129-142.

Lucier, G.W., Rumbaugh, R.C., McCoy, Z., Haas, R., Harvan, D., and Albro, K., 1986. Ingestion of Soil Contaminated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) Alters Hepatic Enzyme Activities in Rats. Fund. and Appl. Toxicol. 6:364-481.

Mobey, W. R., Smith, J.H., Podoll, R.T., Johnson, H.L., Mill, T., Chou, T.W., Gates, J., Patridge, I.W., Jaber, H., and Vandenberg, D., 1982. Aquatic Fate Process Data for Organic Priority Pollutants. Prepared by SRI International. Prepared for Monitoring and Data Support Division, Office of Water Regulations and Standards, Washington, D.C. EPA Contract Nos. 68-01-3867 and 68-03-2981.

McConnel, E.E., Lucier, G.W., Rumbaugh, R.C., Albro, P.W., Harvan, D.J., Hass, J.R. and Harris, M.W., 1984. Dioxin in Soil: Bioavailability After Ingestion by Rats and Guinea Pigs. Science. 223:1077-1079.

Northeast Ohio Areawide Coordinating Agency (NOACA), March 5, 1986. Resolution of the Board No. 86-97.

Ohio Department of Natural Resources, Divisions of Water and Geological Survey, 1987. (Well Log and Drilling Reports for Wells Within One-Half Mile Radius of Quarry).

Ott, W.R., 1988. A Physical Explanation of the Lognormality of Pollutant Concentrations. Air Pollution Control and Hazardous Waste Management Meeting, 81st Annual Meeting, Dallas, TX. June 19-24.

Owrs, U.S. EPA, 1980. Ambient Water Quality Criteria Documents.

Pao, E.M., Fleming, K.H., Guenther, P.M., and Mickle, S.J., 1982. Foods Commonly Eaten by Individuals: Amount per Day and per Eating Occassion. Consumer Nutrition Center, Human Nutrition Information Service, U.S. Dept. of Agriculture. Home Economics Research Report No. 44.

Perry and Chilton, 1973. Chemical Engineer's Handbook. McGraw-Hill, 5th Ed.

Poiger, H. and Schlatter, C., 1980. Influence of Solvents and Adsorbents on Dermal and Intestinal Absorption of TCDD. Fd Cosmet. Toxicol. 18:477-481.

Rau, J.L., 1969. Hydrogeology of the Berea and Cussewago Sandstones in Northeastern Ohio. United States Geological Survey Hydrologic Investigations Atlas HA-341 Prepared in Cooperation with the Ohio Dept. of Natural Resources Division of Water.

Russell, D.J. and McDuffie, B., 1986. Chemodynamic Properties of Phthalate Esters: Partitioning and Soil Migration. Chemosphere. 15:1003-1021.

Schaum, J.L., 1984. Risk Analysis of TCDD Contaminated Soil. Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, DC, November 1984. EPA 600/8-84-031.

Tyler, L.D. and McBride, M.B., 1982. Mobility and Extractability of Cadmium, Copper, Nickel, and Zinc in Organic and Mineral Soil Columns. Soil Sci. 134:198-205.

United States Army Corps of Engineers (Flood Plain Information - Buffalo Office).

United States Dept. of Agriculture, Soil Conservation Service, and Ohio Dept. of Natural Resources Division of Lands and Soil, and the Ohio Agricultural Research and Development Center. 1976. Soil Survey of Lorain County, Ohio, July, 1976.

U.S. Environmental Protection Agency (USEPA), 1982. An Exposure and Risk Assessment for Benzo[a]pyrene and Other Polycyclic Aromatic Hydrocarbons. Vols. I-IV. Prepared by Arthur D. Little, Inc. for Office of Water Regulations and Standards. EPA 440/4-85-020-VI.

U.S. Environmental Protection Agency (USEPA), 1982. Aquatic Fate Process Data for Organic Priority Pollutants. Office of Water Regulations and Standards (WH-553). Washington, DC EPA 440/4-81-014.

U.S. Environmental Protection Agency (USEPA), 1984. "Documentation Records for Hazard Ranking System" for Republic Steel Quarry, Elyria, Ohio.

U.S. Environmental Protection Agency (USEPA), 1985. Endangerment Assessment Guidance Memorandum from Assistant Administrator J. Winston Porter, OSWER, September 20, 1985.

U.S. Environmental Protection Agency (USEPA), 1986. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response, EPA 540/1-86-060.

U.S. Environmental Protection Agency (USEPA), 1987. Superfund Program: Interim Guidance on Compliance with Other Applicable or Relevant and Appropriate Requirements. FR 22:166.

U.S. Environmental Protection Agency (USEPA), 1987. Superfund Exposure Assessment Manual. Final Draft. Office of Emergency and Remedial Response. September 22, 1987. OSWER Directive 9285.5-1.

U.S. Environmental Protection Agency (USEPA), 1987. Interim Guidance on Compliance with Applicable or Relevant and Appropriate Requirements. Memorandum.

U.S. Geological Survey, 1984. Water Resources Data, Ohio, Water Year 1984, Vol. 2, St. Lawrence River Basin Statewide Project Data, Water-Data Report OH-84-2.

Van Den Berg, M., deVroom, E., Van Greevenbroek, M., and Olie, K. 1985. Bioavailability of PCDDs and PCDFs Adsorbed on Fly Ash in Rat, Guinea Pig, and Syrian Golden Hamster. Chemosphere 14: 865-869.

Van Den Berg, M., Van Greevenbroek, M., Olie, K., and Hutzinger, O., 1986. Bio-availability of PCDDs and PCDFs on Fly Ash After Semi-Chronic Oral Ingestion by Rat. Chemosphere 15:509-518.

West, W.R., Smith, P.A., Booth, G.M., Wise, S.A., Lee, M.L., 1986. Determination of Genotoxic Polycyclic Aromatic Hydrocarbons in a Sediment from the Black River, Ohio USA. Archives of Environ. Con. and Tox. 15:3 241-250.

West, W.R., Smith, P.A., Booth, G.M., Lee, M.L., 1988. Isolation and Detection of Genotoxic Components in a Black River Sediment. ES&T 22:2 224-228.

Williams, G.M. and Weisbarger, J.H., 1986. Chemical Carcinogens. In Klaasson, C.D., Amdur, M.C. and Doull, J. (Eds). Toxicology: The Basic Science of Poisons, 3rd Ed., MacMillan Publishing Co., NY, pp 99-173.

Wolfe, N.L., Burns, C.A., and Steen, W.C., 1980. Use of Linear Free Energy Relationships and Evaluation Model to Assess the Fate and Transport of Phthalate Esters in the Aquatic Environment. Chemosphere. 9:373-402.

White, J.B. and Vanderslice, R.R., 1980. POM Source and Ambient Concentrations Data: Review and Analysis. Research Triangle Institute, Research Triangle Park, NC.

Zarba, C.S., 1988. Interim Sediment Criteria Values for Nonpolar Hydrophobic Organic Compounds. Office of Water, Environmental Protection Agency, Washington, DC.

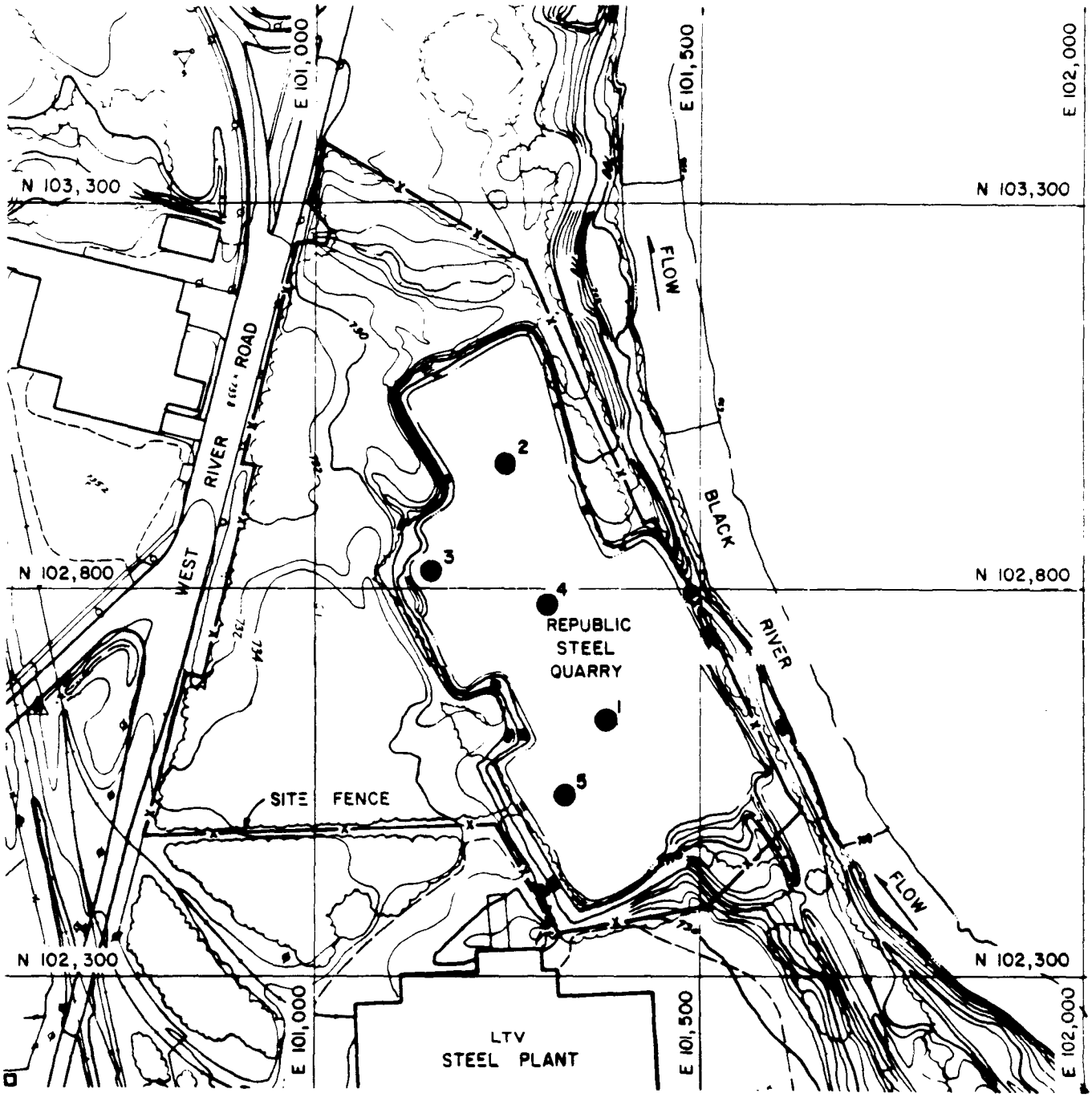
APPENDIX A

RESULTS OF PREVIOUS INVESTIGATIONS

TABLE A-1
Surface Water Sampling Results
Republic Steel Quarry
Sampled 3/24/76

Sample Location	Depth	pH	Total Acidity (mg/l)	Total Iron (mg/l)
#1	Surface	4.5	55	19.0
#1	25 feet	2.1	1830	680.0
#1	50 feet	3.0	2440	1192.0
#2	Surface	4.4	57	22.9
#2	25 feet	2.4	948	302.0
#2 (bottom)	36 feet	2.2	1840	833.0
#3	Surface	4.1	58	21.4
#3	25 feet	2.6	520	160.0
#4	Surface	4.3	56	19.0
#4	25 feet	2.4	1212	389.0
#4 (bottom)	46 feet	3.1	2440	1320.0
#5	Surface	3.9	71	21.4
#5 (bottom)	17 feet	2.1	1740	640.0
Quarry Outlet	Surface	4.3	55	23.7

Notes: 1. See Figure A-1 for locations.
2. Collector of samples is not known.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

● 3 SURFACE WATER SAMPLE LOCATION

NOTE: COLLECTOR OF SAMPLES IS NOT KNOWN

0 200 400
SCALE IN FEET

FIGURE A-1
SURFACE WATER SAMPLE LOCATIONS
REPUBLIC STEEL QUARRY SITE

TABLE A-2
Surface Water Sampling Results
Republic Steel Quarry
Sampled 4/20/76

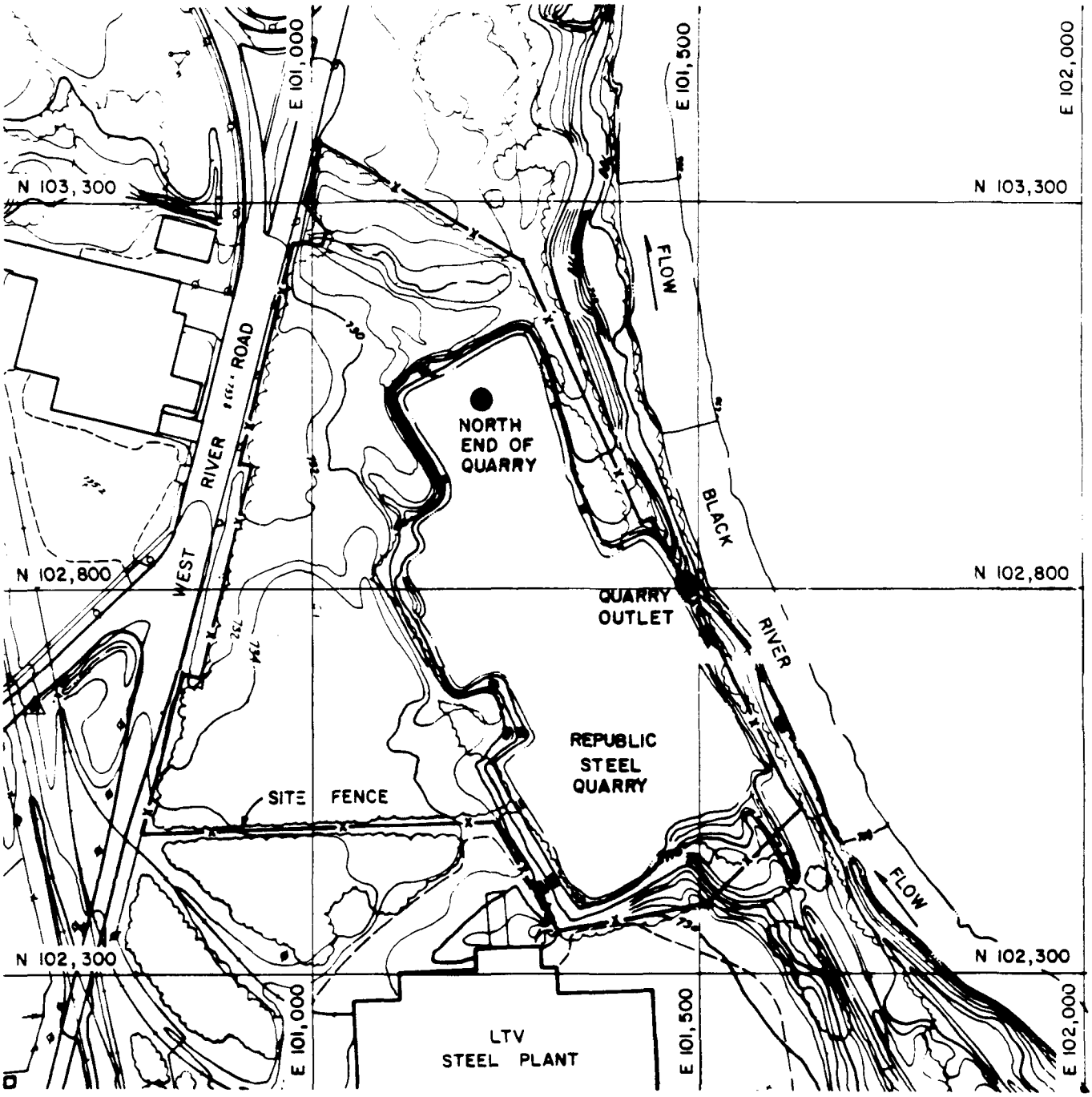
Sample Location	Depth (ft.)	pH	Total Acidity (mg/l)	Total Iron (mg/l)
#1	2	7.25	6	2.08
#1	4	7.11	10	1.25
#1	6	6.47	21	1.10
#1	10	6.47	19	1.45
#2	2	7.42	5	1.10
#2	4	6.74	13	1.60
#2	6	6.75	15	1.10
#2	8	6.56	16	1.35
#3	2	7.24	7	1.50
#3	4	7.33	5	1.35
#3	6	6.79	12	1.25
#3	8	6.45	18	1.30
#4	2	7.11	9	2.33
#4	4	7.21	8	1.38
#4	6	6.46	20	1.10
#4	8	6.51	16	1.35
#4 (Bottom)	45	2.97	2660	1340.00
#5	2	7.32	7	4.82
#5	4	6.79	15	3.28
#5	6	6.97	11	2.83
#5	8	6.97	11	0.95
#5 (Bottom)	32	2.34	1952	811.00
#6	2	6.90	12	0.85
#6	4	6.76	15	0.85
#6	6	6.57	18	0.90
#6	8	6.41	21	0.80
#7	2	7.24	6	0.90
#7	4	6.95	10	0.72
#7	6	6.57	15	0.80
#7	8	6.43	18	0.80
#8	2	7.34	6	2.55
#8	4	7.23	7	1.70
#8	6	6.58	17	1.30
#8	8	6.49	19	1.55
#8 (Bottom)	38	2.84	2304	1227.01
Quarry Outlet		7.41	4	1.0
Black River Upstream		8.59	170	0.9
Black River Downstream		8.37	157	3.4

Notes: 1. Locations not documented.
2. Samples collected by Republic Steel Corporation

TABLE A-3
Surface Water Sampling Results
Republic Steel Quarry
Sampled 8/83

Element	North End Quarry (mg/l)	Quarry Outlet (mg/l)
Aluminum	0.698	<0.10
Antimony	<0.02	<0.02
Arsenic	<0.01	<0.01
Barium	<0.1	<0.1
Beryllium	<0.005	<0.005
Boron	0.303	0.125
Cadmium	<0.001	<0.001
Chromium	<0.01	<0.01
Cobalt	<0.05	<0.05
Copper	<0.05	<0.05
Iron	419.0	0.199
Lead	0.0525	0.0345
Manganese	6.750	0.073
Mercury	<0.0002	<0.0002
Nickel	<0.04	<0.04
Selenium	<0.002	<0.002
Silver	<0.01	<0.01
Thallium	<0.01	<0.01
Tin	<0.02	<0.02
Vanadium	<0.2	<0.2
Zinc	0.517	<0.01.

<Less than detection limit listed.
Notes: 1. See Figure A-2 for locations.
2. Samples collected by Ecology & Environment



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

● SURFACE WATER SAMPLE LOCATION

N

0 200 400

SCALE IN FEET

FIGURE A-2
E & E (FIT) INVESTIGATION
SURFACE WATER
SAMPLE LOCATIONS
REPUBLIC STEEL QUARRY SITE

TABLE A-4

SURFACE WATER SAMPLING RESULTS
REPUBLIC STEEL QUARRY
SAMPLED 11/7/84
CONCENTRATIONS IN PARTS PER MILLION (mg/l)

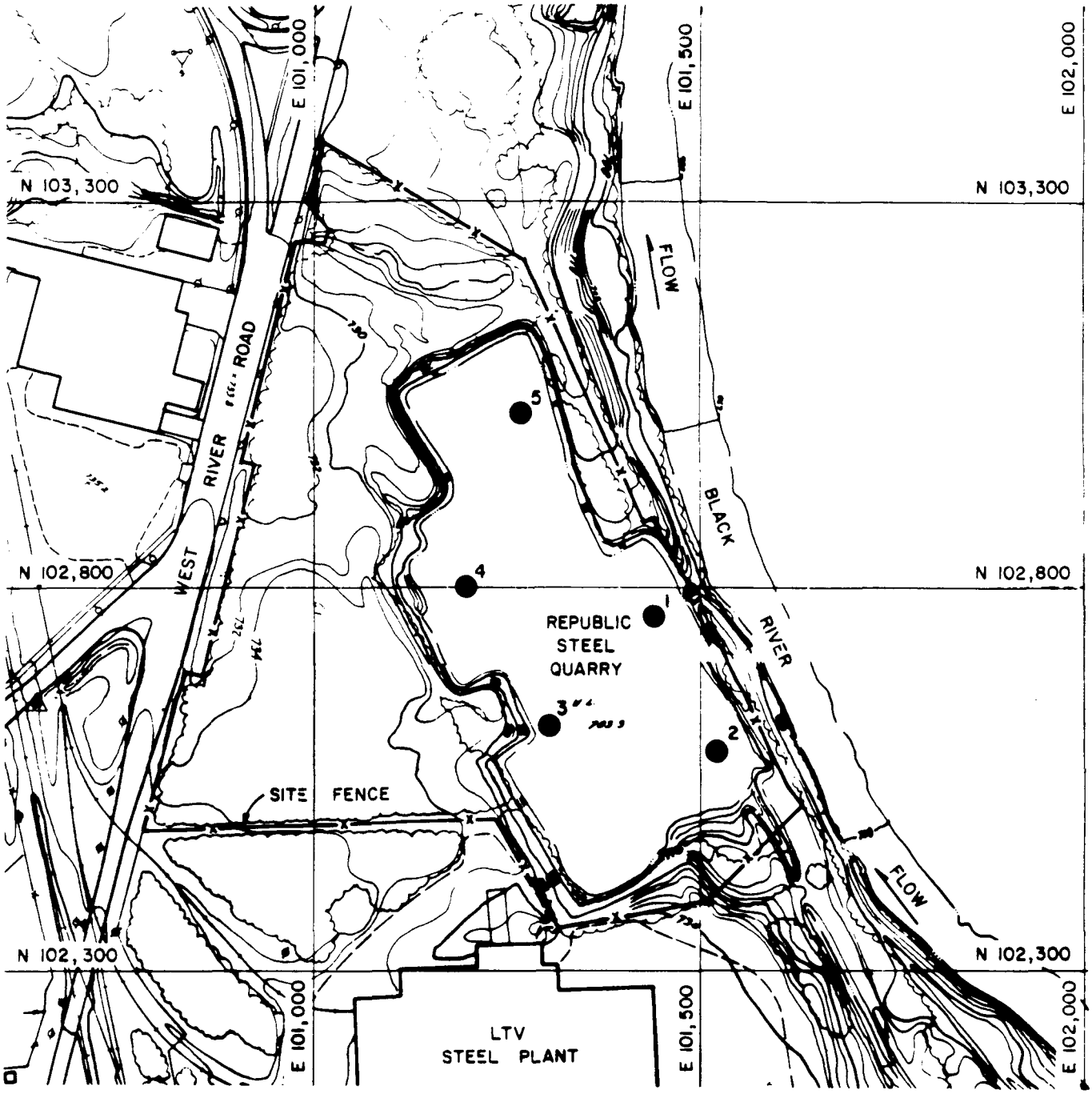
SAMPLE LOCATION	DEPTH OF SAMPLE	As	Cd	Cr	Fe	Pb	Zn	Ba	Mn	Ni	Al	pH
		PARAMETERS										
1	Surface	<0.01	0.02	0.03	0.72	<0.01	0.06	-	-	-	-	6.2
2	Surface	<0.01	<0.01	0.03	1.5	<0.01	0.06	-	-	-	-	6.4
3	Surface	<0.01	<0.01	0.03	1.2	<0.01	0.06	-	-	-	-	6.3
4	Surface	<0.01	0.01	<0.01	0.66	<0.01	0.05	-	-	-	-	6.5
5	Surface	0.01	0.01	0.03	0.66	<0.01	0.06	<0.01	0.58	0.01	0.04	6.4
1	10 Feet	<0.01	0.02	0.03	1.0	<0.01	0.25	-	-	-	-	6.3
2	10 Feet	<0.01	<0.01	0.04	2.2	<0.01	0.07	-	-	-	-	6.4
3	10 Feet	<0.01	<0.01	0.02	1.3	<0.01	0.10	<0.01	0.50	0.01	-	6.4
4	10 Feet	<0.01	0.01	0.07	0.54	<0.01	0.09	-	-	-	-	6.3
5	10 Feet	<0.01	0.01	0.02	0.82	0.01	0.10	-	-	-	-	6.4

<Less than detection limit listed

-Element not tested for

Notes: 1. See Figure A-3 for locations.

2. Samples collected by IT Corporation.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND

● 2 SURFACE WATER SAMPLE LOCATION

N

0 200 400

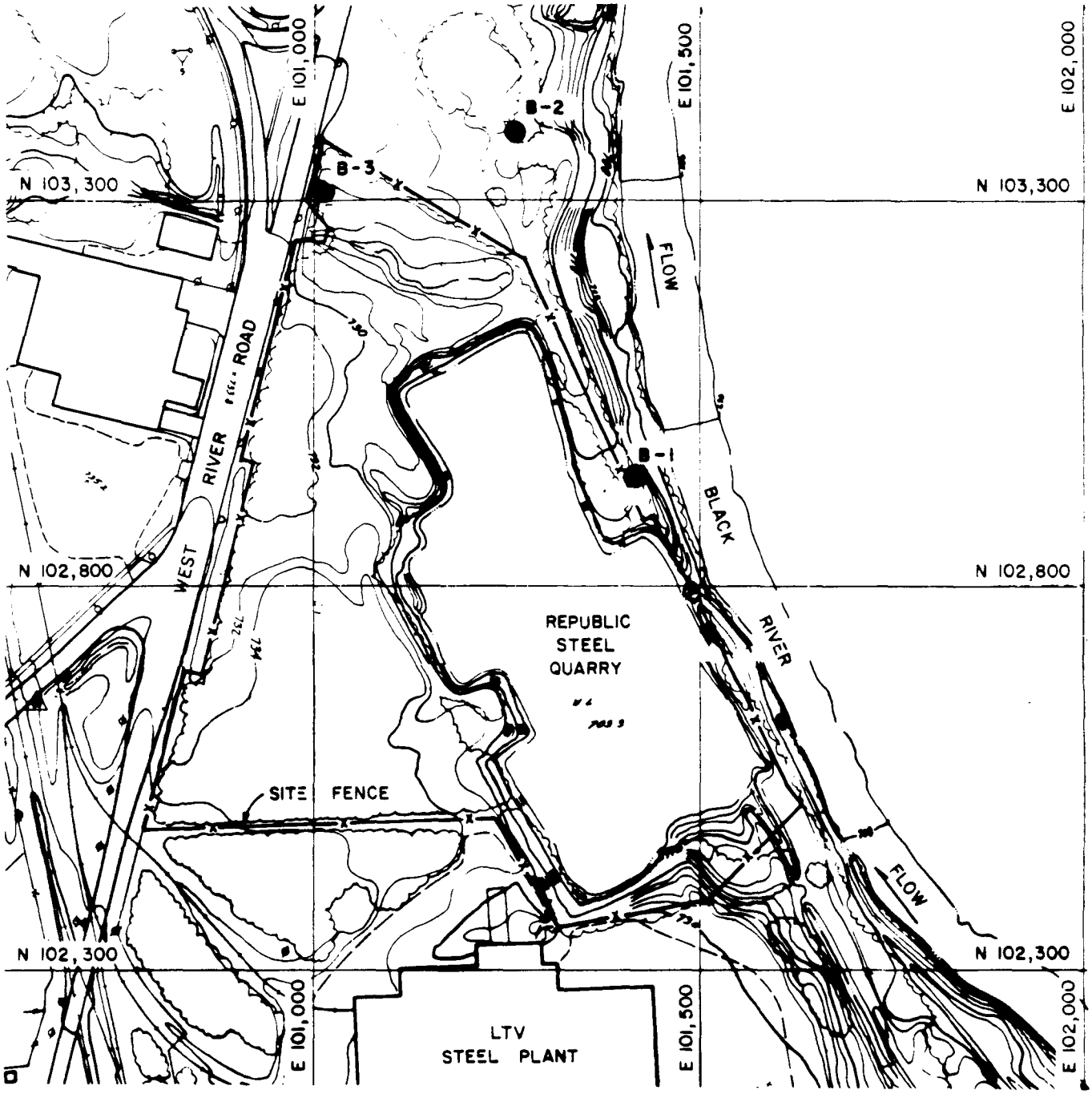
SCALE IN FEET

FIGURE A-3
I.T. INVESTIGATION
SURFACE WATER
SAMPLE LOCATIONS
REPUBLIC STEEL QUARRY SITE

TABLE A-5
Groundwater Sampling Results
Republic Steel Quarry

Element	E & E Site Investigation[1] Sampled 12/83 Concentrations in mg/l (ppm)			IT Site Investigation[2] Sampled 11/84 Concentrations in mg/l (ppm)			U.S. EPA National Interim Primary Drinking Water Standards	U.S. EPA Proposed Secondary Drinking Water Standards
	Well B-1	Well B-2	Well B-3	Well B-1	Well B-2	Well B-3	Maximum Level (ppm)	Maximum Level (ppm)
Aluminum	83.3	2.3	0.4	0.25	0.34	0.88		
Antimony	<0.02	0.02	<0.02	--	--	--		
Arsenic	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	
Barium	0.6	<0.1	<0.1	<0.01	<0.01	0.04	1.0	
Beryllium	<0.005	<0.005	<0.005	--	--	--		
Boron	--	--	--	--	--	--		
Cadmium	0.0085	<0.001	<0.001	0.01	0.01	<0.01	0.01	
Chromium	0.13	<0.01	<0.01	0.03	0.03	0.03	0.05	
Cobalt	0.08	<0.05	<0.05	--	--	--		
Copper	ND*	ND*	ND*	--	--	--		
Iron	233	3.8	26.3	2.8	1.1	9.8		0.3
Lead	0.079*	ND*	ND*	<0.01	<0.01	0.03	0.05	
Manganese	4.77	0.08	0.79	0.39	0.07	0.57		0.05
Mercury	<0.002	0.0003	<0.0002	--	--	--		
Nickel	0.170	<0.040	<0.040	<0.01	<0.01	<0.01		
Selenium	<0.002	<0.002	<0.002	--	--	--		
Silver	<0.01	<0.01	<0.01	--	--	--		
Thallium	<0.01	<0.01	<0.01	--	--	--		
Tin	<0.02	<0.02	<0.02	--	--	--		
Vanadium	0.2	<0.2	<0.2	--	--	--		
Zinc	0.82*	ND*	ND*	0.04	0.06	0.20		5.0
pH				6.5	5.9	7.0		6.6-8.5

* Laboratory blank results were high for Cu, Pb, Zn. Reported values were adjusted by subtracting lab blank values.
[1] Samples were not filtered prior to analysis and reflect total concentrations
[2] Samples were filtered prior to analyis and reflect dissolved concentrations
-- Element not tested for
ND Not Detected
< Less than detection limit listed
Note: See Figure A-4 for locations.



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

● GROUNDWATER SAMPLE LOCATION, (MONITORING WELL)

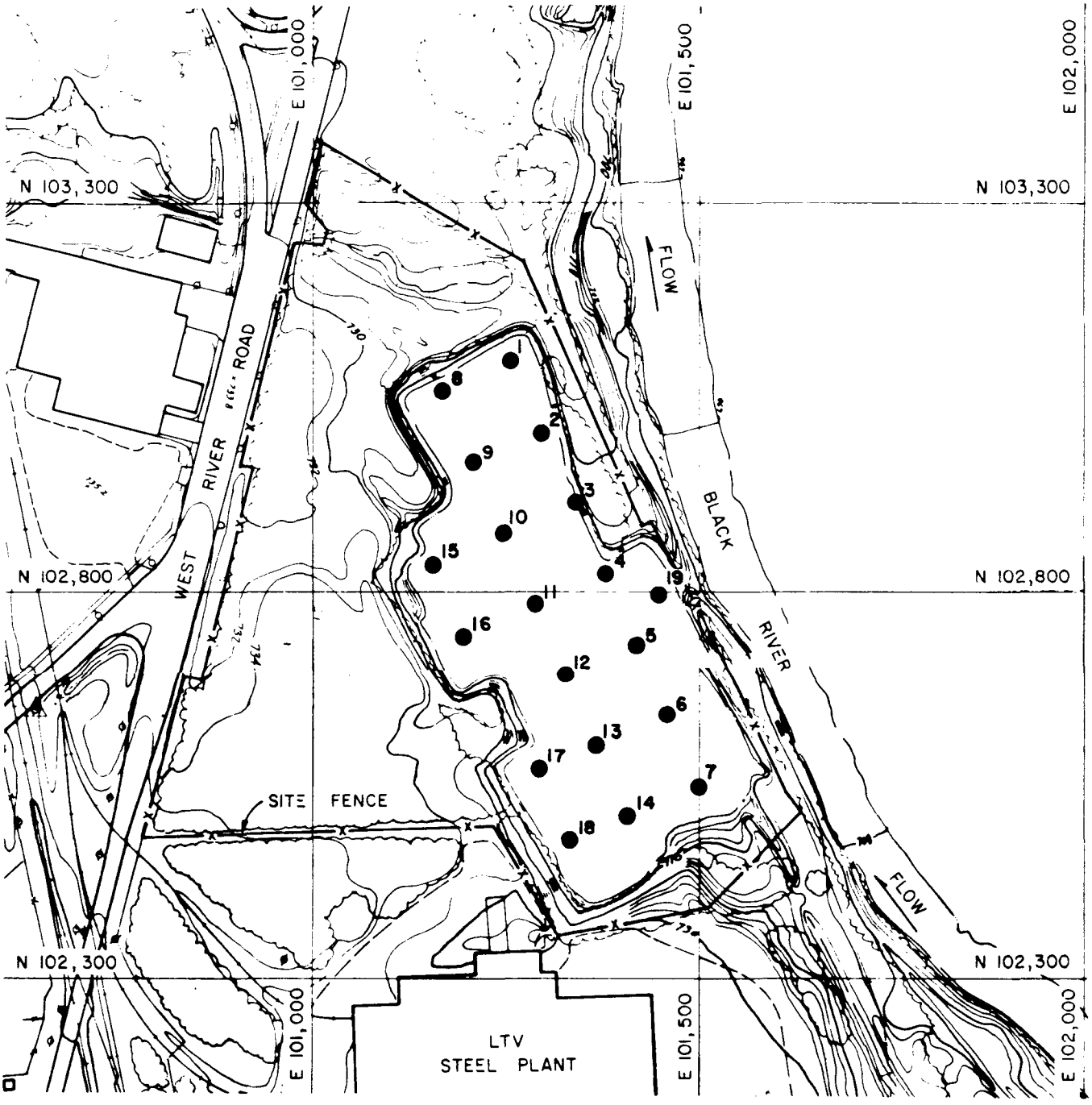
N

0 200 400
SCALE IN FEET

FIGURE A – 4
GROUNDWATER
SAMPLE LOCATIONS
REPUBLIC STEEL QUARRY SITE

APPENDIX B

DEPTH-FINDER RESULTS



SOURCE: CITY OF ELYRIA
ENGINEERING DEPARTMENT
SCALE: 1" = 100'

LEGEND:

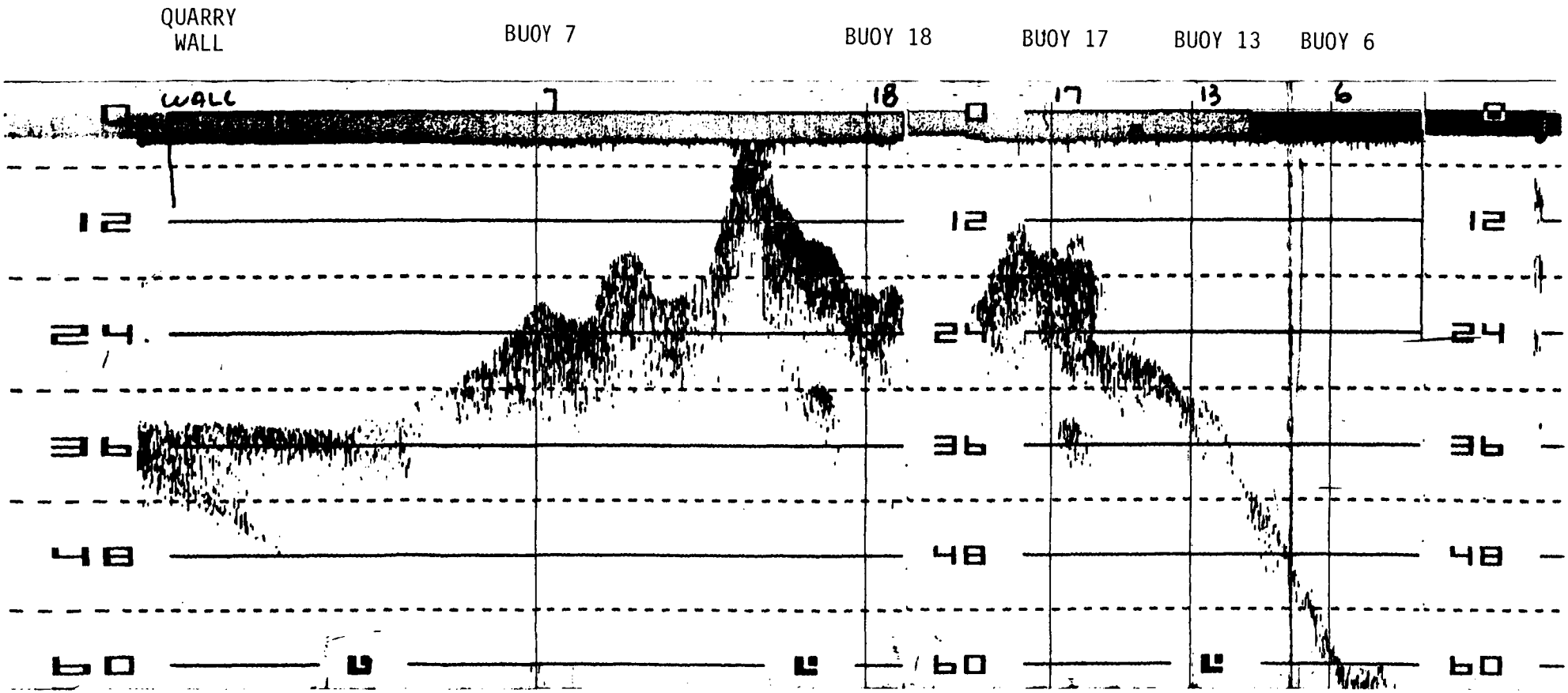
● 8 BUOY LOCATION NO. 8

N

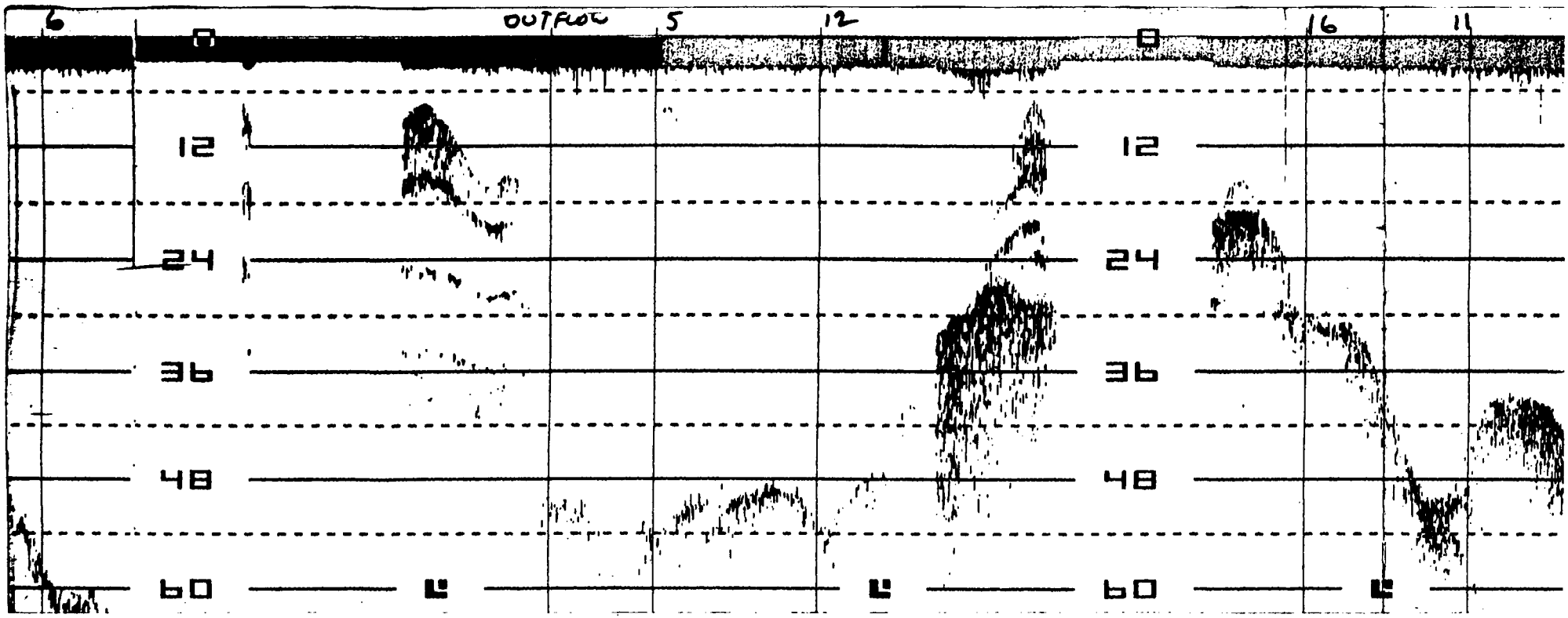
0 200 400

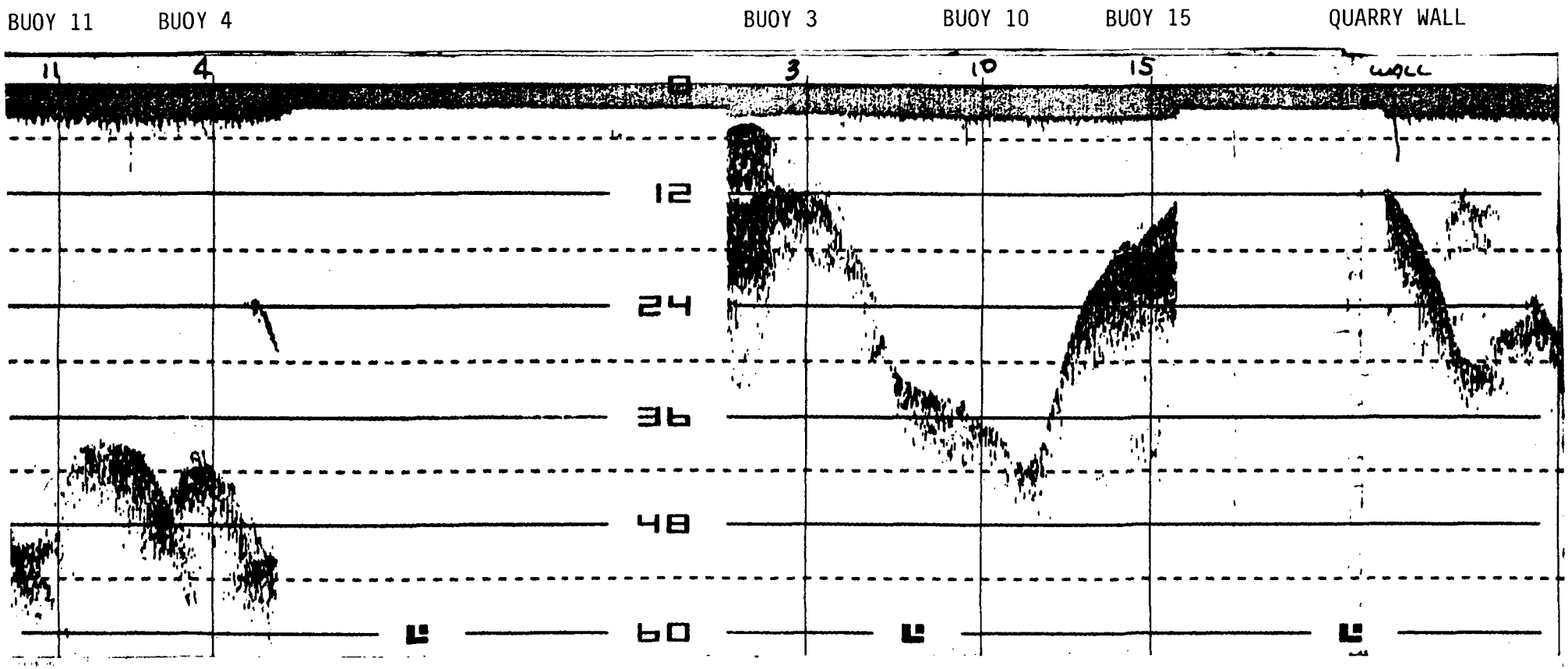
SCALE IN FEET

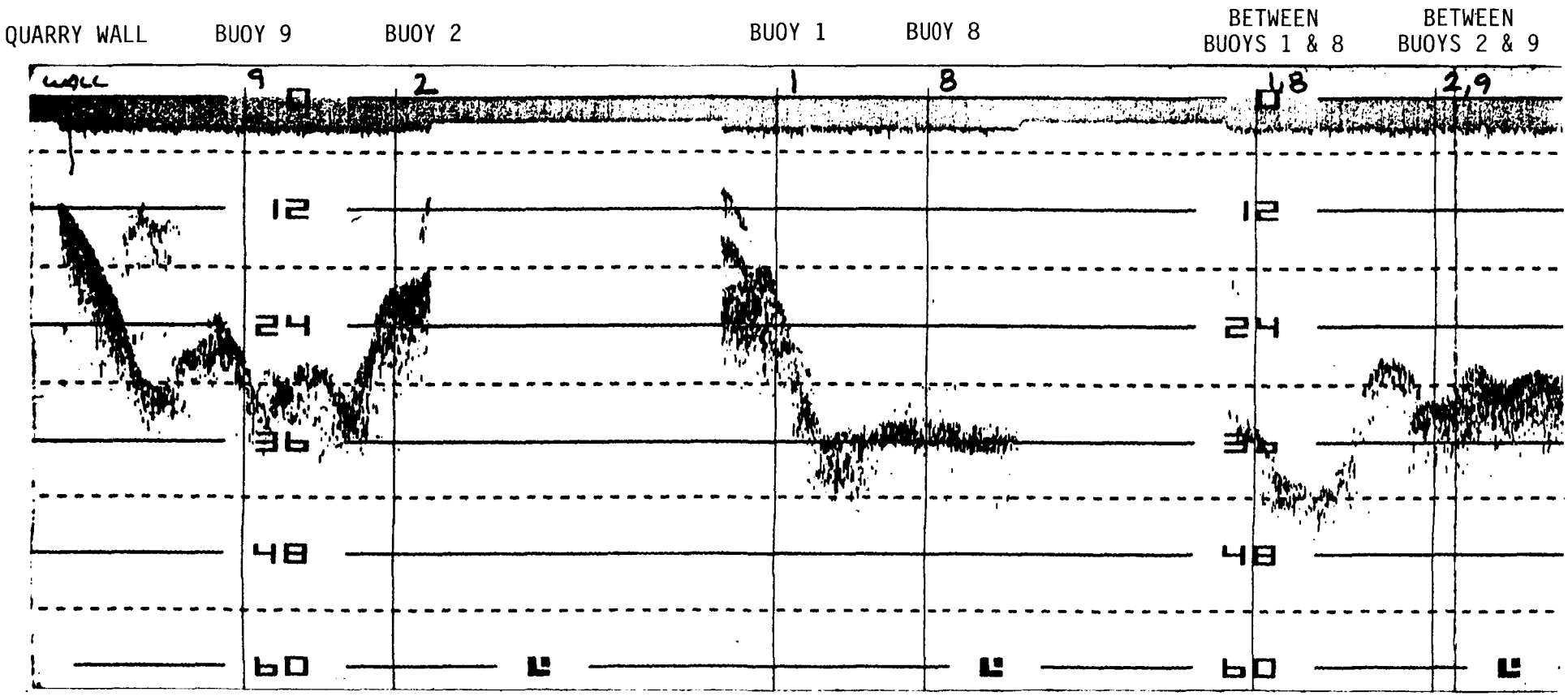
FIGURE B-1
BUOY LOCATIONS USED
FOR DEPTHFINDER SURVEY
REPUBLIC STEEL QUARRY RI

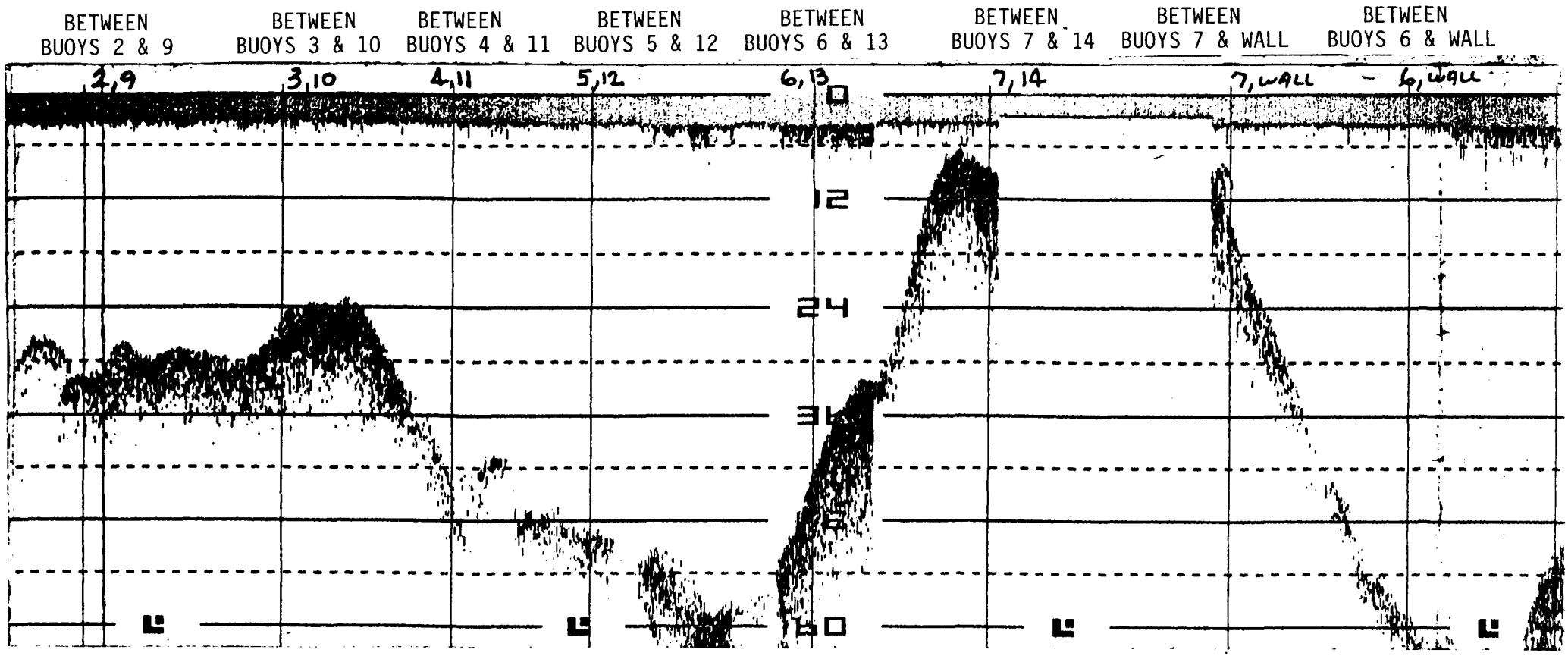

QUARRY WALL
BUOY 7
BUOY 18
BUOY 17
BUOY 13
BUOY 6
WALL
7
18
17
13
6
12
24
36
48
60

BUOY 6 BUOY 19 BUOY 5 BUOY 12 BUOY 16 BUOY 11




BUOY 11
BUOY 4
BUOY 3
BUOY 10
BUOY 15
QUARRY WALL
11
4
3
10
15
WALL
12
24
36
48
60


QUARRY WALL
BUOY 9
BUOY 2
BUOY 1
BUOY 8
BETWEEN BUOYS 1 & 8
BETWEEN BUOYS 2 & 9
WALL
9
2
1
8
1,8
2,9
12
24
36
48
60


BETWEEN BUOYS 2 & 9
BETWEEN BUOYS 3 & 10
BETWEEN BUOYS 4 & 11
BETWEEN BUOYS 5 & 12
BETWEEN BUOYS 6 & 13
BETWEEN BUOYS 7 & 14
BETWEEN BUOYS 7 & WALL
BETWEEN BUOYS 6 & WALL
2,9
3,10
4,11
5,12
6,13
7,14
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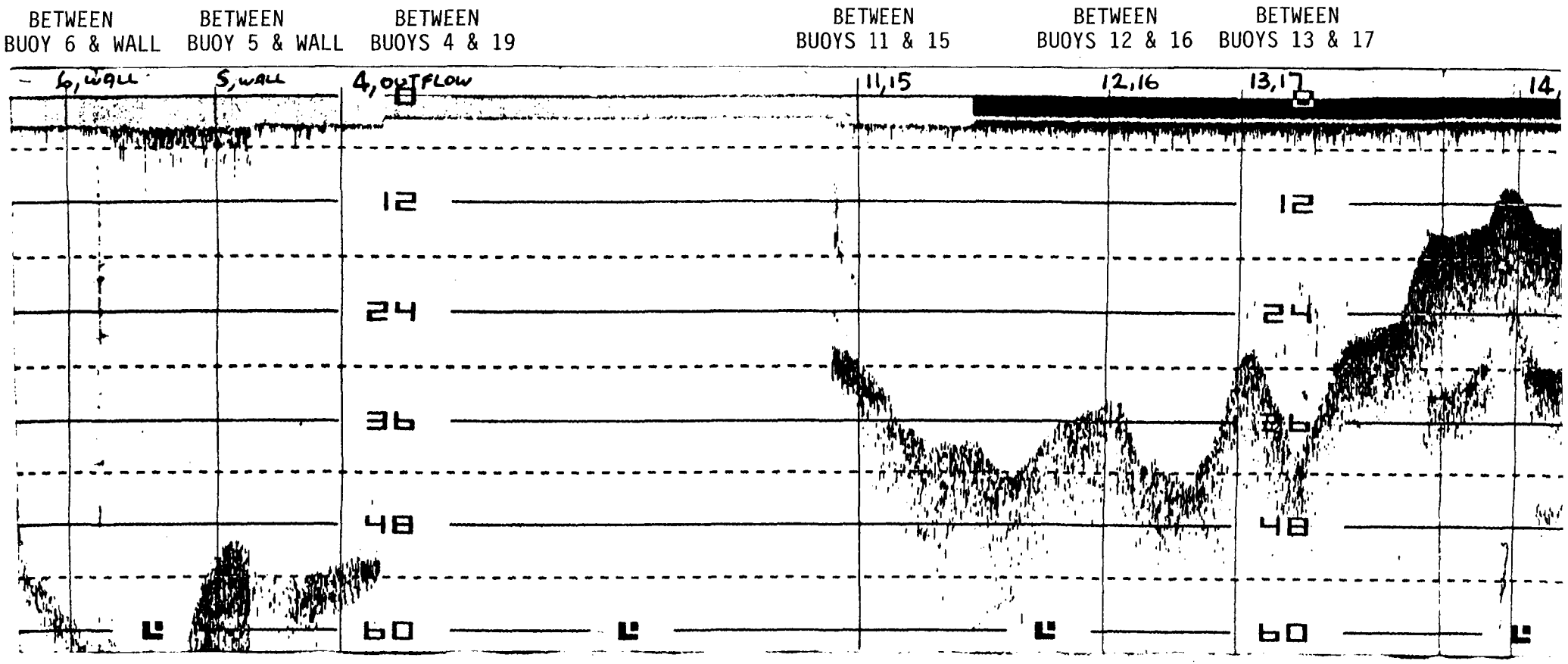
6,WALL
12
24
36
48
60


BETWEEN BUOY 6 & WALL
BETWEEN BUOY 5 & WALL
BETWEEN BUOYS 4 & 19
BETWEEN BUOYS 11 & 15
BETWEEN BUOYS 12 & 16
BETWEEN BUOYS 13 & 17
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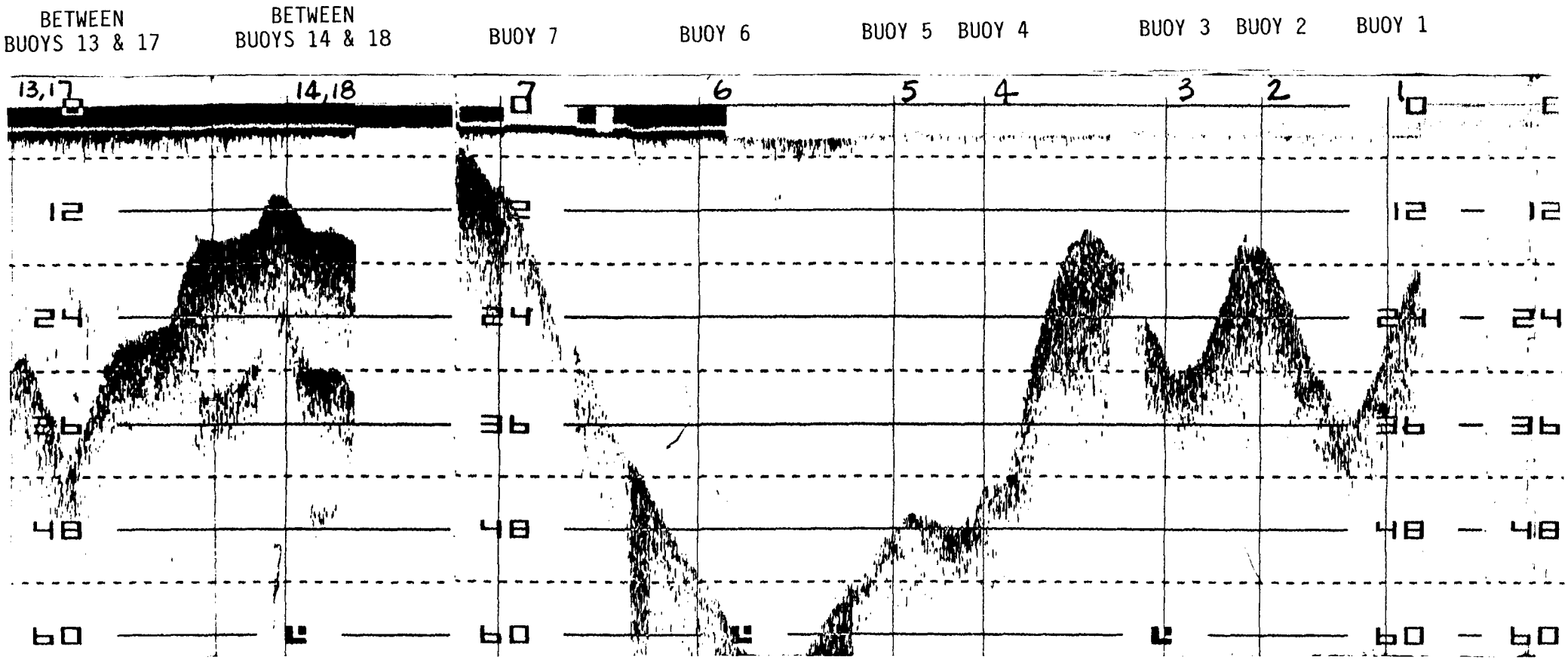
5, WALL
4, OUTFLOW
11,15
12,16
13,17
14
12
24
36
48
60


BETWEEN BUOYS 13 & 17
BETWEEN BUOYS 14 & 18
BUOY 7
BUOY 6
BUOY 5
BUOY 4
BUOY 3
BUOY 2
BUOY 1
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2
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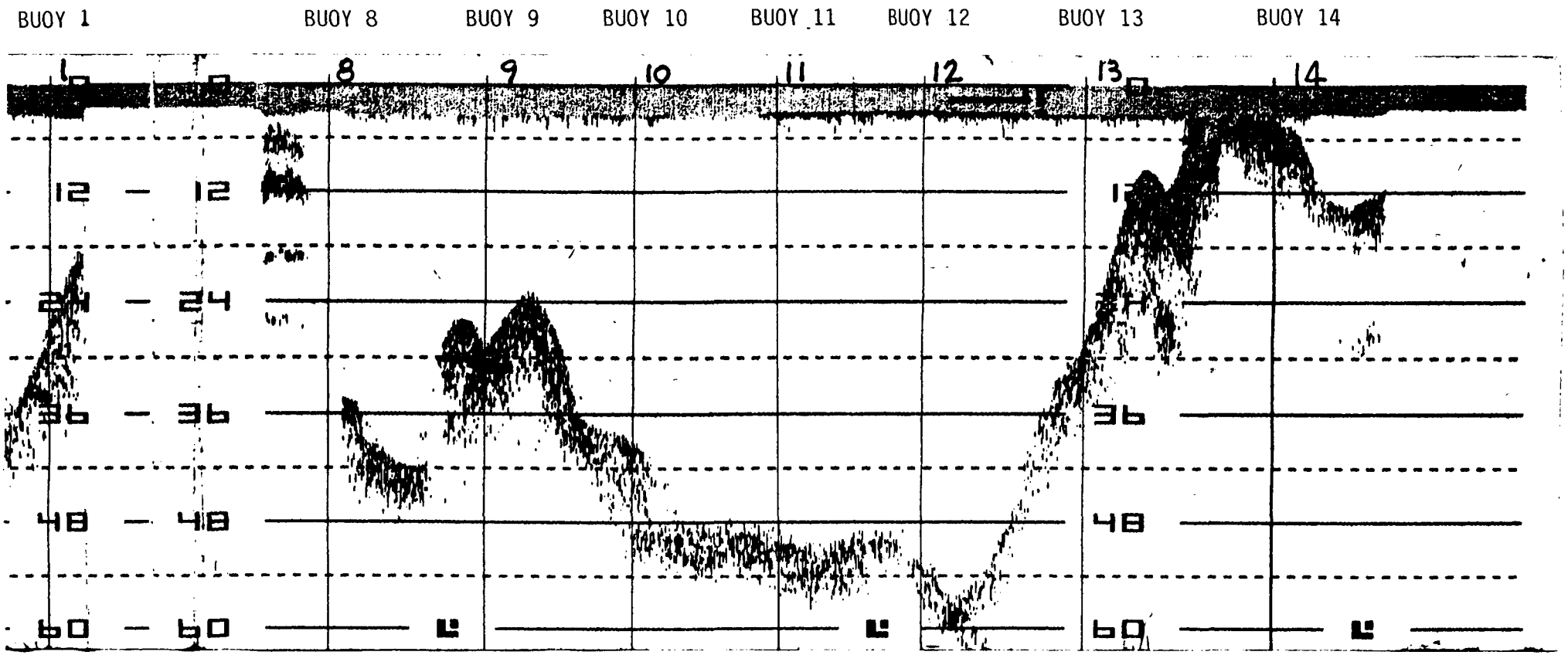
36
48
60


BUOY 1
BUOY 8
BUOY 9
BUOY 10
BUOY 11
BUOY 12
BUOY 13
BUOY 14
1
8
9
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11
12
13
14
12
24
36
48
60

APPENDIX C

SURVEY MAP

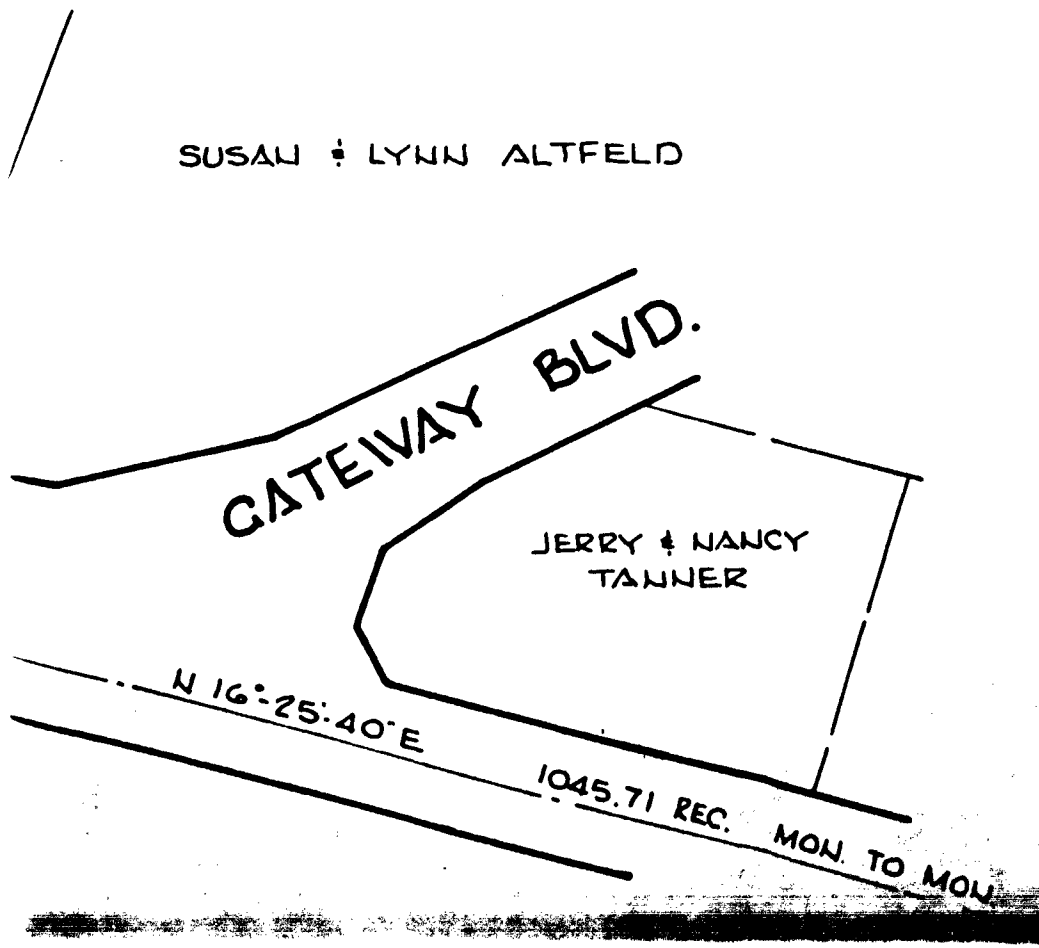
WELL CASING LOCATION

AT

OLD REPUBLIC STEEL QUARRY

CITY OF ELYRIA COUNTY OF LORAIN

STATE OF OHIO



APPENDIX D

WATER QUALITY PROFILE RESULTS

WATER QUALITY PROFILING RESULTS
REPUBLIC STEEL QUARRY RI

BOUY NUMBER	DEPTH (FEET)	TEMPERATURE (DEGREES C.)	CONDUCTIVITY (umhos/cm)	DISSOLVED OXYGEN (mg/l)	pH
1	0	23	700	6.6	--
	5	23	700	6.4	6.87
	10	15	600	7.4	6.76
	15	9	450	7.4	6.42
	20	8	440	5.6	6.05
	25	7	450	4.1	6.06
	30	8	1050	2.2	--
2	0	22	700	6.4	7.09
	5	22	700	6.4	6.80
	10	15	600	7.9	6.43
	15	10.5	460	4.2	6.40
3	0	23	700	6.6	6.93
	5	23	700	6.6	6.79
	10	11	600	9.0	6.42
	15	10	440	7.1	6.39
	20	8	440	5.2	6.14
4	0	22	700	6.7	7.08
	5	22	700	6.7	6.87
	10	17.5	600	7.6	6.48
	15	9.5	440	8.0	6.39
	20	8.5	440	5.2	6.05
	25	7	440	2.3	5.92
	30	7	1250	1.6	6.15
	35	8	2000	1.0	6.07
	40	8.5	2500	0.8	5.90
	45	9	3250	0.6	--
	48	9	3300	0.5	--
5	0	23	700	6.7	7.14
	5	23	700	6.4	6.92
	10	17	600	6.4	6.57
	15	11	500	7.9	6.48
	20	8	430	5.1	6.05
	25	8	440	3.2	5.90
	30	7.5	1200	1.9	6.24
	35	8	2000	1.4	6.06
	40	9	2500	0.9	5.95
	45	9	3300	0.8	5.74
	48	9.5	3300	0.5	--
	50	--	--	--	5.80
	55	--	--	--	5.98
	60	--	--	--	5.99
	62	--	--	--	5.99

NOTES: -- INDICATES THE PARAMETER WAS NOT MEASURED FOR AT THE GIVEN DEPTH

Water Quality Profiling Results
Republic Steel Quarry RI
Page Two

BOUY NUMBER	DEPTH (FEET)	TEMPERATURE (DEGREES C.)	CONDUCTIVITY (umhos/cm)	DISSOLVED OXYGEN (mg/l)	pH
6	0	22	470	6.6	7.62
	5	22	470	6.4	7.52
	10	16	460	7.9	6.81
	15	10	460	8.0	6.47
	20	9	450	5.0	5.89
	25	7	460	2.6	5.95
	30	7	1200	1.0	5.92
	35	8	2000	0.4	6.06
	40	9	2500	0.3	5.92
	45	9	3300	0.2	5.72
	48	9	3300	0.2	--
	50	--	--	--	5.79
	55	--	--	--	5.83
7	0	23	700	6.4	6.85
	5	23	700	6.4	7.09
	10	17	600	7.4	6.60
	13	10	450	5.6	6.64
8	0	21.5	700	6.0	7.16
	5	21.5	700	5.9	7.27
	10	16	600	7.3	6.85
	15	9	450	7.6	6.90
	20	7.5	450	4.9	6.45
	25	7	460	2.5	6.27
	30	8	1300	1.4	6.46
	33	8.5	1300	0.6	6.53
9	0	21.5	700	6.2	7.26
	5	21.5	700	6.2	7.28
	10	15	600	7.8	6.88
	15	9	450	7.1	6.90
	20	8	450	4.7	6.41
	25	7	460	2.5	6.28
	30	7	1000	1.1	--
10	0	22	700	6.4	7.21
	5	22	700	6.3	7.21
	10	15	600	7.2	6.93
	15	9	450	8.2	6.94
	20	7.5	450	4.2	6.35
	25	7	460	2.2	6.24
	30	8	1350	1.2	6.44
	35	8.5	2000	0.8	6.38

NOTES: -- INDICATES THE PARAMETER WAS NOT MEASURED FOR AT THE GIVEN DEPTH

Water Quality Profiling Results
Republic Steel Quarry RI
Page Three

BOUY NUMBER	DEPTH (FEET)	TEMPERATURE (DEGREES C.)	CONDUCTIVITY (umhos/cm)	DISSOLVED OXYGEN (mg/l)	pH
11	0	22	700	8.0	7.45
	5	22	700	6.2	7.45
	10	15	600	7.2	7.02
	15	9	450	7.8	7.07
	20	8	450	4.7	6.80
	25	7	460	2.2	6.70
	30	8	1250	1.2	6.50
	35	8	2100	0.8	6.30
	37.5	9	2350	0.4	6.21
12	0	22	700	6.5	7.35
	5	21.5	700	6.5	7.30
	10	15.5	600	7.7	7.00
	15	9	440	7.6	7.00
	20	8	440	4.5	6.70
	25	7	460	1.6	6.50
	30	8	1300	1.4	6.52
	35	8	2000	1.4	6.38
	40	9	2600	0.6	6.18
	45	10	3250	0.3	6.02
	48	10	3300	0.2	--
	50	--	--	--	5.90
	55	--	--	--	6.23
	58	--	--	--	5.95
13	0	22	700	6.6	6.82
	5	22	700	6.4	6.95
	10	15	600	6.8	6.75
	15	9	450	8.0	6.87
	20	8	460	4.0	6.35
	25	7	470	2.0	6.17
	30	8	1300	1.1	6.40
	33	8	1800	0.6	6.33
14	LOCATED ON ISLAND AT SOUTH END OF QUARRY.				
15	0	22	700	6.5	7.17
	5	22	700	6.6	7.15
	10	14	600	8.0	6.72
	15	9	440	8.0	6.67

NOTES: -- INDICATES THE PARAMETER WAS NOT MEASURED FOR AT THE GIVEN DEPTH

Water Quality Profiling Results
Republic Steel Quarry RI
Page Four

BOUY NUMBER	DEPTH (FEET)	TEMPERATURE (DEGREES C.)	CONDUCTIVITY (umhos/cm)	DISSOLVED OXYGEN (mg/l)	pH
16	0	22	700	6.0	7.17
	5	22	700	5.8	7.18
	10	15	600	7.2	6.70
	15	9	450	7.6	6.73
	20	7	450	4.8	6.19
	25	7	460	2.5	5.98
	27.5	7	1000	1.5	--
17	0	22	700	6.1	7.27
	5	21.5	700	6.0	7.29
	10	15	600	7.2	6.77
	15	10	450	6.6	6.58
	20	7.5	450	4.0	6.09
18	0	22	700	6.3	7.24
	5	21	700	6.4	7.26
	10	14	600	7.7	6.73
	15	9	460	6.2	6.60
BOUY @ QUARRY OUTFLOW	0	22	700	6.2	7.24
	5	22	700	6.2	7.16
	10	15	600	7.4	6.88
	15	9	450	7.2	6.81
	20	7	450	4.8	6.45
	25	7	460	3.2	6.24
	30	8	1200	2.0	6.32
	35	8	2000	1.6	6.34
	40	9	2700	0.9	6.20
	45	10	3100	0.5	6.04
	50	--	--	--	6.12

NOTES: -- INDICATES THE PARAMETER WAS NOT MEASURED FOR AT THE GIVEN DEPTH

APPENDIX E

SUMMARY TABLES OF LABORATORY ANALYSES PERFORMED

SURFACE WATER SAMPLES
LABORATORY ANALYSES PERFORMED

Sample No.	Volatile Organics	Semi-Volatile Organics	Pesticides/PCB's Organics	Metals	Cyanide	SAS*	Hexavalent Chromium
SW001	X	X	X	X	X	X	X
SW002				X			X
SW003	X	X	X	X	X	X	X
SW004				X			X
SW005	X	X	X	X	X	X	X
SW006				X			X
SW007	X	R	X	X	X	X	X
SW008				X			X
SW009	X	X	X	X	X	X	X
SW010				X			X
SW011	X	R	X	X	X	X	X
SW012				X			X
SW013	X	X	X	X	X	X	X
SW014				X			X
SW015	X	X	X	X	X	X	X
SW016				X			X
SW017	X	R	X	X	X	X	X
SW018				X			X
SW019	X	R	X	X	X	X	X
SW020				X			X
SW021	X	R	X	X	X	X	X
SW022				X			X
SW023	X	R	X	X	X	X	X
SW024				X			X
SW025	X	R	X	X	X	X	X
SW026				X			X
SW027	X	R	X	X	X	X	X
SW028				X			X
SW029	X	R	X	X	X	X	X
SW030				X			X
SW031	X	X	X	X	X	X	X
SW032				X			X
SW033	X	R	X	X	X	X	X
SW034				X			X
SW035	X	X	X	X	X	X	X
SW036				X			X
SW037	X	R	X	X	X	X	X
SW038				X			X
SW039	X	R	X	X	X	X	X
SW040				X			X
SW041	X	R	X	X	X	X	X
SW042				X			X
SW043	X	R	X	X	X	X	X
SW044				X			X
SW045	X	R	X	X	X	X	X
SW046				X			X

Surface Water Laboratory Analyses Performed (Continued)

Sample No.	Volatile Organics	Semi-Volatile Organics	Pesticides/PCB's Organics	Metals	Cyanide	SAS*	Hexavalent Chromium
SW047	X	R	X	X	X	X	X
SW048				X			X
SW049	X	R	X	X	X	X	X
SW050				X			X
SW051	X	X	X	X	X	X	X
SW052				X			X
SW053	X	X	X	X	X	X	X
SW054				X			X
GW001	X	X	X	X	X	X	X
GW002				X			X
GW005	X	X	X	X	X	X	X
GW006				X			X
GW101	X						
SW101		X	X				
SW102		X	X				
SW103		R	X				
SW104		X	X				
SW105		X	X				
SW106		R	X				
SW107		X	X				
SW108		X	X				
SW109		X	X				
SW110		X	X				
SW111		X	X				
SW112		X	X				
SW113		X	X				
SW114		X	X				
SW115		X	X				
SW116		R	X				
SW117		R	X				
SW118		R	X				
SW119		X	X				
SW120		X	X				
SW121	X						
SW122		X	X				
SW123		X	X				
SW124		X	X				
SW125		X	X				
SW126		X	X				
SW127		X	X				
SW128		R	X				
SW129		R	X				

*SAS - SPECIAL ANALYTICAL SERVICES ANALYSES PERFORMED WERE OIL AND GREASE, TOTAL SUSPENDED SOLIDS, TOTAL DISSOLVED SOLIDS, TOTAL ALKALINITY, ACIDITY, CHLORIDE AND SULFATE.

R - ANALYTICAL DATA WERE REJECTED FOR THIS SAMPLE DUE TO LABORATORY QUALITY CONTROL

SEDIMENT SAMPLES
LABORATORY ANALYSES PERFORMED

Sample No.	Volatile Organics	Semi-Volatile Organics	Pesticides/PCB's Organics	Metals	Cyanide	SAS*	Particle Size Distribution
SD001	X	X	X	X	X	X	
SD002	X	X	X	X	X	X	
SD003	X	X	X	X	X	X	X
SD004	X	X	X	X	X	X	X
SD005	X	X	X	X	X	X	X
SD006	X	X	X	X	X	X	X
SD007	X	X	X	X	X	X	X
SD008	X	X	X	X	X	X	X
SD009	X	X	X	X	X	X	X
SD010	X	X	X	X	X	X	X
SD011	X	X	X	X	X	X	X
SD012	X	X	X	X	X	X	
SD013	X	X	X	X	X	X	X
SD014	X	X	X	X	X	X	X
SD015	X	X	X	X	X	X	X

*SAS - SPECIAL ANALYTICAL SERVICES ANALYSES PERFORMED WERE OIL AND GREASE, AND TOTAL ORGANIC CARBON.

SURFACE SOIL SAMPLES
LABORATORY ANALYSES PERFORMED

Sample No.	Volatile Organics	Semi-Volatile Organics	Pesticides/PCB's Organics	Metals	Cyanide	SAS*	Particle Distribution
SS001	X	X	X	X	X	X	X
SS002	X	X	X	X	X	X	X
SS003	X	X	X	X	X	X	X
SS004	X	X	X	X	X	X	X
SS005	X	X	X	X	X	X	X
SS006	X	X	X	X	X	X	X
SS007	X	X	X	X	X	X	X
SS008	X	X	X	X	X	X	X
SS009	X	X	X	X	X	X	
SS010	X	X	X	X	X	X	

*SAS - SPECIAL ANALYTICAL SERVICES ANALYSES PERFORMED WERE OIL AND GREASE.

GROUNDWATER SAMPLES
LABORATORY ANALYSES PERFORMED

Sample No.	Volatile Organics	Semi-Volatile Organics	Pesticides/PCB's Organics	Metals	Cyanide	SAS*	Hexavalent Chromium
GW001	X	X	X	X	X	X	X
GW002				X			X
GW003	X	X	X	X	X	X	X
GW004				X			X
GW007	X	X	X	X	X	X	X
GW008				X			X
GW009	X	X	X	X	X	X	X
GW010				X			X
GW011	X	X	X	X	X	X	X
GW012				X			X
GW013	X	X	X	X	X	X	X
GW014				X			X
GW015	X	X	X	X	X	X	X
GW016				X			X
GW017	X	X	X	X	X	X	X
GW018				X			X
GW019	X	X	X	X	X	X	X
GW020				X			X
GW021	X	X	X	X	X	X	X
GW022				X			X
GW023	X	X	X	X	X	X	X
GW024				X			X
GW025	X	X	X	X	X	X	X
GW026				X			X
GW101	X						
GW102	X						
GW103	X						
GW104	X						

*SAS - SPECIAL ANALYTICAL SERVICES ANALYSES PERFORMED WERE OIL AND GREASE, TOTAL SUSPENDED SOLIDS, TOTAL DISSOLVED SOLIDS, TOTAL ALKALINITY, ACIDITY, CHLORIDE, AND SULFATE.

APPENDIX F

LABORATORY RESULTS

APPENDIX F
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TABLE F-1
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW001	SW003	SW005	SW007	SW009
SAMPLING DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Bouy 8	Bouy 8	Bouy 8	Bouy 10	Bouy 10
SAMPLE DEPTH:	0 ft.	17 ft.	35 ft.	0 ft.	17 ft.
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	5 U	5 U	5 U	5 U	5 U
Acetone	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	5 U	5 U	5 U	5 U	5 U
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-1 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW011	SW013	SW015	SW017	SW019
SAMPLING DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Bouy 10	Bouy 5/6	Bouy 5/6	Bouy 5/6	Bouy 5/6
SAMPLE DEPTH:	35 ft.	0 ft.	17 ft.	35 ft.	60 ft.
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	5 U	5 U	5 U	5 U	5 U
Acetone	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	5 U	5 U	5 U	4 J	5 U
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-1 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW021	SW023	SW025	SW027	SW029
SAMPLING DATE:	06/15/87	06/16/87	06/16/87	06/16/87	06/16/87
SAMPLE LOCATION:	Bouy 5/6 Split	Quarry Discharge	Black Rvr Mix Water	Black Rvr Dwngradnt	Black Rvr Upgradnt
SAMPLE DEPTH:	60 ft.	0 ft.	0 ft.	3 ft.	0 ft.
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	5 U	5 U	5 U	5 U	5 U
Acetone	10 UJ	27	10 U	10 U	10 U
Carbon Disulfide	5 U	5 UJ	5 UJ	5 UJ	5 UJ
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 UR	10 UR	10 UR	10 UR
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 UJ	5 UJ	5 UJ	5 UJ
Toluene	2 J	4.3 J	5.4	1.9 J	5 U
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
- U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
- J Indicates an estimated value.
- R The results for this analyte have been rejected due to laboratory quality control problems during analysis.

TABLE F-1 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW031	SW033	SW035	SW037	SW039
SAMPLING DATE:	06/16/87	06/16/87	06/16/87	06/16/87	06/17/87
SAMPLE LOCATION:	Black Rvr Upgradnt	Black Rvr Dwngradnt	Black Rvr Dwngradnt	Sampler Blank	Sampler Blank
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	N/A	N/A
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	5 U	5 U	5 U	5 U	5 U
Acetone	12 J	13	14	12	10 UJ
Carbon Disulfide	5 U	5 UJ	5 UJ	5 UJ	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 UR	10 UR	10 UR	10 UR	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 UJ	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	1.2 J	1.5 J	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	1.1 J	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 UR	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 UJ	5 UJ	5 UJ	5 U
Toluene	5 U	5 U	1.6 J	2.4 J	5 U
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	1.2 J	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
R The results for this analyte have been rejected due to laboratory quality control problems during analysis.

TABLE F-1 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW041	SW043	SW045	SW047	SW049
SAMPLING DATE:	06/17/87	06/17/87	06/17/87	06/17/87	06/18/87
SAMPLE LOCATION:	Bouy 12	Bouy 12	Bouy 12	Bouy 12	Bouy 18
SAMPLE DEPTH:	0 ft.	17 ft.	35 ft.	56 ft.	17 ft.
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	5 U	5 U	5 U	5 U	5 U
Acetone	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	5 U	5 U	5 U	5 U	2 J
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-1 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW051	SW053	GW001	GW005	GW101
SAMPLING DATE:	06/18/87	06/18/87	08/18/87	08/18/87	03/14/88
SAMPLE LOCATION:	Bouy 18	Bouy 18 Split	Bottle Blank	Bouy 5/6 (Oily)	Bottle Blank
SAMPLE DEPTH:	0 ft.	0 ft.	N/A	0 ft.	N/A
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	5 U	5 U	4 J	9	5
Acetone	10 UJ	10 UJ	10 U	10 U	10 U
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	5 U	5 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	13	9	5 U	5 U	1 U
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-1 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW121
SAMPLING DATE:	03/15/88
SAMPLE LOCATION:	Bouy 5/6 (Oily)
SAMPLE DEPTH:	0 ft.
Chloromethane	10 U
Bromomethane	10 U
Vinyl Chloride	10 U
Chloroethane	10 U
Methylene Chloride	5
Acetone	10 U
Carbon Disulfide	5 U
1,1-Dichloroethene	5 U
1,1-Dichloroethane	5 U
Trans-1,2-Dichloroethene	5 U
Chloroform	5 U
1,2-Dichloroethane	5 U
2-Butanone	10 U
1,1,1-Trichloroethane	5 U
Carbon Tetrachloride	5 U
Vinyl Acetate	10 U
Bromodichloromethane	5 U
1,2-Dichloropropane	5 U
Trans-1,3-Dichloropropene	5 U
Trichloroethene	5 U
Dibromochloromethane	5 U
1,1,2-Trichloroethane	5 U
Benzene	5 U
cis-1,3-Dichloropropene	5 U
2-Chloroethylvinylether	10 U
Bromoform	5 U
4-Methyl-2-Pentanone	10 U
2-Hexanone	10 U
Tetrachloroethene	5 U
1,1,2,2-Tetrachloroethane	5 U
Toluene	5 U
Chlorobenzene	5 U
Ethylbenzene	5 U
Styrene	5 U
Total Xylenes	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-2
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW001	SW003	SW005	SW009	SW013
SAMPLING DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Buoy 8	Buoy 8	Buoy 8	Buoy 10	Buoy 5/6
SAMPLE DEPTH:	0 ft.	17 ft.	35 ft.	17 ft.	0 ft.
Phenol	10 U	10 U	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW001	SW003	SW005	SW009	SW013
SAMPLING DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Buoy 8	Buoy 8	Buoy 8	Buoy 10	Buoy 5/6
SAMPLE DEPTH:	0 ft.	17 ft.	35 ft.	17 ft.	0 ft.
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	50 UJ	50 UJ	50 UJ	50 UJ	50 UJ
4-Nitrophenol	50 U	50 U	50 U	50 U	50 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	50 U	50 U	50 U	50 U	50 U
4,6-Dinitro-2-Methylphenol	50 U	50 U	50 U	50 U	50 U
N-Nitrosodiphenylamine(1)	50 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	50 U	50 U	50 U	50 U	50 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	14	10 U	3 J	10 U	8 J
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	2 J	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
- U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
- J Indicates an estimated value.
- B Indicates the analyte was found in the laboratory blank sample as well as the sample.
- R The results of this analyte have been rejected due to laboratory quality quality control problems during analysis.
- (1) Cannot be separated from diphenylamine.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW015	SW031	SW035	SW051	SW053
SAMPLING DATE:	06/15/87	06/16/87	06/16/87	06/18/87	06/18/87
SAMPLE LOCATION:	Buoy 5/6	Black Rvr Upgradnt	Black Rvr Dwngradnt	Buoy 18	Buoy 18 Split
SAMPLE DEPTH:	17 ft.	0 ft.	0 ft.	0 ft.	0 ft.
Phenol	10 U	10 U	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 UJ	10 U	10 U	10 UJ	10 UJ
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 UJ	50 UJ	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW015	SW031	SW035	SW051	SW053
SAMPLING DATE:	06/15/87	06/16/87	06/16/87	06/18/87	06/18/87
SAMPLE LOCATION:	Buoy 5/6	Black Rvr Upgradnt	Black Rvr Dwngradnt	Buoy 18	Buoy 18 Split
SAMPLE DEPTH:	17 ft.	0 ft.	0 ft.	0 ft.	0 ft.
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	50 UJ	50 U	50 U	50 UJ	50 UJ
4-Nitrophenol	50 U	50 U	50 U	50 U	50 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 UJ	10 UJ	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	50 U	50 UJ	50 UJ	50 U	50 U
4,6-Dinitro-2-Methylphenol	50 U	50 U	50 U	50 U	50 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	50 U	50 U	50 U	50 U	50 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	4 J	10 U	10 U
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 UJ	10 UJ	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW001	GW005	SW101	SW102	SW104
SAMPLING DATE:	08/18/87	08/18/87	03/14/88	03/14/88	03/14/88
SAMPLE LOCATION:	Bottle Blank	Buoy 5/6 (Oily)	Buoy 8	Buoy 8	Buoy 10
SAMPLE DEPTH:	N/A	0 ft.	0 ft.	17 ft.	0 ft.
Phenol	10 U	10 U	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW001	GW005	SW101	SW102	SW104
SAMPLING DATE:	08/18/87	08/18/87	03/14/88	03/14/88	03/14/88
SAMPLE LOCATION:	Bottle Blank	Buoy 5/6 (Oily)	Buoy 8	Buoy 8	Buoy 10
SAMPLE DEPTH:	N/A	0 ft.	0 ft.	17 ft.	0 ft.
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	10 U	10 U	50 U	50 U	50 U
4-Nitrophenol	10 U	10 U	50 U	50 U	50 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	10 U	10 U	50 U	50 U	50 U
4,6-Dinitro-2-Methylphenol	10 U	10 U	50 U	50 U	50 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	10 U	10 U	50 U	50 U	50 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 UJ	10 UJ	10 U	10 U	10 U
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW105	SW107	SW108	SW109	SW110
SAMPLING DATE:	03/14/88	03/14/88	03/14/88	03/14/88	03/14/88
SAMPLE LOCATION:	Buoy 10	Bottle Blank	Sampler Blank	Sampler Blank	Quarry Discharge
SAMPLE DEPTH:	17 ft.	N/A	N/A	N/A	0 ft.
Phenol	10 U	10 U	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW105	SW107	SW108	SW109	SW110
SAMPLING DATE:	03/14/88	03/14/88	03/14/88	03/14/88	03/14/88
SAMPLE LOCATION:	Buoy 10	Bottle Blank	Sampler Blank	Sampler Blank	Quarry Discharge
SAMPLE DEPTH:	17 ft.	N/A	N/A	N/A	0 ft.
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	50 U	50 U	50 U	50 U	50 U
4-Nitrophenol	50 U	50 U	50 U	50 U	50 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	50 U	50 U	50 U	50 U	50 U
4,6-Dinitro-2-Methylphenol	50 U	50 U	50 U	50 U	50 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	50 U	50 U	50 U	50 U	50 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	10 U	10 U	10 U
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW111	SW112	SW113	SW114	SW115
SAMPLING DATE:	03/14/88	03/15/88	03/15/88	03/15/88	03/15/88
SAMPLE LOCATION:	Black Rvr Mix Water	Black Rvr Dwngradnt	Black Rvr Dwngradnt	Black Rvr Upgradnt	Buoy 5/6
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	0 ft.	17 ft.
Phenol	10 U	10 U	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW111	SW112	SW113	SW114	SW115
SAMPLING DATE:	03/14/88	03/15/88	03/15/88	03/15/88	03/15/88
SAMPLE LOCATION:	Black Rvr Mix Water	Black Rvr Dwngradnt	Black Rvr Dwngradnt	Black Rvr Upgradnt	Buoy 5/6
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	0 ft.	17 ft.
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	50 U	50 U	50 U	50 U	50 U
4-Nitrophenol	50 U	50 U	50 U	50 U	50 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	50 U	50 U	50 U	50 U	50 U
4,6-Dinitro-2-Methylphenol	50 U	50 U	50 U	50 U	50 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	50 U	50 U	50 U	50 U	50 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	10 U	10 U	10 U
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW119	SW120	SW122	SW123	SW124
SAMPLING DATE:	03/15/88	03/15/88	03/15/88	03/15/88	03/15/88
SAMPLE LOCATION:	Buoy 5/6	Buoy 5/6 Split	Buoy 18	Buoy 18	Black Rvr Dwngradnt
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	17 ft.	3 ft.
Phenol	10 U	10 U	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW119	SW120	SW122	SW123	SW124
SAMPLING DATE:	03/15/88	03/15/88	03/15/88	03/15/88	03/15/88
SAMPLE LOCATION:	Buoy 5/6	Buoy 5/6 Split	Buoy 18	Buoy 12	Black Rvr Dwngradnt
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	17 ft.	3 ft.
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	50 U	50 U	50 U	50 U	50 U
4-Nitrophenol	50 U	50 U	50 U	50 U	50 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	50 U	50 U	50 U	50 U	50 U
4,6-Dinitro-2-Methylphenol	50 U	50 U	50 U	50 U	50 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	50 U	50 U	50 U	50 U	50 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	10 U	10 U	10 U
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW125	SW126	SW127
SAMPLING DATE:	03/15/88	03/16/88	03/16/88
SAMPLE LOCATION:	Black Rvr Upgradnt	Buoy 12	Buoy 12
SAMPLE DEPTH:	0 ft.	0 ft.	17 ft.
Phenol	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-2 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SW125	SW126	SW127
SAMPLING DATE:	03/15/88	03/16/88	03/16/88
SAMPLE LOCATION:	Black Rvr Upgradnt	Buoy 12	Buoy 12
SAMPLE DEPTH:	0 ft.	0 ft.	17 ft.
Acenaphthene	10 U	10 U	10 U
2,4-Dinitrophenol	50 U	50 U	50 U
4-Nitrophenol	50 U	50 U	50 U
Dibenzofuran	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U
4-Nitroaniline	50 U	50 U	50 U
4,6-Dinitro-2-Methylphenol	50 U	50 U	50 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U
Pentachlorophenol	50 U	50 U	50 U
Phenanthrene	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U
Di-n-Butylphthalate	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	10 U
Chrysene	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-3
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW001	SW003	SW005	SW007	SW009
SAMPLING DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLING LOCATION:	Buoy 8	Buoy 8	Buoy 8	Buoy 10	Buoy 10
SAMPLING DEPTH:	0 ft.	17 ft.	35 ft.	0 ft.	17 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.50 U	.50 U	.50 U	.50 U	.50 U
Endrin Ketone	.10 U	.10 U	.10 U	.10 U	.10 U
Chlordane	.50 U	.50 U	.50 U	.50 U	.50 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1221	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1232	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1242	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1248	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	5000 UJ	5000 UJ	5000 UJ	5000 UJ	5000 UJ

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW011	SW013	SW015	SW017	SW019
SAMPLING DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLING LOCATION:	Buoy 10	Buoy 5/6	Buoy 5/6	Buoy 5/6	Buoy 5/6
SAMPLING DEPTH:	35 ft.	0 ft.	17 ft.	35 ft.	60 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.05 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.05 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.05 U
Methoxychlor	.50 U	.50 U	.50 U	.50 U	.50 U
Endrin Ketone	.10 U	.10 U	.10 U	.10 U	.10 U
Chlordane	.50 U	.50 U	.50 U	.50 U	.50 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1221	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1232	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1242	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1248	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	5000 UJ	5000 UJ	5000 UJ	5000 UJ	5000 UJ

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW021	SW023	SW025	SW027	SW029
SAMPLING DATE:	06/15/87	06/16/87	06/16/87	06/16/87	06/16/87
SAMPLING LOCATION:	Buoy 5/6 Split	Quarry Discharge	Black Rvr Mix Water	Black Rvr Dwngradnt	Black Rvr Upgradnt
SAMPLING DEPTH:	60 ft.	0 ft.	0 ft.	3 ft.	0 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.5 U	.10 U	.10 U
Methoxychlor	.50 U	.50 U	.50 U	.50 U	.50 U
Endrin Ketone	.10 U	.10 U	.10 U	.10 U	.10 U
Chlordane	.50 U	.50 U	.50 U	.50 U	.50 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1221	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1232	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1242	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1248	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	5000 UJ	5000 UJ	5000 UJ	5000 UJ	5000 UJ

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW031	SW033	SW035	SW037	SW039
SAMPLING DATE:	06/16/87	06/16/87	06/16/87	06/16/87	06/17/87
SAMPLING LOCATION:	Black Rvr Upgradnt	Black Rvr Dwngradnt	Black Rvr Dwngradnt	Sampler Blank	Sampler Blank
SAMPLING DEPTH:	0 ft.	0 ft.	0 ft.	N/A	N/A
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.50 U	.50 U	.50 U	.50 U	.50 U
Endrin Ketone	.10 U	.10 U	.10 U	.10 U	.10 U
Chlordane	.50 U	.50 U	.50 U	.50 U	.50 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1221	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1232	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1242	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1248	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	5000 UJ	5000 UJ	5000 UJ	12000	11000

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW041	SW043	SW045	SW047	SW049
SAMPLING DATE:	06/17/87	06/17/87	06/17/87	06/17/87	06/18/87
SAMPLING LOCATION:	Buoy 12	Buoy 12	Buoy 12	Buoy 12	Buoy 18
SAMPLING DEPTH:	0 ft.	17 ft.	35 ft.	56 ft.	17 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.08 *
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.50 U	.50 U	.50 U	.50 U	.50 U
Endrin Ketone	.10 U	.10 U	.10 U	.10 U	.10 U
Chlordane	.50 U	.50 U	.50 U	.50 U	.50 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1221	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1232	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1242	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1248	.50 U	.50 U	.50 U	.50 U	.50 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	16000	9500	5000 U	5000 U	5000 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW051	SW053	GW001	GW005	SW101
SAMPLING DATE:	06/18/87	06/18/87	08/18/87	08/18/87	03/14/88
SAMPLING LOCATION:	Buoy 18	Buoy 18 Split	Bottle Blank	Buoy 5/6 (Oily)	Buoy 8
SAMPLING DEPTH:	0 ft.	0 ft.	N/A	0 ft.	0 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.08 *	.09 *	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.50 U	.50 U	.50 U	.50 U	.05 U
Endrin Ketone	.10 U	.50 U	.10 U	.10 U	1.00 U
Chlordane	.50 U	.50 U	.50 U	.50 U	.05 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.50 U	.50 U	.50 U	.50 U	.05 U
Aroclor-1221	.50 U	.50 U	.50 U	.50 U	.05 U
Aroclor-1232	.50 U	.50 U	.50 U	.50 U	.05 U
Aroclor-1242	.50 U	.50 U	.50 U	.50 U	.05 U
Aroclor-1248	.50 U	.50 U	.50 U	.50 U	.05 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	2.90	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	5000 UJ	8400	5000 U	4250000.	N/A

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW102	SW103	SW104	SW105	SW106
SAMPLING DATE:	03/14/88	03/14/88	03/14/88	03/14/88	03/14/88
SAMPLING LOCATION:	Buoy 8	Buoy 8	Buoy 10	Buoy 10	Buoy 10
SAMPLING DEPTH:	17 ft.	35 ft.	0 ft.	17 ft.	35 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.05 U	.05 U	.05 U	.05 U	.05 U
Endrin Ketone	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Chlordane	.05 U	.05 U	.05 U	.05 U	.05 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1221	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1232	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1242	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1248	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW107	SW108	SW109	SW110	SW111
SAMPLING DATE:	03/14/88	03/14/88	03/14/88	03/14/88	03/14/88
SAMPLING LOCATION:	Bottle Blank	Sampler Blank	Sampler Blank	Quarry Discharge	Black Rvr Mix Water
SAMPLING DEPTH:	N/A	N/A	N/A	0 ft.	0 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.05 U	.05 U	.05 U	.05 U	.05 U
Endrin Ketone	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Chlordane	.05 U	.05 U	.05 U	.05 U	.05 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1221	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1232	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1242	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1248	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW112	SW113	SW114	SW115	SW116
SAMPLING DATE:	03/15/88	03/15/88	03/15/88	03/15/88	03/15/88
	Black Rvr	Black Rvr	Black Rvr	Buoy 5/6	Buoy 5/6
SAMPLING LOCATION:	Dwngradnt	Dwngradnt	Upgradnt		
SAMPLING DEPTH:	0 ft.	0 ft.	0 ft.	17 ft.	35 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.05 U	.05 U	.05 U	.05 U	.05 U
Endrin Ketone	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Chlordane	.05 U	.05 U	.05 U	.05 U	.05 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1221	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1232	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1242	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1248	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW117	SW118	SW119	SW120	SW122
SAMPLING DATE:	03/15/88	03/15/88	03/15/88	03/15/88	03/15/88
	Buoy 5/6	Buoy 5/6	Buoy 5/6	Buoy 5/6	Buoy 18
SAMPLING LOCATION:		Split		Split	
SAMPLING DEPTH:	60 ft.	60 ft.	0 ft.	0 ft.	0 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.05 U	.05 U	.05 U	.05 U	.05 U
Endrin Ketone	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Chlordane	.05 U	.05 U	.05 U	.05 U	.05 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1221	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1232	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1242	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1248	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW123	SW124	SW125	SW126	SW127
SAMPLING DATE:	03/15/88	03/15/88	03/15/88	03/16/88	03/16/88
SAMPLING LOCATION:	Buoy 18	Black Rvr Dwngradnt	Black Rvr Upgradnt	Buoy 12	Buoy 12
SAMPLING DEPTH:	17 ft.	3 ft.	0 ft.	0 ft.	17 ft.
Alpha-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Beta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Delta-BHC	.05 U	.05 U	.05 U	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor	.05 U	.05 U	.05 U	.05 U	.05 U
Aldrin	.05 U	.05 U	.05 U	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U	.05 U	.05 U	.05 U
Endosulfan I	.05 U	.05 U	.05 U	.05 U	.05 U
Dieldrin	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDE	.10 U	.10 U	.10 U	.10 U	.10 U
Endrin	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan II	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDD	.10 U	.10 U	.10 U	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U	.10 U	.10 U	.10 U
4,4'-DDT	.10 U	.10 U	.10 U	.10 U	.10 U
Methoxychlor	.05 U	.05 U	.05 U	.05 U	.05 U
Endrin Ketone	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Chlordane	.05 U	.05 U	.05 U	.05 U	.05 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1221	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1232	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1242	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1248	.05 U	.05 U	.05 U	.05 U	.05 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-3 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SW128	SW129
SAMPLING DATE:	03/16/88	03/16/88
SAMPLING LOCATION:	Buoy 12	Buoy 12
SAMPLING DEPTH:	35 ft.	55 ft.
Alpha-BHC	.05 U	.05 U
Beta-BHC	.05 U	.05 U
Delta-BHC	.05 U	.05 U
Gamma-BHC(Lindane)	.05 U	.05 U
Heptachlor	.05 U	.05 U
Aldrin	.05 U	.05 U
Heptachlor Epoxide	.05 U	.05 U
Endosulfan I	.05 U	.05 U
Dieldrin	.10 U	.10 U
4,4'-DDE	.10 U	.10 U
Endrin	.10 U	.10 U
Endosulfan II	.10 U	.10 U
4,4'-DDD	.10 U	.10 U
Endosulfan Sulfate	.10 U	.10 U
4,4'-DDT	.10 U	.10 U
Methoxychlor	.05 U	.05 U
Endrin Ketone	1.00 U	1.00 U
Chlordane	.05 U	.05 U
Toxaphene	1.00 U	1.00 U
Aroclor-1016	.05 U	.05 U
Aroclor-1221	.05 U	.05 U
Aroclor-1232	.05 U	.05 U
Aroclor-1242	.05 U	.05 U
Aroclor-1248	.05 U	.05 U
Aroclor-1254	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
* Confirmed by a second column, but too low for GC/MS confirmation.

TABLE F-4
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW001	SW002	SW003	SW004	SW005
SAMPLE DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Buoy 8	Buoy 8	Buoy 8	Buoy 8	Buoy 8
SAMPLE DEPTH:	0 ft.	0 ft.	17 ft.	17 ft.	35 ft.
ALUMINUM	24U	[40]	24U	[30]	[101]
ANTIMONY	21U	21U	21U	21U	42U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[21]	[21]	[25]	[26]	[90]
BERYLLIUM	1U	1U	1U	1U	2U
CADMIUM	5U	5U	5U	5U	12
CALCIUM	69800	69700	73000	72200	167000
CHROMIUM	4U	4U	4U	4U	8U
COBALT	5U	5U	5U	5U	10U
COPPER	4U	[7.9]	4U	[4]	8U
IRON	[57]	[25]	105	[20]	512000
LEAD	5U	5U	5U	5U	5U
MAGNESIUM	17400	18400	18500	19300	47600
MANGANESE	144	133	557	517	6760
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	8U	8U	8U	8U	16U
POTASSIUM	[4070]	[4480]	[4130]	[4520]	[7820]
SELENIUM	5U	5U	5U	50U	50U
SILVER	4U	[4.6]	4U	4U	8U
SODIUM	39500	42700	39600	42800	43400
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	32U
VANADIUM	4U	4U	4U	4U	[17]
ZINC	[6.6]	[13]	[5.8]	27	6U
CYANIDE	10U	NA	10U	NA	P
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	2000U	NA	2000U	NA	296000
TOTAL DISSOLVED SOLIDS	511000	NA	513000	NA	2950000
TOTAL ALKALINITY	74000	NA	74000	NA	235000
ACIDITY	10000U	NA	10000U	NA	686000
CHLORIDE	63000	NA	63000	NA	46000
SULFATE	165000	NA	170000	NA	1370000

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

V The laboratory data are void and are not presented due to low spike recovery

P The laboratory data are void, and are not presented due to improper preservation of the sample.

R The spike sample recovery is not within control limits.

TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW006	SW007	SW008	SW009	SW010
SAMPLE DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Buoy 8	Buoy 10	Buoy 10	Buoy 10	Buoy 10
SAMPLE DEPTH:	35 ft.	0 ft.	0 ft.	17 ft.	17 ft.
ALUMINUM	275	24U	[52]	24U	[47]
ANTIMONY	21U	21U	21U	21U	21U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[76]	[22]	[22]	[28]	[25]
BERYLLIUM	1U	1U	1U	1U	1U
CADMIUM	7.5	5U	5U	5U	5U
CALCIUM	165000	72400	70400	80300	72000
CHROMIUM	4U	4U	4U	4U	4U
COBALT	5U	5U	5U	5U	5U
COPPER	4U	4U	[9.6]	4U	[8.9]
IRON	472000	[70]	[94]	189	[32]
LEAD	5U	5U	5U	5U	5U
MAGNESIUM	51200	18300	18700	20600	19200
MANGANESE	6420	146	134	669	431
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	[16]	8U	8U	8U	8U
POTASSIUM	8520	[4280]	[4610]	[4790]	[4570]
SELENIUM	50U	5U	5U	5U	5U
SILVER	4U	4U	4U	4U	4U
SODIUM	46100	41800	43600	44100	42200
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	16U
VANADIUM	[16]	4U	4U	4U	4U
ZINC	32	[3.5]	[12]	[7.7]	[9.7]
CYANIDE	NA	10U	NA	10U	NA
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	NA	2000U	NA	2000U	NA
TOTAL DISSOLVED SOLIDS	NA	510000	NA	499000	NA
TOTAL ALKALINITY	NA	75000	NA	71000	NA
ACIDITY	NA	10000U	NA	10000U	NA
CHLORIDE	NA	61000	NA	61000	NA
SULFATE	NA	168000	NA	176000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

V The laboratory data are void and are not presented due to low spike recovery

P The laboratory data are void, and are not presented due to improper preservation of the sample.

R The spike sample recovery is not within control limits.

TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW011	SW012	SW013	SW014	SW015
SAMPLE DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Buoy 10	Buoy 10	Buoy 5/6	Buoy 5/6	Buoy 5/6
SAMPLE DEPTH:	35 ft.	35 ft.	0 ft.	0 ft.	17 ft.
ALUMINUM	[60]	[101]	24U	[30]	24U
ANTIMONY	21U	21U	21U	21U	21U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[42]	[36]	[22]	[21]	[27]
BERYLLIUM	1U	1U	1U	1U	1U
CADMIUM	5U	5U	5U	5U	5U
CALCIUM	116000	89000	73300	69800	79900
CHROMIUM	4U	4U	4U	4U	4U
COBALT	5U	5U	5U	5U	5U
COPPER	4U	4U	4U	4U	4U
IRON	170000	92300	[83]	1030	118
LEAD	5U	5U	5U	5U	8.5
MAGNESIUM	33200	24500	18400	18400	20300
MANGANESE	3170	2060	152	162	596
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	[9.4]	8U	8U	8U	8U
POTASSIUM	5720	5040	[4260]	[4420]	[4650]
SELENIUM	50U	50U	5U	5U	5U
SILVER	4U	4U	4U	4U	4U
SODIUM	42200	42800	41900	42400	43900
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	16U
VANADIUM	[6.8]	[4.4]	4U	4U	4U
ZINC	3U	65	[7]	41	[6.6]
CYANIDE	10U	NA	10U	NA	10U
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	136000	NA	2000U	NA	2000U
TOTAL DISSOLVED SOLIDS	1330000	NA	453000	NA	529000
TOTAL ALKALINITY	62000	NA	75000	NA	71000
ACIDITY	247000	NA	10000U	NA	10000U
CHLORIDE	55000	NA	62000	NA	61000
SULFATE	671000	NA	165000	NA	178000

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TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW016	SW017	SW018	SW019	SW020
SAMPLE DATE:	06/15/87	06/15/87	06/15/87	06/15/87	06/15/87
SAMPLE LOCATION:	Buoy 5/6	Buoy 5/6	Buoy 5/6	Buoy 5/6	Buoy 5/6
SAMPLE DEPTH:	17 ft.	35 ft.	35 ft.	60 ft.	60 ft.
ALUMINUM	[55]	[133]	210	[155]	[743]
ANTIMONY	21U	21U	21U	21U	210U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[25]	[79]	[60]	[57]	[120]
BERYLLIUM	1U	1U	1U	1U	10U
CADMIUM	5U	5U	5U	5U	50U
CALCIUM	71700	138000	118000	149000	307000
CHROMIUM	4U	4U	4U	4U	40U
COBALT	5U	5U	5U	5U	50U
COPPER	[10]	4U	4U	4U	40U
IRON	[51]	413000	315000	485000	1600000
LEAD	8.6	5U	5U	5U	5U
MAGNESIUM	19200	37700	33600	39500	86200
MANGANESE	486	6860	5240	7980	24800
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	8U	[22]	[11]	[22]	80U
POTASSIUM	[4540]	6050	5630	5920	[7450]
SELENIUM	5U	50U	50U	50U	V
SILVER	4U	4U	4U	4U	40U
SODIUM	42200	43500	40600	44300	50700
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	160U
VANADIUM	4U	[14]	[9.6]	[19]	[50]
ZINC	43	3U	106	3U	30U
CYANIDE	NA	10U	NA	10U	NA
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	NA	200000	NA	80000	NA
TOTAL DISSOLVED SOLIDS	NA	2480000	NA	792000	NA
TOTAL ALKALINITY	NA	119000	NA	17000	NA
ACIDITY	NA	646000	NA	39000	NA
CHLORIDE	NA	48000	NA	60000	NA
SULFATE	NA	1180000	NA	346000	NA

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R The spike sample recovery is not within control limits.

TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW021	SW022	SW023	SW024	SW025
SAMPLE DATE:	06/15/87	06/15/87	06/16/87	06/16/87	06/16/87
SAMPLE LOCATION:	Buoy 5/6 Split	Buoy 5/6 Split	Quarry Discharge	Quarry Discharge	Black Rvr Mix Water
SAMPLE DEPTH:	60 ft.	60 ft.	0 ft.	0 ft.	0 ft.
ALUMINUM	[195]	[777]	808	[55]	1460
ANTIMONY	105U	210U	21U	21U	21U
ARSENIC	15	10U	10U	10U	10U
BARIUM	[88]	[124]	[34]	[22]	[44]
BERYLLIUM	5U	10U	1U	1U	1U
CADMIUM	25U	50U	5U	5U	5U
CALCIUM	251000	302000	73500	68100	70300
CHROMIUM	20U	40U	4U	4U	4U
COBALT	25U	50U	5U	5U	5U
COPPER	20U	40U	[5.9]	[4]	[5]
IRON	1150000	1590000	6800	[92]	1720
LEAD	5U	6.2	19	9.7	7.8
MAGNESIUM	67500	85800	18700	18000	19400
MANGANESE	18900	24500	915	277	77
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	40U	80U	8U	[25]	8U
POTASSIUM	[7390]	[8020]	[4470]	[4400]	6010
SELENIUM	V	V	5U	5U	5U
SILVER	20U	40U	4U	4U	4U
SODIUM	44800	54100	41600	41500	24100
THALLIUM	100U	10U	10U	10U	10U
TIN	80U	160U	16U	16U	16U
VANADIUM	[32]	[55]	4U	4U	4U
ZINC	15U	30U	37	58	[9.9]
CYANIDE	P	NA	10U	NA	10U
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	210000	NA	109000	NA	12000
TOTAL DISSOLVED SOLIDS	4850000	NA	510000	NA	461000
TOTAL ALKALINITY	155000	NA	76000	NA	130000
ACIDITY	1520000	NA	10000U	NA	10000U
CHLORIDE	48000	NA	61000	NA	35000
SULFATE	2250000	NA	162000	NA	102000

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R The spike sample recovery is not within control limits.

TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW026	SW027	SW028	SW029	SW030
SAMPLE DATE:	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87
	Black Rvr	Black Rvr	Black Rvr	Black Rvr	Black Rvr
SAMPLE LOCATION:	Mix Water	Downgrdnt	Downgrdnt	Upgradnt	Upgradnt
SAMPLE DEPTH:	0 ft.	3 ft.	3 ft.	0 ft.	0 ft.
ALUMINUM	[58]	983	[36]	1040	[42]
ANTIMONY	21U	21U	21U	21U	21U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[31]	[41]	[33]	[43]	[32]
BERYLLIUM	1U	1U	1U	1U	1U
CADMIUM	5U	5U	5U	5U	5U
CALCIUM	64400	70400	64700	71100	62800
CHROMIUM	4U	[4]	4U	4U	4U
COBALT	5U	5U	5U	5U	5U
COPPER	[11]	[4.3]	[4.7]	[4.6]	[8.6]
IRON	128	1550	[28]	1630	[67]
LEAD	5U	5U	5U	5U	19
MAGNESIUM	18500	19400	18500	19800	18100
MANGANESE	34	71	26	88	36
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	100	[11]	8U	8U	8U
POTASSIUM	5570	5820	5560	5960	5560
SELENIUM	5U	5U	5U	5U	5U
SILVER	4U	4U	4U	4U	4U
SODIUM	24500	24500	24100	24600	24000
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	16U
VANADIUM	4U	4U	4U	4U	4U
ZINC	160	[9.9]	[4.9]	[12]	[14]
CYANIDE	NA	10U	NA	10U	NA
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	NA	13000	NA	16000	NA
TOTAL DISSOLVED SOLIDS	NA	459000	NA	448000	NA
TOTAL ALKALINITY	NA	129000	NA	130000	NA
ACIDITY	NA	10000U	NA	10000U	NA
CHLORIDE	NA	37000	NA	36000	NA
SULFATE	NA	100000	NA	100000	NA

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TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW031	SW032	SW033	SW034	SW035
SAMPLE DATE:	06/16/87	06/16/87	06/16/87	06/16/87	06/16/87
SAMPLE LOCATION:	Black Rvr Upgradnt	Black Rvr Upgradnt	Black Rvr Downgrdnt	Black Rvr Downgrdnt	Black Rvr Downgrdnt
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	0 ft.	0 ft.
ALUMINUM	1030	[45]	642	[41]	754
ANTIMONY	21U	21U	21U	21U	21U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[42]	[34]	[38]	[30]	[39]
BERYLLIUM	[1.9]	1U	1U	1U	1U
CADMIUM	5U	5U	5U	5U	5U
CALCIUM	69800	66100	70500	64200	68500
CHROMIUM	[4.3]	[4.2]	4U	4U	4U
COBALT	5U	5U	5U	5U	5U
COPPER	[8.8]	[4.7]	[5.9]	[6.6]	[4.6]
IRON	1410	[63]	1020	[45]	1240
LEAD	5U	7	5U	6.4	6.3
MAGNESIUM	19200	18900	19200	18200	18800
MANGANESE	76	32	56	17	60
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	[8.3]	8U	[8.3]	8U	8U
POTASSIUM	5920	5750	5780	5490	5720
SELENIUM	5U	5U	5U	5U	5U
SILVER	4U	4U	4U	4U	4U
SODIUM	24400	24900	24600	24000	23000
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	16U
VANADIUM	[4.9]	4U	4U	4U	4U
ZINC	[15]	[6.9]	[9.1]	[4.4]	[11]
CYANIDE	10U	NA	10U	NA	10U
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	10000	NA	7000	NA	8000
TOTAL DISSOLVED SOLIDS	462000	NA	460000	NA	469000
TOTAL ALKALINITY	130000	NA	130000	NA	130000
ACIDITY	10000U	NA	10000U	NA	10000U
CHLORIDE	37000	NA	36000	NA	37000
SULFATE	99000	NA	109000	NA	105000

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TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW036	SW037	SW038	SW039	SW040
SAMPLE DATE:	06/16/87	06/16/87	06/16/87	06/17/87	06/17/87
SAMPLE LOCATION:	Black Rvr Downgrdnt	Sampler Blank	Sampler Blank	Sampler Blank	Sampler Blank
SAMPLE DEPTH:	0 ft.	N/A	N/A	N/A	N/A
ALUMINUM	[33]	24U	24U	[28]	[30]
ANTIMONY	21U	21U	21U	21U	21U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[31]	2U	2U	2U	2U
BERYLLIUM	1U	1U	1U	1U	1U
CADMIUM	5U	5U	5U	5U	5U
CALCIUM	63600	[672]	[267]	[208]	[637]
CHROMIUM	4U	4U	4U	4U	4U
COBALT	5U	5U	5U	5U	5U
COPPER	[8.3]	[4.2]	[7.9]	[14]	[8.2]
IRON	[50]	[94]	[23]	[44]	20U
LEAD	5.8	6.8	8.2	5U	5U
MAGNESIUM	18200	[213]	51U	[55]	[120]
MANGANESE	21	5U	5U	5U	5U
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	8U	8U	8U	8U	8U
POTASSIUM	5530	151U	151U	151U	151U
SELENIUM	5U	5U	5U	5U	5U
SILVER	4U	4U	4U	4U	4U
SODIUM	23800	898U	[956]	898U	[929]
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	16U
VANADIUM	4U	4U	4U	4U	4U
ZINC	[6.7]	[7.7]	[12]	[12]	[12]
CYANIDE	NA	10U	NA	10U	NA
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	NA	2000U	NA	2000U	NA
TOTAL DISSOLVED SOLIDS	NA	50000	NA	10000U	NA
TOTAL ALKALINITY	NA	10000U	NA	10000U	NA
ACIDITY	NA	10000U	NA	10000U	NA
CHLORIDE	NA	3000U	NA	3000U	NA
SULFATE	NA	5000U	NA	5000U	NA

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TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW041	SW042	SW043	SW044	SW045
SAMPLE DATE:	06/17/87	06/17/87	06/17/87	06/17/87	06/17/87
SAMPLE LOCATION:	Buoy 12	Buoy 12	Buoy 12	Buoy 12	Buoy 12
SAMPLE DEPTH:	0 ft.	0 ft.	17 ft.	17 ft.	35 ft.
ALUMINUM	24U	[32]	[45]	[43]	277
ANTIMONY	21U	21U	21U	21U	21U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[22]	[22]	[25]	[26]	[82]
BERYLLIUM	1U	1U	1U	1U	1U
CADMIUM	5U	5U	5U	5U	5U
CALCIUM	70400	69100	74000	72100	147000
CHROMIUM	4U	4U	4U	4U	4U
COBALT	5U	5U	5U	5U	5U
COPPER	[8.8]	[6.6]	[14]	[10]	4U
IRON	[69]	[43]	198	[44]	472000
LEAD	5U	5U	5U	5U	5U
MAGNESIUM	19000	18600	20300	19700	44100
MANGANESE	146	133	681	603	6910
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	8U	8U	8U	8U	[20]
POTASSIUM	[4520]	[4400]	[4690]	[4520]	6700
SELENIUM	5U	5U	5U	5U	50U
SILVER	4U	4U	4U	4U	4U
SODIUM	43600	42700	43600	42400	43500
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	16U
VANADIUM	4U	4U	4U	4U	[15]
ZINC	[12]	[12]	[11]	[14]	3U
CYANIDE	10U	NA	10U	NA	10U
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	210000	NA	2000U	NA	2000U
TOTAL DISSOLVED SOLIDS	6400000	NA	513000	NA	526000
TOTAL ALKALINITY	74000	NA	67000	NA	98000
ACIDITY	10000U	NA	10000U	NA	945000
CHLORIDE	62000	NA	62000	NA	45000
SULFATE	182000	NA	192000	NA	1590000

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TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW046	SW047	SW048	SW049	SW050
SAMPLE DATE:	06/17/87	06/17/87	06/17/87	06/18/87	06/18/87
SAMPLE LOCATION:	Buoy 12	Buoy 12	Buoy 12	Buoy 18	Buoy 18
SAMPLE DEPTH:	35 ft.	56 ft.	56 ft.	17 ft.	17 ft.
ALUMINUM	[333]	[771]	[731]	[36]	[38]
ANTIMONY	42U	210U	210U	21U	21U
ARSENIC	10U	10U	21	10U	10U
BARIUM	[89]	[113]	[111]	[28]	[27]
BERYLLIUM	2U	10U	10U	1U	1U
CADMIUM	10	50U	50U	5U	5U
CALCIUM	155000	315000	288000	75700	73700
CHROMIUM	8U	40U	40U	4U	4U
COBALT	10U	50U	50U	5U	5U
COPPER	8U	40U	40U	[9.5]	[7.9]
IRON	569000	1600000	1440000	404	[62]
LEAD	5U	5U	5U	5U	5U
MAGNESIUM	46100	88900	82200	20600	20000
MANGANESE	8550	25700	23200	776	600
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	[28]	[86]	80U	8U	8U
POTASSIUM	[6560]	[8050]	[7970]	[4680]	[4630]
SELENIUM	50U	50U	50U	5U	5U
SILVER	8U	40U	40U	4U	4U
SODIUM	44600	[49100]	57600	42600	42100
THALLIUM	10U	10U	10U	10U	10U
TIN	32U	160U	160U	16U	16U
VANADIUM	[17]	[60]	[50]	4U	4U
ZINC	[11]	30U	[37]	26	[11]
CYANIDE	NA	10U	NA	10U	NA
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	NA	146000	NA	2000U	NA
TOTAL DISSOLVED SOLIDS	NA	3260000	NA	544000	NA
TOTAL ALKALINITY	NA	117000	NA	69000	NA
ACIDITY	NA	2110000	NA	10000U	NA
CHLORIDE	NA	44000	NA	61000	NA
SULFATE	NA	3220000	NA	195000	NA

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TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	SW051	SW052	SW053	SW054	GW001
SAMPLE DATE:	06/18/87	06/18/87	06/18/87	06/18/87	08/18/87
SAMPLE LOCATION:	Buoy 18	Buoy 18	Buoy 18 Split	Buoy 18 Split	Bottle Blank
SAMPLE DEPTH:	0 ft.	0 ft.	0 ft.	0 ft.	N/A
ALUMINUM	[37]	[39]	[31]	[35]	15U
ANTIMONY	21U	21U	21U	21U	25U
ARSENIC	10U	10U	10U	10U	10U
BARIUM	[22]	[22]	[22]	[22]	3U
BERYLLIUM	1U	1U	1U	1U	1U
CADMIUM	5U	5U	5U	5U	4U
CALCIUM	71000	69000	70200	69000	179U
CHROMIUM	4U	4U	4U	4U	4U
COBALT	5U	5U	5U	5U	9U
COPPER	[7.4]	[7.9]	[12]	[6.6]	6U
IRON	[69]	[43]	105	[34]	24U
LEAD	5U	5U	5U	5U	5U
MAGNESIUM	19200	18500	19100	18600	153U
MANGANESE	149	117	129	116	4U
MERCURY	0.2U	0.2U	0.2U	0.2U	0.2U
NICKEL	8U	8U	8U	8U	8U
POTASSIUM	[4610]	[4500]	[4570]	[4360]	175U
SELENIUM	5U	5U	5U	5U	5U R
SILVER	4U	4U	4U	4U	4U
SODIUM	43300	43100	42900	43400	1090U
THALLIUM	10U	10U	10U	10U	10U
TIN	16U	16U	16U	16U	22U
VANADIUM	4U	4U	4U	4U	7U
ZINC	[16]	[16]	[14]	[10]	[6.8]
CYANIDE	10U	NA	10U	NA	10U
HEXACHROME	5U	5U	5U	5U	5U
TOTAL SUSPENDED SOLIDS	2000U	NA	2000U	NA	1000U
TOTAL DISSOLVED SOLIDS	510000	NA	526000	NA	1000U
TOTAL ALKALINITY	76000	NA	76000	NA	10000U
ACIDITY	10000U	NA	10000U	NA	10000U
CHLORIDE	63000	NA	64000	NA	3000U
SULFATE	165000	NA	168000	NA	1000U

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

V The laboratory data are void and are not presented due to low spike recovery

P The laboratory data are void, and are not presented due to improper preservation of the sample.

R The spike sample recovery is not within control limits.

TABLE F-4 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	GW002	GW005	GW006
SAMPLE DATE:	08/18/87	08/18/87	08/18/87
SAMPLE LOCATION:	Bottle Blank	Buoy 5/6 (Oily)	Buoy 5/6 (Oily)
SAMPLE DEPTH:	N/A	0 ft.	0 ft.
ALUMINUM	[18]	[37]	[21]
ANTIMONY	25U	25U	25U
ARSENIC	10U	10U	10U
BARIUM	3U	[22]	[18]
BERYLLIUM	1U	1U	1U
CADMIUM	4U	4U	4U
CALCIUM	[270]	63700	59600
CHROMIUM	4U	4U	4U
COBALT	9U	9U	9U
COPPER	6U	6U	6U
IRON	[45]	564	24U
LEAD	5U	5U	5U
MAGNESIUM	153U	16800	16000
MANGANESE	4U	28	[12]
MERCURY	0.2U	0.2U	0.2U
NICKEL	8U	8U	8U
POTASSIUM	175U	[4300]	[4250]
SELENIUM	5U R	5U R	5U R
SILVER	4U	4U	4U
SODIUM	[1110]	37300	47200
THALLIUM	10U	10U	10U
TIN	22U	22U	22U
VANADIUM	7U	7U	7U
ZINC	[15]	[3.6]	[5.8]
CYANIDE	NA	10U	NA
HEXACHROME	5U	5U	5U
TOTAL SUSPENDED SOLIDS	NA	57000	NA
TOTAL DISSOLVED SOLIDS	NA	391000	NA
TOTAL ALKALINITY	NA	81200	NA
ACIDITY	NA	10000U	NA
CHLORIDE	NA	52700	NA
SULFATE	NA	149000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

V The laboratory data are void and are not presented due to low spike recovery.

P The laboratory data are void, and are not presented due to improper preservation of the sample.

R The spike sample recovery is not within control limits.

TABLE F-5
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
LABORATORY pH READINGS

SAMPLE NUMBER	SAMPLING DATE	SAMPLE LOCATION	SAMPLE DEPTH (ft.)	LABORATORY pH
SW001/002	6/15/87	Buoy 8	0	NR
SW003/004	6/15/87	Buoy 8	17	NR
SW005/006	6/15/87	Buoy 8	35	NR
SW007/008	6/15/87	Buoy 10	0	NR
SW009/010	6/15/87	Buoy 10	17	NR
SW011/012	6/15/87	Buoy 10	35	NR
SW013/014	6/15/87	Buoy 5/6	0	NR
SW015/016	6/15/87	Buoy 5/6	17	NR
SW017/018	6/15/87	Buoy 5/6	35	NR
SW019/020	6/15/87	Buoy 5/6	60	NR
SW021/022	6/15/87	Buoy 5/6	60	NR
SW023/024	6/16/87	Quarry Discharge	0	NR
SW025/026	6/16/87	Black River Mix Water	0	NR
SW027/028	6/16/87	Black River Downgradient	3	NR
SW029/030	6/16/87	Black River Upgradient	0	NR
SW031/032	6/16/87	Black River Upgradient	0	NR
SW033/034	6/16/87	Black River Downgradient	0	NR
SW035/036	6/16/87	Black River Downgradient	0	NR
SW037/038	6/16/87	Sampler Blank	N/A	NR
SW039/040	6/17/87	Sampler Blank	N/A	NR
SW041/042	6/17/87	Buoy 12	0	NR
SW043/044	6/17/87	Buoy 12	17	NR
SW045/046	6/17/87	Buoy 12	35	NR
SW047/048	6/17/87	Buoy 12	56	NR
SW049/050	6/18/87	Buoy 18	17	NR
SW051/052	6/18/87	Buoy 18	0	NR
SW053/054	6/18/87	Buoy 18	0	NR
GW001/002	8/18/87	Bottle Blank	N/A	6.0
GW005/006	8/18/87	Buoy 5/6	0	6.0
GW101	3/14/88	Bottle Blank	N/A	NR
SW101	3/14/88	Buoy 8	0	6.6
SW102	3/14/88	Buoy 8	17	6.5
SW103	3/14/88	Buoy 8	35	6.2
SW104	3/14/88	Buoy 10	0	6.7
SW105	3/14/88	Buoy 10	17	6.6
SW106	3/14/88	Buoy 10	35	6.1
SW107	3/14/88	Bottle Blank	N/A	6.6
SW108	3/14/88	Sampler Blank	N/A	4.5
SW109	3/14/88	Sampler Blank	N/A	3.9
SW110	3/14/88	Quarry Discharge	0	6.5
SW111	3/14/88	Black River Mix Water	0	7.5
SW112	3/15/88	Black River Downgradient	0	7.5
SW113	3/15/88	Black River Downgradient	0	7.6

NOTES: NR Not Reported by Laboratory

TABLE F-5 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE WATER SAMPLING
LABORATORY pH READINGS

SAMPLE NUMBER	SAMPLING DATE	SAMPLE LOCATION	SAMPLE DEPTH (ft.)	LABORATORY pH
SW114	3/15/88	Black River Upgradient	0	7.5
SW115	3/15/88	Buoy 5/6	17	6.4
SW116	3/15/88	Buoy 5/6	35	5.6
SW117	3/15/88	Buoy 5/6	60	5.6
SW118	3/15/88	Buoy 5/6	60	5.1
SW119	3/15/88	Buoy 5/6	0	6.8
SW120	3/15/88	Buoy 5/6	0	7.1
SW121	3/15/88	Buoy 5/6	0	NR
SW122	3/15/88	Buoy 18	0	6.6
SW123	3/15/88	Buoy 18	17	6.9
SW124	3/15/88	Black River Downgradient	3	7.8
SW125	3/15/88	Black River Upgradient	0	7.7
SW126	3/16/88	Buoy 12	0	7.0
SW127	3/16/88	Buoy 12	17	6.9
SW128	3/16/88	Buoy 12	35	5.9
SW129	3/16/88	Buoy 12	55	5.9

NOTES: NR Not Reported by Laboratory

TABLE F-6
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD001	SD002	SD003	SD004	SD005
SAMPLING DATE:	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87
SAMPLE LOCATION:	Bottle Blank	Sampler Blank	Buoy 18	Buoy 7 at Liq Ditch	Buoy 10
Chloromethane	10 U	10 U	10 U	10 U	10 UJ
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	4 BUJ	3 BUJ	10 BUJ	2 BUJ	17 BUJ
Acetone	4 BUJ	4 BUJ	37 BUJ	11 BUJ	680 BJ
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	7 BUJ	7 BUJ	17 BUJ	6 BUJ	200 BJ
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 UJ
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 UJ
2-Hexanone	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Tetrachloroethene	5 UJ	5 UJ	5 UJ	5 UJ	17 J
1,1,2,2-Tetrachloroethane	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Toluene	6 BUJ	4 BUJ	3 BUJ	1 BUJ	520 BJ
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Styrene	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Total Xylenes	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Percent Moisture	10	11	70	91	88
Sediment pH	7.9	7.8	7.2	6.7	6.4

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-6 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD006	SD007	SD008	SD009	SD010
SAMPLING DATE:	06/23/87	06/23/87	06/24/87	06/24/87	06/24/87
SAMPLE LOCATION:	Buoy 8	Buoy 10 Split	Buoy 12	Between Buoy 5/6	Quarry Discharge
Chloromethane	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	12 BUJ	20 BUJ	25 BUJ	20 BUJ	4 BUJ
Acetone	250 BJ	570 BJ	680 BJ	870 BJ	9 BUJ
Carbon Disulfide	12	20	25	20	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	65 BJ	160 BJ	180 BJ	230 BJ	9 BUJ
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 UJ	5 UJ	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
2-Hexanone	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Tetrachloroethene	5 UJ	20 J	5 UJ	33 J	5 UJ
1,1,2,2-Tetrachloroethane	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Toluene	360 BJ	20 BUJ	370 BJ	290 BJ	9 BUJ
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 UJ	5 UJ	5 UJ	27 J	5 UJ
Styrene	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Total Xylenes	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Percent Moisture	83	85	88	85	54
Sediment pH	6.9	6.3	6.3	6.4	7.7

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-6 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD011	SD012	SD013	SD014	SD015
SAMPLING DATE:	06/24/87	06/24/87	06/24/87	06/24/87	06/25/87
	Buoy 5/6	Sampler	Black Rvr	Black Rvr	Black Rvr
SAMPLE LOCATION:	Split	Blank	Upgradnt	Dwngradnt	Upgradnt
Chloromethane	10 UJ	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	21 BUJ	9 BUJ	16 BUJ	8 BUJ	12 BUJ
Acetone	1400 BJ	12 BUJ	7 BUJ	7 BUJ	19 BUJ
Carbon Disulfide	36	73	32	42	53
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	490 BJ	4 BUJ	4 BUJ	4 BUJ	4 BUJ
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	7 J	5 U	1 J	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 UJ	10 U	10 U	10 U	10 U
2-Hexanone	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Tetrachloroethene	42 J	5 UJ	5 UJ	5 UJ	5 UJ
1,1,2,2-Tetrachloroethane	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Toluene	36 BJ	26 BUJ	8 BUJ	7 BUJ	3 BUJ
Chlorobenzene	5 U	2 J	3 J	5 U	5 U
Ethylbenzene	29 J	5 UJ	5 UJ	5 UJ	5 UJ
Styrene	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Total Xylenes	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Percent Moisture	86	10	26	28	32
Sediment pH	6.3	7.7	7.5	7.3	6.5

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-7
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD001	SD002	SD003	SD004	SD005
SAMPLING DATE:	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87
SAMPLE LOCATION:	Bottle Blank	Sampler Blank	Buoy 18	Buoy 7 at Liq Ditch	Buoy 10
Phenol	330 U	330 U	1700 U	1300 U	3300 U
bis(-2-Chloroethyl)Ether	330 U	330 U	1700 U	1300 U	3300 U
2-Chlorophenol	330 U	330 U	1700 U	1300 U	3300 U
1,3-Dichlorobenzene	330 U	330 U	1700 U	1300 U	3300 U
1,4-Dichlorobenzene	330 U	330 U	1700 U	1300 U	3300 U
Benzyl Alcohol	330 U	330 U	1700 U	1300 U	3300 U
1,2-Dichlorobenzene	330 U	330 U	1700 U	1300 U	3300 U
2-Methylphenol	330 U	330 U	1700 U	1300 U	3300 U
bis(2-chloroisopropyl)Ether	330 U	330 U	1700 U	1300 U	3300 U
4-Methylphenol	330 U	330 U	1700 U	1300 U	3300 U
N-Nitroso-Di-n-Propylamine	330 U	330 U	1700 U	1300 U	3300 U
Hexachloroethane	330 U	330 U	1700 U	1300 U	3300 U
Nitrobenzene	330 U	330 U	1700 U	1300 U	3300 U
Isophorone	330 U	330 U	1700 U	1300 U	3300 U
2-Nitrophenol	330 U	330 U	1700 U	1300 U	3300 U
2,4-Dimethylphenol	330 U	330 U	1700 U	1300 U	3300 U
Benzoic Acid	280 J	260 J	8000 U	6400 U	16000 U
bis(-2-Chloroethoxy)Methane	330 U	330 U	1700 U	1300 U	3300 U
2,4-Dichlorophenol	330 U	330 U	1700 U	1300 U	3300 U
1,2,4-Trichlorobenzene	330 U	330 U	1700 U	1300 U	3300 U
Naphthalene	42 J	330 U	1700 U	1300 U	3300 U
4-Chloroaniline	330 U	330 U	1700 U	1300 UJ	3300 UJ
Hexachlorobutadiene	330 U	330 U	1700 U	1300 U	3300 U
4-Chloro-3-Methylphenol	330 U	330 U	1700 U	1300 U	3300 U
2-Methylnaphthalene	330 U	330 U	1700 U	1300 U	3300 U
Hexachlorocyclopentadiene	330 U	330 U	1700 U	1300 U	3300 U
2,4,6-Trichlorophenol	330 U	330 U	1700 U	1300 U	3300 U
2,4,5-Trichlorophenol	1600 U	1600 U	8000 U	6400 U	16000 U
2-Chloronaphthalene	330 U	330 U	1700 U	1300 U	3300 U
2-Nitroaniline	1600 U	1600 U	8000 U	6400 U	16000 U
Dimethyl Phthalate	330 U	330 U	1700 U	1300 U	3300 U
Acenaphthylene	330 U	330 U	1700 U	1300 U	3300 U
3-Nitroaniline	1600 U	1600 U	8000 U	6400 U	16000 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-7 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD001	SD002	SD003	SD004	SD005
SAMPLING DATE:	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87
SAMPLE LOCATION:	Bottle Blank	Sampler Blank	Buoy 18	Buoy 7 at Liq Ditch	Buoy 10
Acenaphthene	330 U	330 U	1700 U	1300 U	3300 U
2,4-Dinitrophenol	1600 U	1600 U	8000 U	6400 U	16000 U
4-Nitrophenol	1600 U	1600 U	8000 U	6400 U	16000 U
Dibenzofuran	330 U	330 U	1700 U	1300 U	3300 U
2,4-Dinitrotoluene	330 U	330 U	1700 U	1300 U	3300 U
2,6-Dinitrotoluene	330 U	330 U	1700 U	1300 U	3300 U
Diethylphthalate	130 BUJ	110 BUJ	2500 BUJ	3700 BJ	9200 BJ
4-Chlorophenyl-phenylether	330 U	330 U	1700 U	1300 U	3300 U
Fluorene	330 U	330 U	1700 U	1300 U	3300 U
4-Nitroaniline	1600 UJ	1600 UJ	8000 UJ	6400 UJ	16000 UJ
4,6-Dinitro-2-Methylphenol	1600 U	1600 U	8000 U	6400 U	16000 U
N-Nitrosodiphenylamine(1)	330 U	330 U	1700 U	1300 U	3300 U
4-Bromophenyl-phenylether	330 U	330 U	1700 U	1300 U	3300 U
Hexachlorobenzene	330 U	330 U	1700 U	1300 U	3300 U
Pentachlorophenol	76 J	1600 U	8000 U	6400 U	34000
Phenanthrene	40 J	39 J	1200 J	1300 U	10000
Anthracene	330 U	330 U	1700 U	1300 U	4800
Di-n-Butylphthalate	83 UJ	74 UJ	2000 UJ	1300 U	3300 U
Fluoranthene	330 U	330 U	2000	1300 U	6100
Pyrene	330 U	330 U	3100	1300 U	8200
Butylbenzylphthalate	330 U	330 U	1700 U	1300 U	3300 U
3,3'-Dichlorobenzidine	660 U	660 U	3300 U	2600 U	6600 U
Benzo(a)Anthracene	330 U	330 U	930 J	1300 U	6000
bis(2-Ethylhexyl)Phthalate	2900 BUJ	1900 BUJ	7700 BUJ	1300 UJ	3300 UJ
Chrysene	330 U	330 U	970 J	1300 U	5300
Di-n-Octyl Phthalate	69 J	530	2600	3400	9200
Benzo(b)Fluoranthene	330 U	330 U	1700	1300 U	11000
Benzo(k)Fluoranthene	330 U	330 U	1700	1300 U	11000
Benzo(a)Pyrene	330 U	330 U	1000 J	1300 U	7200
Indeno(1,2,3-cd)Pyrene	330 U	330 U	800 J	1300 U	3300 U
Dibenz(a,h)Anthracene	330 U	330 U	1700 U	1300 U	3300 U
Benzo(g,h,i)Perylene	330 U	330 U	700 J	1300 U	3300 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine

TABLE F-7 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD006	SD007	SD008	SD009	SD010
SAMPLING DATE:	06/23/87	06/23/87	06/24/87	06/24/87	06/24/87
SAMPLE LOCATION:	Buoy 8	Buoy 10 Split	Buoy 12	Between Buoy 5/6	Quarry Discharge
Phenol	1300 U	6600 U	20000 U	20000 U	330 U
bis(-2-Chloroethyl)Ether	1300 U	6600 U	20000 U	20000 U	330 U
2-Chlorophenol	1300 U	6600 U	20000 U	20000 U	330 U
1,3-Dichlorobenzene	1300 U	6600 U	20000 U	20000 U	330 U
1,4-Dichlorobenzene	1300 U	6600 U	20000 U	20000 U	330 U
Benzyl Alcohol	1300 U	6600 U	20000 U	20000 U	330 U
1,2-Dichlorobenzene	1300 U	6600 U	20000 U	20000 U	330 U
2-Methylphenol	1300 U	6600 U	20000 U	20000 U	330 U
bis(2-chloroisopropyl)Ether	1300 U	6600 U	20000 U	20000 U	330 U
4-Methylphenol	1300 U	6600 U	20000 U	20000 U	150 J
N-Nitroso-Di-n-Propylamine	1300 U	6600 U	20000 U	20000 U	330 U
Hexachloroethane	1300 U	6600 U	20000 U	20000 U	330 U
Nitrobenzene	1300 U	6600 U	20000 U	20000 UJ	330 UJ
Isophorone	1300 U	6600 U	20000 U	20000 U	99 J
2-Nitrophenol	1300 U	6600 U	20000 U	20000 UJ	330 UJ
2,4-Dimethylphenol	1300 U	6600 U	20000 U	20000 U	330 U
Benzoic Acid	6400 U	32000 U	96000 U	96000 U	780 J
bis(-2-Chloroethoxy)Methane	1300 U	6600 U	20000 U	20000 U	330 U
2,4-Dichlorophenol	1300 U	6600 U	20000 U	20000 U	330 U
1,2,4-Trichlorobenzene	1300 U	6600 U	20000 U	20000 UJ	330 U
Naphthalene	1300 U	6600 U	20000 U	20000 U	330 U
4-Chloroaniline	1300 UJ	6600 UJ	20000 U	20000 UJ	330 UJ
Hexachlorobutadiene	1300 U	6600 U	20000 U	20000 U	330 U
4-Chloro-3-Methylphenol	1300 U	6600 U	20000 U	20000 U	330 U
2-Methylnaphthalene	1300 U	6600 U	20000 U	20000 U	330 U
Hexachlorocyclopentadiene	1300 U	6600 U	20000 U	20000 U	330 UJ
2,4,6-Trichlorophenol	1300 U	6600 U	20000 U	20000 U	330 U
2,4,5-Trichlorophenol	6400 U	32000 U	96000 U	96000 U	1600 U
2-Chloronaphthalene	1300 U	6600 U	20000 U	20000 U	330 U
2-Nitroaniline	6400 U	32000 U	96000 U	96000 UJ	1600 UJ
Dimethyl Phthalate	1300 U	6600 U	20000 U	20000 U	330 U
Acenaphthylene	1300 U	6600 U	20000 U	20000 U	330 U
3-Nitroaniline	6400 U	32000 U	96000 U	96000 UJ	1600 UJ

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-7 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD006	SD007	SD008	SD009	SD010
SAMPLING DATE:	06/23/87	06/23/87	06/24/87	06/24/87	06/24/87
SAMPLE LOCATION:	Buoy 8	Buoy 10 Split	Buoy 12	Between Buoy 5/6	Quarry Discharge
Acenaphthene	1300 U	6600 U	20000 U	20000 U	330 U
2,4-Dinitrophenol	6400 U	32000 U	96000 U	96000 U	1600 U
4-Nitrophenol	6400 U	32000 U	96000 U	96000 UJ	1600 U
Dibenzofuran	1300 U	6600 U	20000 U	20000 U	330 U
2,4-Dinitrotoluene	1300 U	6600 U	20000 U	20000 U	330 U
2,6-Dinitrotoluene	1300 U	6600 U	20000 U	20000 U	330 U
Diethylphthalate	2500 BUJ	1700 BUJ	54000 BJ	47000 BJ	230 BUJ
4-Chlorophenyl-phenylether	1300 U	6600 U	20000 U	20000 U	330 U
Fluorene	1300 U	6600 U	20000 U	20000 U	330 U
4-Nitroaniline	6400 UJ	32000 UJ	96000 U	96000 UJ	1600 UJ
4,6-Dinitro-2-Methylphenol	6400 U	32000 U	96000 U	96000 U	1600 U
N-Nitrosodiphenylamine(1)	1000 J	6600 U	20000 U	20000 U	330 U
4-Bromophenyl-phenylether	1300 U	6600 U	20000 U	20000 U	330 U
Hexachlorobenzene	1300 U	6600 U	20000 U	20000 U	330 U
Pentachlorophenol	7100	32000 U	96000 U	96000 U	1600 U
Phenanthrene	940 J	15000	20000 U	20000 U	210 J
Anthracene	1300 U	6600 U	20000 U	20000 U	72 J
Di-n-Butylphthalate	2400	6600 U	29000	31000	280 BUJ
Fluoranthene	1200 J	6100 J	17000 J	17000 J	450
Pyrene	5900	11000	20000 U	15000 J	310 J
Butylbenzylphthalate	1300 U	6600 U	73000	130000	330 U
3,3'-Dichlorobenzidine	2600 U	13000 U	40000 U	40000 U	660 U
Benzo(a)Anthracene	1300 U	6600 U	20000 U	20000 U	210 J
bis(2-Ethylhexyl)Phthalate	4400 BUJ	6600 UJ	58000 J	68000 J	1600 BUJ
Chrysene	880 J	6600 U	20000 U	20000 U	160 J
Di-n-Octyl Phthalate	1300 U	6600 U	20000 U	20000 U	330 U
Benzo(b)Fluoranthene	1700	6600 U	20000 U	20000 U	300 J
Benzo(k)Fluoranthene	1700	6600 U	20000 U	20000 U	300 J
Benzo(a)Pyrene	940 J	6600 U	20000 U	20000 U	130 J
Indeno(1,2,3-cd)Pyrene	1300 U	6600 U	20000 U	20000 U	170 J
Dibenz(a,h)Anthracene	1300 U	6600 U	20000 U	20000 U	330 U
Benzo(g,h,i)Perylene	1300 U	6600 U	20000 U	20000 U	190 J

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine

TABLE F-7 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD011	SD012	SD013	SD014	SD015
SAMPLING DATE:	06/24/87	06/24/87	06/24/87	06/24/87	06/25/87
SAMPLE LOCATION:	Buoy 5/6 Split	Sampler Blank	Black Rvr Upgradnt	Black Rvr Dwngradnt	Black Rvr Upgradnt
Phenol	20000 U	330 U	48 J	330 U	330 U
bis(-2-Chloroethyl)Ether	20000 U	330 U	330 U	330 U	330 U
2-Chlorophenol	20000 U	330 U	330 U	330 U	330 U
1,3-Dichlorobenzene	20000 U	330 U	330 U	330 U	330 U
1,4-Dichlorobenzene	20000 U	330 U	330 U	330 U	330 U
Benzyl Alcohol	20000 U	330 U	330 U	330 U	330 U
1,2-Dichlorobenzene	20000 U	330 U	330 U	330 U	330 U
2-Methylphenol	20000 U	330 U	330 U	330 U	330 U
bis(2-chloroisopropyl)Ether	20000 U	330 U	330 U	330 U	330 U
4-Methylphenol	20000 U	330 U	330 U	330 U	330 U
N-Nitroso-Di-n-Propylamine	20000 U	330 U	330 U	330 U	330 U
Hexachloroethane	20000 U	330 U	330 U	330 U	330 U
Nitrobenzene	20000 UJ	330 UJ	330 UJ	330 UJ	330 UJ
Isophorone	20000 U	43 J	74 J	330 U	330 U
2-Nitrophenol	20000 UJ	330 UJ	330 UJ	330 UJ	330 UJ
2,4-Dimethylphenol	20000 U	330 U	330 U	330 U	330 U
Benzoic Acid	96000 U	1600 U	1600 U	1600 U	1600 U
bis(-2-Chloroethoxy)Methane	20000 U	330 U	330 U	330 U	330 U
2,4-Dichlorophenol	20000 U	330 U	330 U	330 U	330 U
1,2,4-Trichlorobenzene	20000 U	330 U	330 U	330 U	330 U
Naphthalene	20000 U	46 J	240 J	88 J	330 U
4-Chloroaniline	20000 UJ	330 UJ	330 UJ	330 UJ	330 UJ
Hexachlorobutadiene	20000 U	330 U	330 U	330 U	330 U
4-Chloro-3-Methylphenol	20000 U	330 U	330 U	330 U	330 U
2-Methylnaphthalene	20000 U	330 U	230 J	74 J	330 U
Hexachlorocyclopentadiene	20000 UJ	330 UJ	330 UJ	330 UJ	330 UJ
2,4,6-Trichlorophenol	20000 U	330 U	330 U	330 U	330 U
2,4,5-Trichlorophenol	96000 U	1600 U	1600 U	1600 U	1600 U
2-Chloronaphthalene	20000 U	330 U	330 U	330 U	330 U
2-Nitroaniline	96000 UJ	1600 UJ	1600 UJ	1600 UJ	1600 UJ
Dimethyl Phthalate	20000 U	330 U	330 U	330 U	330 U
Acenaphthylene	20000 U	330 U	59 J	330 U	330 U
3-Nitroaniline	96000 UJ	1600 UJ	1600 UJ	1600 UJ	1600 UJ

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-7 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SD011	SD012	SD013	SD014	SD015
SAMPLING DATE:	06/24/87	06/24/87	06/24/87	06/24/87	06/25/87
	Buoy 5/6	Sampler	Black Rvr	Black Rvr	Black Rvr
SAMPLE LOCATION:	Split	Blank	Upgradnt	Dwngradnt	Upgradnt
Acenaphthene	20000 U	330 U	140 J	330 U	330 U
2,4-Dinitrophenol	96000 U	1600 U	1600 U	1600 U	1600 U
4-Nitrophenol	96000 U	1600 U	1600 U	1600 U	1600 U
Dibenzofuran	20000 U	330 U	190 J	330 U	330 U
2,4-Dinitrotoluene	20000 U	330 U	330 U	330 U	330 U
2,6-Dinitrotoluene	20000 U	330 U	330 U	330 U	330 U
Diethylphthalate	65000 BJ	140 BUJ	150 BUJ	94 BUJ	110 BUJ
4-Chlorophenyl-phenylether	20000 U	330 U	330 U	330 U	330 U
Fluorene	20000 U	330 U	230 J	330 U	330 U
4-Nitroaniline	96000 UJ	1600 UJ	1600 UJ	1600 UJ	1600 UJ
4,6-Dinitro-2-Methylphenol	96000 U	1600 U	1600 U	1600 U	1600 U
N-Nitrosodiphenylamine(1)	20000 U	330 U	330 U	330 U	330 U
4-Bromophenyl-phenylether	20000 U	330 U	330 U	330 U	330 U
Hexachlorobenzene	20000 U	330 U	330 U	330 U	330 U
Pentachlorophenol	96000 U	1600 U	1600 U	1600 U	1600 U
Phenanthrene	20000 U	41 J	2400	69 J	650
Anthracene	20000 U	330 U	490	330 U	590
Di-n-Butylphthalate	20000 U	120 BUJ	320 BUJ	62 BUJ	330 B
Fluoranthene	20000 U	330 U	3300	71 J	2800
Pyrene	20000 U	330 U	2200	86 J	2900
Butylbenzylphthalate	20000 U	330 U	690	330 U	330 U
3,3'-Dichlorobenzidine	40000 U	660 U	660 U	660 U	660 U
Benzo(a)Anthracene	20000 U	330 U	1600	330 U	4900
bis(2-Ethylhexyl)Phthalate	20000 UJ	2100 BUJ	1300 BUJ	570 BUJ	210 BUJ
Chrysene	20000 U	330 U	1100	330 U	3400
Di-n-Octyl Phthalate	20000 U	63 J	330 U	330 U	330 U
Benzo(b)Fluoranthene	20000 U	330 U	1900	56 J	4800
Benzo(k)Fluoranthene	20000 U	330 U	1900	56 J	4800
Benzo(a)Pyrene	20000 U	330 U	830	46 J	2400
Indeno(1,2,3-cd)Pyrene	20000 UJ	330 UJ	690 J	330 UJ	840 J
Dibenz(a,h)Anthracene	20000 U	330 U	330 U	330 U	280 J
Benzo(g,h,i)Perylene	20000 UJ	330 UJ	750 J	330 UJ	660 J

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine

TABLE F-8
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SD001	SD002	SD003	SD004	SD005
SAMPLING DATE:	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87
SAMPLE LOCATION:	Bottle Blank	Sampler Blank	Buoy 18	Buoy 7 at Liq Ditch	Buoy 10
Alpha-BHC	8 U	8 U	80 U	8 U	800 U
Beta-BHC	8 U	8 U	80 U	8 U	800 U
Delta-BHC	8 U	8 U	80 U	8 U	800 U
Gamma-BHC(Lindane)	8 U	8 U	80 U	8 U	800 U
Heptachlor	8 U	8 U	80 U	8 U	800 U
Aldrin	8 U	8 U	80 U	8 U	800 U
Heptachlor Epoxide	8 U	8 U	80 U	8 U	800 U
Endosulfan I	8 U	8 U	80 U	8 U	80 U
Dieldrin	16 U	16 U	160 U	16 U	160 U
4,4'-DDE	16 U	16 U	160 U	16 U	160 U
Endrin	16 U	16 U	160 U	16 U	160 U
Endosulfan II	16 U	16 U	160 U	16 U	160 U
4,4'-DDD	16 U	16 U	160 U	16 U	160 U
Endosulfan Sulfate	16 U	16 U	160 U	16 U	160 U
4,4'-DDT	16 U	16 U	160 U	16 U	160 U
Methoxychlor	80 U	80 U	800 U	80 U	800 U
Endrin Ketone	16 U	16 U	160 U	16 U	160 U
Chlordane	80 U	80 U	800 U	80 U	800 U
Toxaphene	160 U	160 U	1600 U	160 U	1600 U
Aroclor-1016	80 U	80 U	800 U	80 U	8000 U
Aroclor-1221	80 U	80 U	800 U	80 U	8000 U
Aroclor-1232	80 U	80 U	800 U	80 U	800 U
Aroclor-1242	80 U	80 U	800 U	80 U	800 U
Aroclor-1248	80 U	80 U	800 U	80 U	800 U
Aroclor-1254	160 U	160 U	1600 U	160 U	1600 U
Aroclor-1260	160 U	160 U	1600 U	160 U	1600 U
Oil and Grease (SAS)	650000 U	650000 U	18200000	18100000	85700000
Total Organic Carbon (SAS)	3670000	4620000	75000000	201000000	148000000

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-8 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SD006	SD007	SD008	SD009	SD010
SAMPLING DATE:	06/23/87	06/23/87	06/24/87	06/24/87	06/24/87
SAMPLE LOCATION:	Buoy 8	Buoy 10 Split	Buoy 12	Between Buoy 5/6	Quarry Discharge
Alpha-BHC	800 UJ	800 U	120 U	120 U	8 U
Beta-BHC	800 UJ	800 U	120 U	120 U	8 U
Delta-BHC	800 UJ	800 U	120 U	120 U	8 U
Gamma-BHC(Lindane)	800 UJ	800 U	120 U	120 U	8 U
Heptachlor	800 UJ	800 U	120 U	120 U	8 U
Aldrin	800 UJ	800 U	120 U	120 U	8 U
Heptachlor Epoxide	800 UJ	800 U	120 U	120 U	8 U
Endosulfan I	80 UJ	800 U	120 U	120 U	8 U
Dieldrin	160 UJ	1600 U	240 U	240 U	16 U
4,4'-DDE	160 UJ	1600 U	240 U	240 U	16 U
Endrin	160 UJ	1600 U	240 U	240 U	16 U
Endosulfan II	160 UJ	1600 U	240 U	240 U	16 U
4,4'-DDD	160 UJ	1600 U	240 U	240 U	16 U
Endosulfan Sulfate	160 UJ	1600 U	240 U	240 U	16 U
4,4'-DDT	160 UJ	1600 U	240 U	240 U	16 U
Methoxychlor	800 UJ	8000 U	1200 U	1200 U	80 U
Endrin Ketone	160 UJ	1600 U	240 U	240 U	16 U
Chlordane	8000 UJ	8000 U	1200 U	1200 U	80 U
Toxaphene	1600 UJ	16000 U	2400 U	2400 U	160 U
Aroclor-1016	8000 UJ	8000 U	1200 U	1200 U	80 U
Aroclor-1221	8000 UJ	8000 U	1200 U	1200 U	80 U
Aroclor-1232	8000 UJ	8000 U	1200 U	1200 U	80 U
Aroclor-1242	8000 UJ	8000 U	1200 U	1200 U	80 U
Aroclor-1248	8000 UJ	8000 U	1200 U	1200 U	1000
Aroclor-1254	1600 UJ	16000 U	2400 U	2400 U	160 U
Aroclor-1260	1600 UJ	16000 U	2400 U	2400 U	160 U
Oil and Grease (SAS)	20600000	10500000	99800000	111000000	1300000
Total Organic Carbon (SAS)	112000000	128000000	161000000	139000000	29300000

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-8 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
PESTICIDE/PCB'S AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SD011	SD012	SD013	SD014	SD015
SAMPLING DATE:	06/24/87	06/24/87	06/24/87	06/24/87	06/25/87
	Buoy 5/6	Sampler	Black Rvr	Black Rvr	Black Rvr
SAMPLE LOCATION:	Split	Blank	Upgradnt	Dwngradnt	Upgradnt
Alpha-BHC	120 U	8 U	80 U	8 U	80 U
Beta-BHC	120 U	8 U	80 U	8 U	80 U
Delta-BHC	120 U	8 U	80 U	8 U	80 U
Gamma-BHC(Lindane)	120 U	8 U	80 U	8 U	80 U
Heptachlor	120 U	8 U	80 U	8 U	80 U
Aldrin	120 U	8 U	80 U	8 U	80 U
Heptachlor Epoxide	120 U	8 U	80 U	8 U	80 U
Endosulfan I	120 U	8 U	80 U	8 U	80 U
Dieldrin	240 U	16 U	16 U	16 U	16 U
4,4'-DDE	240 U	16 U	16 U	16 U	16 U
Endrin	240 U	16 U	16 U	16 U	16 U
Endosulfan II	240 U	16 U	16 U	16 U	16 U
4,4'-DDD	240 U	16 U	16 U	16 U	16 U
Endosulfan Sulfate	240 U	16 U	16 U	16 U	16 U
4,4'-DDT	240 U	16 U	16 U	16 U	16 U
Methoxychlor	1200 U	80 U	80 U	80 U	80 U
Endrin Ketone	240 U	16 U	16 U	16 U	16 U
Chlordane	1200 U	80 U	80 U	80 U	80 U
Toxaphene	2400 U	160 U	160 U	160 U	160 U
Aroclor-1016	1200 U	80 U	800 U	80 U	800 U
Aroclor-1221	1200 U	80 U	800 U	80 U	800 U
Aroclor-1232	1200 U	80 U	800 U	80 U	80 U
Aroclor-1242	1200 U	80 U	800 U	80 U	800 U
Aroclor-1248	1200 U	80 U	1000	490	3400
Aroclor-1254	2400 U	160 U	160 U	290	160 U
Aroclor-1260	2400 U	160 U	160 U	160 U	160 U
Oil and Grease (SAS)	109000000	2085000	890000	650000 U	650000 U
Total Organic Carbon (SAS)	115000000	23800000	13700000	22800000	3520000

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-9
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
INORGANIC ANALYSES

SAMPLE NO:	SD001	SD002	SD003	SD004	SD005
SAMPLE DATE:	06/23/87	06/23/87	06/23/87	06/23/87	06/23/87
SAMPLE LOCATION:	Bottle Blank	Sampler Blank	Buoy 18	Buoy 7 at Liq Ditch	Buoy 10
ALUMINUM	9580	9320	10500	[949]	12300
ANTIMONY	12U	12U	35U	109U	81U
ARSENIC	5.6U RJ	5.6U RJ	17U RJ	52U RJ	38U RJ
BARIUM	156	163	[112]	[35]	[93]
BERYLLIUM	[1.2]	[1.2]	[2.3]	5.2U	3.8U
CADMIUM	2.8U	2.8U	8.3U	26U	19U
CALCIUM	12100	13100	73700	[2440]	[4080]
CHROMIUM	14	12	29	21U	54
COBALT	[13]	[12]	8.3U	26U	19U
COPPER	41	42	97	21U	[88]
IRON	20600	20500	53900	145000	52500
LEAD	11 RJ	11 RJ	100 RJ	26U RJ	20 RJ
MAGNESIUM	3530	3540	20300	[699]	[2480]
MANGANESE	485	515	1060	255	372
MERCURY	0.11U	0.11U	0.73	1.0U	0.77U
NICKEL	30	31	[18]	42U	[54]
POTASSIUM	[1420]	[1410]	[947]	786U	[1480]
SELENIUM	2.8U RJ	2.8U RJ	8.3U RJ	26U RJ	19U RJ
SILVER	2.2U	2.2U	6.7U	21U	15U
SODIUM	499U	505U	1500U	4680U	3450U
THALLIUM	5.6U	5.6U	17U	52U	38U
TIN	8.9U	9U	27U	83U	62U
VANADIUM	[16]	[17]	[27]	21U	[29]
ZINC	136	146	294	[81]	334
CYANIDE	0.56U RJ	0.56U RJ	1.7U RJ	5.2U RJ	3.8U RJ

NOTE: All concentrations are presented in milligrams per kilogram, mg/kg.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

E The value presented is estimated due to the presence of interference.

R The spike sample recovery is not within control limits.

J The value presented is estimated.

TABLE F-9 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
INORGANIC ANALYSES

SAMPLE NO:	SD006	SD007	SD008	SD009	SD010
SAMPLE DATE:	06/23/87	06/23/87	06/24/87	06/24/87	06/24/87
SAMPLE LOCATION:	Buoy 8	Buoy 10 Split	Buoy 12	Between Buoy 5/6	Quarry Discharge
ALUMINUM	9680	4280	17700	12200	3040
ANTIMONY	55U	75U	87U RJ	62U RJ	12U RJ
ARSENIC	26U RJ	36U RJ	[42]	41	5.7U
BARIUM	[53]	[26]	[97]	[94]	[25]
BERYLLIUM	2.6U	3.6U	4.2U	2.9U	0.57U
CADMIUM	13U	18U	21U	15U	2.8U
CALCIUM	[2240]	[1600]	[6480] E	[6010] E	[2460] E
CHROMIUM	40	14U	60	63	9.7
COBALT	13U	18U	21U	15U	[4.9]
COPPER	[58]	[23]	156	343	18
IRON	31500	15100	79700	115000	19100
LEAD	232 RJ	18U RJ	58	94	14
MAGNESIUM	[2080]	[1100]	[4740]	[3220]	[1580]
MANGANESE	201	141	454	1190	860
MERCURY	0.53U	0.71U	0.83U	0.71	0.11U
NICKEL	[26]	29U	[103]	[61]	[12]
POTASSIUM	[1040]	[721]	[2290]	[1700]	[477]
SELENIUM	13U RJ	18U RJ	21U	15U	2.8U
SILVER	11U	14U	17U	12U	2.3U
SODIUM	2360U	3210U	3740U	2640U	510U
THALLIUM	26U	36U	42U	29U	5.7U
TIN	42U	57U	[79]	[59]	[10]
VANADIUM	[26]	14U	[37]	[32]	[8.1]
ZINC	180	89	369	270	80
CYANIDE	2.6U RJ	3.6U RJ	V	V	V

NOTE: All concentrations are presented in milligrams per kilogram, mg/kg.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

E The value presented is estimated due to the presence of interference.

R The spike sample recovery is not within control limits.

J The value presented is estimated.

V The laboratory data are void, and are not presented due to low spike recovery.

TABLE F-9 (Continued)
REPUBLIC STEEL QUARRY RI
SEDIMENT SAMPLING
INORGANIC ANALYSES

SAMPLE NO:	SD011	SD012	SD013	SD014	SD015
SAMPLE DATE:	06/24/87	06/24/87	06/24/87	06/24/87	06/25/87
SAMPLE LOCATION:	Buoy 5/6 Split	Sampler Blank	Black Rvr Upgradnt	Black Rvr Dwngradnt	Black Rvr Upgradnt
ALUMINUM	11300	16100	9340	6410	6380
ANTIMONY	58U RJ	14U RJ	22U RJ	17U RJ	16U RJ
ARSENIC	39	12	15	29	31
BARIUM	[84]	196	[81]	[85]	[52]
BERYLLIUM	2.8U	[1.7]	[1.8]	[0.98]	[1.1]
CADMIUM	14U	3.3U	5.3U	4.6	3.9U
CALCIUM	[5640] E	15100 E	59300 E	8440 E	4950 E
CHROMIUM	66	28	27	82	63
COBALT	14U	[18]	[7]	[4.8]	[10]
COPPER	263	61	62	86	72
IRON	109000	39300	49900	170000	159000
LEAD	106	24	202	41	41
MAGNESIUM	[3010]	4930	18900	[2430]	[2010]
MANGANESE	1100	628	1070	1570	1450
MERCURY	0.56U	0.13U	0.21U	0.16U	0.16U
NICKEL	[61]	46	[40]	67	61
POTASSIUM	[1540]	[2500]	[940]	[886]	[513]
SELENIUM	14U	3.3U	5.3U	4U	3.9U
SILVER	11U	2.6U	4.3U	3.2U	3.1U
SODIUM	2490U	[981]	955U	713U	702U
THALLIUM	28U	6.6U	11U	7.9U	7.8U
TIN	198	11U	[18]	[16]	[15]
VANADIUM	[26]	37	[22]	[18]	[16]
ZINC	240	190	261	97	108
CYANIDE	V	V	V	V	V

NOTE: All concentrations are presented in mg/kg.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

E The value presented is estimated due to the presence of interference.

R The spike sample recovery is not within control limits.

J The value presented is estimated.

V The laboratory data are void, and are not presented due to low spike recovery.

TABLE F-10
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SS001	SS002	SS003	SS004	SS005
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87
SAMPLE LOCATION:	E. Quarry Discharge	S. Pickle Liq Ditch	S. Boat Launch	S. Steel Plant Yd	N. Black R Downgradnt
Chloromethane	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	29 B	33 B	9 BUJ	9 BUJ	10 BUJ
Acetone	5 UJ	130 B	150 B	78 BUJ	4 BUJ
Carbon Disulfide	5 U	5 U	5 U	5 U	14
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 BUJ	25 UJ	78	20 UJ	9 BUJ
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	9
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	33 BUJ	65 B	4 BUJ	4 BUJ	7 BUJ
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U
Percent Moisture	42	28	32	20	30
Soil pH	3.2	6.9	7.2	7.7	6.8

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-10 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SS006	SS007	SS008	SS009	SS010
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/23/87	06/23/87
	N. Offsite Background	W. Offsite Background	SS001 Split	Bottle Blank	Sampler Blank
Chloromethane	10 UJ	10 UJ	10 UJ	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	3 BUJ	3 BUJ	5 BUJ	3 BUJ	6 BUJ
Acetone	3 BUJ	3 BUJ	13 BUJ	4 BUJ	6 BUJ
Carbon Disulfide	18	7	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	7 BUJ	8 BUJ	10 BUJ	7 BUJ	7 BUJ
1,1,1-Trichloroethane	4 J	3 J	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	7 BUJ	95 B	16 BUJ	12 BUJ	6 BUJ
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U
Percent Moisture	27	24	29	10	11
Soil pH	5.4	5.3	3.1	7.9	8.0

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-11
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SS001	SS002	SS003	SS004	SS005
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87
SAMPLE LOCATION:	E. Quarry Discharge	S. Pickle Liq Ditch	S. Boat Launch	S. Steel Plant Yd	N. Black R Downgradnt
Phenol	17000 U	20000 U	1700 U	1700 U	330 U
bis(-2-Chloroethyl)Ether	17000 U	20000 U	1700 U	1700 U	330 U
2-Chlorophenol	17000 U	20000 U	1700 U	1700 U	330 U
1,3-Dichlorobenzene	17000 U	20000 U	1700 U	1700 U	160 J
1,4-Dichlorobenzene	17000 U	20000 U	1700 U	1700 U	330 U
Benzyl Alcohol	17000 U	20000 U	1700 U	1700 U	330 U
1,2-Dichlorobenzene	17000 U	20000 U	1700 U	1700 U	330 U
2-Methylphenol	17000 U	20000 U	1700 U	1700 U	330 U
bis(2-chloroisopropyl)Ether	17000 U	20000 U	1700 U	1700 U	330 U
4-Methylphenol	17000 U	20000 U	1700 U	1700 U	330 U
N-Nitroso-Di-n-Propylamine	17000 U	20000 U	1700 U	1700 U	330 U
Hexachloroethane	17000 U	20000 U	1700 U	1700 U	330 U
Nitrobenzene	17000 U	20000 U	1700 U	1700 U	330 U
Isophorone	17000 U	20000 U	1700 U	1700 U	330 U
2-Nitrophenol	17000 U	20000 U	1700 U	1700 U	330 U
2,4-Dimethylphenol	17000 U	20000 U	1700 U	1700 U	330 U
Benzoic Acid	80000 U	96000 U	8000 U	8000 U	510 J
bis(-2-Chloroethoxy)Methane	17000 U	20000 U	1700 U	1700 U	330 U
2,4-Dichlorophenol	17000 U	20000 U	1700 U	1700 U	330 U
1,2,4-Trichlorobenzene	17000 U	20000 U	1700 U	1700 U	330 U
Naphthalene	17000 U	20000 U	1700 U	1700 U	330 U
4-Chloroaniline	17000 U	20000 U	1700 U	1700 U	330 U
Hexachlorobutadiene	17000 U	20000 U	1700 U	1700 U	330 U
4-Chloro-3-Methylphenol	17000 U	20000 U	1700 U	1700 U	330 U
2-Methylnaphthalene	17000 U	20000 U	1700 U	1700 U	330 U
Hexachlorocyclopentadiene	17000 U	20000 U	1700 U	1700 U	330 U
2,4,6-Trichlorophenol	17000 U	20000 U	1700 U	1700 U	330 U
2,4,5-Trichlorophenol	80000 U	96000 U	8000 U	8000 U	1600 U
2-Chloronaphthalene	17000 U	20000 U	1700 U	1700 U	330 U
2-Nitroaniline	80000 U	96000 U	8000 U	8000 U	1600 U
Dimethyl Phthalate	17000 U	20000 U	1700 U	1700 U	330 U
Acenaphthylene	17000 U	20000 U	1700 U	1700 U	330 U
3-Nitroaniline	80000 U	96000 U	8000 U	8000 U	1600 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-11 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SS001	SS002	SS003	SS004	SS005
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87
SAMPLE LOCATION:	E. Quarry Discharge	S. Pickle Liq Ditch	S. Boat Launch	S. Steel Plant Yd	N. Black R Downgradnt
Acenaphthene	17000 U	20000 U	1700 U	1700 U	330 U
2,4-Dinitrophenol	80000 U	96000 U	8000 U	8000 U	1600 U
4-Nitrophenol	80000 U	96000 U	8000 U	8000 U	1600 U
Dibenzofuran	17000 U	20000 U	1700 U	1700 U	330 U
2,4-Dinitrotoluene	17000 U	20000 U	1700 U	1700 U	330 U
2,6-Dinitrotoluene	17000 U	20000 U	1700 U	1700 U	330 U
Diethylphthalate	7400 BUJ	8900 BUJ	750 BUJ	490 BUJ	120 BUJ
4-Chlorophenyl-phenylether	17000 U	20000 U	1700 U	1700 U	330 U
Fluorene	80000 U	20000 U	1700 U	1700 U	330 U
4-Nitroaniline	80000 U	96000 U	8000 U	8000 U	1600 UJ
4,6-Dinitro-2-Methylphenol	17000 U	96000 U	8000 U	8000 U	1600 UJ
N-Nitrosodiphenylamine(1)	17000 U	20000 U	1700 U	1700 U	77 J
4-Bromophenyl-phenylether	17000 U	20000 U	1700 U	1700 U	330 U
Hexachlorobenzene	17000 U	20000 U	1700 U	1700 U	330 U
Pentachlorophenol	80000 U	96000 U	8000 U	8000 UR	100 J
Phenanthrene	17000 U	20000 U	1700 U	250 J	110 J
Anthracene	17000 U	20000 U	1700 U	1700 U	330 U
Di-n-Butylphthalate	17000 U	3100 J	1900	250 UJ	64 UJ
Fluoranthene	17000 U	20000 U	780 J	510 J	130 J
Pyrene	17000 U	4300 J	560 J	330 J	160 J
Butylbenzylphthalate	17000 U	20000 U	1700 U	1700 U	330 U
3,3'-Dichlorobenzidine	33000 U	40000 U	3300 U	3300 U	660 U
Benzo(a)Anthracene	17000 U	3000 BUJ	510 J	260 J	110 J
bis(2-Ethylhexyl)Phthalate	8300 BUJ	8500 BUJ	7800 B	1900 BUJ	340 BUJ
Chrysene	3400 BUJ	3500 BUJ	510 J	250 J	140 J
Di-n-Octyl Phthalate	17000 U	20000 U	1900	1700 U	330 U
Benzo(b)Fluoranthene	17000 U	3600 BUJ	780 J	1700 U	260 J
Benzo(k)Fluoranthene	17000 U	3600 BUJ	780 J	1700 U	260 J
Benzo(a)Pyrene	17000 U	4300 BUJ	1700 U	1700 U	130 J
Indeno(1,2,3-cd)Pyrene	17000 U	20000 U	1700 U	1700 U	330 U
Dibenz(a,h)Anthracene	17000 U	20000 U	1700 U	1700 U	330 U
Benzo(g,h,i)Perylene	17000 U	20000 U	1700 U	1700 U	330 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
- U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
- J Indicates an estimated value.
- B Indicates the analyte was found in the laboratory blank sample as well as the sample.
- R The results of this analyte have been rejected due to laboratory quality quality control problems during analysis.
- (1) Cannot be separated from diphenylamine.

TABLE F-11 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SS006	SS007	SS008	SS009	SS010
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/23/87	06/23/87
SAMPLE LOCATION:	N. Offsite Background	W. Offsite Background	SS001 Split	Bottle Blank	Sampler Blank
Phenol	330 U	330 U	16000 U	330 U	330 U
bis(-2-Chloroethyl)Ether	330 U	330 U	16000 U	330 U	330 U
2-Chlorophenol	330 U	330 U	16000 U	330 U	330 U
1,3-Dichlorobenzene	330 U	330 U	16000 U	330 U	330 U
1,4-Dichlorobenzene	330 U	330 U	16000 U	330 U	330 U
Benzyl Alcohol	330 U	330 U	16000 U	330 U	330 U
1,2-Dichlorobenzene	330 U	330 U	16000 U	330 U	330 U
2-Methylphenol	330 U	330 U	16000 U	330 U	330 U
bis(2-chloroisopropyl)Ether	330 U	330 U	16000 U	330 U	330 U
4-Methylphenol	330 U	330 U	16000 U	330 U	330 U
N-Nitroso-Di-n-Propylamine	330 U	330 U	16000 U	330 U	330 U
Hexachloroethane	330 U	330 U	16000 U	330 U	330 U
Nitrobenzene	330 U	330 U	16000 U	330 U	330 U
Isophorone	330 U	330 U	16000 U	330 U	330 U
2-Nitrophenol	330 U	330 U	16000 U	330 U	330 U
2,4-Dimethylphenol	330 U	330 U	16000 U	330 U	330 U
Benzoic Acid	1600 U	630 J	75000 U	560 J	450 J
bis(-2-Chloroethoxy)Methane	330 U	330 U	16000 U	330 U	330 U
2,4-Dichlorophenol	330 U	330 U	16000 U	330 U	330 U
1,2,4-Trichlorobenzene	330 U	330 U	16000 U	330 U	330 U
Naphthalene	330 U	160 J	16000 U	40 J	44 J
4-Chloroaniline	330 U	330 U	16000 U	330 U	330 U
Hexachlorobutadiene	330 U	330 U	16000 U	330 U	330 U
4-Chloro-3-Methylphenol	330 U	330 U	16000 U	330 U	330 U
2-Methylnaphthalene	330 U	210 J	16000 U	49 J	330 U
Hexachlorocyclopentadiene	330 U	330 U	16000 U	330 U	330 U
2,4,6-Trichlorophenol	330 U	330 U	16000 U	330 U	330 U
2,4,5-Trichlorophenol	1600 U	1600 U	75000 U	1600 U	1600 U
2-Chloronaphthalene	330 U	330 U	16000 U	330 U	330 U
2-Nitroaniline	1600 U	1600 U	75000 U	1600 U	1600 U
Dimethyl Phthalate	330 U	330 U	16000 U	330 U	330 U
Acenaphthylene	330 U	330 U	16000 U	330 U	330 U
3-Nitroaniline	1600 U	1600 U	75000 U	1600 U	1600 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.

TABLE F-11 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	SS006	SS007	SS008	SS009	SS010
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/23/87	06/23/87
SAMPLE LOCATION:	N. Offsite Background	W. Offsite Background	SS001 Split	Bottle Blank	Sampler Blank
Acenaphthene	330 U	330 U	16000 U	330 U	330 U
2,4-Dinitrophenol	1600 U	1600 U	75000 U	1600 U	1600 U
4-Nitrophenol	1600 U	1600 U	75000 U	1600 U	1600 U
Dibenzofuran	330 U	60 J	16000 U	330 U	330 U
2,4-Dinitrotoluene	330 U	330 U	16000 U	330 U	330 U
2,6-Dinitrotoluene	330 U	330 U	16000 U	330 U	330 U
Diethylphthalate	170 BUJ	73 BUJ	5900 UJ	130 BUJ	110 BUJ
4-Chlorophenyl-phenylether	330 U	330 U	16000 U	330 U	330 U
Fluorene	330 U	330 U	16000 U	330 U	330 U
4-Nitroaniline	1600 U	1600 UJ	75000 UJ	1600 UJ	1600 UJ
4,6-Dinitro-2-Methylphenol	1600 U	1600 UJ	75000 UJ	1600 U	1600 U
N-Nitrosodiphenylamine(1)	330 U	58 J	16000 U	330 U	330 U
4-Bromophenyl-phenylether	330 U	330 U	16000 U	330 U	330 U
Hexachlorobenzene	330 U	330 U	16000 U	330 U	330 U
Pentachlorophenol	1600 U	1600 U	75000 U	380 J	160 J
Phenanthrene	330 U	130 J	16000 U	39 J	330 U
Anthracene	330 U	330 U	16000 U	330 U	330 U
Di-n-Butylphthalate	140 UJ	79 UJ	3400 J	72 UJ	67 UJ
Fluoranthene	62 J	63 J	16000 U	330 U	330 U
Pyrene	57 J	60 J	16000 U	42 J	330 U
Butylbenzylphthalate	330 U	49 J	16000 U	330 U	330 U
3,3'-Dichlorobenzidine	660 U	660 U	31000 U	660 U	660 U
Benzo(a)Anthracene	70 J	330 U	16000 U	330 U	330 U
bis(2-Ethylhexyl)Phthalate	270 BUJ	240 BUJ	8400 BUJ	2000 BUJ	2400 BUJ
Chrysene	65 J	56 J	3000 BUJ	330 U	330 U
Di-n-Octyl Phthalate	330 U	330 U	16000 U	330 U	58 J
Benzo(b)Fluoranthene	330 U	76 J	3200 BUJ	330 U	330 U
Benzo(k)Fluoranthene	330 U	76 J	3200 BUJ	330 U	330 U
Benzo(a)Pyrene	73 J	42 J	16000 U	330 U	330 U
Indeno(1,2,3-cd)Pyrene	330 U	330 U	16000 U	330 U	330 U
Dibenz(a,h)Anthracene	330 U	330 U	16000 U	330 U	330 U
Benzo(g,h,i)Perylene	330 U	330 U	16000 U	330 U	330 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-12
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
PESTICIDE/PCB's AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SS001	SS002	SS003	SS004	SS005
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87
SAMPLE LOCATION:	E. Quarry Discharge	S. Pickle Liq Ditch	S. Boat Launch	S. Steel Plant Yd	N. Black R Downgradnt
Alpha-BHC	120 U	120 U	80 U	80 U	80 U
Beta-BHC	120 U	120 U	80 U	80 U	80 U
Delta-BHC	120 U	120 U	80 U	80 U	80 U
Gamma-BHC(Lindane)	120 U	120 U	80 U	80 U	80 U
Heptachlor	120 U	120 U	80 U	80 U	80 U
Aldrin	120 U	120 U	80 U	80 U	80 U
Heptachlor Epoxide	120 U	120 U	80 U	80 U	80 U
Endosulfan I	120 U	120 U	80 U	80 U	8 U
Dieldrin	240 U	240 U	16 U	160 U	16 U
4,4'-DDE	240 U	240 U	16 U	160 U	16 U
Endrin	240 U	240 U	16 U	160 U	16 U
Endosulfan II	240 U	240 U	16 U	160 U	16 U
4,4'-DDD	240 U	240 U	16 U	160 U	16 U
Endosulfan Sulfate	240 U	240 U	16 U	160 U	16 U
4,4'-DDT	450	240 U	16 U	160 U	16 U
Methoxychlor	1200 U	1200 U	80 U	800 U	80 U
Endrin Ketone	240 U	240 U	16 U	160 U	16 U
Chlordane	1200 U	1200 U	80 U	800 U	800 U
Toxaphene	2400 U	2400 U	160 U	1600 U	160 U
Aroclor-1016	1200 U	1200 U	800 U	800 U	800 U
Aroclor-1221	1200 U	1200 U	800 U	800 U	800 U
Aroclor-1232	1200 U	1200 U	800 U	800 U	800 U
Aroclor-1242	1200 U	1200 U	800 U	800 U	800 U
Aroclor-1248	1200 U	1200 U	80 U	800 U	800 U
Aroclor-1254	2400 U	2400 U	160 U	1600 U	280
Aroclor-1260	2400 U	2400 U	160 U	1600 U	160 U
Oil and Grease (SAS)	9480000	5680000	4850000	2210000	650000 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.

TABLE F-12 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
PESTICIDE/PCB's AND SAS ORGANICS ANALYSES

SAMPLE NUMBER:	SS006	SS007	SS008	SS009	SS010
SAMPLING DATE:	06/22/87	06/22/87	06/22/87	06/23/87	06/23/87
SAMPLE LOCATION:	N. Offsite Background	W. Offsite Background	SS001 Split	Bottle Blank	Sampler Blank
Alpha-BHC	8 U	80 U	120 U	8 U	8 U
Beta-BHC	8 U	80 U	120 U	8 U	8 U
Delta-BHC	8 U	80 U	120 U	8 U	8 U
Gamma-BHC(Lindane)	8 U	80 U	120 U	8 U	8 U
Heptachlor	8 U	80 U	120 U	8 U	8 U
Aldrin	8 U	8 U	120 U	8 U	8 U
Heptachlor Epoxide	8 U	8 U	120 U	8 U	8 U
Endosulfan I	8 U	8 U	120 U	8 U	8 U
Dieldrin	16 U	16 U	240 U	16 U	16 U
4,4'-DDE	16 U	16 U	240 U	16 U	16 U
Endrin	16 U	16 U	240 U	16 U	16 U
Endosulfan II	16 U	16 U	240 U	16 U	16 U
4,4'-DDD	16 U	16 U	240 U	16 U	16 U
Endosulfan Sulfate	16 U	16 U	240 U	16 U	16 U
4,4'-DDT	16 U	16 U	390	16 U	16 U
Methoxychlor	80 U	80 U	1200 U	80 U	80 U
Endrin Ketone	16 U	16 U	240 U	16 U	16 U
Chlordane	80 U	80 U	1200 U	80 U	80 U
Toxaphene	160 U	160 U	2400 U	160 U	160 U
Aroclor-1016	80 U	800 U	1200 U	80 U	80 U
Aroclor-1221	80 U	800 U	1200 U	80 U	80 U
Aroclor-1232	80 U	80 U	1200 U	80 U	80 U
Aroclor-1242	80 U	80 U	1200 U	80 U	80 U
Aroclor-1248	80 U	80 U	1200 U	80 U	80 U
Aroclor-1254	160 U	160 U	2400 U	160 U	160 U
Aroclor-1260	160 U	160 U	2400 U	160 U	160 U
Oil and Grease (SAS)	650000 U	650000 U	8780000	650000 U	650000 U

NOTES: All concentrations are presented in micrograms per kilogram, ug/kg.

U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.

TABLE F-13
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
INORGANIC ANALYSES

SAMPLE NO:	SS001	SS002	SS003	SS004	SS005
SAMPLE DATE:	06/22/87	06/22/87	06/22/87	06/22/87	06/22/87
SAMPLE LOCATION:	E. Quarry Discharge	S. Pickle Liq Ditch	S. Boat Launch	S. Steel Plant Yd	N. Black R Downgradnt
ALUMINUM	921	2400	2860	3620	3640
ANTIMONY	35U	14U	15U	26U	15U
ARSENIC	17U RJ	6.6U RJ	7.1U RJ	13U RJ	8.3 RJ
BARIUM	[82]	[94]	[24]	[90]	[42]
BERYLLIUM	1.7U	0.66U	0.71U	1.2U	0.69U
CADMIUM	8.3U	3.3U	3.6U	6.3U	3.5U
CALCIUM	[651]	3780	[2710]	16000	[2650]
CHROMIUM	[16]	22	16	178	40
COBALT	8.3U	[4]	[4]	6.3U	[5]
COPPER	81	94	88	50	38
IRON	521000	51200	24800	380000	85800
LEAD	27 RJ	63 RJ	47 RJ	26 RJ	24 RJ
MAGNESIUM	85U	[1280]	[872]	[3020]	[1730]
MANGANESE	138	554	451	5990	903
MERCURY	0.33U	0.32	0.34	0.25U	0.14U
NICKEL	13U	[23]	[15]	73	34
POTASSIUM	[777]	[550]	[430]	[536]	[489]
SELENIUM	8.3U RJ	3.3U RJ	3.6U RJ	6.3U RJ	3.5U RJ
SILVER	6.7U	2.6U	2.9U	5U	2.8U
SODIUM	1500U	591U	641U	1120U	624U
THALLIUM	17U	6.6U	7.1U	13U	6.9U
TIN	27U	11U	11U	20U	98
VANADIUM	[34]	[7.5]	[6.7]	[32]	[12]
ZINC	[17]	79	46	84	62
CYANIDE	1.8 RJ	0.66U RJ	0.71U RJ	0.63U RJ	0.69U RJ

NOTE: All concentrations are presented in mg/kg.
[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.
U The element was analyzed for, but not detected.
R The spike sample recovery is not within control limits.
J The value presented is estimated.

TABLE F-13 (Continued)
REPUBLIC STEEL QUARRY RI
SURFACE SOIL SAMPLING
INORGANIC ANALYSES

SAMPLE NO:	SS006	SS007	SS008	SS009	SS010
SAMPLE DATE:	06/22/87	06/22/87	06/22/87	06/23/87	06/23/87
SAMPLE LOCATION:	N. Offsite Background	W. Offsite Background	SS001 Split	Bottle Blank	Sampler Blank
ALUMINUM	9860	7980	801	8810	9510
ANTIMONY	15U	14U	17U	12U	12U
ARSENIC	7U RJ	6.6U RJ	23 RJ	5.6U RJ	5.6U RJ
BARIUM	[66]	[55]	[60]	146	153
BERYLLIUM	[0.98]	[0.92]	0.81U	[1.3]	[1.3]
CADMIUM	3.5U	3.3U	5	2.8U	2.8U
CALCIUM	[1250]	[1660]	[355]	11800	12400
CHROMIUM	8.4	9.6	16	13	12
COBALT	[11]	[8]	4U	[12]	[13]
COPPER	[11]	31	77	39	41
IRON	20900	19200	377000	19400	21100
LEAD	30 RJ	32 RJ	21 RJ	11 RJ	11 RJ
MAGNESIUM	[1800]	[1990]	41U	3300	3520
MANGANESE	823	631	98	470	500
MERCURY	0.14U	0.13U	0.16U	0.11U	0.11U
NICKEL	[12]	[15]	6.5U	29	30
POTASSIUM	[554]	[875]	[669]	[1350]	[1420]
SELENIUM	3.5U RJ	3.3U RJ	4U RJ	2.8U RJ	2.8U RJ
SILVER	2.8U	2.6U	3.2U	2.2U	2.2U
SODIUM	632U	591U	724U	499U	499U
THALLIUM	7U	6.6U	8.1U	5.6U	5.6U
TIN	11U	11U	13U	8.9U	8.9U
VANADIUM	[20]	[17]	[26]	[16]	[17]
ZINC	62	84	24	122	135
CYANIDE	0.7U RJ	0.66U RJ	1 RJ	0.56U RJ	0.56U RJ

NOTE: All concentrations are presented in mg/kg.
[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.
U The element was analyzed for, but not detected.
R The spike sample recovery is not within control limits.
J The value presented is estimated.

TABLE F-14
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW001	GW003	GW007	GW009	GW011
SAMPLING DATE:	08/18/87	08/18/87	08/18/87	08/19/87	08/18/87
SAMPLE LOCATION:	BOTTLE BLANK	BAILER BLANK	ELYRIA WATER	WELL B-7	WELL B-2
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	4 J	8	11	5 U	6
Acetone	10 U	10 U	10 U	10 U	10 U
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	74	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	19	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	5 U	5 U	5 U	5 U	5 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	5 U	3 J	2 J	5 U	1 J
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-14 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW013	GW015	GW017	GW019	GW021
SAMPLING DATE:	08/18/87	08/19/87	08/19/87	08/19/87	08/20/87
	WELL B-2	WELL B-1	WELL B-8	WELL B-6	WELL B-5
SAMPLE LOCATION:	SPLIT				
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	5 U	140	5 U	5 U	5 U
Acetone	10 U	55	10 U	10 U	10 U
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	9	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	5 U	5 U	5 U	5 U	5 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	5 U	4 J	2 J	5 U	5 U
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-14 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW023	GW025	GW101	GW102	GW103
SAMPLING DATE:	08/20/87	08/20/87	03/14/88	03/14/88	03/14/88
SAMPLE LOCATION:	WELL B-4	WELL B-3	Bottle Blank	Sampler Blank	Well B-1
Chloromethane	10 U	10 U	10 U	10 U	10 U
Bromomethane	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U
Methylene Chloride	3 J	5 U	3 J	5 U	5 U
Acetone	10 U	10 U	10 U	10 U	10 U
Carbon Disulfide	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethene	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	5 U	5 U	5 U
Trans-1,2-Dichloroethene	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
Trichloroethene	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropene	5 U	5 U	5 U	5 U	5 U
2-Chloroethylvinylether	10 U	10 U	10 U	10 U	10 U
Bromoform	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	5 U	5 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	5 U	5 U	5 U
Toluene	5 U	5 U	1 J	5 U	1 J
Chlorobenzene	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	5 U	5 U	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
- U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
- J Indicates an estimated value.
- B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-14 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
VOLATILE ORGANIC ANALYSES

SAMPLE NUMBER: GW104
SAMPLING DATE: 03/14/88
SAMPLE LOCATION: WELL B-3

Chloromethane	10 U
Bromomethane	10 U
Vinyl Chloride	10 U
Chloroethane	10 U
Methylene Chloride	5 U
Acetone	10 U
Carbon Disulfide	5 U
1,1-Dichloroethene	5 U
1,1-Dichloroethane	5 U
Trans-1,2-Dichloroethene	5 U
Chloroform	5 U
1,2-Dichloroethane	5 U
2-Butanone	10 U
1,1,1-Trichloroethane	5 U
Carbon Tetrachloride	5 U
Vinyl Acetate	10 U
Bromodichloromethane	5 U
1,2-Dichloropropane	5 U
Trans-1,3-Dichloropropene	5 U
Trichloroethene	5 U
Dibromochloromethane	5 U
1,1,2-Trichloroethane	5 U
Benzene	5 U
cis-1,3-Dichloropropene	5 U
2-Chloroethylvinylether	10 U
Bromoform	5 U
4-Methyl-2-Pentanone	10 U
2-Hexanone	10 U
Tetrachloroethene	5 U
1,1,2,2-Tetrachloroethane	5 U
Toluene	4 J
Chlorobenzene	5 U
Ethylbenzene	5 U
Styrene	5 U
Total Xylenes	5 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-15
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW001	GW003	GW007	GW009	GW011
SAMPLING DATE:	08/18/87	08/18/87	08/18/87	08/19/87	08/18/87
SAMPLE LOCATION:	BOTTLE BLANK	BAILER BLANK	ELYRIA WATER	WELL B-7	WELL B-2
Phenol	10 U	10 U	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	50 U	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-15 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW001	GW003	GW007	GW009	GW011
SAMPLING DATE:	08/18/87	08/18/87	08/18/87	08/19/87	08/18/87
SAMPLE LOCATION:	BOTTLE BLANK	BAILER BLANK	ELYRIA WATER	WELL B-7	WELL B-2
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	10 U	10 U	10 U	10 U	10 U
4-Nitrophenol	10 U	10 U	10 U	10 U	10 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	10 U	10 U	10 U	10 U	10 U
4,6-Dinitro-2-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	10 U	10 U	10 U	5 J	10 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	7 UJ	9 UJ	10 UJ	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	3 J	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 UJ	10 UJ	10 UJ	10 U	10 U
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
- U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
- J Indicates an estimated value.
- B Indicates the analyte was found in the laboratory blank sample as well as the sample.
- R The results of this analyte have been rejected due to laboratory quality quality control problems during analysis.
- (1) Cannot be separated from diphenylamine.

TABLE F-15 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW013	GW015	GW017	GW019	GW021
SAMPLING DATE:	08/18/87	08/19/87	08/19/87	08/19/87	08/20/87
	WELL B-2	WELL B-1	WELL B-8	WELL B-6	WELL B-5
SAMPLE LOCATION:	SPLIT				
Phenol	10 U	10	10 U	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
Benzyl Alcohol	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
Benzoic Acid	50 U	42 J	50 U	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U	50 U	50 U	50 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	50 U	50 U	50 U	50 U	50 U
Dimethyl Phthalate	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	50 U	50 U	50 U	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-15 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW013	GW015	GW017	GW019	GW021
SAMPLING DATE:	08/18/87	08/19/87	08/19/87	08/19/87	08/20/87
	WELL B-2	WELL B-1	WELL B-8	WELL B-6	WELL B-5
SAMPLE LOCATION:	SPLIT				
Acenaphthene	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	10 U	10 U	10 U	10 U	10 U
4-Nitrophenol	10 U	10 U	10 U	10 U	10 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	10 U	10 U	10 U	10 U	10 U
4,6-Dinitro-2-Methylphenol	10 U	10 U	10 U	10 U	10 U
N-Nitrosodiphenylamine(1)	10 U	10 U	10 U	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	10 U	10 U	10 U	10 U	10 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Di-n-Butylphthalate	3 J	10 U	10 U	10 U	4 UJ
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U	20 U	20 U	20 U
Benzo(a)Anthracene	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10	11 B	10 U	10 U	10 UJ
Chrysene	10 U	10 U	10 U	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U	10 U	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-15 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW023	GW025
SAMPLING DATE:	08/20/87	08/20/87
SAMPLE LOCATION:	WELL B-4	WELL B-3
Phenol	10 U	10 U
bis(-2-Chloroethyl)Ether	10 U	10 U
2-Chlorophenol	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U
Benzyl Alcohol	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U
2-Methylphenol	10 U	10 U
bis(2-chloroisopropyl)Ether	10 U	10 U
4-Methylphenol	10 U	10 U
N-Nitroso-Di-n-Propylamine	10 U	10 U
Hexachloroethane	10 U	10 U
Nitrobenzene	10 U	10 U
Isophorone	10 U	10 U
2-Nitrophenol	10 U	10 U
2,4-Dimethylphenol	10 U	10 U
Benzoic Acid	50 U	50 U
bis(-2-Chloroethoxy)Methane	10 U	10 U
2,4-Dichlorophenol	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U
Naphthalene	10 U	10 U
4-Chloroaniline	10 U	10 U
Hexachlorobutadiene	10 U	10 U
4-Chloro-3-Methylphenol	10 U	10 U
2-Methylnaphthalene	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U
2,4,5-Trichlorophenol	50 U	50 U
2-Chloronaphthalene	10 U	10 U
2-Nitroaniline	50 U	50 U
Dimethyl Phthalate	10 U	10 U
Acenaphthylene	10 U	10 U
3-Nitroaniline	50 U	50 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.

TABLE F-15 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
SEMIVOLATILE ORGANIC ANALYSES

SAMPLE NUMBER:	GW023	GW025
SAMPLING DATE:	08/20/87	08/20/87
SAMPLE LOCATION:	WELL B-4	WELL B-3
Acenaphthene	10 U	10 U
2,4-Dinitrophenol	10 U	10 U
4-Nitrophenol	10 U	10 U
Dibenzofuran	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U
Diethylphthalate	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U
Fluorene	10 U	10 U
4-Nitroaniline	10 U	10 U
4,6-Dinitro-2-Methylphenol	10 U	10 U
N-Nitrosodiphenylamine(1)	10 U	10 U
4-Bromophenyl-phenylether	10 U	10 U
Hexachlorobenzene	10 U	10 U
Pentachlorophenol	10 U	10 U
Phenanthrene	10 U	10 U
Anthracene	10 U	10 U
Di-n-Butylphthalate	3 UJ	10 UJ
Fluoranthene	10 U	10 U
Pyrene	10 U	10 U
Butylbenzylphthalate	10 U	10 U
3,3'-Dichlorobenzidine	20 U	20 U
Benzo(a)Anthracene	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 UJ	10 UJ
Chrysene	10 U	10 U
Di-n-Octyl Phthalate	10 U	10 U
Benzo(b)Fluoranthene	10 U	10 U
Benzo(k)Fluoranthene	10 U	10 U
Benzo(a)Pyrene	10 U	10 U
Indeno(1,2,3-cd)Pyrene	10 U	10 U
Dibenz(a,h)Anthracene	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.
J Indicates an estimated value.
B Indicates the analyte was found in the laboratory blank sample as well as the sample.
(1) Cannot be separated from diphenylamine.

TABLE F-16
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
PESTICIDE/PCB's AND SAS ORGANIC ANALYSES

SAMPLE NUMBER:	GW001	GW003	GW007	GW009	GW011
SAMPLING DATE:	08/18/87	08/18/87	08/18/87	08/19/87	08/18/87
SAMPLE LOCATION:	BOTTLE BLANK	BAILER BLANK	ELYRIA WATER	WELL B-7	WELL B-2
Alpha-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Beta-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Delta-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Gamma-BHC(Lindane)	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Heptachlor	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Aldrin	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Heptachlor Epoxide	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Endosulfan I	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Dieldrin	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDE	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Endrin	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Endosulfan II	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDD	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Endosulfan Sulfate	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDT	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Methoxychlor	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Endrin Ketone	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Chlordane	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Alpha-Chlordane	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Gamma-Chlordane	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1221	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1232	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1242	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1248	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	5000 U	5000 U	5000 U	5000 U	5000 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.

TABLE F-16 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
PESTICIDE/PCB's AND SAS ORGANIC ANALYSES

SAMPLE NUMBER:	GW013	GW015	GW017	GW019	GW021
SAMPLING DATE:	08/18/87	08/19/87	08/19/87	08/19/87	08/20/87
	WELL B-2	WELL B-1	WELL B-8	WELL B-6	WELL B-5
SAMPLE LOCATION:	SPLIT				
Alpha-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Beta-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Delta-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Gamma-BHC(Lindane)	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Heptachlor	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Aldrin	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Heptachlor Epoxide	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Endosulfan I	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Dieldrin	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDE	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Endrin	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Endosulfan II	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDD	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Endosulfan Sulfate	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDT	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Methoxychlor	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Endrin Ketone	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Chlordane	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Alpha-Chlorodane	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Gamma-Chlordane	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Toxaphene	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1016	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1221	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1232	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1242	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1248	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Aroclor-1254	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Oil and Grease (SAS)	5000 U	5000 U	5000 U	5000 U	5000 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.

TABLE F-16 (Continued)
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
PESTICIDE/PCB's AND SAS ORGANIC ANALYSES

SAMPLE NUMBER:	GW023	GW025
SAMPLING DATE:	08/20/87	08/20/87
SAMPLE LOCATION:	WELL B-4	WELL B-3
Alpha-BHC	0.05 U	0.05 U
Beta-BHC	0.05 U	0.05 U
Delta-BHC	0.05 U	0.05 U
Gamma-BHC(Lindane)	0.05 U	0.05 U
Heptachlor	0.05 U	0.05 U
Aldrin	0.05 U	0.05 U
Heptachlor Epoxide	0.05 U	0.05 U
Endosulfan I	0.05 U	0.05 U
Dieldrin	0.10 U	0.10 U
4,4'-DDE	0.10 U	0.10 U
Endrin	0.10 U	0.10 U
Endosulfan II	0.10 U	0.10 U
4,4'-DDD	0.10 U	0.10 U
Endosulfan Sulfate	0.10 U	0.10 U
4,4'-DDT	0.10 U	0.10 U
Methoxychlor	0.50 U	0.50 U
Endrin Ketone	0.10 U	0.10 U
Chlordane	0.50 U	0.50 U
Alpha-Chlordane	0.50 U	0.50 U
Gamma-Chlordane	0.50 U	0.50 U
Toxaphene	1.00 U	1.00 U
Aroclor-1016	0.50 U	0.50 U
Aroclor-1221	0.50 U	0.50 U
Aroclor-1232	0.50 U	0.50 U
Aroclor-1242	0.50 U	0.50 U
Aroclor-1248	0.50 U	0.50 U
Aroclor-1254	1.00 U	1.00 U
Aroclor-1260	1.00 U	1.00 U
Oil and Grease (SAS)	5000 U	5000 U

NOTES: All concentrations are presented in micrograms per liter, ug/l.
U Indicates the compound was analyzed for but not detected. The value presented is the minimum attainable detection limit for the sample.

TABLE F-17
REPUBLIC STEEL QUARRY RI
GROUND WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	GW001	GW002	GW003	GW004	GW007
SAMPLE DATE:	08/18/87	08/18/87	08/18/87	08/18/87	08/18/87
SAMPLE LOCATION:	BOTTLE BLANK	BOTTLE BLANK	BAILER BLANK	BAILER BLANK	ELYRIA WATER
ALUMINUM	15 U	[18]	15 U	15 U	425
ANTIMONY	25 U	25 U	[57]	25 U	25 U
ARSENIC	10 U	10 U	10 U	10 U	10 U
BARIUM	3 U	3 U	3 U	3 U	[20]
BERYLLIUM	1 U	1 U	1 U	1 U	1 U
CADMIUM	4 U	4 U	4 U	4 U	4 U
CALCIUM	179 U	[270]	179 U	[475]	36200
CHROMIUM	4 U	4 U	4 U	4 U	4 U
COBALT	9 U	9 U	9 U	9 U	9 U
COPPER	6 U	6 U	6 U	6 U	[11]
IRON	24 U	[45]	24 U	24 U	24 U
LEAD	5 U	5 U	5 U	5 U	5 U
MAGNESIUM	153 U	153 U	153 U	153 U	7860
MANGANESE	4 U	4 U	4 U	[8.7]	45
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	8 U	8 U	8 U	8 U	8 U
POTASSIUM	175 U	175 U	175 U	175 U	[1400]
SELENIUM	5 UR	5 UR	5 UR	5 UR	5 UR
SILVER	4 U	4 U	4 U	4 U	4 U
SODIUM	1090 U	[1110]	1090 U	1090 U	8920
THALLIUM	10 U	10 U	10 U	10 U	10 U
TIN	22 U	22 U	119	22 U	22 U
VANADIUM	7 U	7 U	7 U	7 U	7 U
ZINC	[6.8]	[15]	[8.7]	[18]	[6.5]
CYANIDE	10 U	NA	10 U	NA	10 U
HEXACHROME	5 U	5 U	5 U	5 U	5 U
TOTAL SUSPENDED SOLIDS	1000 U	NA	3000	NA	1000
TOTAL DISSOLVED SOLIDS	1000 U	NA	1000 U	NA	139000
TOTAL ALKALINITY	10000 U	NA	10000 U	NA	87300
ACIDITY	10000 U	NA	10000 U	NA	10000 U
CHLORIDE	3000 U	NA	3000 U	NA	19000
SULFATE	1000 U	NA	1000 U	NA	34000

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation and shipment for analysis.

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

R The spike sample recovery is not within control limits.

E The value is estimated due to the presence of interference.

TABLE F-17 (Continued)
REPUBLIC STEEL QUARRY RI
GROUND WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	GW008	GW009	GW010	GW011	GW012
SAMPLE DATE:	08/18/87	08/19/87	08/19/87	08/18/87	08/18/87
SAMPLE LOCATION:	ELYRIA WATER	WELL B-7	WELL B-7	WELL B-2	WELL B-2
ALUMINUM	250	2030	[32]	[114]	15 U
ANTIMONY	25 U	25 U	25 U	25 U	25 U
ARSENIC	10 U	13	10 U	10 U	10 U
BARIUM	[15]	[35]	[21]	[20]	[19]
BERYLLIUM	1 U	1 U	1 U	1 U	1 U
CADMIUM	4 U	4 U	4 U	5.1	4 U
CALCIUM	33500	69700	65600	120000	117000
CHROMIUM	4 U	4 U	4 U	4 U	4 U
COBALT	9 U	[9.4]	9 U	9 U	9 U
COPPER	6 U	6 U	6 U	6 U	6 U
IRON	24 U	153000	132000	426	120
LEAD	5 U	5 U	5 U	5 U	5 U
MAGNESIUM	7540	23100	21800	55400	54100
MANGANESE	[8]	3340	3160	145	137
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	8 U	[30]	[21]	8 U	8 U
POTASSIUM	[1420]	7480	6890	[3250]	[3280]
SELENIUM	5 UR	50 UR	50 UR	5 UR	5 UR
SILVER	4 U	[4.1]	4 U	4 U	4 U
SODIUM	19300	29700	31900	66000	72900
THALLIUM	10 U	10 U	10 U	10 U	10 U
TIN	22 U	22 U	22 U	22 U	22 U
VANADIUM	7 U	[8.7]	7 U	7 U	7 U
ZINC	[5.9]	77	36	[7.7]	21
CYANIDE	NA	10 U	NA	10 U	NA
HEXACHROME	5 U	5 U	5 U	5 U	5 U
TOTAL SUSPENDED SOLIDS	NA	20000	NA	31000	NA
TOTAL DISSOLVED SOLIDS	NA	697000	NA	733000	NA
TOTAL ALKALINITY	NA	420000	NA	425000	NA
ACIDITY	NA	10000 U	NA	10000 U	NA
CHLORIDE	NA	3000 U	NA	3000 U	NA
SULFATE	NA	242000	NA	242000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

R The spike sample recovery is not within control limits.

E The value is estimated due to the presence of interference.

TABLE F-17 (Continued)
REPUBLIC STEEL QUARRY RI
GROUND WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	GW013	GW014	GW015	GW016	GW017
SAMPLE DATE:	08/18/87	08/18/87	08/19/87	08/19/87	08/19/87
	WELL B-2	WELL B-2	WELL B-1	WELL B-1	WELL B-8
SAMPLE LOCATION:	SPLIT	SPLIT			
ALUMINUM	292	[30]	11600	75 U	5840
ANTIMONY	25 U	25 U	50 U	125 U	25 U
ARSENIC	10 U	10 U	10 U	10 U	10 U
BARIUM	[22]	[20]	[104]	[70]	[114]
BERYLLIUM	1 U	1 U	[2.1]	5 U	[1]
CADMIUM	4 U	[4]	8 U	20 U	6.4
CALCIUM	124000	117000	348000	352000	238000
CHROMIUM	4 U	4 U	[8.5]	20 U	[9.7]
COBALT	9 U	9 U	18 U	45 U	[13]
COPPER	[7.1]	6 U	12 U	30 U	[15]
IRON	616	130	571000	554000	15500
LEAD	5 U	5 U	5 U	5 U	5 U
MAGNESIUM	55300	53800	88000	83300	50800
MANGANESE	152	140	11600	11400	842
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	8 U	8 U	131	[96]	[24]
POTASSIUM	[3380]	[3300]	37200	31400	[4790]
SELENIUM	5 UR	5 UR	50 URE	50 URE	50 UR
SILVER	4 U	4 U	8 U	20 U	4 U
SODIUM	65800	73400	91100	87200	324000
THALLIUM	10 U	10 U	10 U	100 U	100 U
TIN	22 U	22 U	[73]	110 U	22 U
VANADIUM	7 U	7 U	[57]	35 U	[14]
ZINC	21	26	99	[44]	35
CYANIDE	10 U	NA	10 U	NA	10 U
HEXACHROME	5 U	5 U	5 U	5 U	5 U
TOTAL SUSPENDED SOLIDS	474000	NA	224000	NA	180000
TOTAL DISSOLVED SOLIDS	2210000	NA	3320000	NA	548000
TOTAL ALKALINITY	324000	NA	62500	NA	10000 U
ACIDITY	10000 U	NA	587000	NA	158000
CHLORIDE	808000	NA	38100	NA	37900
SULFATE	120000	NA	1760000	NA	360000

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

R The spike sample recovery is not within control limits.

E The value is estimated due to the presence of interference.

TABLE F-17 (Continued)
REPUBLIC STEEL QUARRY RI
GROUND WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	GW018	GW019	GW020	GW021	GW022
SAMPLE DATE:	08/19/87	08/19/87	08/19/87	08/20/87	08/20/87
SAMPLE LOCATION:	WELL B-8	WELL B-6	WELL B-6	WELL B-5	WELL B-5
ALUMINUM	15 U	10800	[17]	482 R	15 UR
ANTIMONY	25 U	25 U	25 U	25 U	25 U
ARSENIC	10 U	21	10 U	10 UR	10 U
BARIUM	[88]	[48]	[15]	[20]	[18]
BERYLLIUM	1 U	[1.6]	1 U	1 U	1 U
CADMIUM	[4.6]	4 U	4 U	[4.1]	4 U
CALCIUM	233000	170000	161000	477000	464000
CHROMIUM	4 U	20	4 U	4 U	4 U
COBALT	9 U	[18]	9 U	9 U	9 U
COPPER	6 U	28	6 U	6 U	6 U
IRON	738	46900	[61]	17400 R	15800 R
LEAD	5 U	19	5 U	5 U	5 U
MAGNESIUM	49300	53100	45400	33500	32300
MANGANESE	672	799	189	286	274
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	8 U	48	8 U	8 U	8 U
POTASSIUM	[2780]	6580	[3700]	[4850]	[4600]
SELENIUM	5 UR	50 UR	5 UR	50 UR	50 UR
SILVER	4 U	4 U	4 U	4 UR	4 UR
SODIUM	330000	62700	64400	55800	54000
THALLIUM	100 U	100 U	10 U	10 UR	10 UR
TIN	22 U	22 U	22 U	22 U	22 U
VANADIUM	7 U	[33]	7 U	7 U	7 U
ZINC	[15]	106	[9.5]	[15]	[11]
CYANIDE	NA	10 U	NA	10 U	NA
HEXACHROME	5 U	5 U	5 U	5 U	5 U
TOTAL SUSPENDED SOLIDS	NA	948000	NA	34000	NA
TOTAL DISSOLVED SOLIDS	NA	899000	NA	2220000	NA
TOTAL ALKALINITY	NA	209000	NA	280000	NA
ACIDITY	NA	10000 U	NA	10000 U	NA
CHLORIDE	NA	154000	NA	42500	NA
SULFATE	NA	270000	NA	935000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

R The spike sample recovery is not within control limits.

E The value is estimated due to the presence of interference.

TABLE F-17 (Continued)
REPUBLIC STEEL QUARRY RI
GROUND WATER SAMPLING
INORGANIC AND NON-ORGANIC SAS ANALYSES

SAMPLE NO:	GW023	GW024	GW025	GW026
SAMPLE DATE:	08/20/87	08/20/87	08/20/87	08/20/87
SAMPLE LOCATION:	WELL B-4	WELL B-4	WELL B-3	WELL B-3
ALUMINUM	2180 R	[24] R	[188] R	15 UR
ANTIMONY	25 U	82	25 U	25 U
ARSENIC	10 UR	10 UR	26 R	21 R
BARIUM	[16]	[8.2]	38	[38]
BERYLLIUM	1 U	1 U	1 U	1 U
CADMIUM	4 U	[4.5]	4 U	6.8
CALCIUM	31500	30200	130000	129000
CHROMIUM	[7]	4 U	4 U	4 U
COBALT	9 U	9 U	9 U	9 U
COPPER	[7.9]	6 U	6 U	6 U
IRON	2450 R	[70] R	647 R	186 R
LEAD	5 U	5 U	5 U	5 U
MAGNESIUM	16600	15700	63300	62700
MANGANESE	32	[6.2]	661	658
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	[8.5]	8 U	[14]	[15]
POTASSIUM	5360	[4720	[3070]	[3070]
SELENIUM	5 UR	5 UR	50 UR	50 UR
SILVER	4 UR	4 UR	4 UR	4 UR
SODIUM	143000	139000	75400	75500
THALLIUM	10 UR	10 UR	10 UR	100 UR
TIN	22 U	115	22 U	22 U
VANADIUM	7 U	[7]	7 U	7 U
ZINC	[13]	[7.7]	[9.3]	[9.1]
CYANIDE	10 U	NA	10 U	NA
HEXACHROME	5 U	5 U	5 U	5 U
TOTAL SUSPENDED SOLIDS	37000	NA	13000	NA
TOTAL DISSOLVED SOLIDS	744000	NA	952000	NA
TOTAL ALKALINITY	417000	NA	414000	NA
ACIDITY	10000 U	NA	10000 U	NA
CHLORIDE	6500	NA	5500	NA
SULFATE	27200	NA	264000	NA

NOTE: All concentrations are presented in ug/l. Even numbered samples represent the previous odd numbered sample which was filtered through a 0.45 micron filter prior to preservation

[] The value presented in brackets is greater than or equal to the instrument detection limit, but less than the contract required detection limit.

U The element was analyzed for, but not detected.

NA The sample was not analyzed for this parameter. Laboratory analysis was not requested for the sample for the given parameters.

R The spike sample recovery is not within control limits.

E The value is estimated due to the presence of interference.

TABLE F-18
REPUBLIC STEEL QUARRY RI
GROUNDWATER SAMPLING
LABORATORY pH READINGS

SAMPLE NUMBER	SAMPLING DATE	SAMPLE LOCATION	LABORATORY pH
GW001/002	8/18/87	Bottle Blank	6.0
GW003/004	8/18/87	Bailer Blank	6.0
GW007/008	8/18/87	Elyria Water	6.0
GW009/010	8/19/87	Well B-7	5.5
GW011/012	8/18/87	Well B-2	6.5
GW013/014	8/18/87	Well B-2	6.5
GW015/016	8/19/87	Well B-1	6.0
GW017/018	8/19/87	Well B-8	6.0
GW019/020	8/19/87	Well B-6	NR
GW021/022	8/20/87	Well B-5	7.0
GW023/024	8/20/87	Well B-4	7.0
GW025/026	8/20/87	Well B-3	7.0
GW101	3/14/88	Bottle Blank	NR
GW102	3/14/88	Sampler Blank	NR
GW103	3/14/88	Well B-1	NR
GW104	3/14/88	Well B-3	NR

NOTES: NR Not Reported by Laboratory

APPENDIX G

DATA CONSIDERATIONS

APPENDIX G

DATA CONSIDERATIONS

G.1 QA/QC ASSESSMENT - LABORATORY AND EPA PROTOCOL

All of the data developed during the remedial investigation and presented on the various summary tables have been reviewed in accordance with EPA CLP quality assurance protocols. Requirements for the organic and inorganic routine analytical services quality control and the CLP quality assurance guidelines are provided in EPA's User's Guide to the Contract Laboratory Program (July 1984). All data results and supporting raw data have been reviewed by EPA Region V technical staff. During this review, a number of analytical problems were identified and presented on EPA Organic and Inorganic QA checklists. The requirements for the Special Analytical Services (SAS) analyses performed during the RI were specified on the SAS requests included in the RI/FS Quality Assurance Project Plan dated February 13, 1987. The majority of the data were found to be usable even with the qualification noted on the QA review sheets. A list of significant analytical problems is present in Tables G-1 through G-4. Constituent concentrations invalidated by the QA review were omitted from the summary tables.

There were two significant data quality problems identified during data evaluation. These problems were the invalidation of some of the semi-volatile organic analyses from both samplings of the quarry water, and the inconsistent inorganic data from filtered and unfiltered water samples.

Seventeen of the semi-volatile analyses performed on samples of quarry water obtained in June 1987 were rejected during data validation by EPA. Additionally, seven of the semi-volatile analyses performed on quarry water samples from the March 1988 sampling were also rejected. The analyses were performed by two different laboratories and on both occasions samples were rejected for low surrogate spike recoveries. Since two independent laboratories had the same problems, it is believed quarry water chemistry is responsible. Only the seven samples from the quarry at or below 35 ft. depth were rejected during the March 1988 sampling program. These deeper waters were determined to have a complex chemistry, having high conductivity, acidity and metals concentrations, and low dissolved oxygen. The cause of the data rejection in both cases was poor spike recoveries. The cause of the spike recovery problems was either due to chemical, physical or matrix interferences.

It is normally expected that the metals detected in filtered water samples will be less than or equal to concentrations detected in unfiltered samples. However, for water samples analyzed during this RI, in many cases inorganics were detected at higher concentrations in filtered samples than in unfiltered samples. This occurred inconsistently, with various metals for a given sample set (filtered/unfiltered portions at one location) being either higher or lower in the filtered sample. Although the analyses are suspect, this problem does not affect the RI results. To

TABLE G-1
GROUNDWATER DATA QUALIFIERS SUMMARY
REPUBLIC STEEL QUARRY RI

Sample Nos.	Sample Type	Analyses	Qualifiers
GW001-GW025 (odd sample nos.)	Groundwater	Organic (Volatile, Semi-Volatile, Pesticide/PCBs)	Semi-volatile blanks had detectable levels of di-n-butylphthalate and bis(2-ethyl hexyl) phthalate. Data usable with caution. Percent recoveries for several surrogate spike compounds were outside QC limits in GW007, GW009, GW015, GW023 and GW029 for the semi-volatile fraction. Data usable with caution. Percent recovery for surrogate dibutylchlorendate was above QC limit in GW003 for the pesticide fraction. Data usable with caution. Matrix spike and matrix spike duplicate percent recoveries for n-nitrosodi-n-propylamine and 2,4-dinitrotoluene were above QC limits for the BNA fractions. Data usable with caution. Matrix spike and matrix spike, duplicate percent recoveries for 4-chloro-3-methylphenol and 4-nitrophenol were above QC limits for the acid fraction. Data usable with caution. Matrix spike duplicate recovery for endrin was above QC limit for the pesticide fraction. Data usable with caution.
GW001-GW020	Groundwater	Inorganic (Metals)	Selenium data is estimated and flagged with "R" in GW001 through GW026 due to low spike recoveries. Data usable with caution. Selenium value not reported and flagged with "E" in GW015 and GW016 due to interference. Data usable with caution. Aluminum, iron, silver and thallium data are estimated and are flagged with "R" in GW021 through GW026 due to low spike recoveries. Data usable with caution. Arsenic data are estimated and are flagged with "R" in GW025 and GW026 due to high spike recoveries. Data usable with caution.

TABLE G-1 (Continued)
GROUND WATER DATA QUALIFIERS SUMMARY
REPUBLIC STEEL QUARRY RI

Sample Nos.	Sample Type	Analyses	Qualifiers
GW001-GW025 (odd sample nos.)	Groundwater	SAS	None
GW001-GW026	Groundwater	Hexavalent Chromium	None

TABLE G-2
SURFACE WATER DATA QUALIFIERS SUMMARY
REPUBLIC STEEL QUARRY RI

Sample Nos.	Sample Type	Analyses	Qualifiers
SW001-SW054	Surface Water	Organic (Volatiles, Semi-Volatiles, Pesticides/PCBs)	Re-extracted samples SW007/008, SW011/012, SW017/018 through SW021/022 and SW045/046 through SW049/050 exceeded required holding times. Data usable with caution. Volatile blank MBL5 had detectable level of ethylbenzene. This compound was detected in matrix spike and matrix spike duplicate for SW039/040 at less than 5 times the blank concentration. Data usable with caution. BNA data are not usable SW007/008, SW011/012, SW017/018 through SW021/022 and SW045/046 through SW049 due to low surrogate spike recoveries and are not presented inthe laboratory results. Data not usable. BNA data are not usable for SW017/018 through SW029/030, SW033/034 and SW037/038 through SW045/046 due to poor instrument performance and are not presented in the laboratory rsults. Data not usable.
SW001-SW038	Surface Water	Inorganic (Metals plus Cyanide)	Cyanide data for SW005 and SW021 is not usable and flagged with "P" due to improper preservation. Data not usable. Cyanide samples exceeded required holding time by one day. Data usable with caution. Selenium data for SW020, SW021 and SW022 is not usable and flagged with "V" due to low spike recovery. Data not usable. Samples SW015, SW017 and SW026 were improperly preserved. Data usable with caution.
SW039-SW054	Surface Water	Inorganic (Metals plus Cyanide)	None

TABLE G-2 (Continued)
SURFACE WATER DATA QUALIFIERS SUMMARY
REPUBLIC STEEL QUARRY RI

Sample Nos.	Sample Type	Analyses	Qualifiers
SW001-SW053 (odd sample nos.)	Surface Water	SAS	Oil and grease data for all samples with exception of SW037-SW047 and SW053 are estimated and flagged with "J" due to low spike recoveries. Data usable with caution.
SW001-SW054	Surface Water	Hexavalent Chromium	None
GW101-GW104 and SW121	Groundwater/ Surface Water	Organic (Volatiles)	Volatile blanks 1 and 2 contained estimated quantities of methylene chloride and trichloroethane, respectively. Data usable with caution. Toluene was detected at concentrations below detection limits in GW103 and GW104. Estimated levels of this compound are flagged with "J' for these samples. Data usable with caution.
SW101-SW116	Surface Water	Organic (Semi-Volatiles)	Negative results for the semi-volatile fraction have been flagged with "R" for SW103, SW106, and SW116 due to surrogate recoveries below QC limits. Data not usable. Pentachlorophenol and 4-nitrophenol exceeded QC limits for relative percent difference for the acid fraction. Data usable with caution.
SW101-SW115	Surface Water	Organic (Pesticides/PCBs)	SW110 matrix spike and matrix spike duplicate percent recoveries for endrin and 4,4-DDT were above QC limits for the pesticide fraction. Data usable with caution.
SW117-SW120, SW122-SW129	Surface Water	Organic (Semi-Volatile Pesticide/PCBs)	Negative results for the semi-volatile fraction are flagged with "R" for SW117, SW118, and SW129 due to surrogate recoveries below QC limits. Data not usable.

TABLE G-3
SEDIMENT QUALIFIERS SUMMARY
REPUBLIC STEEL QUARRY RI

Sample Nos.	Sample Type	Analyses	Qualifiers
SD001-SD015	Sediment	Organic (Volatile, Semi-Volatile, Pesticides/PCBs)	For SD008, the holding time for ABN and pesticide fractions was exceeded by one day. Data usable with caution. For SD015, the holding time for pesticide fraction was exceeded by 7 days. Data usable with caution. VOA blanks showed methylene chloride, toluene, acetone, 2-butanone, 2-hexanone, tetrachloroethylene, 1,1,2,2-tetrachloroethane, ethyl benzene, styrene, and xylene in low concentration. Positive results for these compounds are flagged with "J" and negative results with "UJ". Data usable with caution. BNA blanks showed diethylphthalate and bis(2-ethyl hexyl) phthalate below detection limits. Positive results for the above compounds are flagged with "J" and negative results with "UJ". Data usable with caution. The VOA surrogate recoveries for toluene for SD005, SD008, SD009, SED011 are outside QC limits. Results for this compound are estimated and are flagged with "J". Data usable with caution. The Pesticide/PCB fraction of the SD006 and SD015 matrix spike and the SD015 matrix spike duplicate had no surrogate recovery for DBC. Data usable with caution. The matrix spike and matrix spike duplicate for toluene in sample SD012 was outside QC limits. Data usable with caution. 4-nitrophenol recovery was high in both the matrix spike and matrix spike duplicate for SD014. Data usable with caution. Matrix spike recoveries for aldrin, heptachlor and endrin were outside QC limits. Data usable with caution.

TABLE G-3 (Continued)
SEDIMENT DATA QUALIFIERS SUMMARY
REPUBLIC STEEL QUARRY RI

Sample Nos.	Sample Type	Analyses	Qualifiers
SD001-SD015	Sediment	Inorganic (Metals plus Cyanide)	For SD001-SD007, matrix spike recoveries were outside QC limits for arsenic, cyanide, selenium and lead. Results for these compounds are estimated and flagged with "J". Data usable with caution. For SD008-SD015, CN results are unusable due to matrix spike recovery of 0%. Results are flagged with "V". Data not usable. For SD008-SD015, Sb matrix spike recoveries were outside QC limit. Negative results are estimated and flagged with "UJ". Data usable with caution. For SD008-SD015, calcium data is estimated and flagged "E" due to interferences during analyses. Data usable with caution.
SD001-SD015	Sediment	SAS	None

TABLE G-4
SOIL DATA QUALIFIERS SUMMARY
REPUBLIC STEEL QUARRY RI

Sample Nos.	Sample Type	Analyses	Qualifiers
SS001-SS010	Soil	Organic (Volatile, Semi-Volatile, Pesticides/PCBs)	The surrogate matrix spike and matrix spike duplicate for SS001 had high recoveries for 2-fluoro biphenyl and 2,4,6-tribromo phenol. Data usable with caution. The matrix spike and matrix spike duplicate recoveries for toluene in sample SS009 were high. Data usable with caution. In SS004, matrix spike and matrix spike duplicate recoveries were low for 2,4-nitroluene and pentachlorophenol. Data usable with caution. 8 out of 11 matrix spike recoveries were outside QC limits for SS001. Data usable with caution. In SS005, matrix spike recovery for aldrin and matrix spike duplicate recovery for heptachlor were outside QC limits. Data usable with caution.
SS001-SS010	Soil	Inorganic (Metals plus Cyanide)	Matrix spike recoveries are outside QC limits for arsenic, cyanide, selenium and lead. Positive results for these elements are estimated and flagged with "J". Data usable with caution.
SS001-SS010	Soil	SAS	None

be conservative, the highest concentration of inorganics detected, whether from filtered or unfiltered samples, was used to analyze the extent of contamination and assess risks. See Figures G-1 and G-2.

During the review of the quality control data supplied by the contract laboratories (CLP), several organic compounds were noted to have been detected in low concentrations in some of the laborer-prepared blank samples and in some of the field-prepared blank samples. As a result, analytical results for environmental samples that also detected these constituents were used with caution. Positive results for these compounds may be due to laboratory glassware or sample container contamination. When contaminants were detected in laboratory blanks, the sample results were reported with an appropriate qualifier indicating the contaminants was found in the blank. The use of these data is therefore limited. Additional discussion of field blanks is presented in Section G.2.

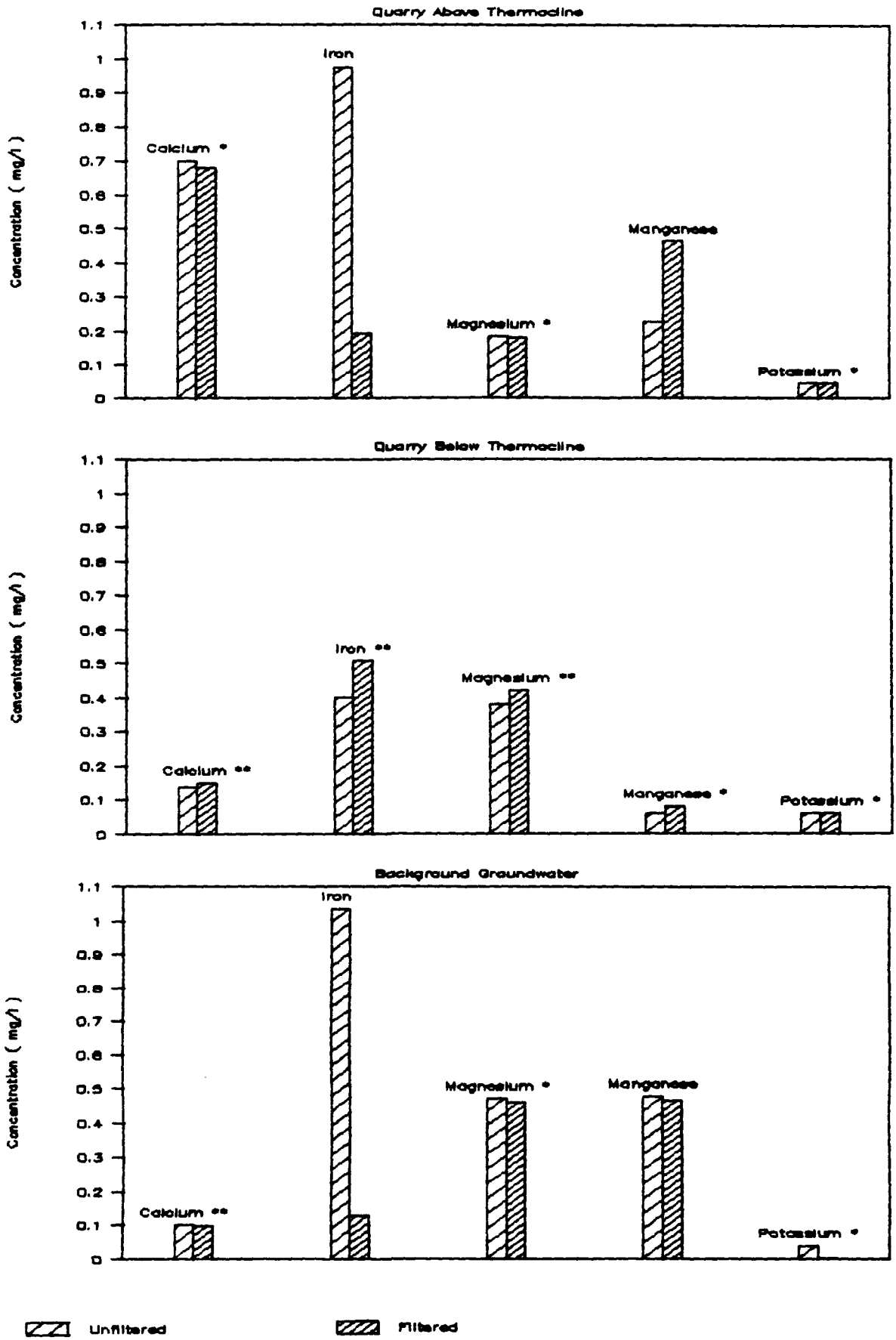
All of the laboratories used under the CLP program provided proper certification that the control detection limits were met by their analytical instrumentation. However, for individual samples, several factors may cause a reduction in sensitivity that raises the detectable concentration above normal limits. Some of these influences include matrix effects, extraction procedures, moisture content (soils and sediments), and high concentrations of one or more constituents in a sample which dictates that a sample or its extract be diluted prior to analysis. Thus, the limits contract detection limits should be considered as the lower limits of detection for the parameters.

G.2 In-Field Protocol

In addition to the required CLP quality control procedures and EPA's review, in-field procedures were implemented to provide additional quality control data. These procedures are presented in the RI/FS Phase I QA Project Plan dated February 13, 1987. The QA Project Plan (QAPP) is required by EPA for all contractors to assure the precision, accuracy, completeness, and representative of all generated data that is known and documented. Therefore, the QAPP presents, in specific terms, the policies, organization objectives, functional activities, and specific QC and quality control activities designed to achieve the data quality goals of this report.

In accordance with procedures outlined in the QAPP, duplicate samples and field blanks were obtained for each medium sample. The actual number of duplicate samples and field blanks varied for each medium and are presented as follows:

Medium	Duplicate Samples	Field Blanks
Surface Water	4	5
Sediment	2	3
Groundwater	4	1
Soil	1	2



NOTES:

* CONCENTRATION/100

** CONCENTRATION/1000

FIGURE G-1
FILTERED VS. UNFILTERED
SAMPLES METAL CONCENTRATIONS
REPUBLIC STEEL QUARRY RI

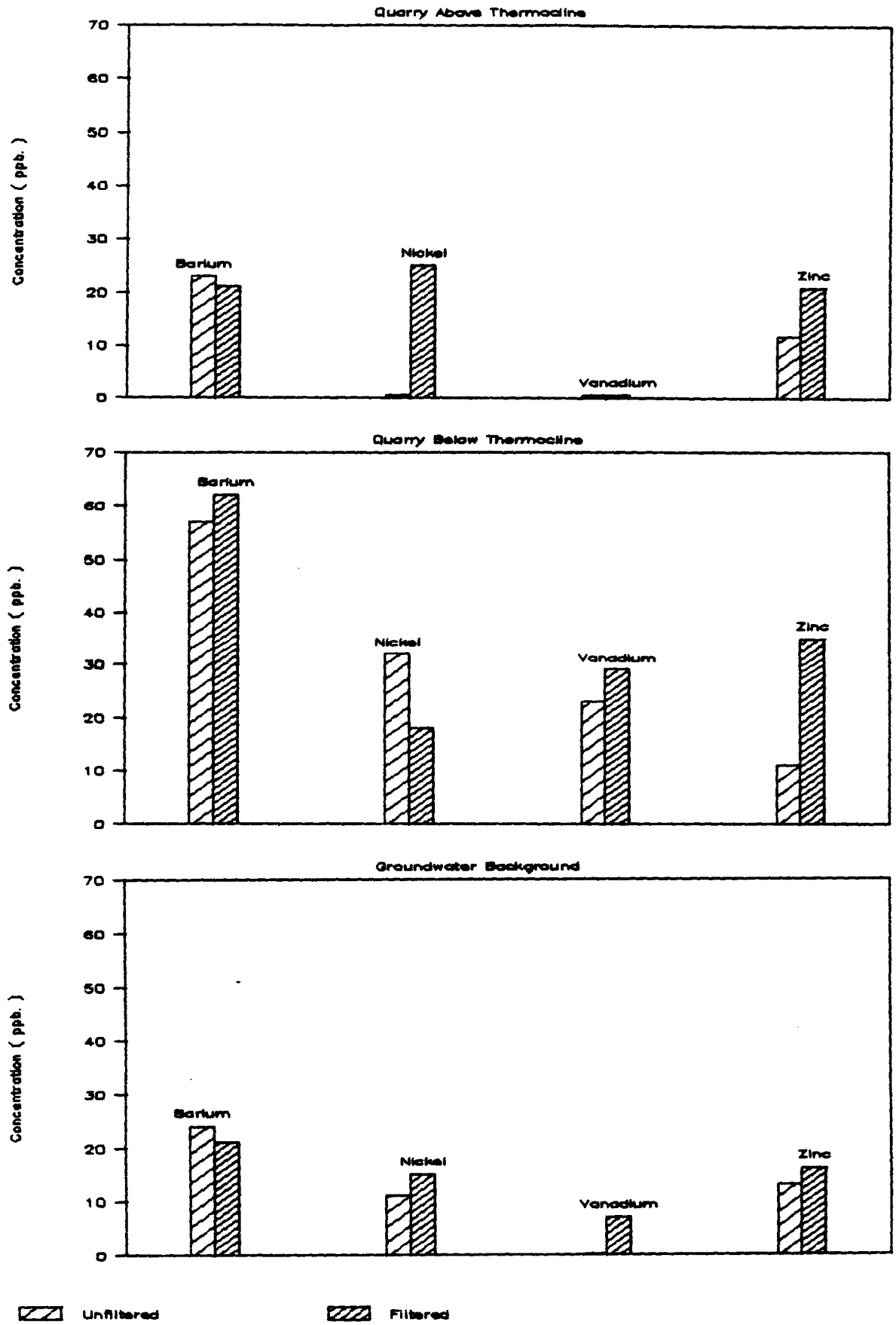


FIGURE G-2
FILTERED VS. UNFILTERED
SAMPLES METAL CONCENTRATIONS
REPUBLIC STEEL QUARRY RI

Field blanks for each medium were obtained and included in the laboratory analyses. The surface water and groundwater field blanks were distilled water while field blanks for the sediment and soil consisted of a supply of blank soil maintained by ICF. The field blanks were provided to detect any possible introduction of contaminants through sampling or laboratory handling procedures.

Duplicate samples were two distinct samples taken from the same location during a very short period of time using identical equipment that was decontaminated in a similar manner and placed in two identical sets of sample bottles. The purpose of duplicate sampling was to obtain an estimate of variability due to sampling.

The quality assurance samples obtained in the field were used to evaluate the nature and extent of site related contamination. These analyses are discussed on a media-by-media basis in Sections 4.0 through 7.0 of this report.

G.3 ENVIRONMENTAL SAMPLING VARIABILITY

When attempting to identify site related chemicals or contamination, criteria must be established to distinguish background concentrations from those that are site related. These criteria are established in an attempt to eliminate influences from the normal variability of concentrations that occurs during environmental sampling. In Sections 4 through 7 of the RI, which examined contamination in surface water, sediments, soils and groundwater, the criteria used to identify site-related chemicals was when the concentrations in samples exceeded twice the background concentration.

The rationale for the selection of two times the background concentration as an evaluation criterion is due to the highly variable nature of environmental sampling. Many different factors affect each sample collected, including decontamination of sampling equipment, field QA procedures, sample homogeneity, laboratory analytical QA procedures and natural variation in environmental media chemical concentrations at different locations. To illustrate these factors influencing variability in sample concentrations, a media by media examination of split sample concentrations was performed. Split samples were collected during the field investigations at the same location, mixed and placed in sample jars to attempt to obtain identical reproducible data. As such, the split samples do not include variation due to natural changes in chemical concentrations at different locations.

Surface Water

Samples SW019 and SW021 were unfiltered split samples collected from the quarry at Buoy 5/6 at 60 ft. depth. The following parameters display the highly variable results from environmental sampling:

	SW019 (ug/l)	SW021 (ug/l)	Ratio (SW021/SW019)
Calcium	149000	251000	1.7
Iron	485000	1150000	2.4
Magnesium	39500	67500	1.7
Manganese	7980	18900	2.4
Total Suspended Solids	80000	210000	2.6
Total Dissolved Solids	792000	4850000	6.1
Total Alkalinity	17000	155000	9.1
Acidity	39000	1520000	39.0
Chloride	60000	48000	0.8
Sulfate	346000	2250000	6.5

Sediment

Samples SD009 and SD011 were sediment split samples collected from the bottom of the quarry at Buoy 5/6. The following parameters display the highly variable results from environmental sampling:

	SD009 (ug/kg)	SD011 (ug/kg)	Ratio (SD009/SD011)
Di-n-Butylphthalate	31000	<20000	>1.6
Butylbenzylphthalate	130000	<20000	>6.5
bis(2-ethylhexyl) phthalate	68000	<20000	>3.4

Surface Soil

Samples SS001 and SS008 were surface soil split samples collected at the quarry discharge point along the west bank of the Black River. Analytical results from these samples showed less variability than in other media sampled at the site. The following parameters demonstrate variability present within surface soil sample results:

	SS019	SS021	Ratio (SS001/SS008)
Calcium	651	355	1.8
Iron	521000	377000	1.4
Cyanide	1.8	1.0	1.8

Groundwater

Samples GW011 and GW013 were unfiltered split samples collected from Monitoring Well B-2. The following parameters illustrate variability present within groundwater sampling results:

	GW013	GW011	Ratio (GW013/GW011)
Aluminum	292	114	2.6
Zinc	21	7.7	2.7
Total Suspended Solids	474000	31000	15.3
Total Dissolved Solids	2210000	733000	3.0
Total Alkalinity	324000	425000	0.8
Chloride	808000	<3000	>269.3
Sulfate	120000	242000	0.5

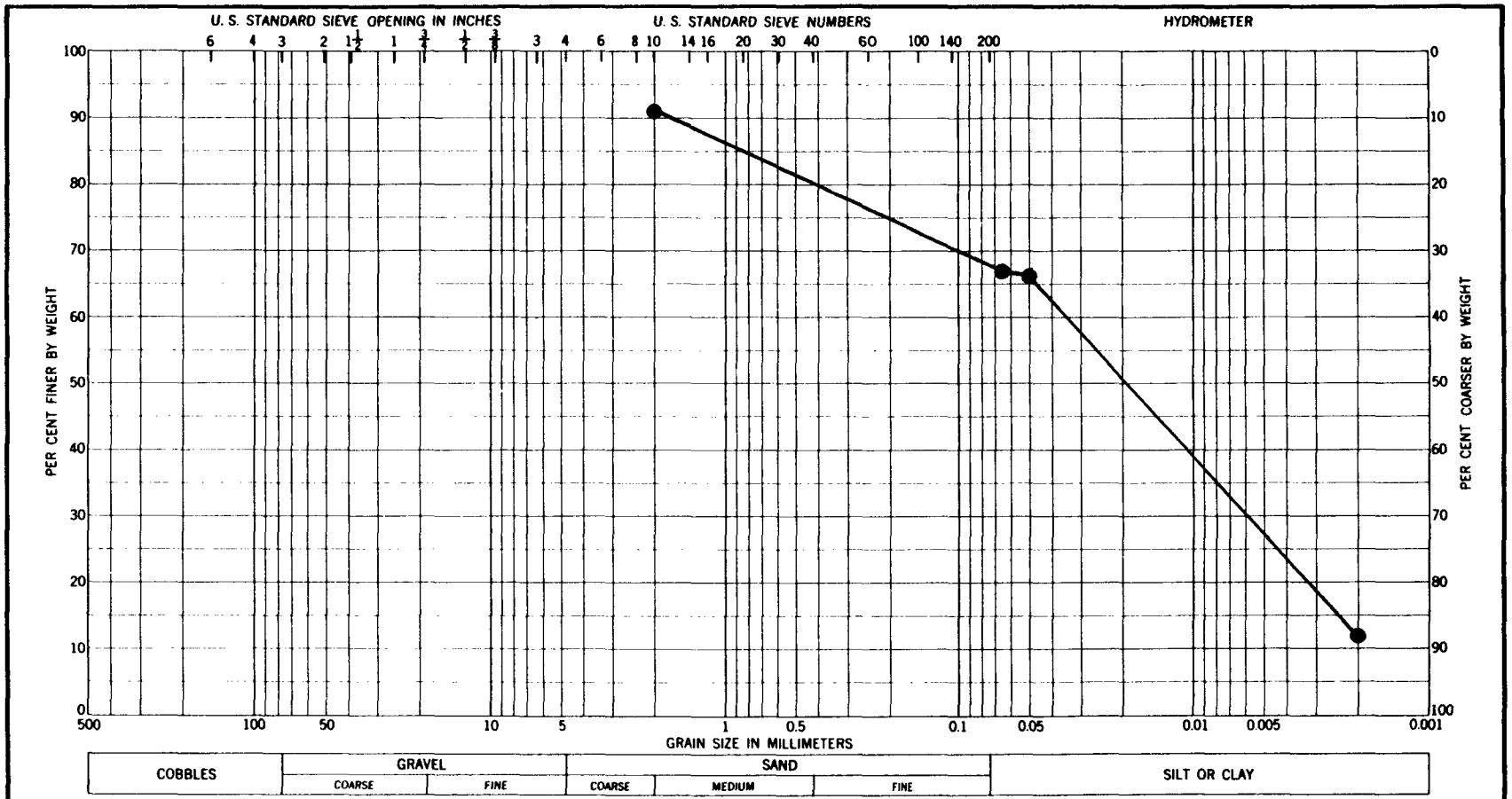
Conclusion

As demonstrated in the preceding items, parameters that would be expected to be similar in split samples many times have concentrations that vary by ratios much greater than two. Two was selected as the criteria for this RI since it represents a conservative indicator of what may be considered site-related chemicals.

APPENDIX H

PARTICLE SIZE ANALYSIS

GRAIN SIZE DISTRIBUTION ANALYSIS



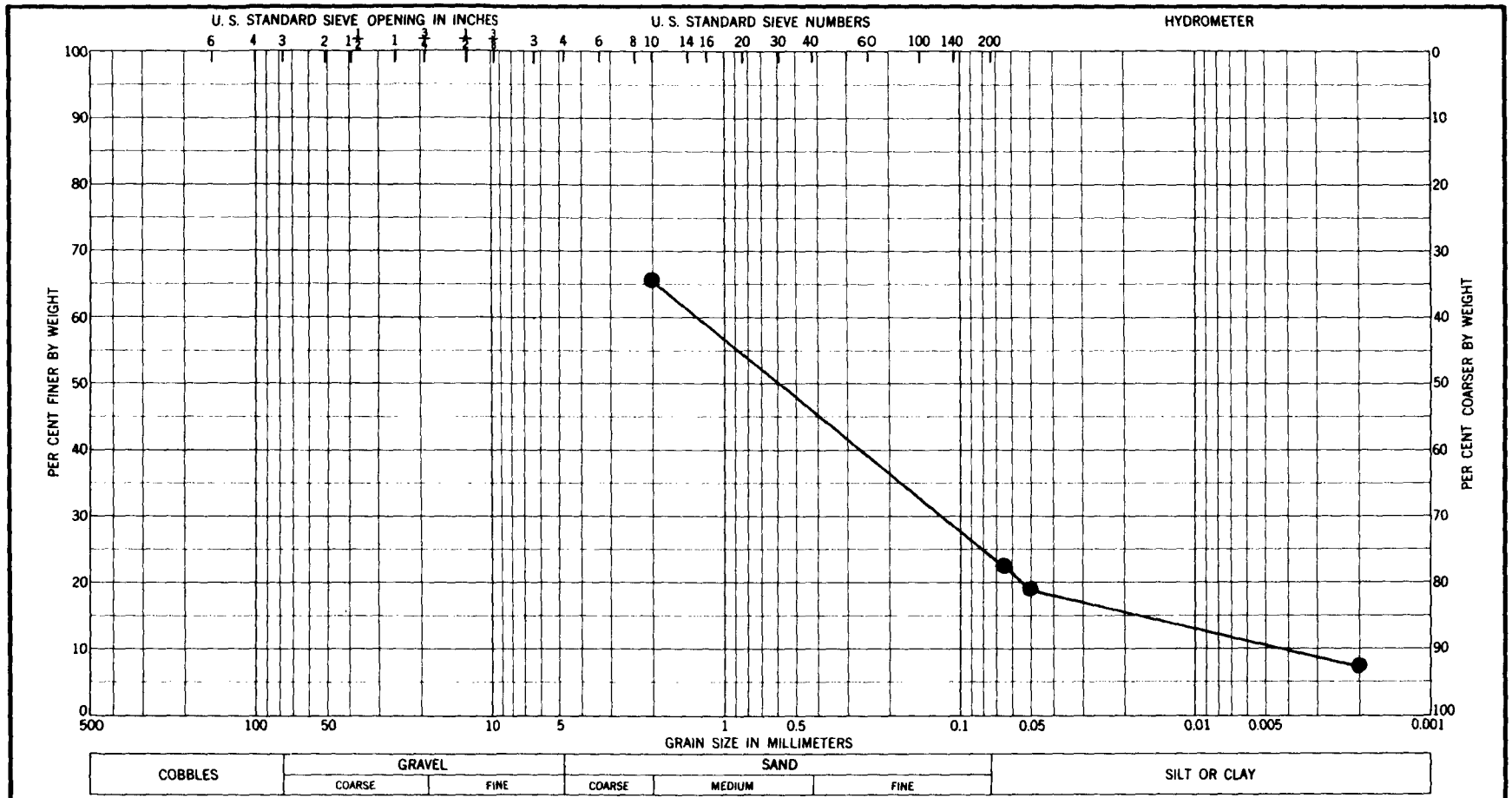
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS001	0.0-0.5	(ML)	67			

PROJECT: Republic Steel Quarry
Remedial Investigation

DESCRIPTION :
Surface Soil: Orange Sandy Silt (Iron Stained)

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS002	0.0-0.1	(SM)	32			

DESCRIPTION :

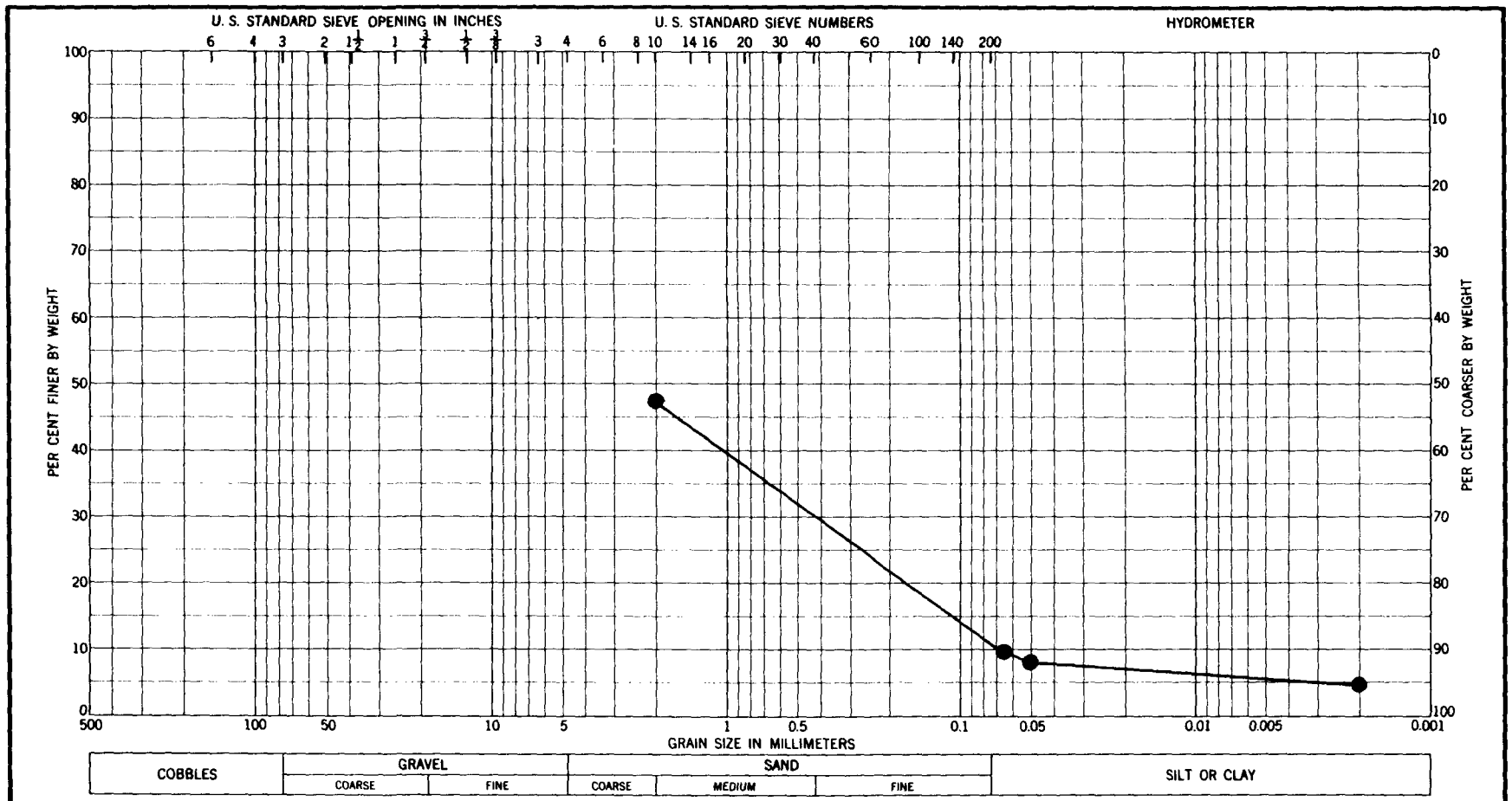
Surface Soil: Brown Silty Sand

PROJECT: Republic Steel Quarry

Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



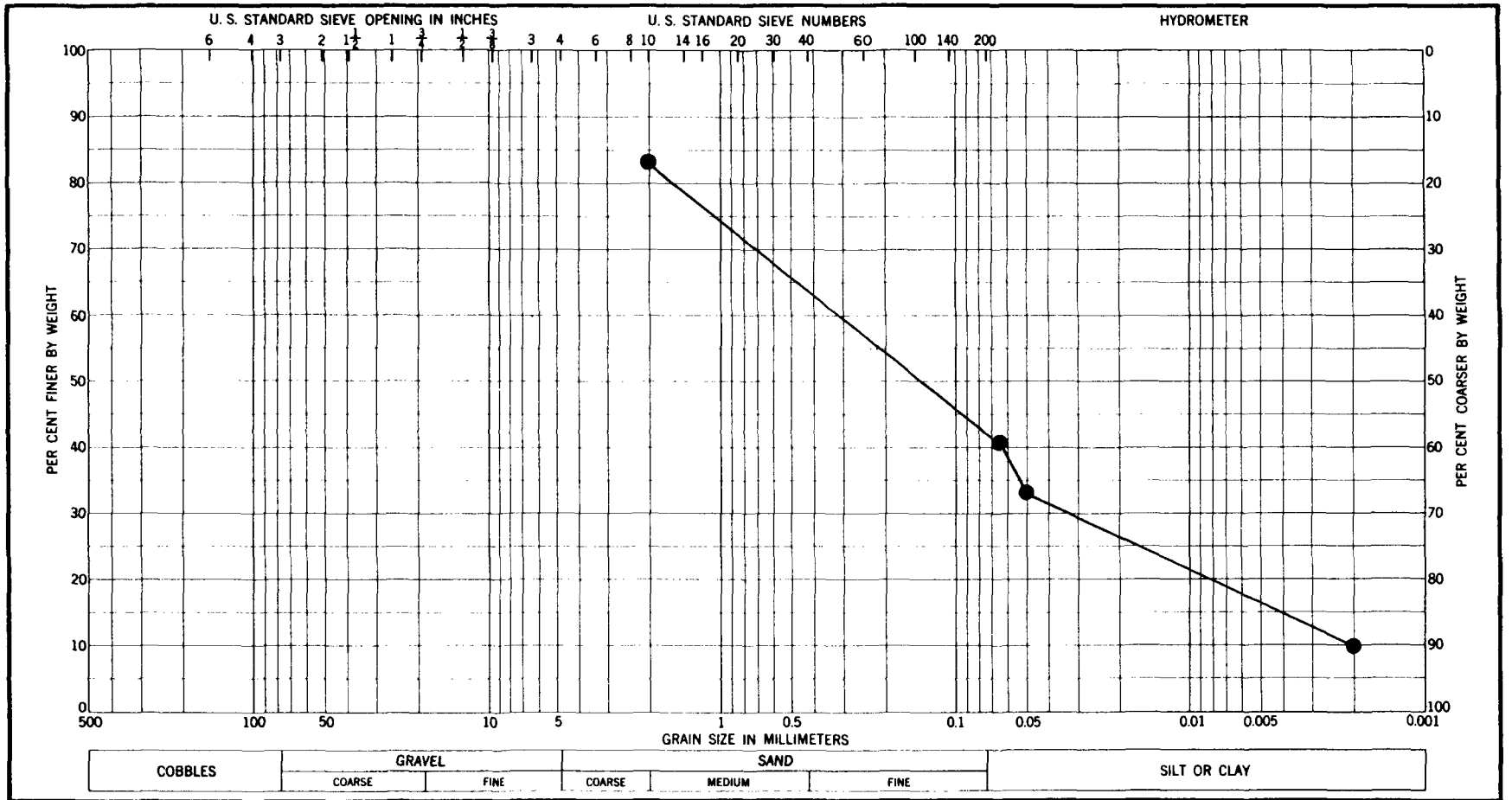
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS003	0.0-0.1	(SM)	43			

DESCRIPTION :
Surface Soil: Light Brown Silty Sand with Rock Fragments

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



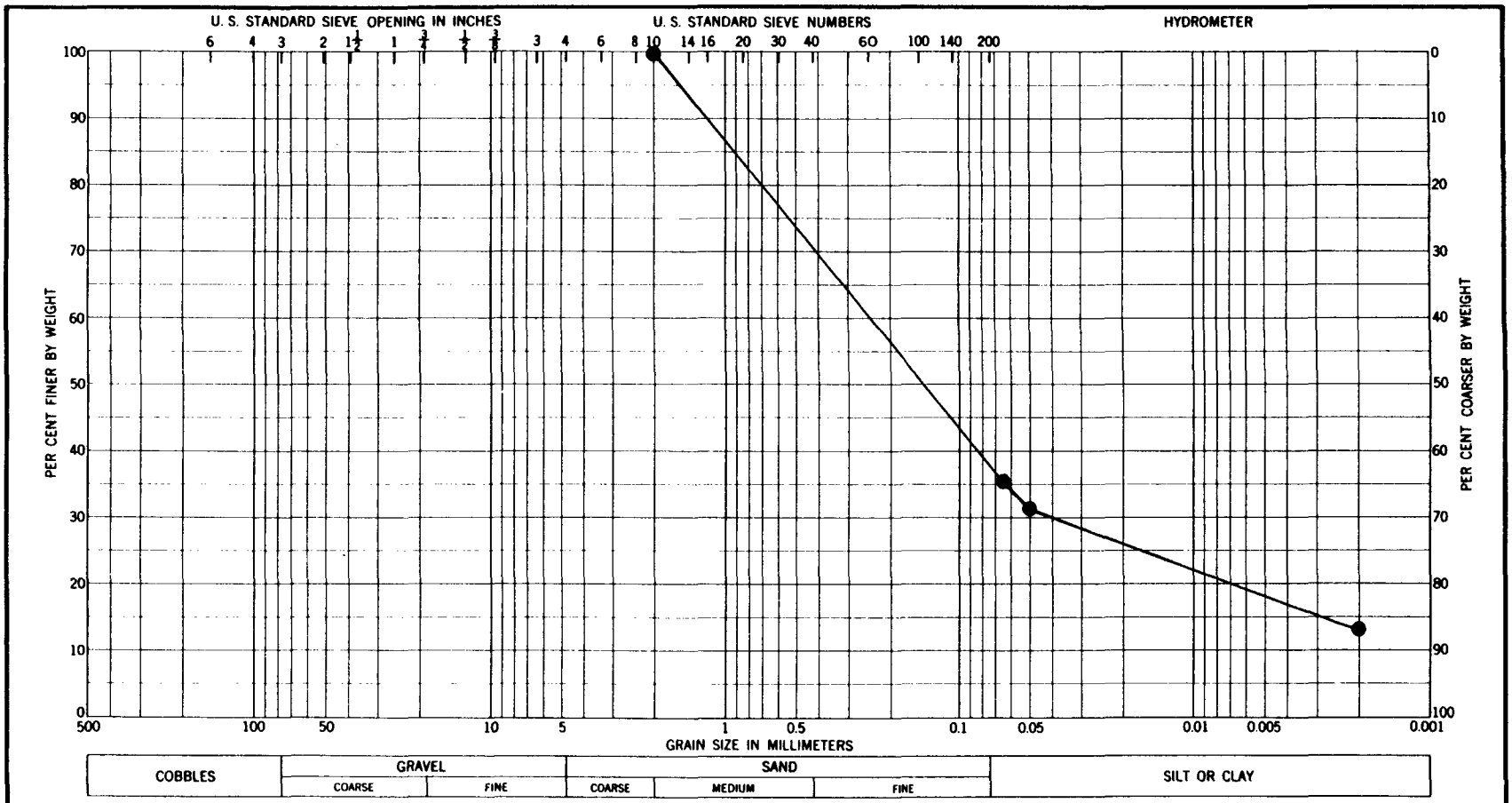
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS004	0.0-0.5	(SM)	25			

DESCRIPTION :
Surface Soil: Black Silty Sand

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



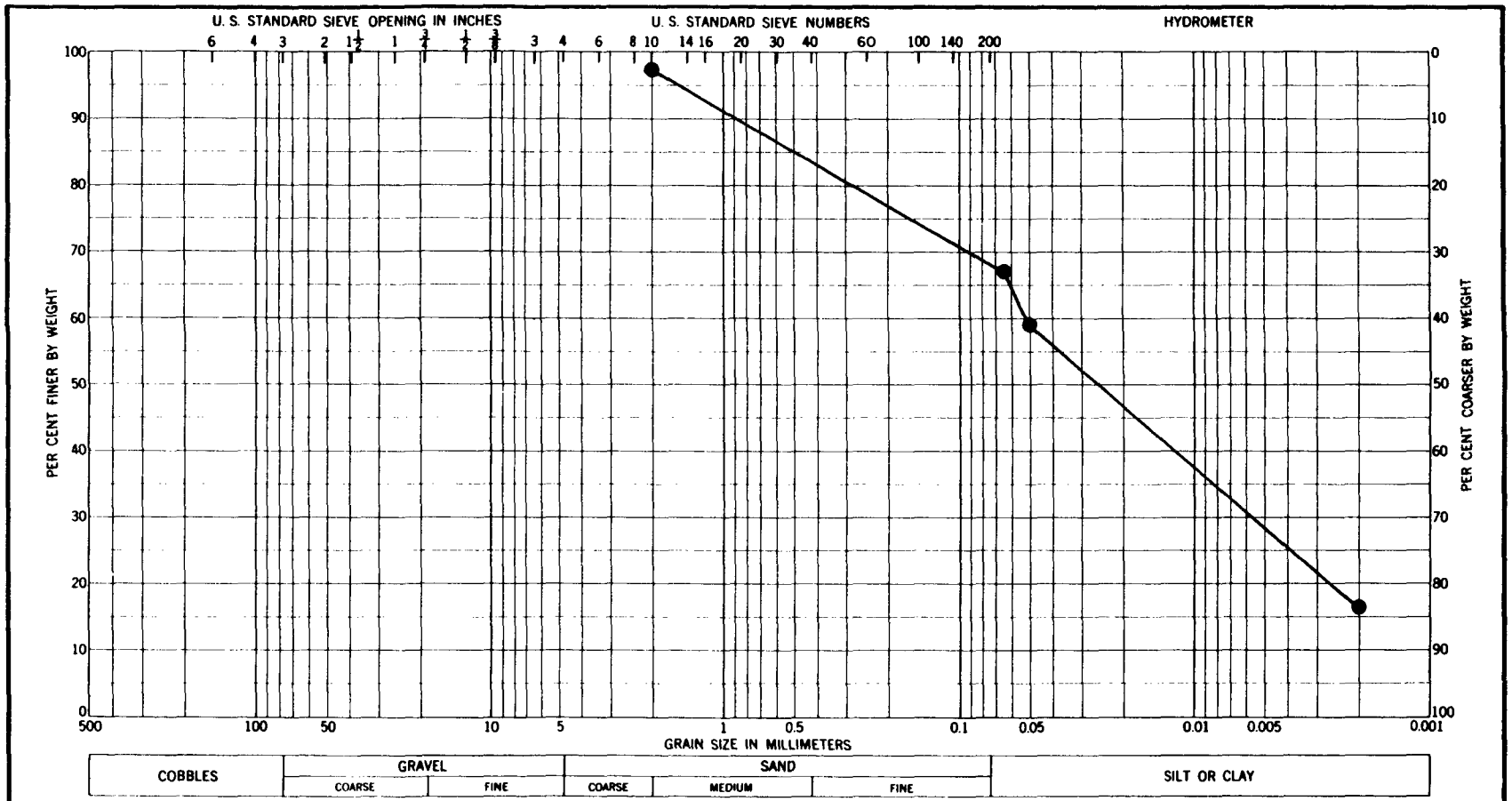
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS005	0.0-0.5	(SM)	39			

DESCRIPTION :
Surface Soil: Brown Silty Sand

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



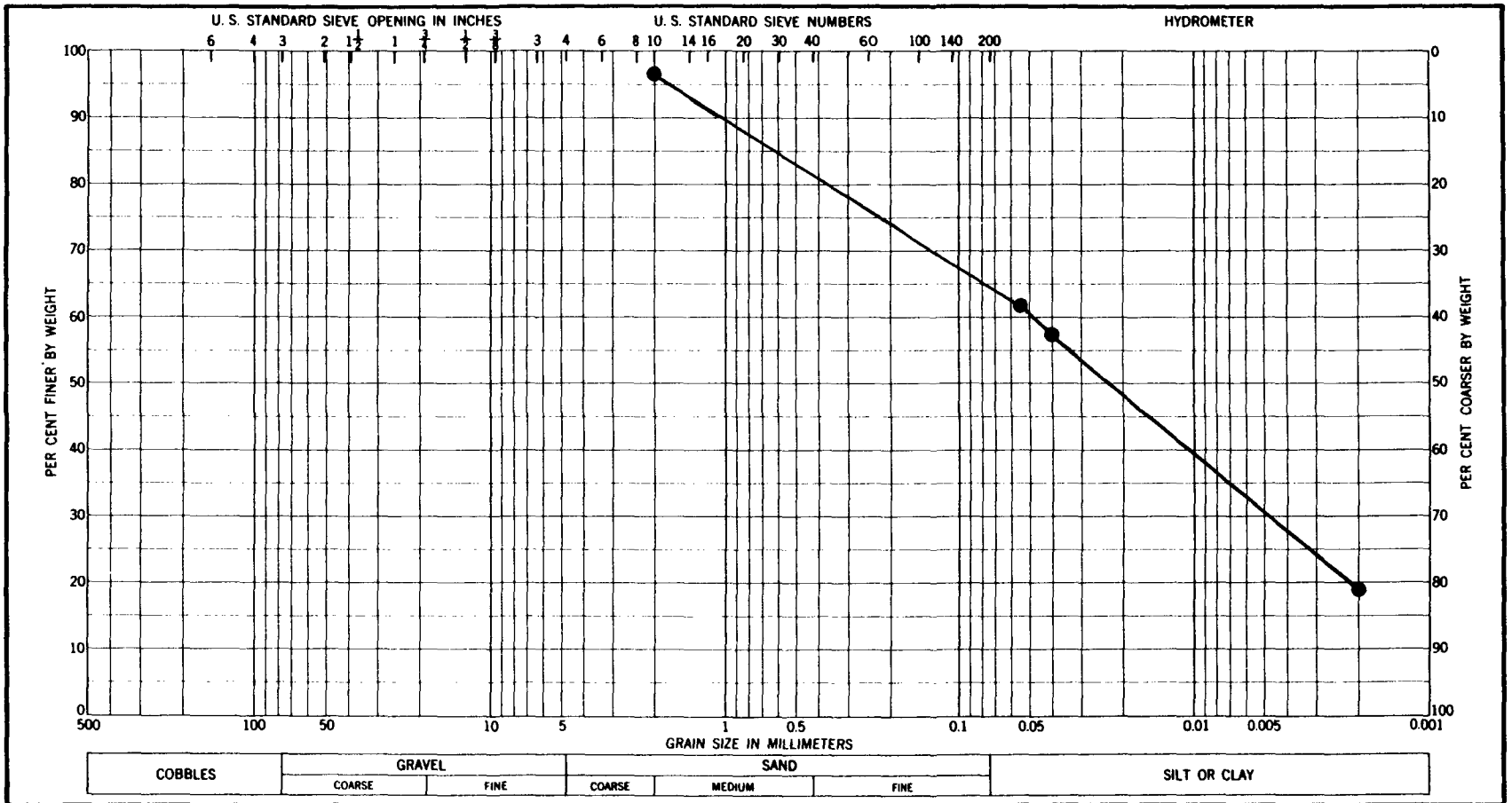
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS006	0.0-0.5	(ML)	41			

PROJECT: Republic Steel Quarry
Remedial Investigation

DESCRIPTION :
Surface Soil: Brown Sandy Silt

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS007	0.0-0.5	(ML)	32			

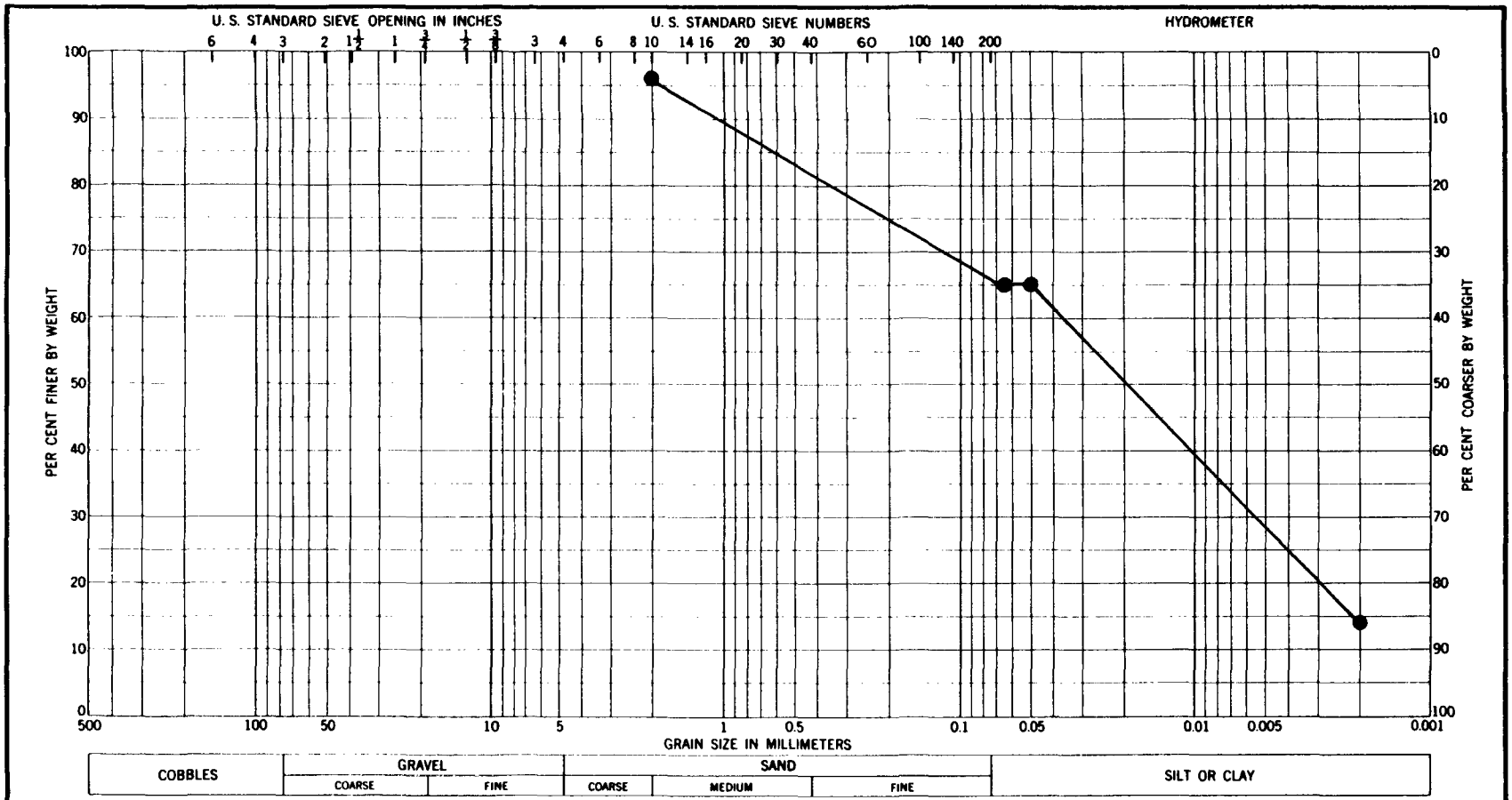
DESCRIPTION :

Surface Soil: Brown Sandy Silt

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SS008	0.0-0.5	(ML)	61			

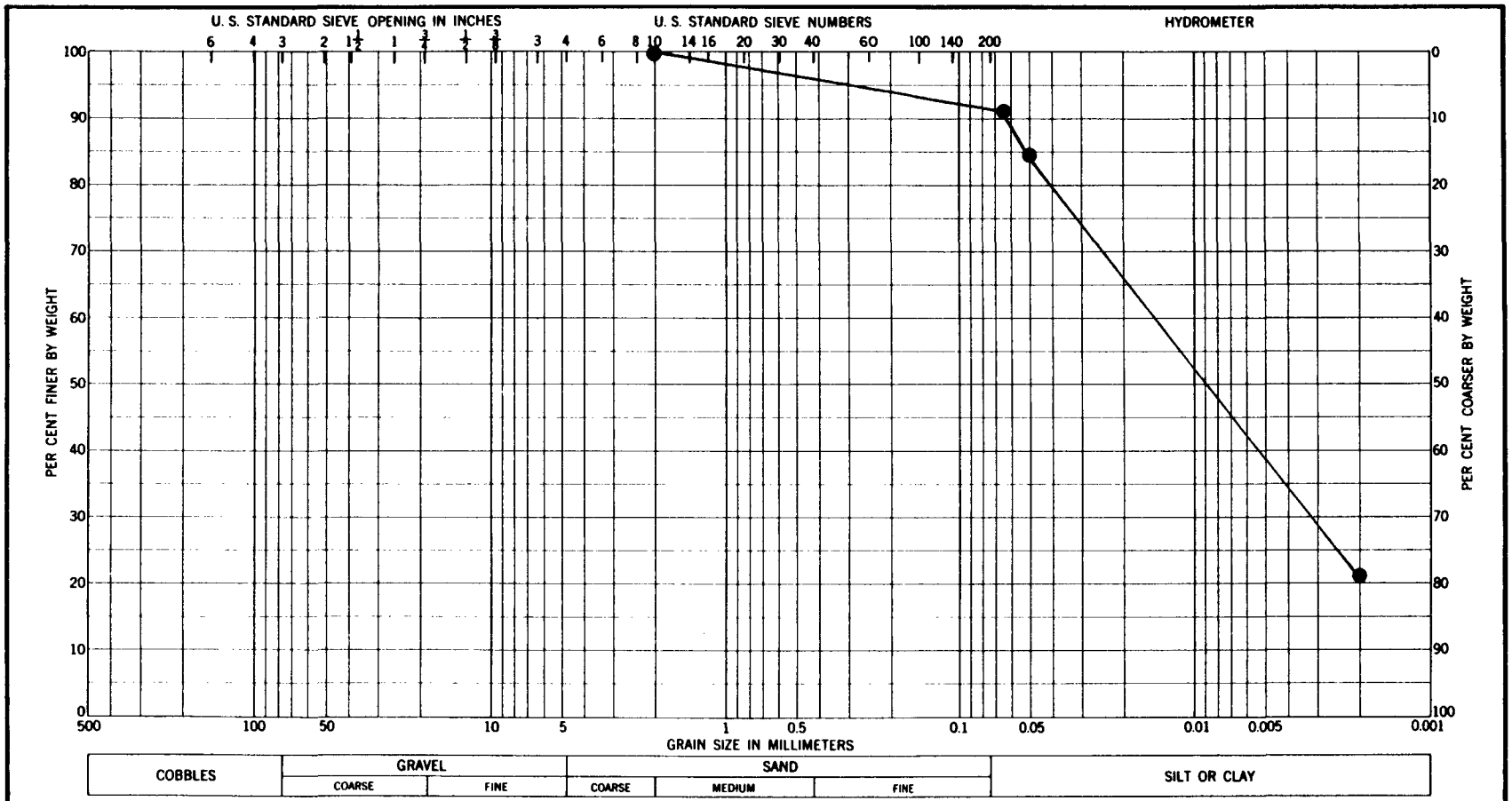
DESCRIPTION :

Surface Soil: Orange Sandy Silt (Iron Stained)

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 18	SD003	19.0	(ML)	233			

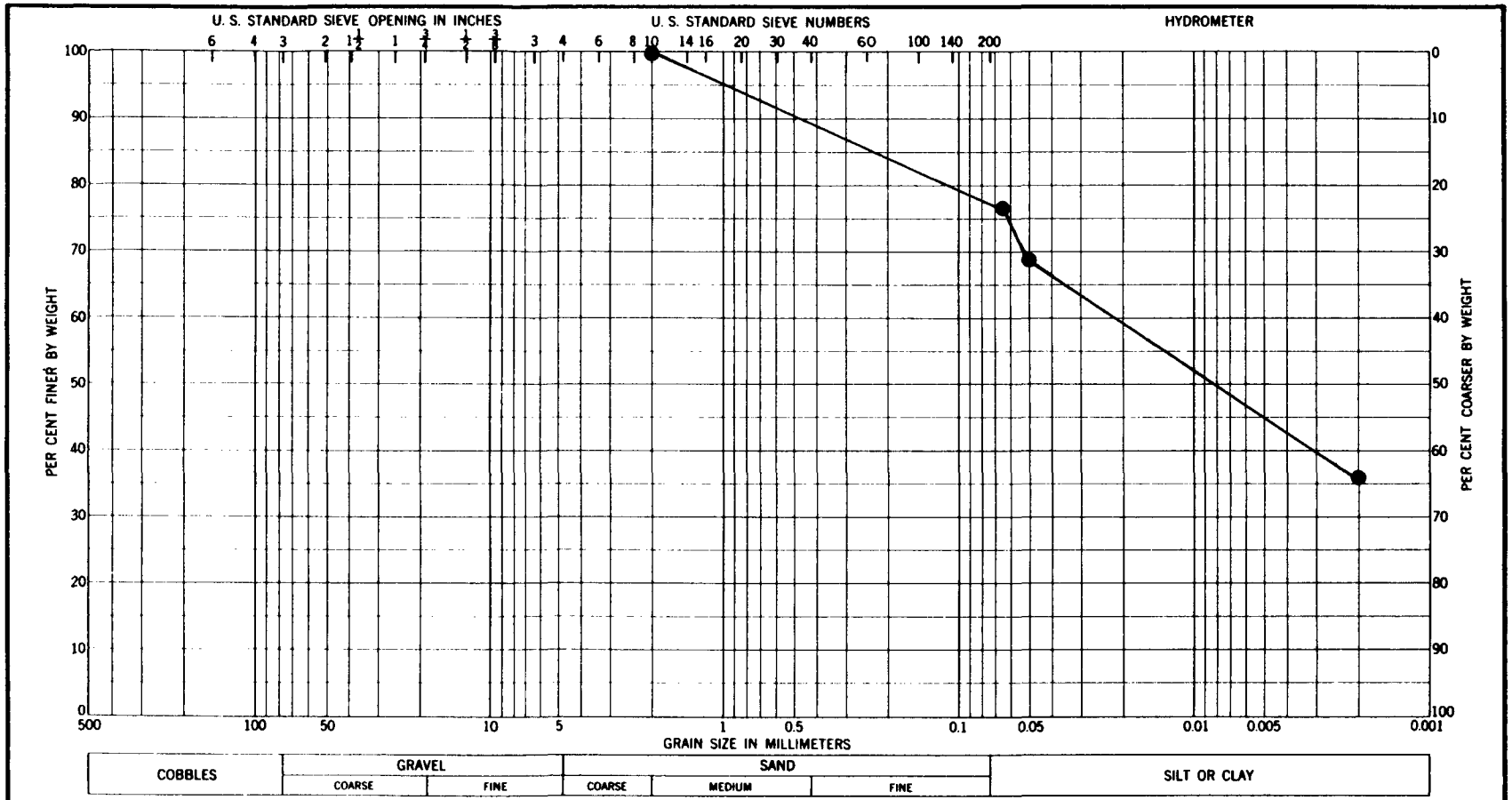
DESCRIPTION :

Quarry Sediment: Black Organic Silt

PROJECT: Republic Steel Quarry Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 7	SD004	20.0	(OL)	942			

DESCRIPTION :

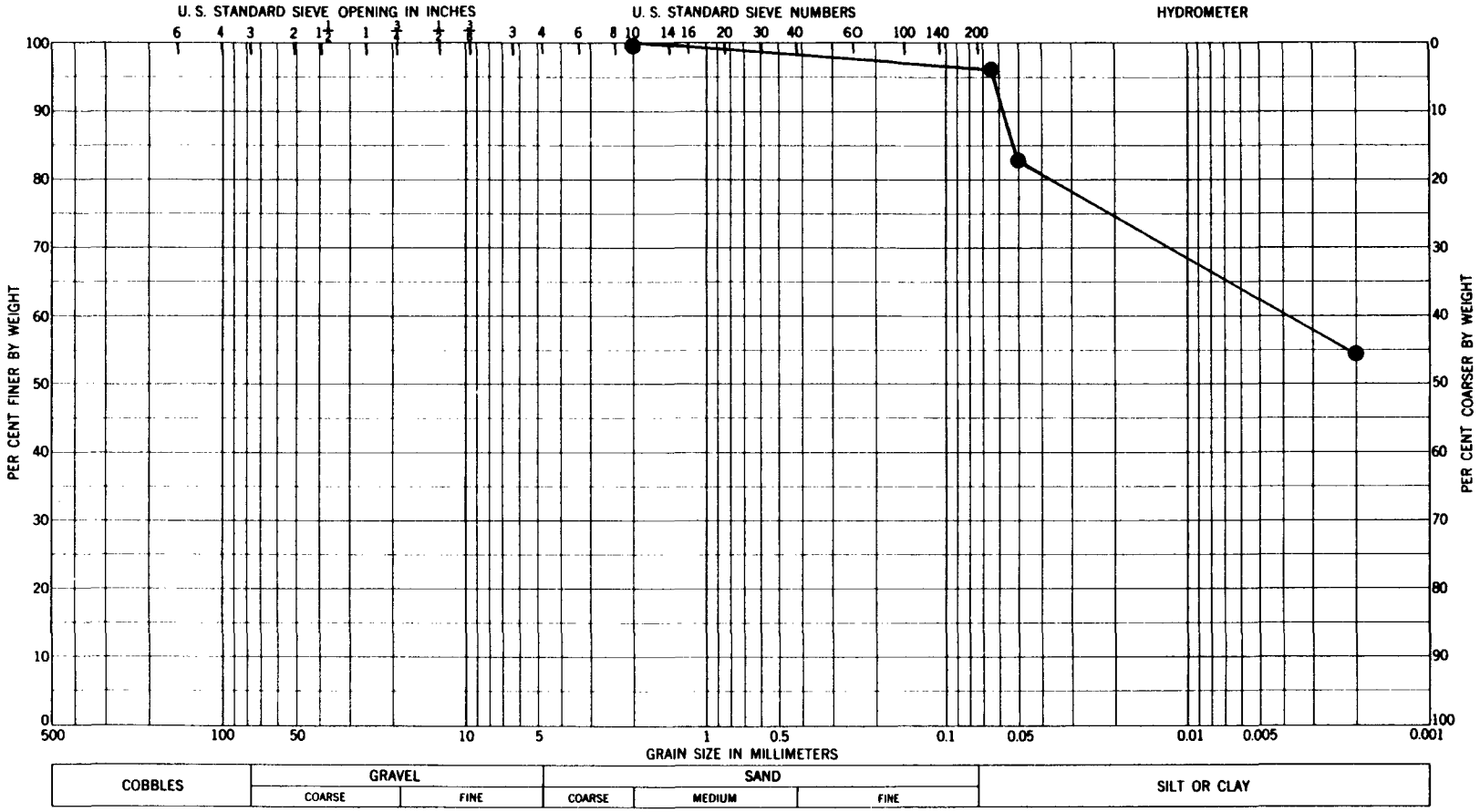
Quarry Sediment: Orange Silt with Sand (Iron Stained)

PROJECT: Republic Steel Quarry

Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 10	SD005	39.0	(OL)	669			

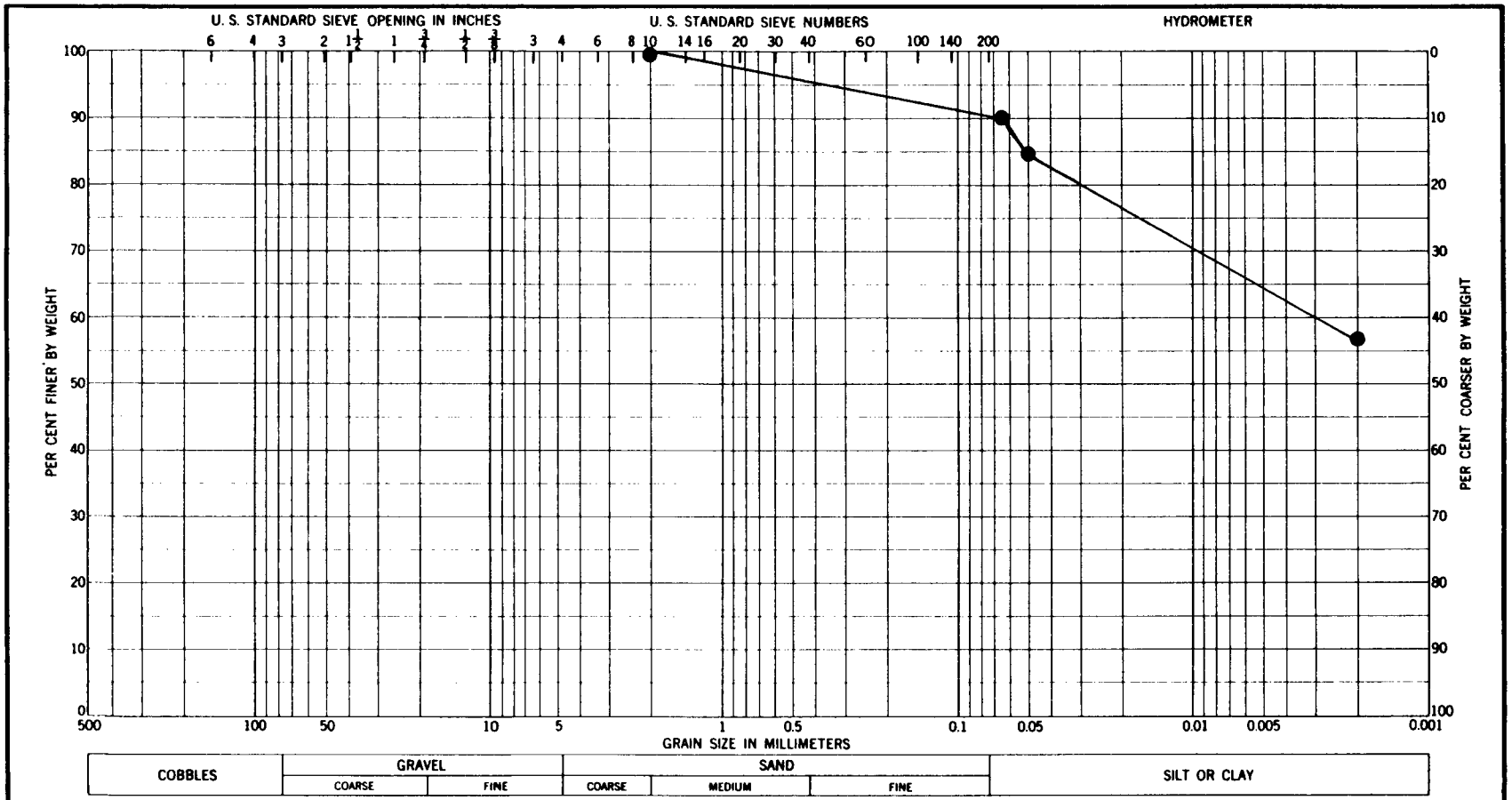
DESCRIPTION :

Quarry Sediment: Black Organic Silt

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 8	SD006	35.0	(OL)	426			

DESCRIPTION :

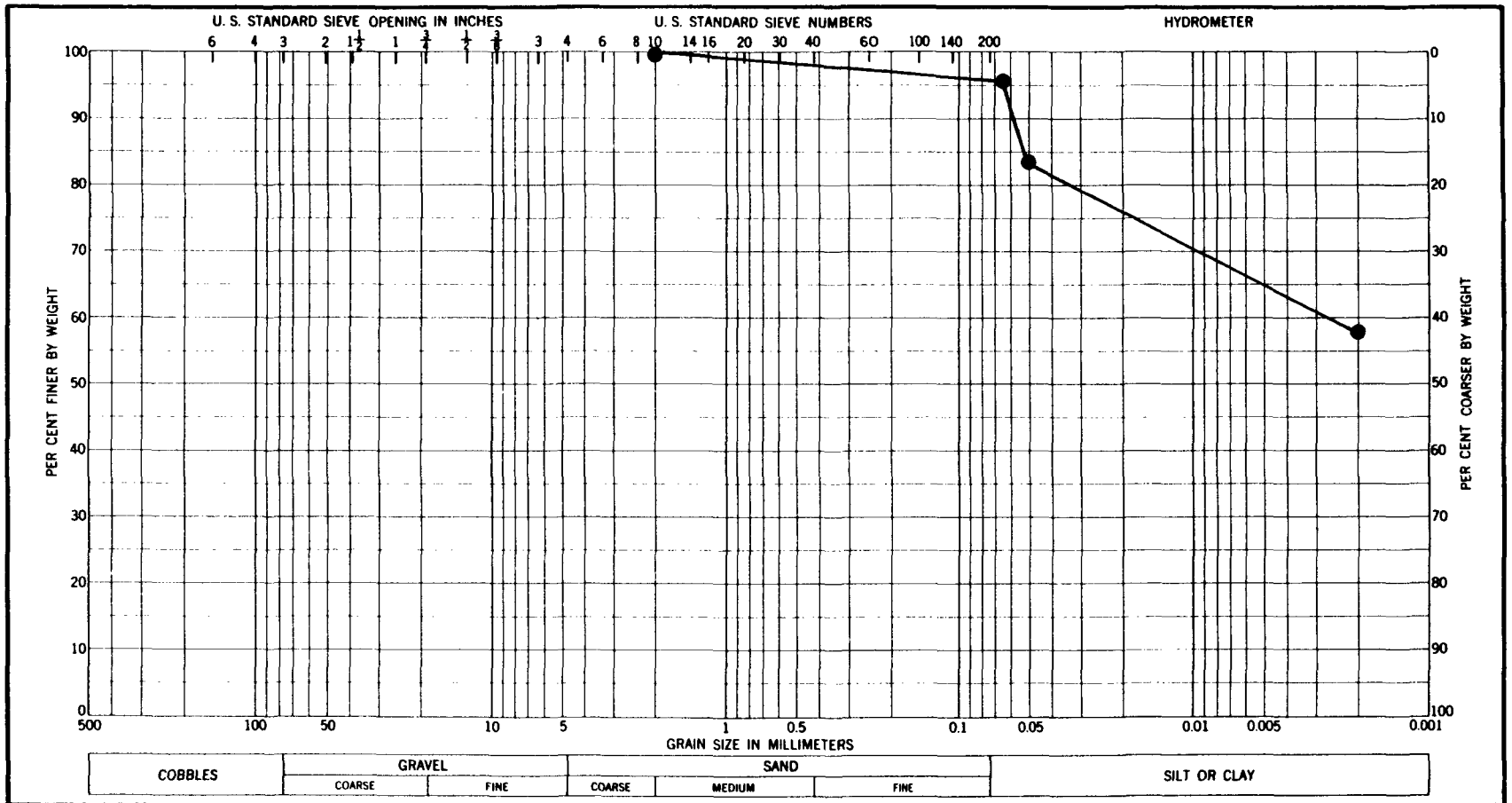
Quarry Sediment: Black Organic Silt

PROJECT: Republic Steel Quarry

Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



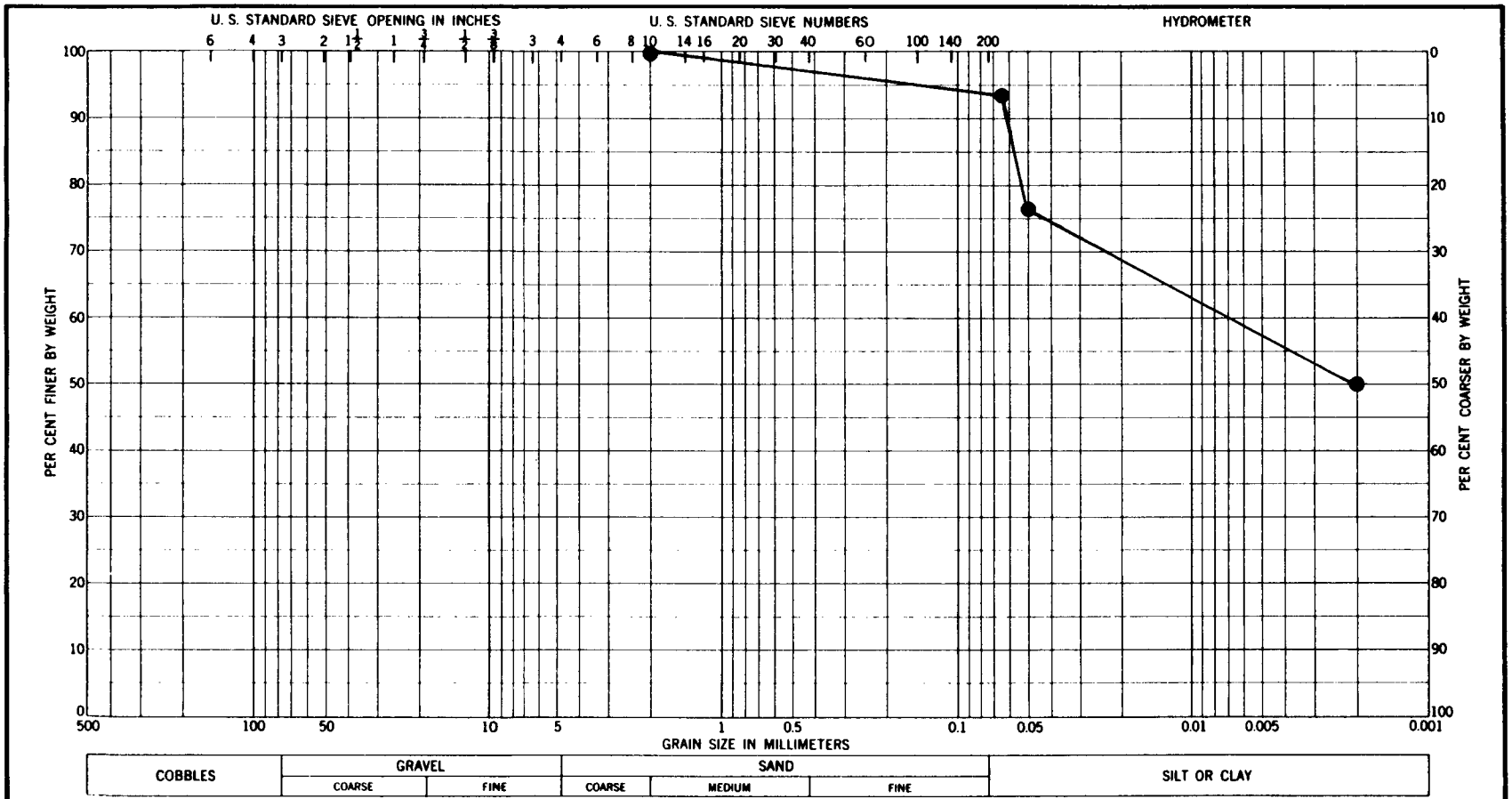
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 10	SD007	16.0	(OL)	614			

DESCRIPTION :
Quarry Sediment: Black Organic Silt

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



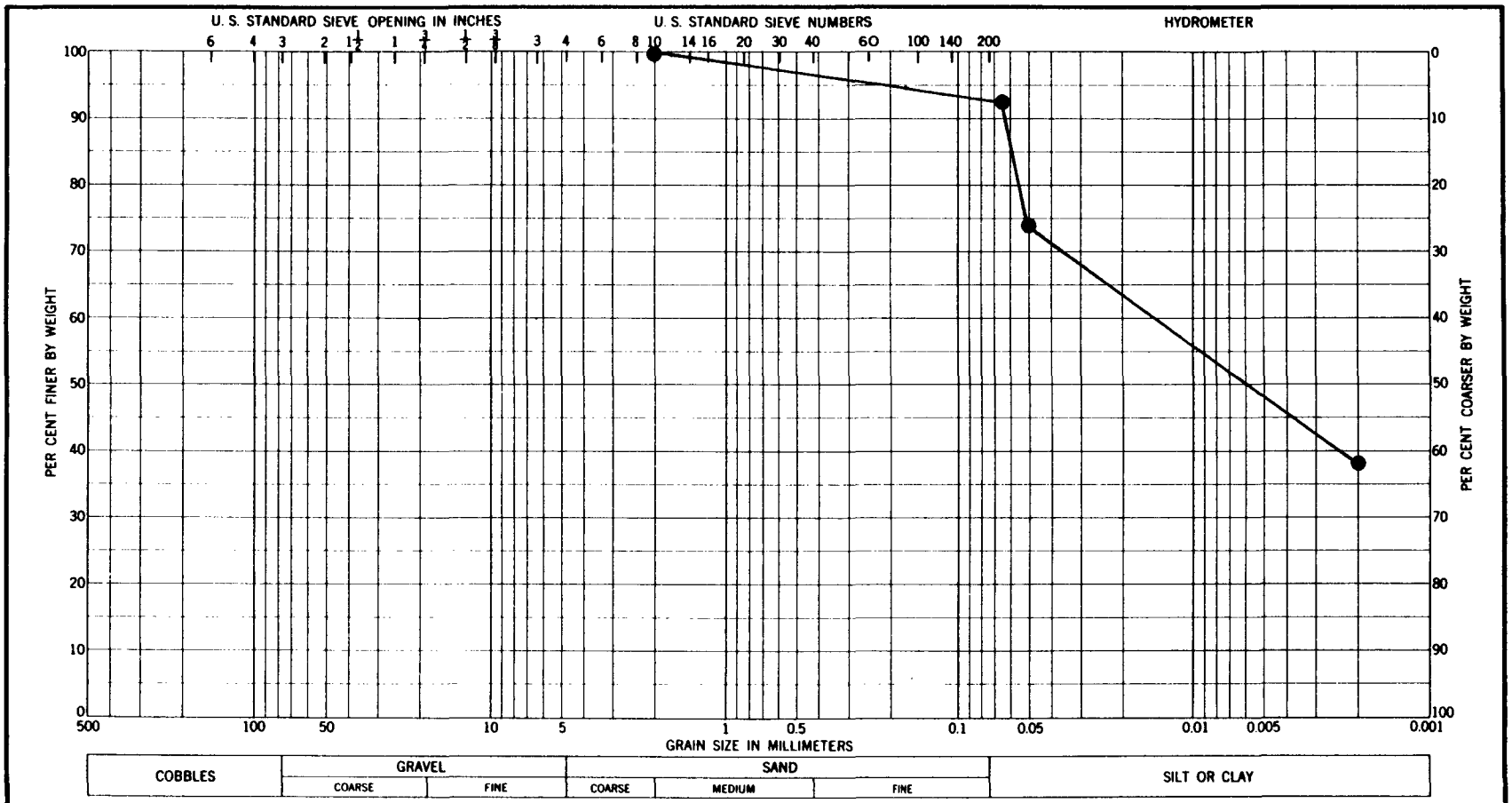
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 12	SD008	58.0	(OL)	733			

PROJECT: Republic Steel Quarry
Remedial Investigation

DESCRIPTION :
Quarry Sediment: Black Organic Silt

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



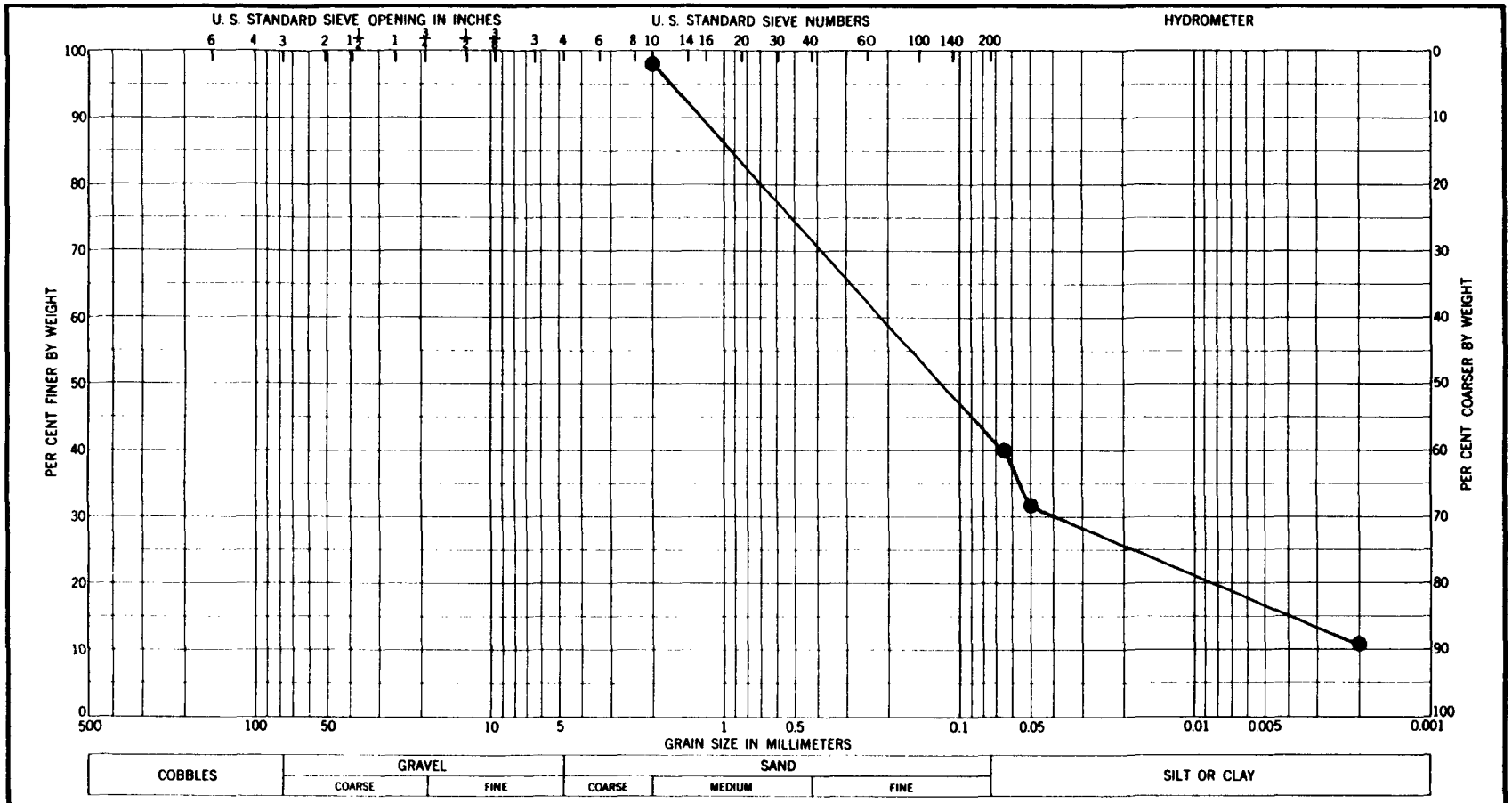
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 5-6	SD009	62.0	(OL)	488			

DESCRIPTION :
Quarry Sediment: Black Organic Silt

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



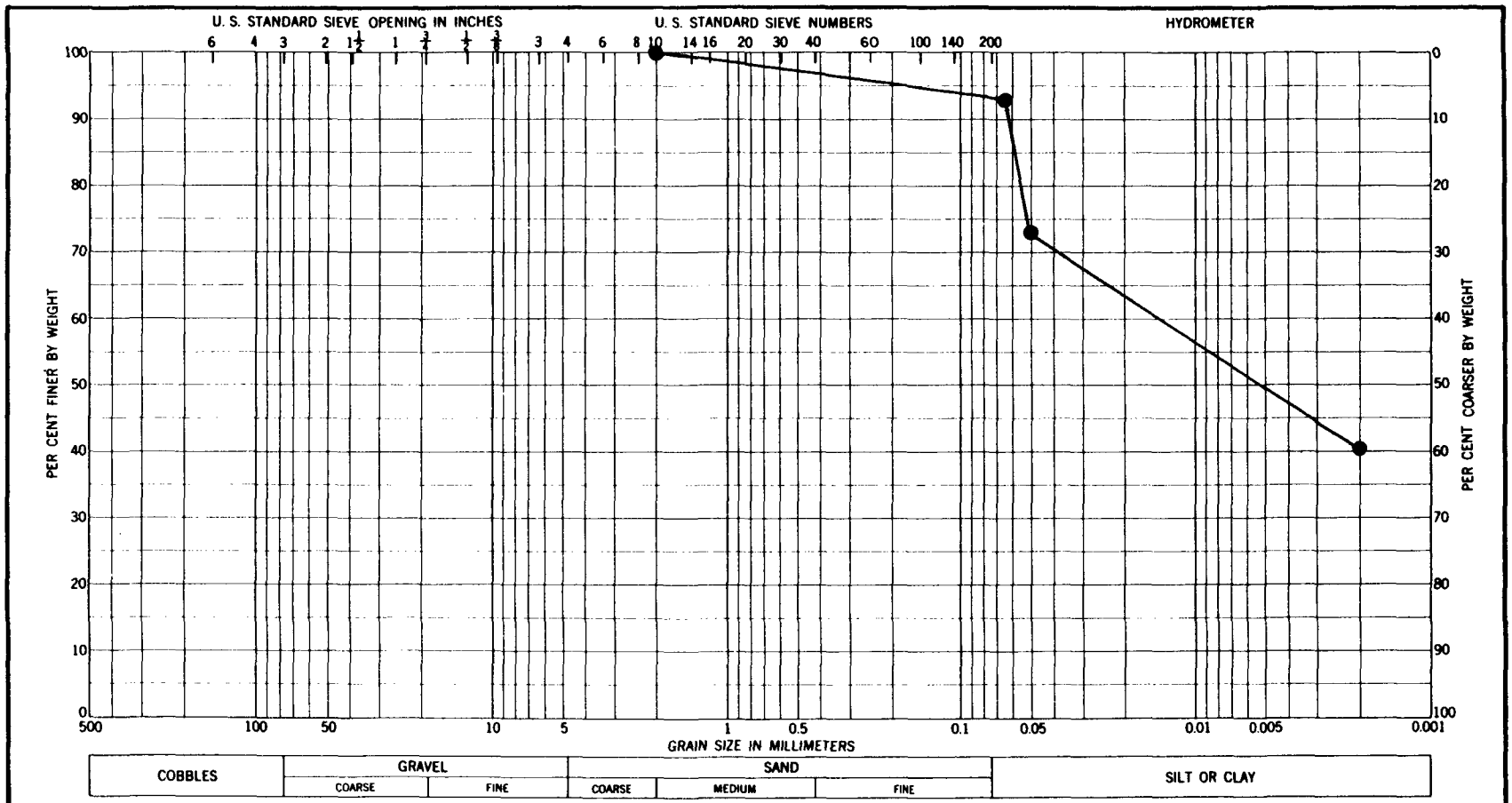
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Outflow	SD010	0.0-0.2	(SM)	14			

DESCRIPTION :
Quarry Outflow Sediment: Brown Silty Sand

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
Buoy 5-6	SD011	62.0	(OL)	456			

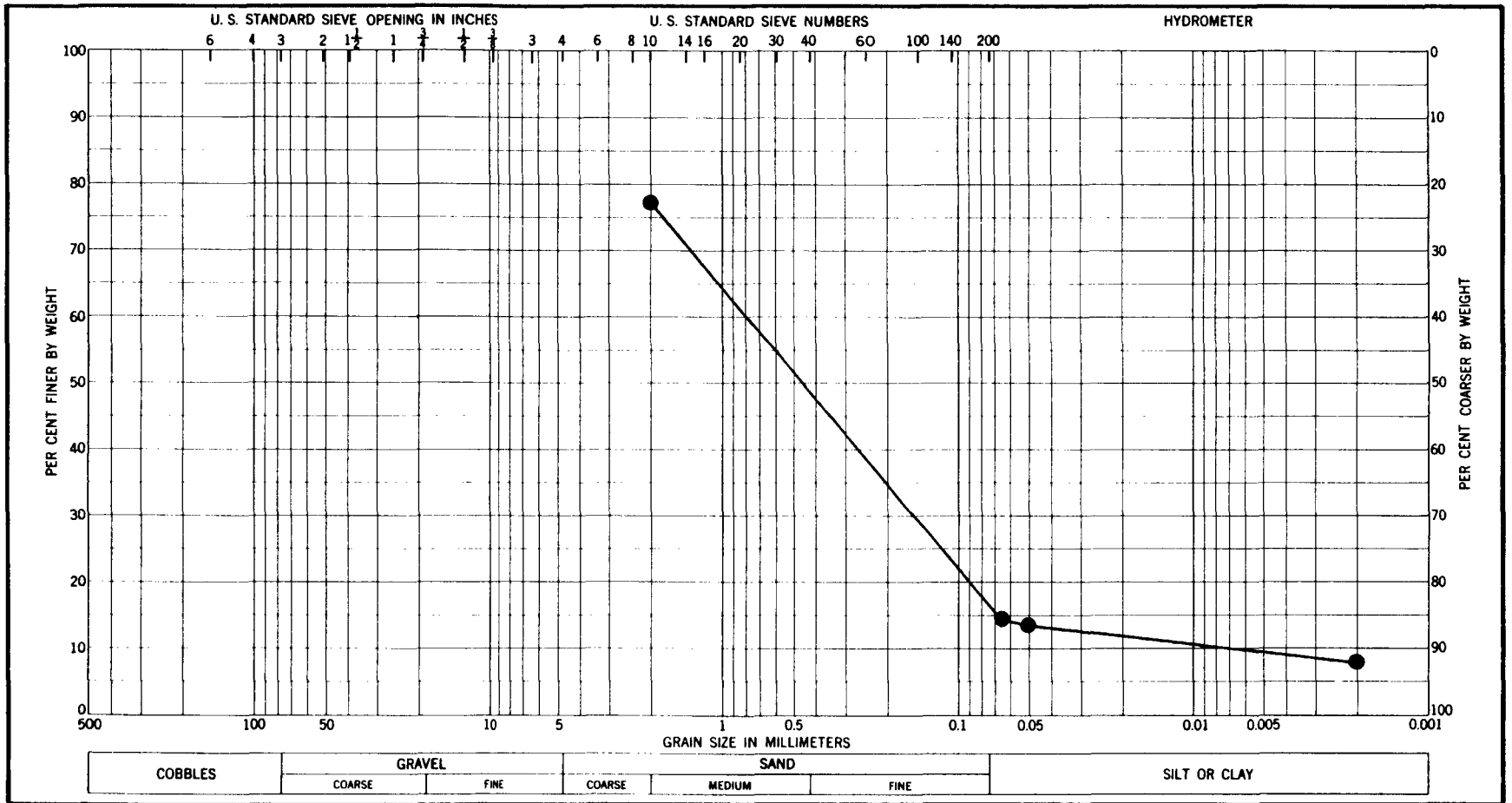
DESCRIPTION :

Quarry Sediment: Black Organic Silt

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SD013	0.0-0.1	(SM)	113			

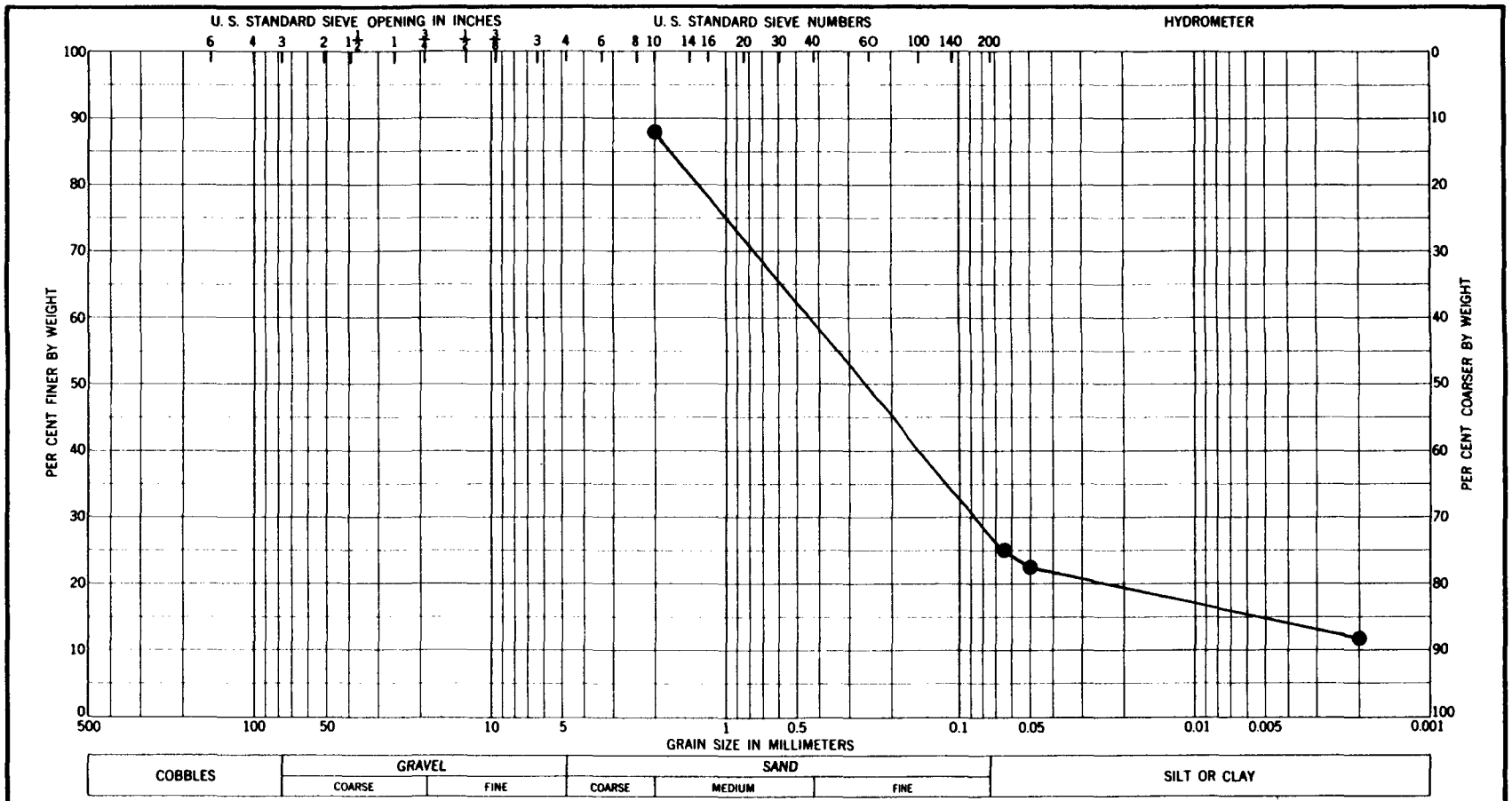
DESCRIPTION :

Black River Sediment: Brown Silty Sand

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



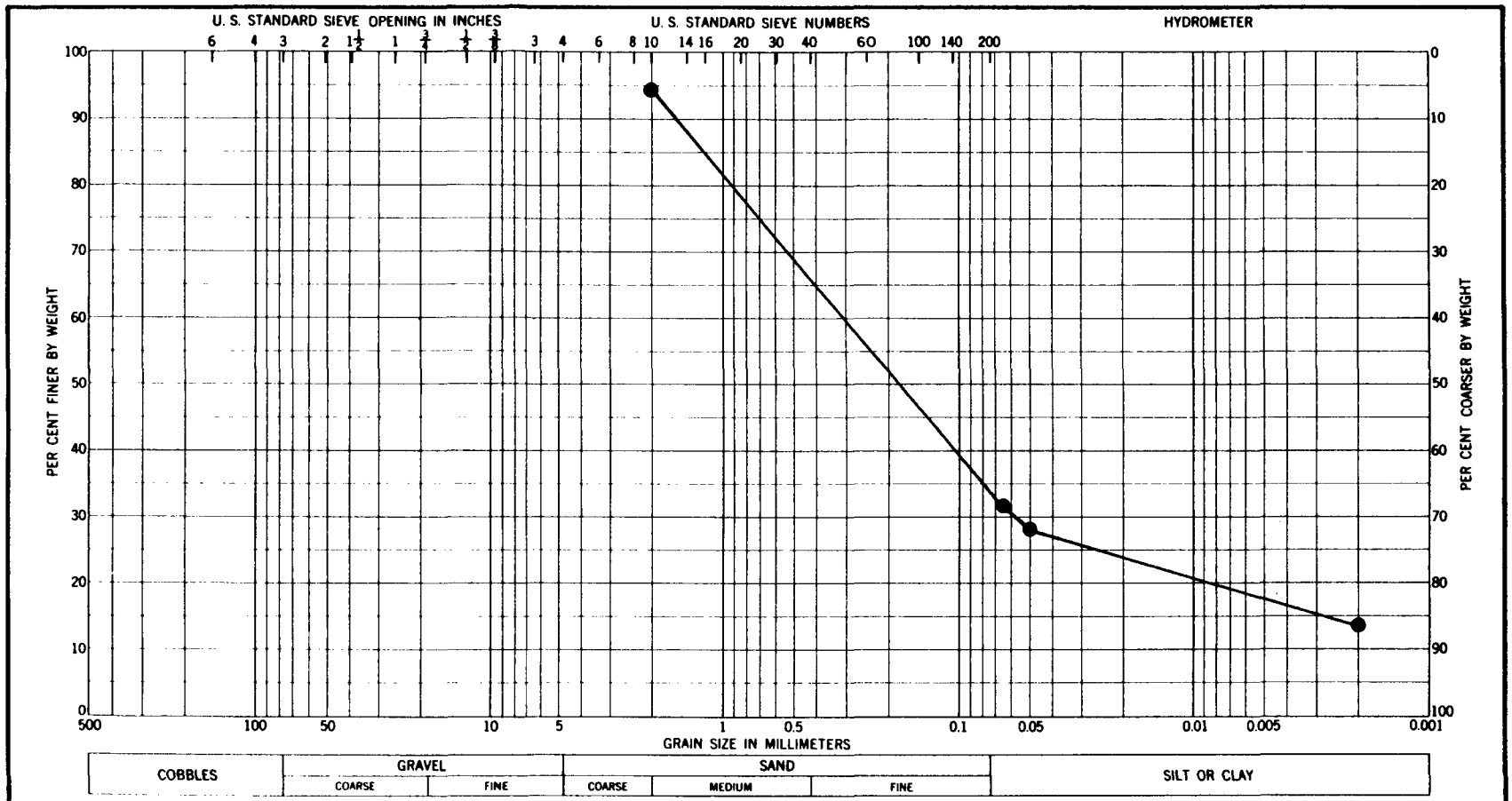
HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SD014	0.0-0.1	(SM)	59			

PROJECT: Republic Steel Quarry
Remedial Investigation

DESCRIPTION :
Black River Sediment: Brown Silty Sand

Assumed Specific Gravity = 2.65

GRAIN SIZE DISTRIBUTION ANALYSIS



HOLE NO.	SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W %	LL	PL	PI
	SD015	0.0-0.1	(SM)	56			

DESCRIPTION :

Black River Sediment: Brown Silty Sand

PROJECT: Republic Steel Quarry
Remedial Investigation

Assumed Specific Gravity = 2.65

APPENDIX I

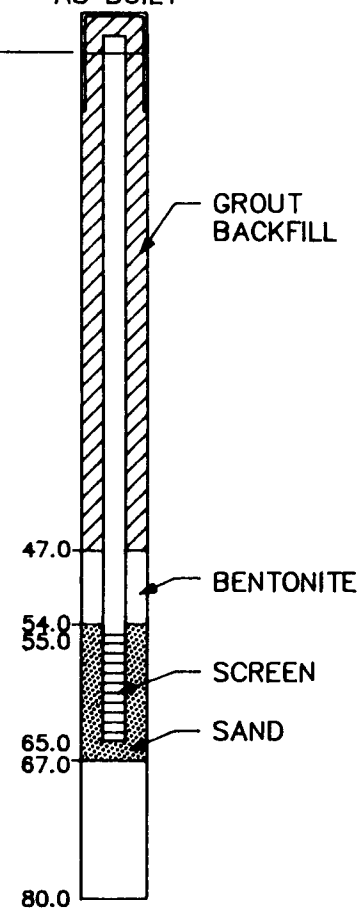
GEOLOGIC AND WELL COMPLETION LOGS

REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO. B-1
DATE STARTED: 7/14/87
DATE COMPLETED: 7/28/87

DRILLING METHOD: AIR ROTARY TO 40',
NX WIRELINE CORING TO 80'
5" REAMING TO 80'
ENG./GEO.: STEVE COX

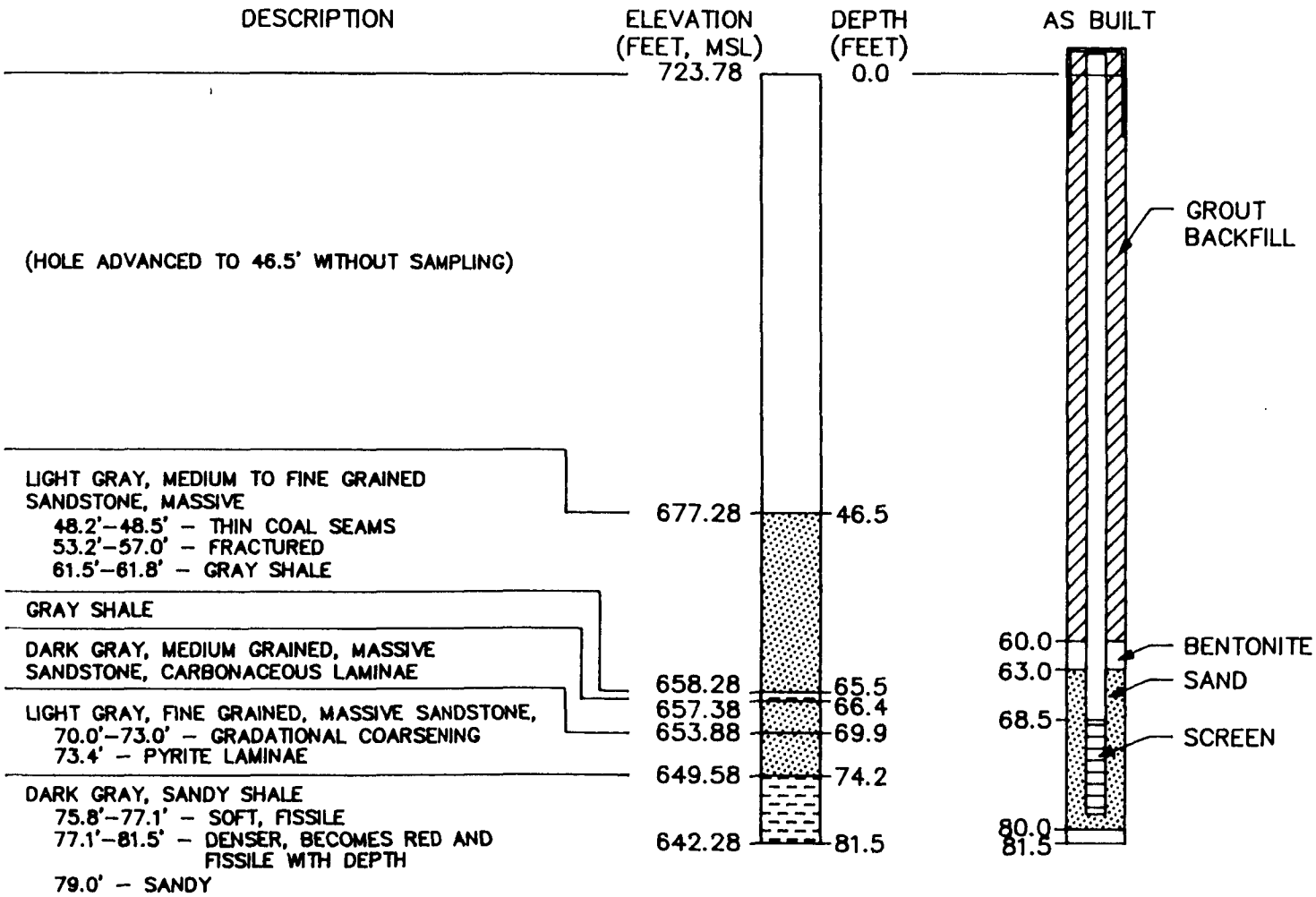
DESCRIPTION	ELEVATION (FEET, MSL)	DEPTH (FEET)
	721.45	0.0
(EXISTING OPEN HOLE, NO SAMPLES)		
(NO RECOVERY)	681.45	40.0
GRAY TO BROWN, VERY FINE GRAINED SANDSTONE; POORLY SORTED; CROSS-BEDDED	678.15	43.3
	676.45	45.0
(NO RECOVERY)	671.05	50.4
LIGHT GRAY TO BROWN, MEDIUM TO FINE GRAINED SANDSTONE, CROSS-BEDDED 51.1' AND 54.6' – CARBONACEOUS LAMINAE 60.2' – MASSIVE PYRITE BANDS	661.25	60.2
DARK GRAY, SLIGHTLY SANDY SHALE, FISSILE	659.85	61.6
DARK RED SHALE, SOFT, FISSILE	651.45	70.0
DARK GRAY, SLIGHTLY SANDY SHALE; AND LIGHT GRAY MUDSTONE	641.45	80.0

AS BUILT



REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO.: B-2
DATE STARTED: 7/27/87
DATE COMPLETED: 7/28/87

DRILLING METHOD: AIR ROTARY TO 46.5'
NX WIRELINE CORING TO 81.5'
5" REAMING TO 81.5'
ENG./GEO.: STEVE COX/KEN MILLER

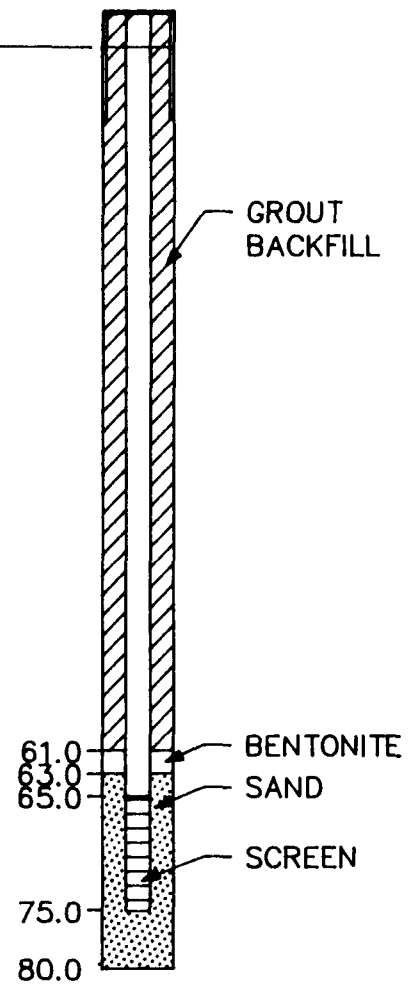


REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO.: B-3
DATE STARTED: 7/28/87
DATE COMPLETED: 7/29/87

DRILLING METHOD: HOLLOW STEM AUGER TO 38'
NX WIRELINE CORING TO 77.5'
5" REAMING TO 80'
ENG./GEO.: STEVE COX

DESCRIPTION	ELEVATION (FEET, MSL)	DEPTH (FEET)
	725.67	0.0
(NO SAMPLING)		
DARK GRAY SHALE, SOFT, FISSILE	687.67	38.0
LIGHT GRAY MEDIUM TO FINE GRAINED SANDSTONE	685.37	40.3
LIGHT GRAY SHALE, FISSILE,SLIGHTLY PYRITE	684.17	41.5
	683.17	42.5
LIGHT GRAY MEDIUM TO FINE GRAINED, SANDSTONE, MASSIVE, OCCASIONAL CARBONACEOUS LAMINAE 43.8'–44.1' – HIGHLY FRACTURED 48.1'–48.3' – DARK GRAY SHALE SEAM 48.6'–49.2' – DARK GRAY SHALE SEAM 52.5'–52.8' – DARK GRAY SHALE SEAM 53.6'–53.9' – DARK GRAY SHALE SEAM 58.9'–60.4' – LIGNITE SEAM 71.0'–71.9' – PYRITE NODULES		
DARK GRAY SHALE, FISSILE	653.77	71.9
DARK RED SHALE, FISSILE, SOFT ZONES	651.07	74.6
	648.17	77.5

AS BUILT

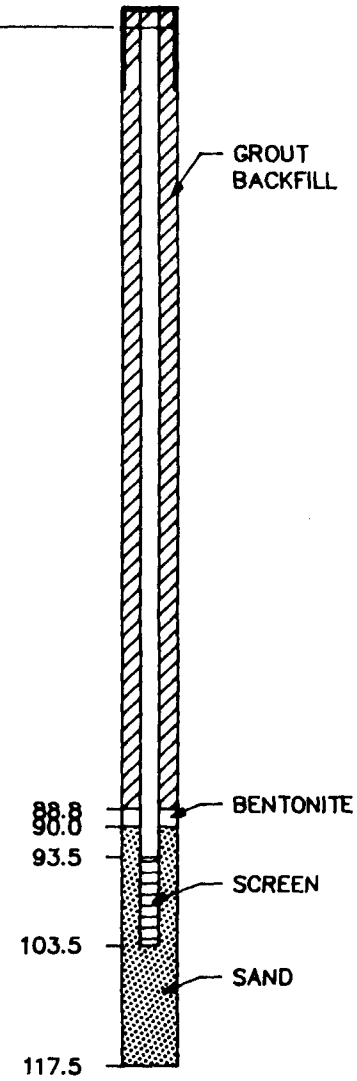


REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO.: B-4
DATE STARTED: 6/30/87
DATE COMPLETED: 7/16/87

DRILLING METHOD: HOLLOW STEM AUGER TO 18'
NX WIRELINE CORING TO 115.5'
5" REAMING TO 117.5'
ENG./GEO.: STEVE COX, MARTY KNUTH, KEN MILLER

DESCRIPTION	ELEVATION (FEET,MSL)	DEPTH (FEET)
	734.35	0.0
BLACK TO BROWN, FINE TO COARSE SAND, WITH TRACE ORGANICS, TRACE WEATHERED ROCK FRAGMENTS, MOIST TO WET	728.35	6.0
GRAY CLAY, SOME SUBANGULAR ROCK FRAGMENTS TRACE FINE SAND, MOIST	725.85	8.5
BROWN, MEDIUM GRAINED, WELL SORTED SAND, WITH GRAY CLAY MATRIX, SOME ROCK FRAGMENTS, MOIST	723.35	11.0
GRAY SILTY CLAY, TRACE ROUNDED SANDSTONE FRAGMENTS, STIFF, MOIST	719.85	14.5
GRAY MEDIUM TO FINE GRAINED SANDSTONE FRAGMENTS, WEATHERED	716.35	18.0
LIGHT GRAY , MEDIUM GRAINED SANDSTONE, MASSIVE, OCCATIONAL CARBONACEOUS LAMINAE		
GRAY MUDSTONE, SOFT	683.85	50.5
	682.65	51.7
LIGHT GRAY , MEDIUM TO FINE GRAINED SANDSTONE, MASSIVE, RELATIVELY UNFRACTURED		
LIGHT GRAY VERY FINE GRAINED SANDSTONE, INTERBEDDED WITH SANDY SHALE 104.0'-107.0' - PYRITE NODULES	631.35	103.0
DARK GRAY SHALE	625.35	109.0
	624.15	110.2
DARK GRAY TO RED SHALE	622.85	111.5

AS BUILT

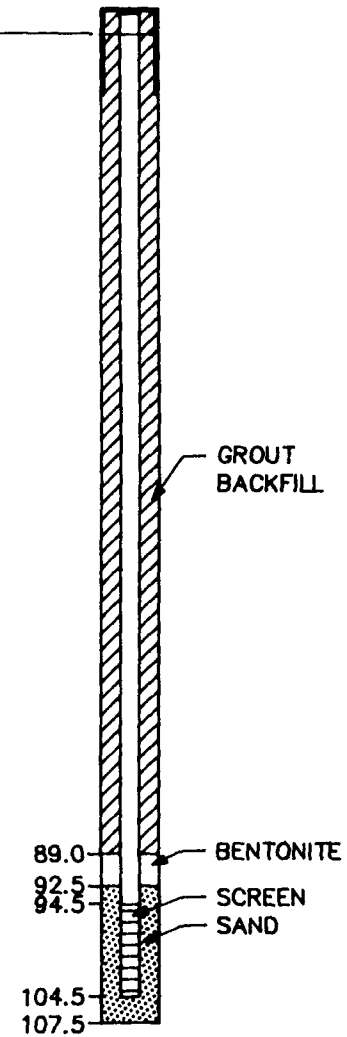


REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO.: B-5
DATE STARTED: 7/27/87
DATE COMPLETED: 7/29/87

DRILLING METHOD: HOLLOW STEM AUGER TO 15'
NX WIRELINE CORING TO 105.8'
5" REAMING TO 107.5'
ENG./GEO.: KEVIN HAMMER

DESCRIPTION	ELEVATION (FEET, MSL)	DEPTH (FEET)
	713.39	0.0
BROWN, MEDIUM GRAINED, SILTY SAND	707.39	6.0
BROWN CLAY, MOIST	702.39	11.0
BROWN SILTY, CLAYEY, SAND, SATURATED	698.39	15.0
GRAY FINE GRAINED SANDSTONE 15.0'–19.9' – BROWN STAINING 37.4'–37.7' – CARBONACEOUS BANDS	649.89	63.5
GRAY COARSE TO MEDIUM GRAINED SANDSTONE 69.0'–72.3' – CARBONACEOUS BANDS	638.89	74.5
GRAY MEDIUM GRAINED SANDSTONE, OCCASIONAL CARBONACEOUS STREAKS	628.39	85.0
GRAY MEDIUM TO FINE GRAINED SANDSTONE 98.5'–99.0' – PYRITIC NODULES	612.59	100.8
GRAY SHALE, FISSILE	612.09	101.3
RED SHALE	607.59	105.8

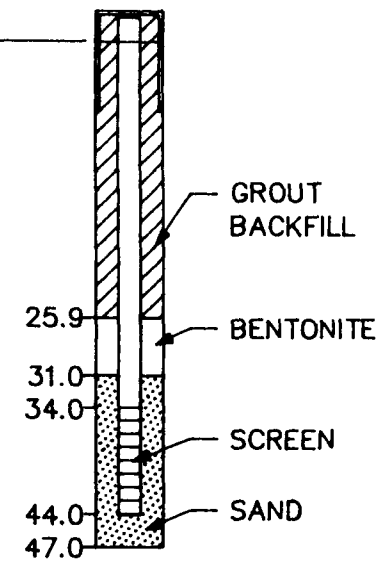
AS BUILT



REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO.: B-6
DATE STARETED: 7/30/87
DATE COMPLETED: 7/30/87

DRILLING METHOD: HOLLOW STEM AUGER TO 11.5'
NX WIRELINE CORING TO 44'
ENG./GEO.: KEVIN HAMMER, LEE MILLER

DESCRIPTION	ELEVATION (FEET, MSL)	DEPTH (FEET)
	731.36	0.0
BROWN SILTY CLAY, HARD		
RED-BROWN CLAY AND WEATHERED SANDSTONE	721.86	9.5
	719.86	11.5
BROWN FINE GRAINED SANDSTONE, WEATHERED 11.5'-14.6' - BROKEN 14.6'-16.9' - GRAY, MASSIVE 16.9'-20.7' - FRACTURED 19.2'-27.7' - IRON STAINING	703.66	27.7
GRAY FINE GRAINED SANDSTONE 29.0'-33.5' - MASSIVE 33.5'-39.0' - OCCATIONAL VERTICAL AND DIAGONAL FRACTURES	692.36	39.0
GRAY SHALE, FISSILE	690.36	41.0
RED SHALE, FISSILE	687.36	44.0

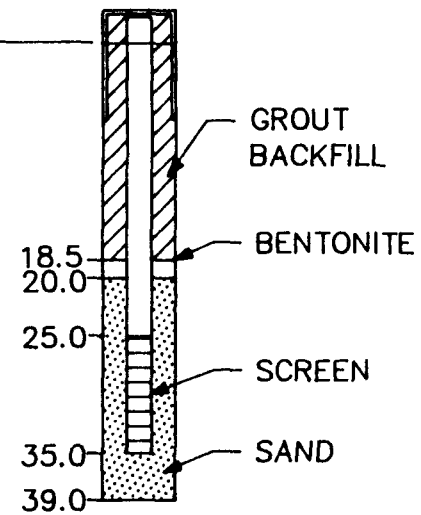


REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO.: B-7
DATE STARTED: 7/14/87
DATE COMPLETED: 7/15/87

DRILLING METHOD: HOLLOW STEM AUGER TO 20'
NX WIRELINE CORING TO 39'
5" REAMING TO 39'
ENG./GEO.: STEVE COX

DESCRIPTION	ELEVATION (FEET, MSL)	DEPTH (FEET)
	722.11	0.0
RED-BROWN SILTY, MEDIUM TO FINE GRAINED SAND 0.0-2.0' - DRY 2.0'-12.0' - MOIST		
	710.11	12.0
RED-BROWN CLAYEY SILT, TRACE FINE SAND 17.5'-18.5' - BROWN SILTY CLAY		
	703.61	18.5
WEATHERED BEDROCK (NOT SAMPLED)	702.11	20.0
LIGHT GRAY MEDIUM TO FINE GRAINED SANDSTONE, MASSIVE 21.3'-24.3' - FRACTURED, COARSE GRAINED 28.6'-31.5' - VERY FINE GRAINED, TRACE OF PYRITE 31.5'-35.1' - OCCASIONAL CARBONACEOUS LAMINA, AND PYRITIC NODULES		
	685.11	37.0

AS BUILT

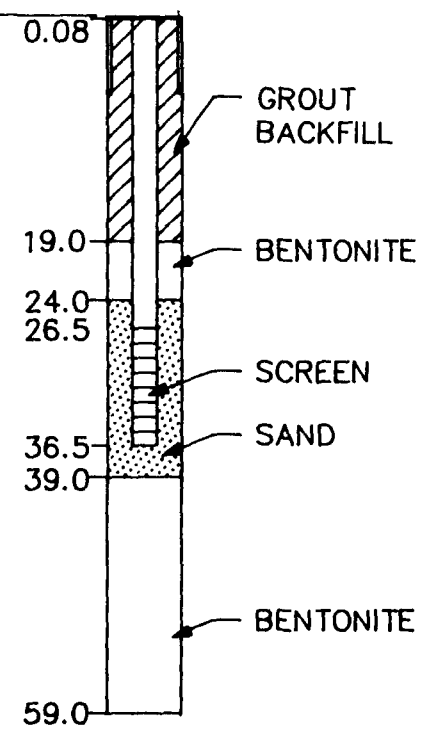


REPUBLIC STEEL QUARRY, ELYRIA, OHIO
BORING NO.: B-8
DATE STARTED:
DATE COMPLETED:

DRILLING METHOD: HOLLOW STEM AUGER TO 10'
NX WIRELINE CORING TO 59'
5" REAMING TO 59'
ENG./GEO.: LESLIE HALLIDAY

DESCRIPTION	ELEVATION (FEET, MSL)	DEPTH (FEET)
DARK BROWN SILTY CLAY, FIRM, DAMP, FILL	719.39 / 717.89	0.0 / 1.5
DARK BROWN SILTY CLAY WITH SAND AND ROCK FRAGMENTS, OCCASIONAL SAND LENSES, FIRM TO LOOSE, DAMP, FILL	712.39	7.0
RED-BROWN SANDY LEAN CLAY WITH OCCASIONAL ROCK FRAGMENTS, FIRM, DAMP, NATURAL SOIL	710.39	9.0
RED-BROWN SILT, VERY SOFT TO SOFT, DAMP TO WET	709.39	10.0
LIGHT GRAY FINE TO MEDIUM GRAINED SANDSTONE, MASSIVE, OCCASIONAL CABONACEOUS STREAKS 10.0'-21.0' - IRON STAINING 12.6'-12.9' - PYRITE BANDS 15.3'-15.4' - PYRITE BANDS 18.6'-18.7' - PYRITE BANDS 21.0'-34.0' - FRACTURED	685.39	34.0
GRAY SILTY CLAYSHALE, FISSILE 35.0'-36.9' - BROKEN	682.49	36.9
RED CLAYSHALE, FRACTURED, SLICKENSIDES 41.9'-59.0' - SILTY, SANDY	660.39	59.0

AS BUILT



APPENDIX J

RESULTS OF GEOPHYSICAL SURVEY

APPALACHIAN COAL SURVEYS

P.O. Box 17203
Pittsburgh, PA 15235
Telephone (412) 243-3039

ICF TECHNOLOGY, INC.
Suite 200
Robinson Plaza II
Pittsburgh, PA 15205

July 28, 1987

Attn: Kenneth Miller
Vice President

Re: Geophysical Borehole Logging Activities, July 16 and July 23, 1987, REPUBLIC STEEL QUARRY SITE, Elyria, Lorain County, Ohio

LETTER REPORT

Dear Mr. Miller:

APPALACHIAN COAL SURVEYS is pleased to submit this letter report on our geophysical borehole logging activities at the captioned project site. Attached to this report are five items. Attachment 1 is a general description of the various log curves, including a brief explanation of the physics involved as well as the geological significance of each curve. Attachment 2 is a Table for Estimating Fluid Ion Content in PPM NaCl equivalency from Temperature and Fluid Conductivity Logs. Attachment 3 is a Table of the depths of significant and correlatable features observed on the various logs in each borehole. Attachment 4 is the original interpreted logs, and Attachment 5 is a set of reduced copies of the logs.

A graphic interpretation can be found on both the original logs and the reduced copies. The lithology is represented between the 4 and 4.5 inch lines on the first run suite (caliper, natural gamma, density and resistance). A "fracture log" is marked between the 4.5 and 5 inch lines on the the same run suite. A water inflow interpretation, indicated by a USGS spring symbol, has been placed between the 4 and 4.5 inch lines on the second and third run suites (neutron, temperature, fluid conductivity, resistivity and spontaneous potential). Finally, a water saturation log (normally indicating aquicludes and perched water), shown by water level symbols, has been drafted between the 4.5 and 5 inch lines on these same suites.

OBSERVATIONS

GEOLOGY

The dominant lithology in all of the boreholes logged appears, by the overall low natural gamma counts and intermediate density, to be a major sandstone unit. This has been identified (by ICF/SRW) as the Berea Sandstone, a channel sandstone formation of Mississippian age. The Berea is regionally underlain by the Bedford Shale also of Mississippian Age. This unit, identified by much higher natural gamma counts, was encountered only in the bottom few feet of the deeper boreholes.

Berea Sandstone

The Berea Sandstone, as it appears on the geophysical logs, can be divided into three units for correlation purposes. The lowermost unit shows predominantly low gamma counts (low clay), and has density charistics of channel sandstones. That is, it has a high density interval, a few inches thick, at the base of the unit which is probably "channel lag" or "bed load". This unit also showed up dramatically on the neutron log as high neutron counts, or very low porosity. This signature corresponds with the "Base" of the Berea Sandstone on Attachment 3. This basal unit also has bed sets, 5 to 10 feet thick, of increasing density, a feature indicative of graded bedding and often associated with point bar sand deposits.

Some 50 feet above the base of the Berea Sandstone there is a high gamma count zone one to three feet thick. This zone is most probably a shale parting within the Berea and can be used to separate the basal unit from the overlying units. This signature corresponds with the "Shale Parting" of the Berea Sandstone on Attachment 3. Immediately above the shale parting is a unit very similar in character (probably point bar sands) to the basal unit, although the "channel lag" signature is not so well developed. This unit is some 30 to 35 feet in thickness and has a gradational top. The highest unit of the Berea Sandstone encountered in the boreholes has a mixed high and medium natural gamma signature. This is typical of levee (overbank) and splay deposites (with occasional point bar sand) associated with the fringe area of a major channel. A persistant gamma signature near the base of this unit was selected as the "Upper Marker" for use on Attachment 3. The Top of the Berea Sandstone was not observed on any of the logs.

Bedford Shale

The Bedford Shale was encountered in three of the boreholes. As indicated by the natural gamma log, the shale is dominantly high counts (over 50% clay minerals) with some sandy or silty zones. The contact with the overlying Berea is errosional as indicated by the "channel lag" signature. This indicates that the contact is (locally) unconformable. It therefore cannot be assumed that the beds immediately below the contact will directly correlate between any two boreholes.

Hydrology

As indicated on the temperature and neutron logs, the Berea Sandstone is hydrologically divided by the shale parting some fifty feet above the base. Temperature anomalies indicate inflow in a 10 to 12 foot zone immediatly above the shale parting as well as in an 8 to 10 foot zone above the base of the unit. There is no indication of water flow in the Bedford Shale. No assumptions of volume of flow should be made from the temperature logs.

The temperature log at this site uncharacteristically showed temperature increases at points of inflow. This is most likely due to communication with surface waters which were being heated by the sun and high air temperatures (90-95 degrees F). The most anomalous of these was in borehole B-8 where the lower inflow zone (26-35 feet), at the base of the Berea, showed a temperature of ± 65 degrees F on the log.

Water Quality

Fluid conductivity log readings in all of the boreholes except B-3 showed fluid resistance to be in the 25 to 50 ohm meter range (200 to 500 micromhos per centimeter). This corresponds to approximatly 100 to 250 mg/l NaCl equivalency. Borehole B-3 however, gave anomalously high readings, in the range of ± 5 ohm meters (± 2000 micromhos per centimeter) corresponding to 1000 to 1500 mg/l NaCl equivlancy. The inflow in this borehole appeared to be in the zone of 16 to 25 feet, and was tentitavly correlated to the upper zone of the Berea. This correlation was tentative because neither of the sharp markers, the shale parting nor the basal contact, was observed on the log of this borehole. It should be noted that the calibration of the conductivity logging tool was done electronically and was not compared to readings in water of known conductivity. These readings should be taken as approximations and should be confirmed with readings from actual samples.

CONCLUSION

The attached geophysical logs, of course, represent high quailty raw data which can stand on its own merit. The interpretations, both the graphic representations on the logs and those in this report are reasonable extentions of that data. Every reasonable attempt has been made to assure the accuracy of these interpretations. As all interpretations, however, they can and should be refined and improved with the addition of new data.

I thank you for allowing APPALACHIAN COAL SURVEYS to participate in this program. We sincerely hope you find our information and interpretations useful. If you have any questions please do not hesitate to call. As always, it has been a pleasure working with ICF/SRW ASSOCIATES.

Respectfully Submitted,

Craig B. Clemmens
CPGS No. 4850
Managing Partner

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS
CERTIFICATE NUMBER
4850
AIPG
CRAIG B. CLEMMENS

APPALACHIAN COAL SURVEYS

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Telephone (412) 243-3039

ATTACHMENT 1
LOG DESCRIPTIONS
ICF/SRW ASSOCIATES
REPUBLIC STEEL QUARRY PROJECT
ELYRIA, LORAIN COUNTY, OHIO

CALIPER: The caliper sonde used at the REPUBLIC STEEL QUARRY PROJECT site was a 3-arm bridge type. The log was generated by measuring the change in resistance across a variable resistor which is coupled to three dependent arms by a geared, spring-loaded rack assembly. As the arms open wider for large hole diameters or less wide for smaller hole diameters, the resistance increases or decreases respectively. The instrument was calibrated by measuring the resistance values of known diameters on the surface prior to logging.

NATURAL GAMMA: The Natural gamma sonde run by APPALACHIAN COAL SURVEYS was a scintillometer type, utilizing a Sodium Iodide detector. Gamma rays from naturally occurring radioactive isotopes pass through the crystal, creating a flash of light. These light flashes are counted electronically to generate the log. In so far as most naturally occurring radioactive isotopes (K_{40} and others) are associated with clay minerals and virtually all clay rich strata are more radioactive than other strata, the natural gamma log is universally accepted as a clay or shale indicator. The natural gamma curve may be the best single curve for correlation and sedimentary lithology determination. The tool was calibrated by exposure to an artificial gamma ray source of known intensity prior to logging.

DENSITY, HIGH RESOLUTION: The density sonde we used was a High Resolution gamma-gamma scintillometer type electronically similar to the natural gamma sonde. The density sonde, however, contains a small radioactive source (Am_{241}) located near, but shielded from, the detector and exposed to the borehole wall. Gamma rays are reflected (back-scattered) by the material in the borehole wall at a rate inversely proportional to the density of the material. Dense materials, such as lead, "absorb" gamma rays and light materials, such as coal, "reflect" gamma rays. (The reflected gamma rays are several orders of magnitude stronger and more frequent than natural gamma rays, so natural interference is minimal.) The instrument was calibrated by placing material of known density over the tool prior to logging. This curve helps to identify grainsize and to differentiate clay poor (low gamma) strata such as limestone, sandstone and coal. It is usually the best single curve for identifying fractures passing through the borehole.

LOG DESCRIPTIONS

DENSITY, GAMMA-GAMMA: In borehole B-1, where some 43 feet of surface casing was required, we also ran long-spaced gamma-gamma density using the High Resolution density sonde. For this log the Am_{241} source was removed and a Ra_{226} source was added. A variable length source holder permits the selection of a source-detector spacing between 4 and 18 inches. This modification permits uncalibrated, relative density logging through thin-wall casing or wire-line drill rod. A 6 inch spacing was selected as this spacing would focus the density readings at a point within the borehole wall while retaining the maximum possible accuracy of bed thickness. The tool was calibrated down-hole by comparison to high and low density strata.

NEUTRON: The neutron sonde we used was a thermal neutron-neutron type, utilizing a Lithium Iodide crystal detector and scintillometer electronics similar to the natural gamma tool. This tool uses a neutron generator (Am_{241}/Be) to expose the rocks in the borehole wall to neutrons. Since most Hydrogen is neutron deficient (H_1), the neutrons are readily absorbed by water and hydrocarbons. Neutrons not absorbed by these materials are "reflected" back to the detector. The saturation (water or hydrocarbon) of the rocks in the borehole wall is inferred from the frequency of reflected neutrons. In detrital sedimentary strata, zones of high water saturation (low counts) are most often aquicludes. In crystalline rocks, however, zones of high water saturation (low counts) are most often aquifers. The instrument was calibrated, for open-hole logging, by placing the sonde in a chamber of known hydrogen content prior to logging. The neutron log can also be run, as a relative log, through casing.

RESISTANCE: The resistance sonde used by APPALACHIAN COAL SURVEYS was a single point horizontal type. This tool measures the resistance of the material in the borehole wall around the circumference of the hole by electrodes located on the caliper tips. The tool was calibrated by placing a resistance of known value between the electrodes. Specific resistance of strata in the borehole can be calculated using this log with the fluid conductivity and caliper logs.

TEMPERATURE: The temperature sonde we used was a pulse type tool. A thermistor located at the bottom of the sonde, sensitive to small changes in water temperature, works to change the frequency of pulses generated by the tool. Measurement of these frequency changes constitutes the log. The tool was calibrated by generation of known frequencies at the surface, however the calibration was not verified by comparison to water of known temperature. The significance of this log is that water flowing within a borehole will show no temperature change, while still water in the borehole will reflect the geothermal gradient of the earth, increasing with depth. Points of groundwater movement are inferred from relative temperature changes on the log.

FLUID CONDUCTIVITY: This tool measures the conductivity (resistance) of the borehole fluid by continuously drawing small volumes of water into an isolated chamber within the tool. The water completes an electrical circuit between two electrodes in this chamber. The log was generated by measuring changes in the resistance of this circuit. The tool was calibrated using a known resistance at the surface, however the calibration was not verified by comparison to water of known conductivity.

LOG DESCRIPTIONS

RESISTIVITY: The resistivity logs we ran were single point vertical type. The sonde measures the resistance of rock in the borehole wall from an electrode on the tool body to the tool body in a vertical direction. The tool requires a water filled hole and was calibrated by relative response.

SPONTANEOUS POTENTIAL: This curve was run with the resistivity sonde described above. The logging equipment is electrically grounded at the surface. The log is a relative electronic measurement of the natural potential between the surface ground and the borehole fluid and was also calibrated by relative response.

RECORDING AND PROCESSING: In order to achieve the highest level of field precision, we used high gain analog recording systems (T.I. Servo II). The interpretation of all logs is made by a CERTIFIED PROFESSIONAL GEOLOGICAL SCIENTIST (AIPG Certification) and the logs are manually coded with graphic symbols corresponding to this interpretation.

APPALACHIAN COAL SURVEYS

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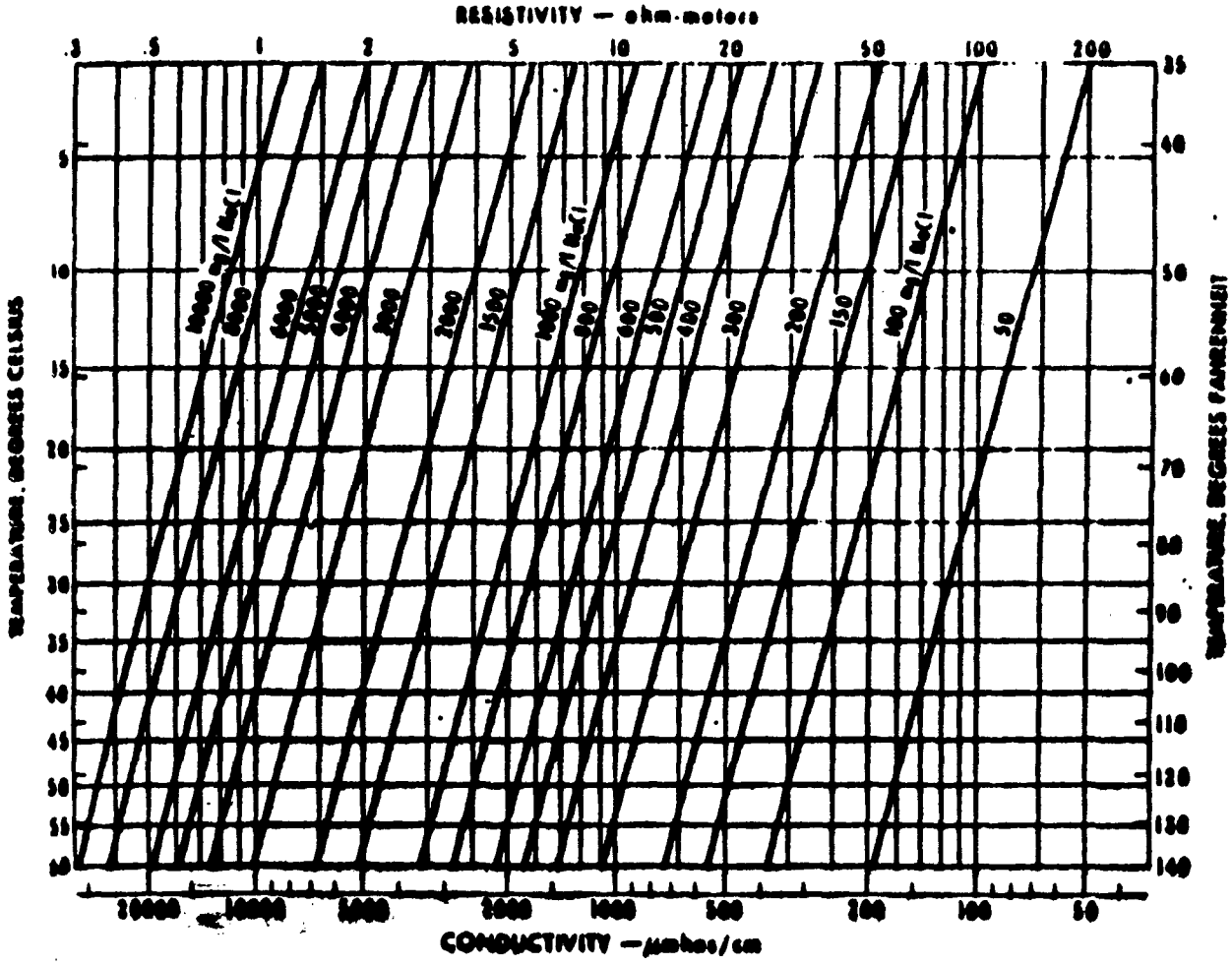
ATTACHMENT 2
TABLE for ESTIMATING FULID ION CONTENT in ppm NaCl equivlancy from Temperature and Fluid Conductivity Logs
ICF/SRW ASSOCIATES
REPUBLIC STEEL QUARRY PROJECT
ELYRIA, LORAIN COUNTY, OHIO



Taken from Techniques of Water Resource Investigations of the United States Geological Survey, Chapter E-1, Application of Borehole Geophysics to Water Resource Investigations.

APPALACHIAN COAL SURVEYS
GEOPHYSICAL LOG DATABASE
30-Jul-87

ATTACHMENT 3
CORRELATION TABLE
ICF/SRW ASSOCIATES
REPUBLIC STEEL QUARRY PROJECT
ELYRIA, LORAIN COUNTY, OHIO

CLIENT: ICF/SRW ASSOCIATES
PROJECT: REPUBLIC STEEL QUARY
LOCATION: Elyria
COUNTY: Lorain
STATE: OHIO

BOREHOLE NO.	DATE	DATUM	FEET TOTAL DEPTH	BELOW WATER LEVEL	DATUM* TOP OF ROCK	BEREA SANDSTONE UPPER MARKER	BEREA SANDSTONE SHALE PARTING	BEREA SANDSTONE BASE	GROUNDWATER INFLOW ZONES UPPER ZONE	GROUNDWATER INFLOW ZONES LOWER ZONE
B-1	23-Jul-87	GROUND LEVEL	75	17	24	below elevation	8-9 ft.	58 ft.	above water level	45-56 ft.
B-2	16-Jul-87	TOP OF CASING	46	17	8	5-13 ft.	39-42 ft.	below TD	27-42 ft.	below TD
B-3	16-Jul-87	TOP OF CASING	37	6	13	16-25 ft.**	below TD**	below TD**	29-37 ft.	below TD
B-4	16-Jul-87	GROUND LEVEL	117	4	15	13-22 ft.	49-50 ft.	101 ft.	40-49 ft.	93-104 ft.
B-8	23-Jul-87	GROUND LEVEL	49	17	9	below elevation	below elevation	35 ft.	below elevation	26-32 ft.

* Approximate depth, based on interpretation of geophysical borehole logs. (Some variation from actual depth may exist.)

** No sharp marker beds exposed, therefore correlation is not definite.

APPALACHIAN COAL SURVEYS

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ATTACHMENT 5
REDUCED GEOPHYSICAL LOGS
ICF/SRW ASSOCIATES
REPUBLIC STEEL QUARRY PROJECT
ELYRIA, LORAIN COUNTY, OHIO

P.O. Box 17[illegible]
Pittsburgh, PA 15236
Telephone (412) 343-[illegible]

APPALACHIAN COAL SURVEYS

HOLE NO. [illegible]

COMPANY [illegible]	LOCATION	UNIT [illegible] OFFICE [illegible]
PROJECT [illegible] HOLE NO. [illegible]		OPERATOR [illegible]
CLIENT REPRESENTATIVE [illegible]	COUNTY [illegible] STATE [illegible]	DATE [illegible]
DRILLED DEPTH [illegible] FT. ELEVATION [illegible] FT.	CASING DEPTH [illegible] FT.	DRILLING FLUID WATER
HOLE DIAMETER [illegible] IN. WATER LEVEL [illegible] FT.	DIAMETER [illegible] IN. FACTOR [illegible]	DRILLING CO. [illegible] DRILLER [illegible]
	WALL THICKNESS [illegible] IN.	

RUN NO.	LOG	INTERVAL (DEPTH) FT.	RANGE	TIME CONSTANT	SOURCE	SPACING
1	CALIPER	63 - 75	1 [illegible]			
2	NATURAL [illegible]	0 - [illegible]	100 CPS	3 SEC	NATURAL	
3	H.R. DENSITY	63 - 75	10 CPS	1 SEC	Am 241	6.0 in.
3	$\bar{C}\bar{C}$ DENSITY	6 - 63	100 CPS	1 SEC	Ra 226	6.0 in.
4	NEUTRON	6 - 75	200 CPS	1 SEC	Am-Be	12.0 in.
1,3	RESISTIVITY	63 - 75	20 Ω			
5	SPONTANEOUS POTENTIAL	63 - 72	200 mV			
6	TEMPERATURE	17 - 75	5 °F			
8	FLUID CONDUCTIVITY	17 - 75	20 Ω-m			
	SONIC	-	[illegible]			2.0 FT.
	OTHER	-				

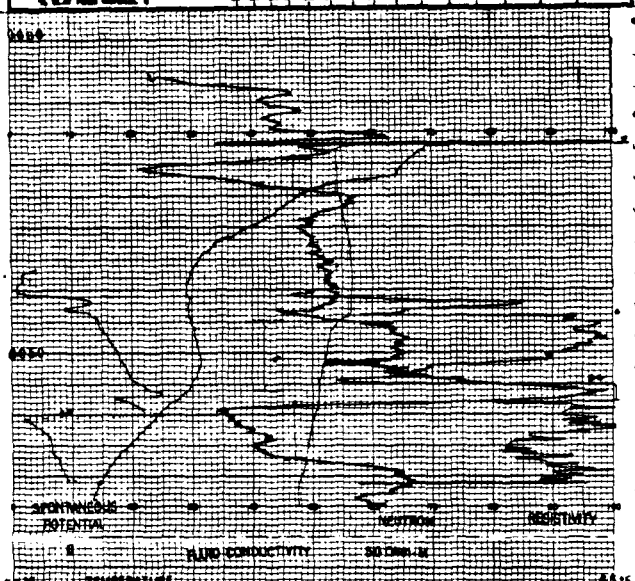
INTERPRETATION

- COAL < 10% ASH
- COAL > 10% ASH
- SONIC/CARBONACEOUS SHALE > 50% ASH
- FIREBLAY/HOT SHALE
- LIMESTONE/OTHER CARBONATE
- SANDSTONE
- SILTY SANDSTONE
- SHALE/CLAYSTONE
- SANDY SHALE/SILTSTONE
- GROUNDWATER INFLOW
- GROUNDWATER OUTFLOW

RUNS

RUN NO.	INTERVAL (DEPTH) FT.	SCALE FT./IN.	LOGGING SPEED FT./MIN.
1	[illegible] - 75	10	20
2	[illegible] - 75	10	20
3	[illegible] - 63	10	20
4	[illegible] - 75	10	20
5	[illegible] - 75	10	20
	-		
	-		
	-		

NOTES: DATUM IS GROUND LEVEL



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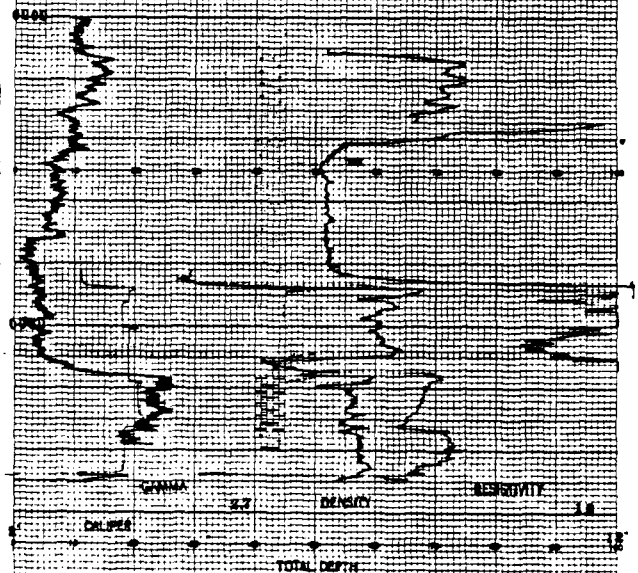

32

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Pittsburgh, PA 15235
Telephone (412) 243-3000

APPALACHIAN COAL SURVEYS

LOG HEADING
HOLE NO.
B-2

COMPANY [illegible]	LOCATION	UNIT [illegible] OFFICE [illegible]
PROJECT [illegible] HOLE NO. [illegible]		OPERATOR [illegible]
CLIENT REPRESENTATIVE [illegible]	COUNTY [illegible] STATE [illegible]	DATE [illegible]
DRILLED DEPTH [illegible] FT. ELEVATION FT.	CASING DEPTH [illegible] FT.	DRILLING FLUID
HOLE DIAMETER [illegible] IN. WATER LEVEL 17 FT.	DIAMETER [illegible] IN. FACTOR [illegible]	DRILLING CO. DRILLER
	WALL THICKNESS IN.	

RUN #	LOG	INTERVAL (DEPTH) FT.	RANGE	TIME CONSTANT	SOURCE	SPACING
1	CALIPER	10 - 40	1 in/in			
2	NATURAL $\bar{\gamma}$	0 - 40	100CPS	2 SEC	NATURAL	
3	H.R. DENSITY	10 - 40	1KCPS	1 SEC	Am 241	1.0 in.
	$\bar{\gamma}\bar{\gamma}$ DENSITY	-	CPS	SEC	Ra 226	in.
3	NEUTRON	6 - 40	200CPS	1 SEC	Am-Be	12.0 in.
1, 4	RESISTIVITY	10 - 40	20 Ω			
4	SPONTANEOUS POTENTIAL	17 - 40	200 MV			
4	TEMPERATURE	17 - 40	5 mv			
4	FLUID CONDUCTIVITY	17 - 40	20 Ω/in			
	SONIC	-	[illegible]			2.0 FT.
	OTHER	-				

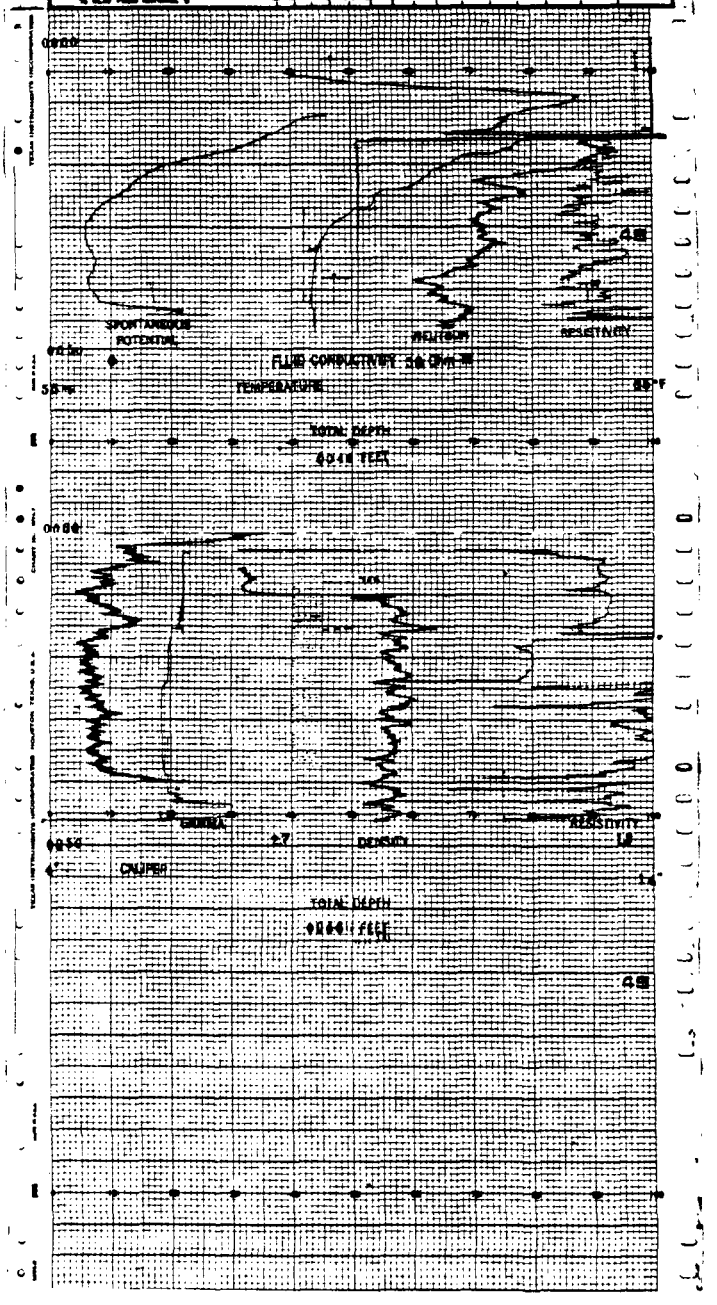
INTERPRETATION

- COAL < 10% ASH
- COAL > 10% ASH
- SONE/CARBONACEOUS SHALE > 50% ASH
- FIREDLAY/HOT SHALE
- LIMESTONE/OTHER CARBONATE
- SANDSTONE
- SILTY SANDSTONE
- SHALE/CLAYSTONE
- SANDY SHALE/SILTSTONE
- GROUNDWATER INFLOW
- GROUNDWATER OUTFLOW

RUNS

RUN #	INTERVAL (DEPTH) FT.	SCALE FT./IN.	LOGGING SPEED FT./MIN.
1	[illegible] - 40	10	20
2	[illegible] - 40	10	20
3	[illegible] - 40	10	20
4	[illegible] - 40	10	20
	-		
	-		
	-		
	-		

NOTES: DATUM IS TOP OF CASING



P O Box 17255
Pittsburgh, PA 15235
Telephone (412) 243-[illegible]

APPALACHIAN COAL SURVEYS

LOG HEADING
HOLE NO.
[illegible]

COMPANY [illegible]	LOCATION	UNIT [illegible] OFFICE [illegible]
PROJECT [illegible] HOLE NO. [illegible]		OPERATOR [illegible]
CLIENT REPRESENTATIVE [illegible]	COUNTY [illegible] STATE [illegible]	DATE [illegible]
DRILLED DEPTH [illegible] FT. ELEVATION FT.	CASING DEPTH [illegible] FT.	DRILLING FLUID
HOLE DIAMETER [illegible] IN. WATER LEVEL FT.	DIAMETER [illegible] IN. FACTOR [illegible]	DRILLING CO. DRILLER
	WALL THICKNESS IN.	

RUN #	LOG	INTERVAL DEPTH FT.	RANGE	TIME CONSTANT	SOURCE	SPACING
1	CALIPER	16 - 37	1 [illegible]			
2	NATURAL $\bar{\gamma}$	0 - 31	100 CPS	2 SEC	NATURAL	
3	H.R. DENSITY	16 - 37	11 CPS	1 SEC	Am 241	1.0 in.
	$\bar{\gamma}\bar{\gamma}$ DENSITY	-	CPS	SEC	Ra 2.55	in.
3	NEUTRON	6 - 37	500 CPS	1 SEC	Am-Be	12.0 in.
1,4	RESISTIVITY	16 - 37	20 Ω			
4	SPONTANEOUS POTENTIAL	16 - 35	200 MV			
4	TEMPERATURE	6 - 37	5 °F			
4	FLUID CONDUCTIVITY	6 - 37	50 Ω M			
	SONIC	-	[illegible]			2.0 FT.
	OTHER	-				

INTERPRETATION

- COAL < 10% ASH
- COAL > 10% ASH
- BONE/CARBONACEOUS SHALE > 50% ASH
- FRIEDLAW HOT SHALE
- LIMESTONE/OTHER CARBONATE
- SANDSTONE
- SILTY SANDSTONE
- SHALE/CLAYSTONE
- SANDY SHALE/SILTSTONE
- GROUNDWATER INFLOW
- GROUNDWATER OUTFLOW

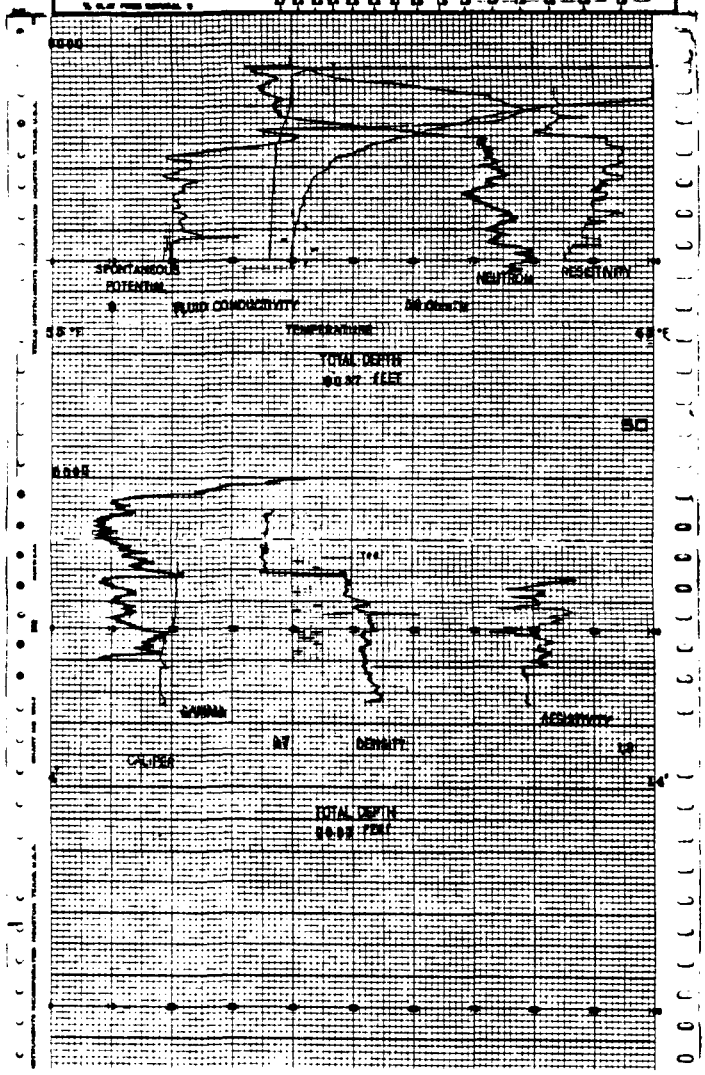
RUNS

RUN #	INTERVAL (DEPTH) FT.	SCALE FT./IN.	LOGGING SPEED FT./MIN.
1	[illegible] - 37	10	20
2	[illegible] - 37	10	20
3	[illegible] - 37	10	20
4	[illegible] - 37	10	20
	-		
	-		
	-		
	-		

NOTES: DATUM IS TOP OF CASING

% CLAY FREE NATURAL [illegible]

H.R. DENSITY CALIBRATED [illegible]



P.O. Box 17283
Pittsburgh, PA 15235
Telephone (412) 243-3038

APPALACHIAN COAL SURVEYS

LOG HEADING
HOLE NO.
[illegible]

COMPANY ICF/[illegible]	LOCATION	UNIT 41 OFFICE [illegible]
PROJECT [illegible] HOLE NO. [illegible]		OPERATOR [illegible]
CLIENT REPRESENTATIVE [illegible]	COUNTY Lorain STATE [illegible]	DATE 16-Jul-87
DRILLED DEPTH 117 FT ELEVATION FT	CASING DEPTH 18 FT	DRILLING FLUID
HOLE DIAMETER 3.9 IN WATER LEVEL FT	DIAMETER 4.0 IN FACTOR	DRILLING CO. DRILLER
	WALL THICKNESS IN	

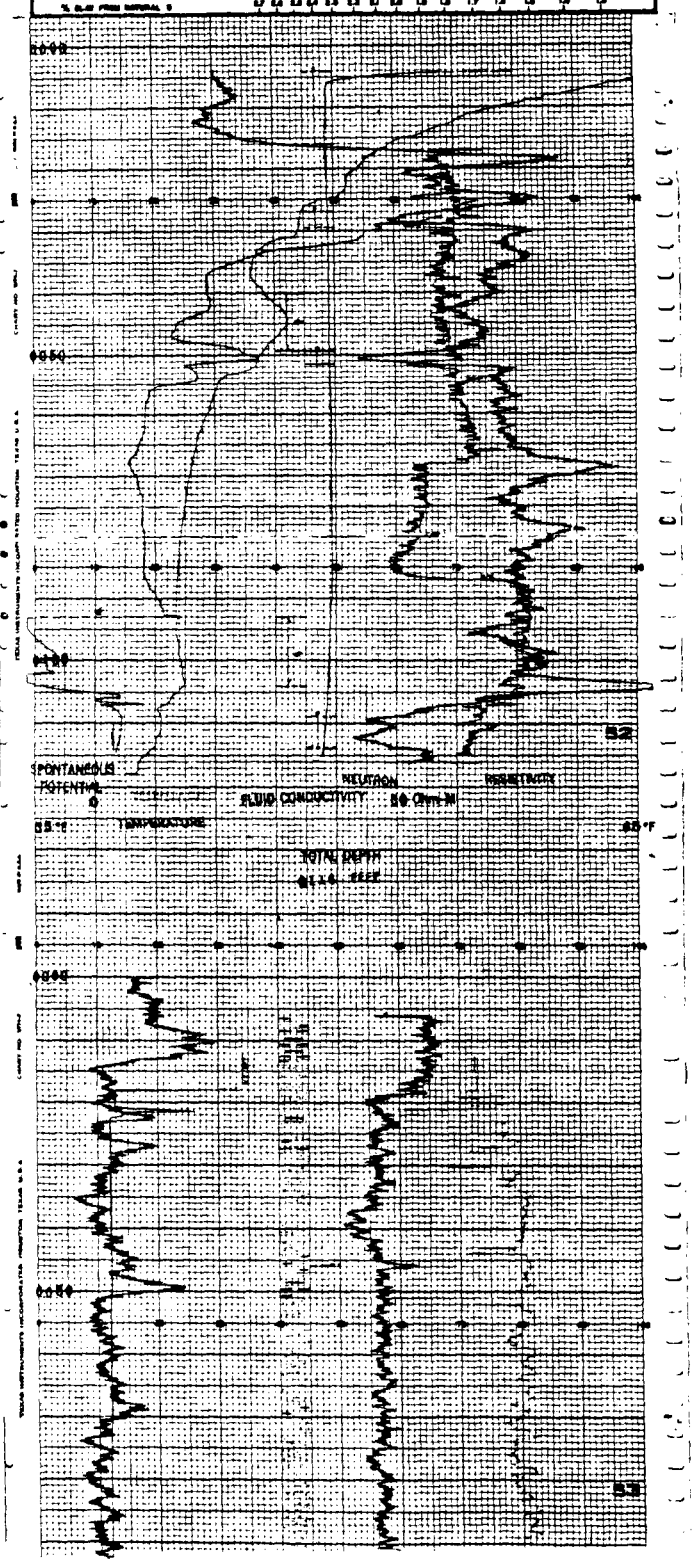
RUN #	LOG	INTERVAL (DEPTH) FT.	RANGE	TIME CONSTANT	SOURCE	SPACING
1	CALIPER	18 - 117	1 in/in			
2	NATURAL	0 - 111	100 CPS	2 SEC	NATURAL	
2	H.R. DENSITY	18 - 117	1 in CPS	1 SEC	Am 241	1.0 in.
	$\bar{O}\bar{O}$ DENSITY	-	CPS	SEC	Ra 226	in.
3	NEUTRON	0 - 117	200 CPS	1 SEC	Am-Be	12.0 in.
1, 4	RESISTIVITY	18 - 117	20 Ω			
4	SPONTANEOUS POTENTIAL	18 - 117	200 mV			
4	TEMPERATURE	4 - 117	3 °F			
4	FLUID CONDUCTIVITY	4 - 117	20 Ω/in			
	SONIC	-	in/ft			2.0 FT.
	OTHER	-				

INTERPRETATION
- COAL < 10% ASH
- COAL > 10% ASH
- BONE/CARBONACEOUS SHALE > 50% ASH
- PINEOLAY/HOT SHALE
- LIMESTONE/OTHER CARBONATE
- SANDSTONE
- SILTY SANDSTONE
- SHALE/CLAYSTONE
- SANDY SHALE/SILTSTONE
- GROUNDWATER INFLOW
- GROUNDWATER OUTFLOW

RUNS

RUN #	INTERVAL (DEPTH) FT.	SCALE FT./IN.	LOGGING SPEED FT./MIN.
1	SUB - 117	10	20
2	SUB - 117	10	20
3	SUB - 117	10	20
4	SUB - 117	10	20
	-		
	-		
	-		
	-		

NOTES: DATUM IS GROUND LEVEL.



SPONTANEOUS POTENTIAL
TEMPERATURE
FLUID CONDUCTIVITY
NEUTRON
RESISTIVITY
TOTAL DEPTH
GAMMA
DENSITY
RESISTIVITY
CALIPER
TOTAL DEPTH
FEET

P.O. Box 17200
Pittsburgh, PA 15236
Telephone (412) 243-3030

APPALACHIAN COAL SURVEYS

LOG HEADING
HOLE NO.
m - m

COMPANY ICF/SBV	LOCATION	UNIT 61 OFFICE Pgh	
PROJECT Bonnville HOLE NO. 3-8		OPERATOR CRC	
CLIENT REPRESENTATIVE E. Cox	COUNTY Lorain STATE OH	DATE 23-Jul-87	
DRILLED DEPTH 49 FT ELEVATION FT	CASING DEPTH 13 FT	DRILLING FLUID WATER	
HOLE DIAMETER 3.9 IN WATER LEVEL 17 FT	DIAMETER 6 IN. FACTOR	DRILLING CO. DRILLER	
	WALL THICKNESS IN.		

RUN #	LOG	INTERVAL (DEPTH) FT.	RANGE	TIME CONSTANT	SOURCE	SPACING
1	CALIPER	12 - 49	1 in/in			
2	NATURAL $\bar{\gamma}$	0 - 43	100 CPS	2 SEC	NATURAL	
2	H.R. DENSITY	12 - 49	15 CPS	1 SEC	Am 241	0.5 in.
	$\bar{\gamma}\bar{\gamma}$ DENSITY	-	CPS	SEC	Ra 226	in.
3	NEUTRON	6 - 49	500 CPS	1 SEC	Am-Be	12.0 in.
1, 4	RESISTIVITY	12 - 49	20 Ω			
4	SPONTANEOUS POTENTIAL	17 - 47	200 MV			
4	TEMPERATURE	17 - 49	5 °F			
4	FLUID CONDUCTIVITY	17 - 49	50 Ω M			
	SONIC	-	μs/ft			2.0 FT.
	OTHER	-				

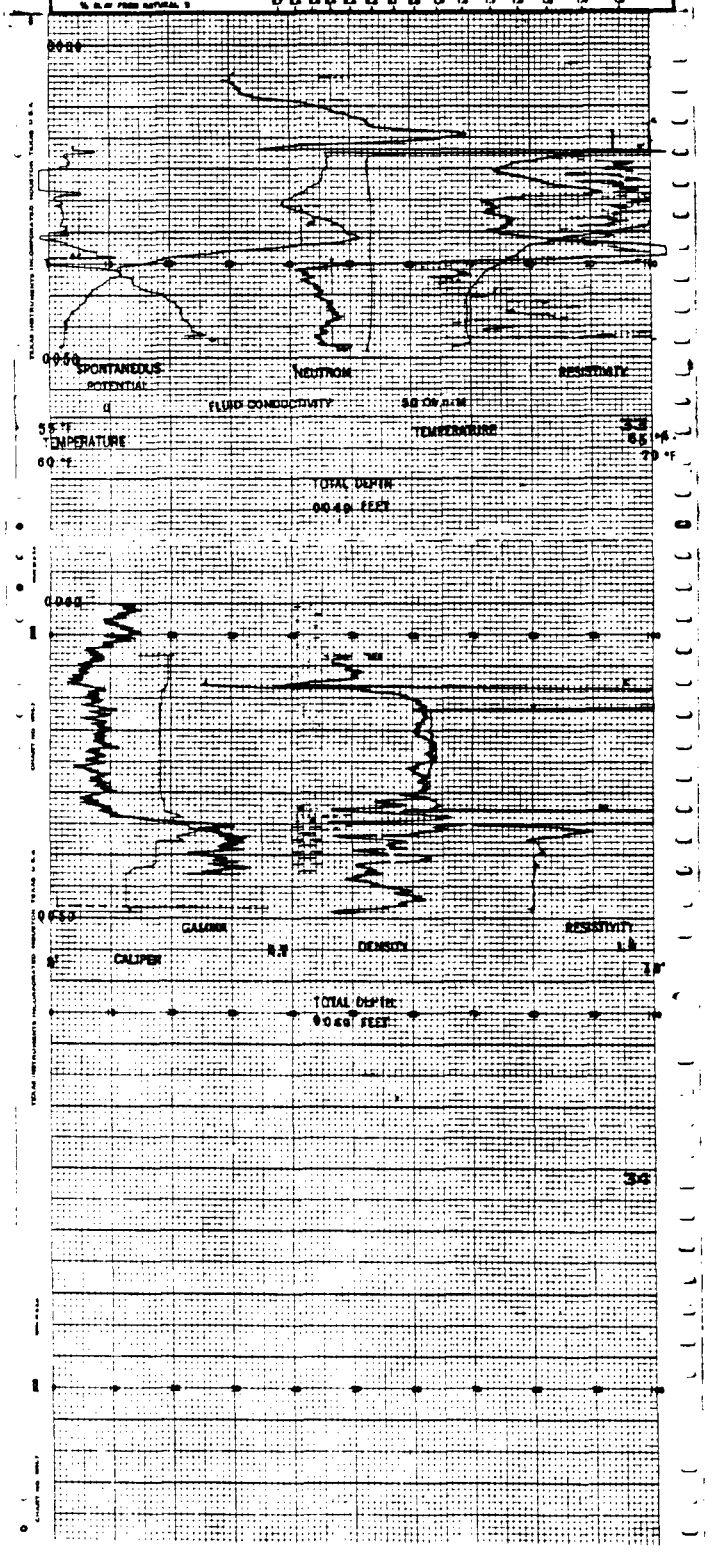
INTERPRETATION

- COAL < 10% ASH
- COAL > 10% ASH
- SONE/CARBONACEOUS SHALE > 50% ASH
- FIRECLAY/HOT SHALE
- LIMESTONE/OTHER CARBONATE
- SANDSTONE
- SILTY SANDSTONE
- SHALE/CLAYSTONE
- SANDY SHALE/SILTSTONE
- GROUNDWATER INFLOW
- GROUNDWATER OUTFLOW

RUNS

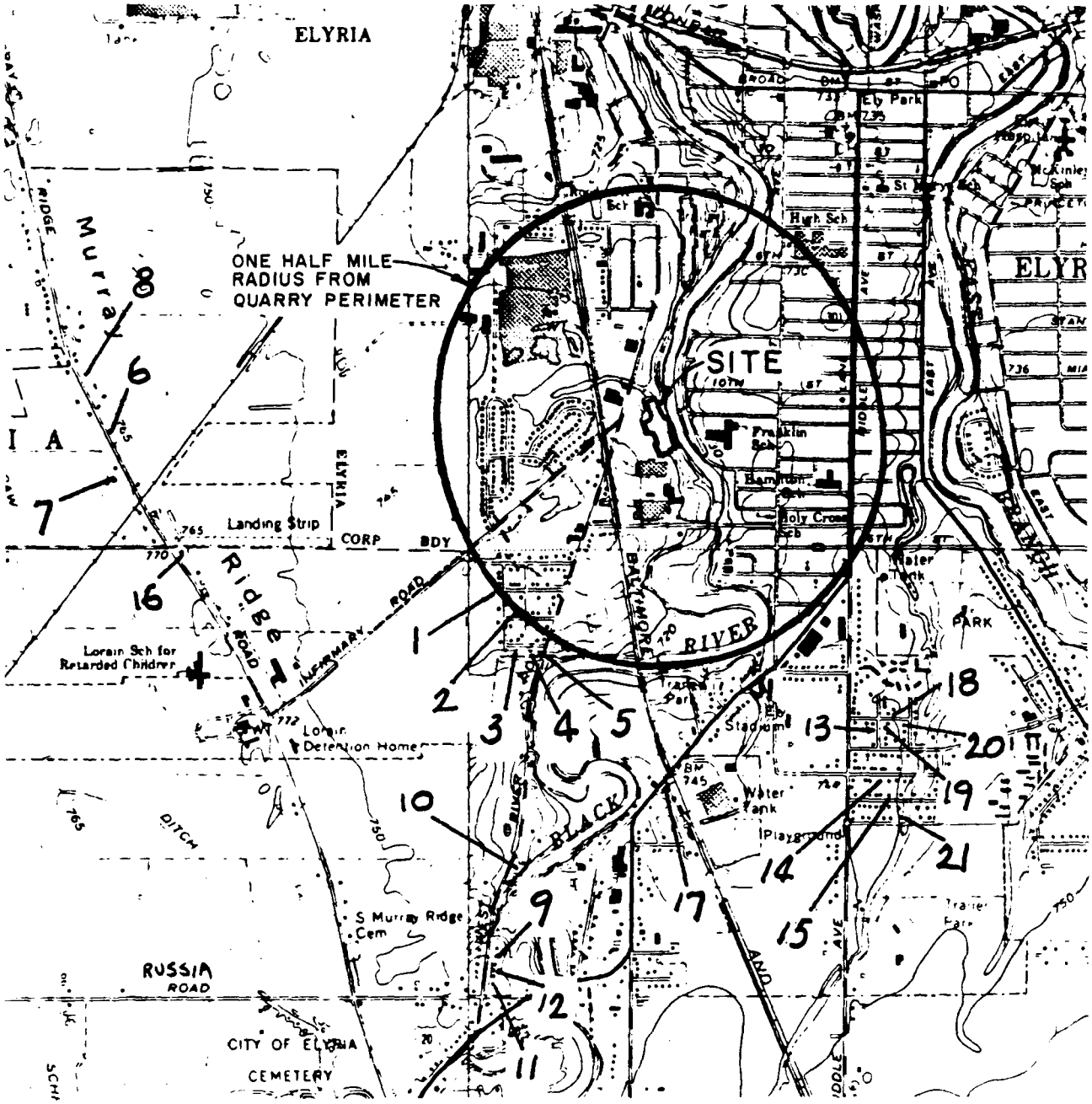
RUN #	INTERVAL (DEPTH) FT.	SCALE FT/IN	LOGGING SPEED FT/MIN
1	SUB - 49	10	20
2	SUB - 49	10	20
3	SUB - 49	10	20
4	SUB - 49	10	20
	-		
	-		
	-		
	-		

NOTES: DATUM IS GROUND LEVEL



APPENDIX K

ODNR WELL INVENTORY



LEGEND:

10 ODNR WELL LOG NO. 10 APPROXIMATE LOCATION

N

0 2000 4000

SCALE IN FEET

FIGURE K-1
ODNR WELL LOG LOCATIONS
REPUBLIC STEEL QUARRY RI

WELL LOG AND DRILLING REPORT

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

(24) LOCATED

ORIGINAL

№ 143332

47 County LORAIN 8 Township CARLISLE Section of Township or Lot Number 24

Owner JOE WILLIAMS Address ELYRIA, O

Location of property END OF WEST 12TH ST SOUTH OF ELYRIA

CONSTRUCTION DETAILS

Casing diameter 6 Length of casing 13½

Type of screen — Length of screen —

Type of pump —

Capacity of pump

Depth of pump setting

PUMPING TEST

Pumping rate — G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity

Static level—depth to water 7 ft

Pump installed by

WELL LOG

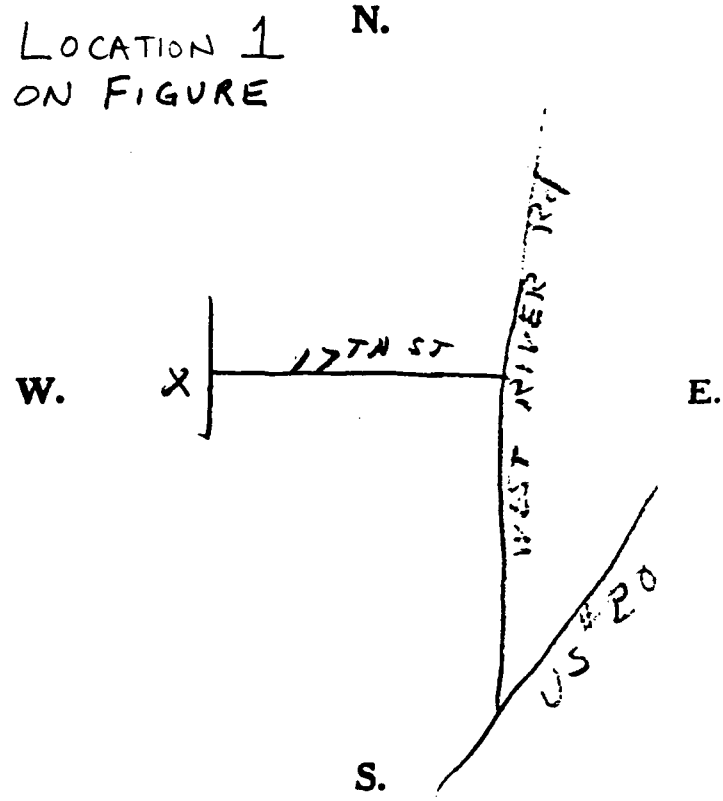
Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY & SAND	0 Feet	11 Ft.
SAND STONE	11	37

(4)

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 1 ON FIGURE



See reverse side for instructions

Drilling Firm L SCHUSTER & SON Date 6-14-55

Address ELYRIA O Signed B [illegible]

24

WELL LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

Nº 126875

County Lorain Township ~~Elyria~~ Carlile Section of Township or Lot Number West River Sect

Owner Mrs Houston Address 725 West 18 St off West Ely

Location of property 1 mile north off West River Rd Elyria

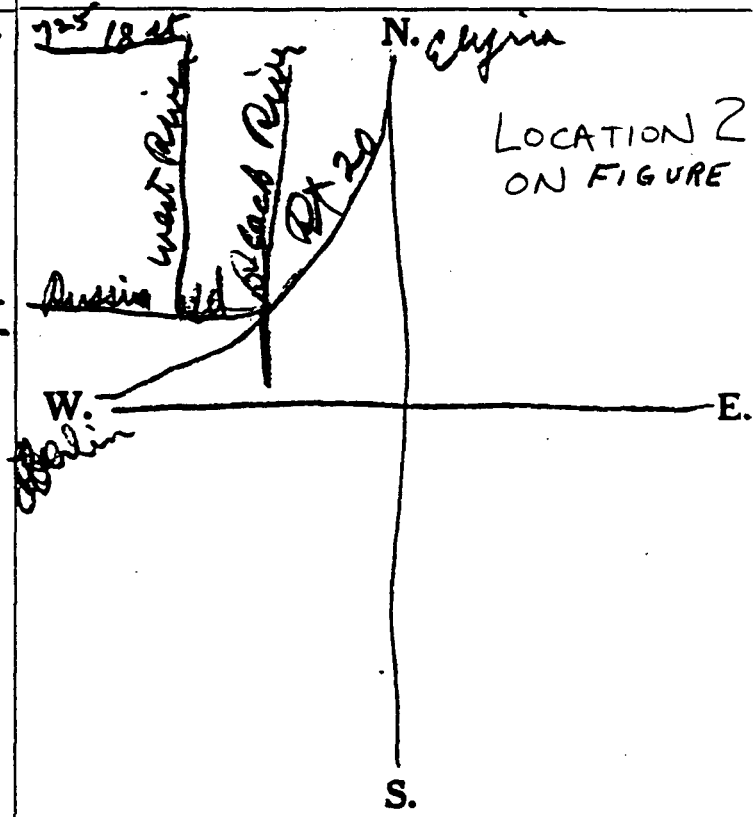
CONSTRUCTION DETAILS	PUMPING TEST
Casing diameter 6 Length of casing 17'	Pumping rate 10 G.P.M. Duration of test 8 hrs.
Type of screen — Length of screen —	Drawdown 18 ft. Date Aug 24/55
Type of pump Shallow	Developed capacity 12 GPM
Capacity of pump 10 GPM	Static level—depth to water 14' ft.
Depth of pump setting 35'	Pump installed by Owner

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
	0 Feet	~~13~~ Ft.
Clay		
Sand	13	15
Gravel	15	17
Stone	17	37½
water 29'		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm J. Garrish Date Aug 24/55

Address R D Elyria O. Signed J. Garrish

23

WELL LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

Nº 138410

County LORAIN Township Carlile [redacted] Section of Township or Lot Number

Owner RALPH BOSWELL Address 736 W. 19 ST. ELYRIA, OHIO.

Location of property

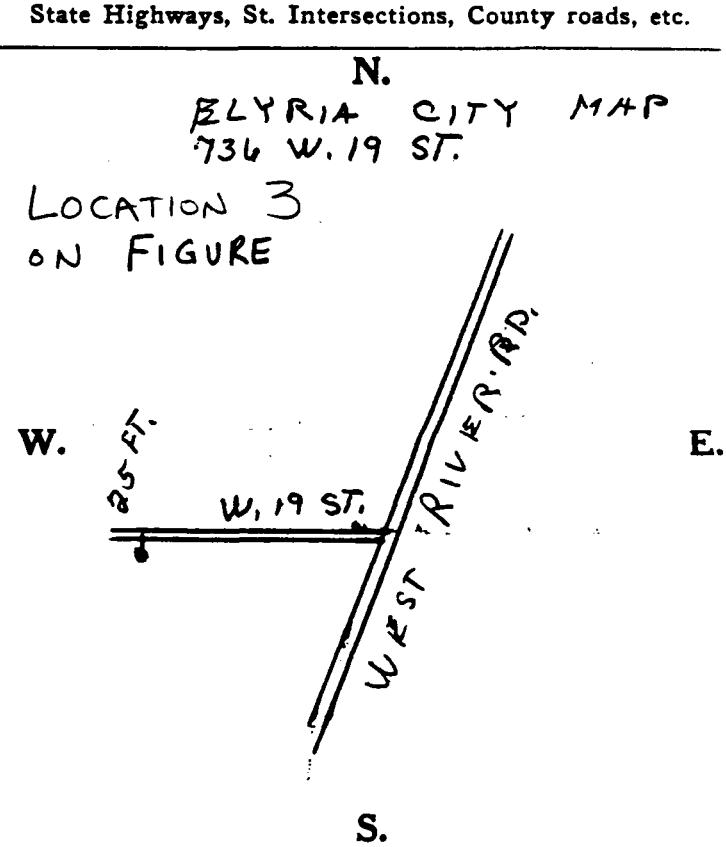
CONSTRUCTION DETAILS	PUMPING TEST
Casing diameter 5½ OD Length of casing 29 FT.	Pumping rate 10 G.P.M. Duration of test 2 hrs.
Type of screen — Length of screen —	Drawdown — ft. Date 3 MAY, 1955
Type of pump —	Developed capacity —
Capacity of pump —	Static level—depth to water 12 FT. ft
Depth of pump setting —	Pump installed by —

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
	0 Feet	Ft.
YELLOW CLAY		
GREY SANDY CLAY		
SOFT GREY SANDSTONE		
GREY SANDSTONE		
WATER SHELL		
GREY SANDSTONE		
WATER SHELL		
GREY SANDSTONE		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm Harry McClelland & Son Date 5 May, 1955

Address 398 N. Cline St. Signed William C. McClelland

(24)

WELL LOG AND DRILLING REPORT

ORIGINAL

26

LOCATED

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

No. 143321

47 County LORAIN 8 Township CARLISLE Section of Township or Lot Number 26

Owner JACK COOK Address 719 19TH ST. ELYRIA O

Location of property ON WEST 19TH ST NEAR WEST RIVER Rd

CONSTRUCTION DETAILS

Casing diameter 6 Length of casing 29

Type of screen — Length of screen —

Type of pump —

Capacity of pump

Depth of pump setting

PUMPING TEST

Pumping rate — G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity

Static level—depth to water 18 ft.

Pump installed by

WELL LOG

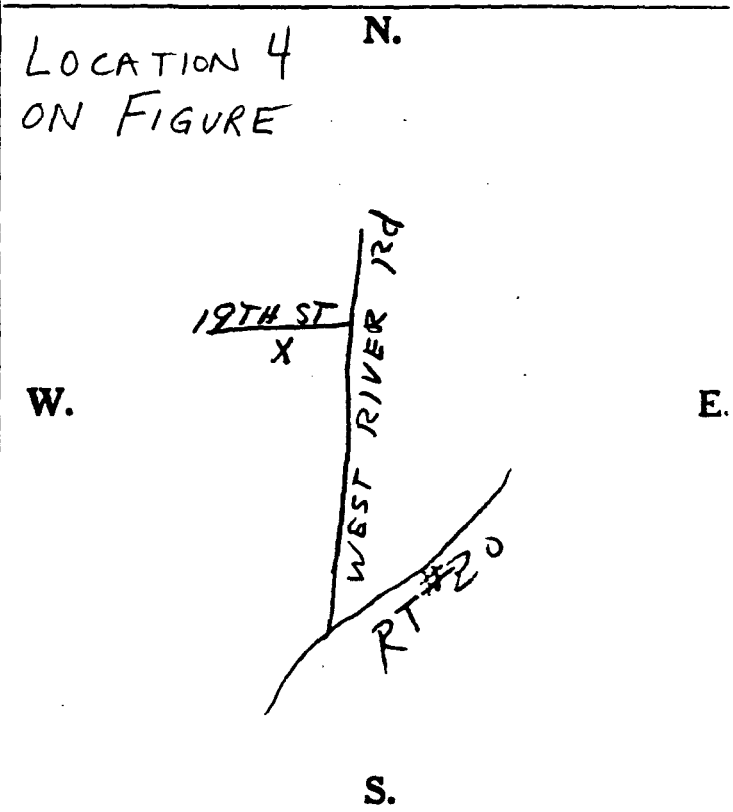
Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY	0 Feet	~~14~~ Ft.
SAND ~~STONE~~	14	22
BROKEN STONE	22	26
SANDSTONE	26	46
LIGHT SHALE	46	47

4

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 4 ON FIGURE



See reverse side for instructions

Drilling Firm L SCHUSTER & SON Date 5-4-55

Address ELYRIA, O Signed B Schuster

26

WELL LOG AND DRILLING REPORT

25

ORIGINAL

LOCATED

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

№ 143322

47

County LORAIN Township 8 CARLISLE Section of Township or Lot Number 25

Owner JAMES FORCROW Address WEST 19TH ST ELYRIA, O

Location of property ON WEST 19TH ST OFF WEST RIVER Rd

CONSTRUCTION DETAILS

Casing diameter 6 Length of casing 31

Type of screen — Length of screen —

Type of pump

Capacity of pump

Depth of pump setting

PUMPING TEST

Pumping rate — G.P.M. Duration of test hrs

Drawdown ft. Date

Developed capacity

Static level—depth to water 18 ft

Pump installed by

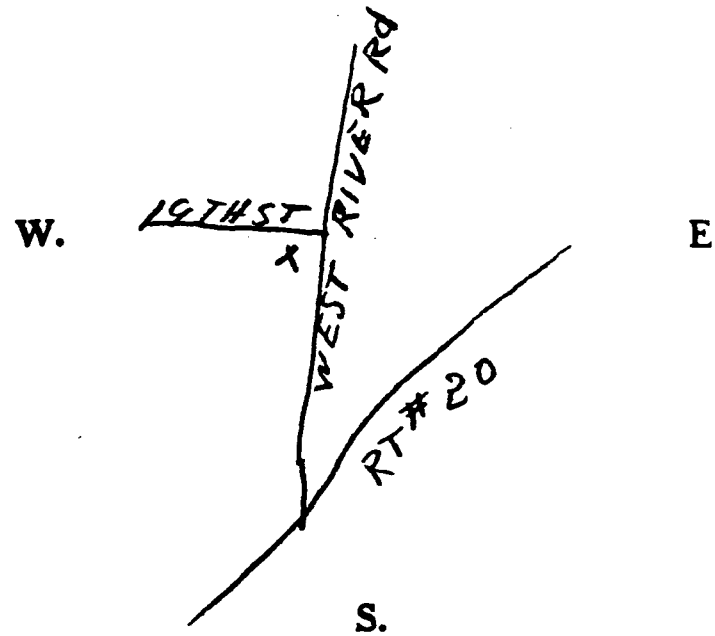
WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY	0 Feet	14 Ft.
SAND	14	22
BROKEN STONE	22	27
SANDSTONE	27	40
4		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 5 ON FIGURE



See reverse side for instructions

Drilling Firm L SCHUSTERSON Date 5-5-55

Address ELYRIA O Signed B. Schuster

25

WELL LOG AND DRILLING REPORT

ORIGINAL

NO CARBON PAPER NECESSARY– SELF-TRANSCRIBING

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Geological Survey
Fountain Square
Columbus, Ohio 43224 Phone (614) 466-5344

490016

COUNTY LORAIN TOWNSHIP ELYRIA SECTION OF TOWNSHIP OR LOT NUMBER

OWNER Herman Larkins ADDRESS 130 TAFT AVE ELYRIA

LOCATION OF PROPERTY MURRAY RIDGE Rd SOUTH OF RT 113

CONSTRUCTION DETAILS

Casing diameter 6 1/4 Length of casing 18

Type of screen — Length of screen

Type of pump HAND PUMP

Capacity of pump

Depth of pump setting 25'

Date of completion 11-5-75

BAILING OR PUMPING TEST
(specify one by circling)

Test rate 30 gpm Duration of test 1 hrs

Drawdown 20 ft Date 11-4-75

Static level (depth to water) 5 1/2 ft

Quality (clear, cloudy, taste, odor) CLEARING NO ODOR

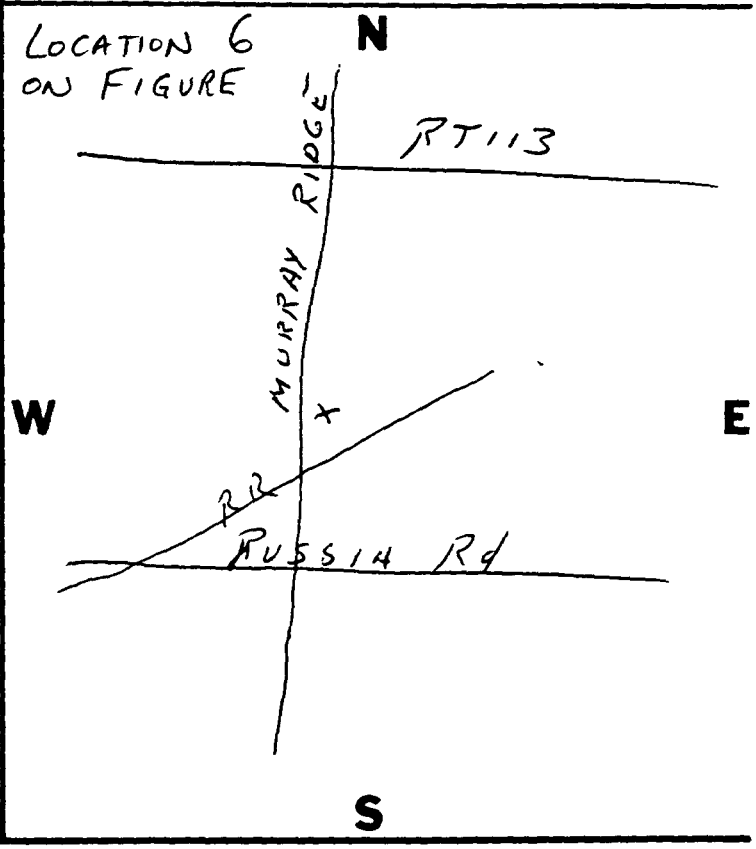
Pump installed by B. SCHUSTER

WELL LOG*

Formations: sandstone, shale, limestone, gravel, clay	From	To
SANDY CLAY	0 ft	7 ft
BROKEN YELLOW STONE	7	12
LIGHT SANDSTONE	12	55
CASING CEMENTED IN STONE		

SKETCH SHOWING LOCATION

Locate in reference to numbered state highways, street intersections, county roads, etc.



DRILLING FIRM BERN SCHUSTER DATE 11-4-75

ADDRESS ELYRIA SIGNED B. Schuster

*If additional space is needed to complete well log, use next consecutive numbered form.

WELL LOG AND DRILLING REPORT

ORIGINAL

NO CARBON PAPER NECESSARY— SELF-TRANSCRIBING

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
65 S. Front St., Rm. 815 Phone (614) 469-2646
Columbus, Ohio 43215

438611

County LORAIN Township ELYRIA Section of Township

Owner DOUGLAS G SKLADAN Address 9136 S. MURRY RIDGE Rd ELYRIA

Location of property [illegible]

CONSTRUCTION DETAILS	BAILING OR PUMPING TEST (Specify one by circling)
Casing diameter [illegible] Length of casing [illegible]	Test Rate 30 G.P.M. Duration of test ½ hrs
Type of screen — Length of screen	Drawdown 25 ft. Date 6-13-72
Type of pump [illegible]	Static level-depth to water 7½ ft.
Capacity of pump 20 GPM	Quality (clear, cloudy, taste, odor)
Depth of pump setting 32	NO ODOR
Date of completion [illegible]	Pump installed by [illegible]

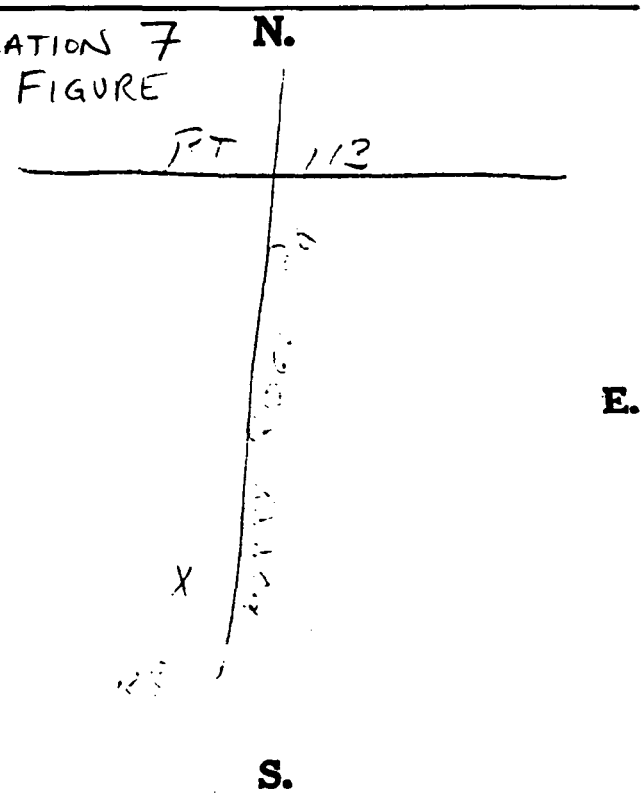
WELL LOG*

Formations Sandstone, shale, limestone, gravel and clay	From	To
YELLOW CLAY	0 Feet	12 Ft.
BLUE CLAY	12	15
BLUE CLAY & SAND	15	22
SAND	22	28
SAND & GRAVEL	28	40
WATER [illegible]	[illegible]	

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 7 ON FIGURE



Drilling Firm BERN SCHUSTER Date 6-13-72

Address ELYRIA Signed [illegible]

*If additional space is needed to complete well log, use next consecutive numbered form.

WELL LOG AND DRILLING REPORT

ORIGINAL

NO CARBON PAPER NECESSARY– SELF-TRANSCRIBING

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Fountain Square
Columbus, Ohio 43224

512717

COUNTY LORAIN TOWNSHIP ELYRIA SECTION OF TOWNSHIP

OWNER HERMAN LARKINS ADDRESS 138 TAFT AVE ELYRIA

LOCATION OF PROPERTY MURRY RIDGE Rd

CONSTRUCTION DETAILS

Casing diameter 6 1/4 Length of casing 26 1/2

Type of screen — Length of screen

Type of pump SUBMERSIBLE

Capacity of pump 16 GPM

Depth of pump setting 50'

Date of completion 1-20-78

BAILING OR PUMPING TEST
(specify one by circling)

Test rate 10 gpm Duration of test 3 1/2 hrs

Drawdown 48 ft Date 1-20-78

Static level (depth to water) 11 1/2 ft

Quality (clear, cloudy, taste, odor) NO ODOR CLEARING

Pump installed by BERN SCHUSTER

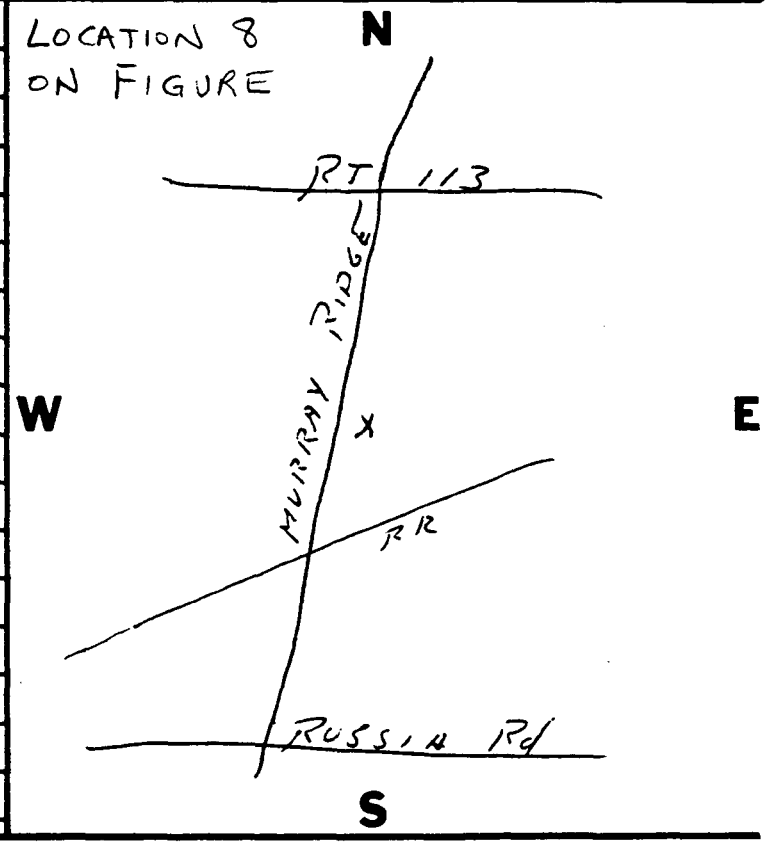
WELL LOG*

Formations: sandstone, shale, limestone, gravel, clay	From	To
SAND & GRAVEL	0 ft	14 ft
CLAY	14	22
SAND	22	23
SANDSTONE	23	55

SKETCH SHOWING LOCATION

Locate in reference to numbered state highways, street intersections, county roads, etc.

LOCATION 8 ON FIGURE



DRILLING FIRM BERN SCHUSTER DATE 1-11-78

ADDRESS ELYRIA O SIGNED B Schuster

*If additional space is needed to complete well log, use next consecutive numbered form.

WELL LOG AND DRILLING

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

LOCATED

No 79391

64

County Lorain Township Elyria Section of Township or Lot Number South West River

Owner Sam Polen Address R.D. South W River Rd

Location of property 1/2 mile North off Rt 20 on west River Rd.

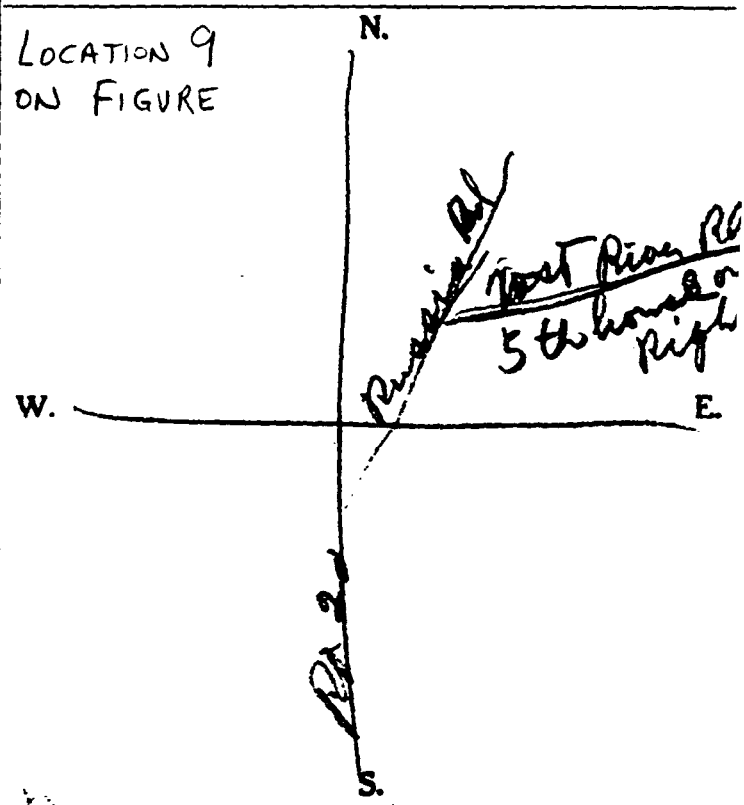
CONSTRUCTION DETAILS	PUMPING TEST
Casing diameter 5" Length of casing 6'	Pumping rate 10 G.P.M. Duration of test 8 hrs.
Type of screen none Length of screen —	Drawdown 20' ft. Date Aug 23/54
Type of pump Pitcher Pump	Developed capacity 8 GPM
Capacity of pump	Static level—depth to water 15' ft.
Depth of pump setting 30'	Pump installed by Owner

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
	0 Feet	4 Ft.
Clay		
Stone	4'	50'
water	48	54'

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm J. C. Garrish Date Feb

Address R.D. West River Rd Signed J. C. Garrish

64

LOG AND DRILLING REPORT

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

LOCATED

(13)

№ 79363

65

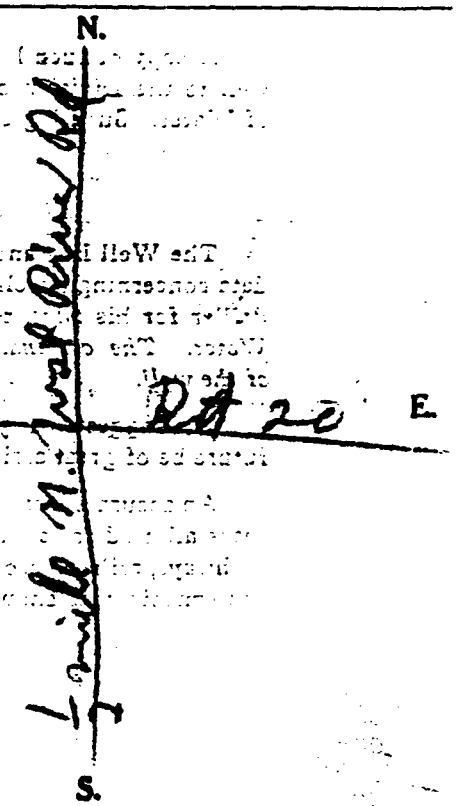
County Lorain Township Elyria Section of Township or Lot Number West River ~~Sect.~~

Owner Mr TRANCAN Address R D 3 West River Rd

Location of property West River Rd North off Rt 20 - 1/2 mile on Right

CONSTRUCTION DETAILS		PUMPING TEST	
Casing diameter 6	Length of casing 26'	Pumping rate 12 G.P.M.	Duration of test 8 hrs.
Type of screen —	Length of screen —	Drawdown 15 ft.	Date July 20-51
Type of pump Hand Pump		Developed capacity 18 G.P.M.	
Capacity of pump		Static level—depth to water 14' ft.	
Depth of pump setting By owner		Pump installed by owner	

WELL LOG			SKETCH SHOWING LOCATION
Formations Sandstone, shale, limestone, gravel and clay	From	To	Locate in reference to numbered State Highways, St. Intersections, County roads, etc.
	0 Feet	15 Ft.	LOCATION 10 ON FIGURE
Clay	15	26'	
Sand			
Stone	26	27'	
Gravel	27		
water	27		



See reverse side for instructions

Drilling Firm Harrish Jr. Date July 20 51

Address R D Elyria O Signed J. Yeomans

65

WELL LOG AND DRILLING REPORT

ORIGINAL

NO CARBON PAPER NECESSARY– SELF-TRANSCRIBING

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Geological Survey
Fountain Square
Columbus, Ohio 43224 Phone (614) 466-5344

490024

COUNTY LORAIN TOWNSHIP CARLISLE SECTION OF TOWNSHIP OR LOT NUMBER

OWNER JAMES RYAN ADDRESS 2116 WEST RIVER

LOCATION OF PROPERTY 2116 WEST RIVER

CONSTRUCTION DETAILS

Casing diameter 6 1/4 Length of casing 20

Type of screen Length of screen

Type of pump

Capacity of pump

Depth of pump setting

Date of completion

BAILING OR PUMPING TEST
(specify one by circling)

Test rate 1 gpm Duration of test 1 hrs

Drawdown 67 ft Date 1/16/76

Static level (depth to water) 10 ft

Quality (clear, cloudy, taste, odor) CLEARING

Pump installed by

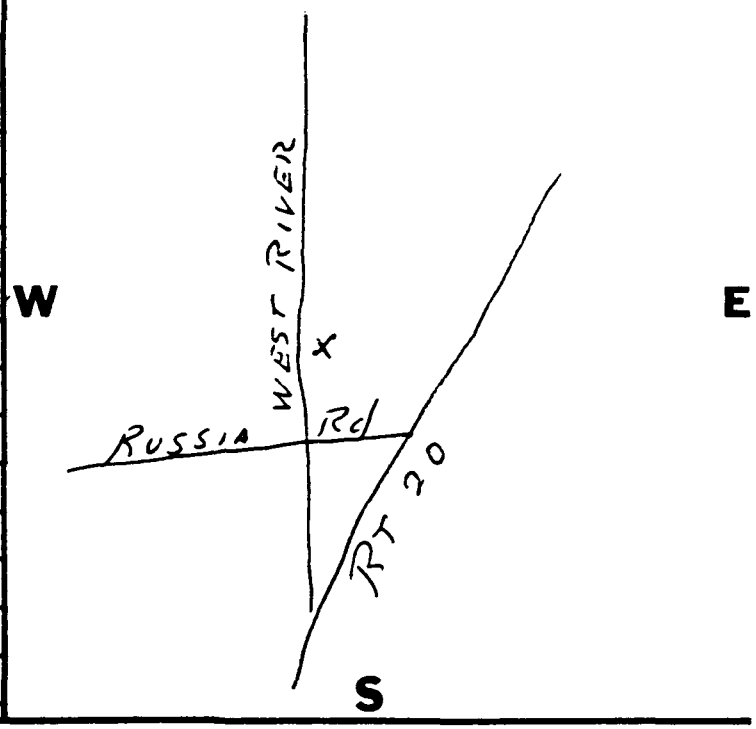
WELL LOG*

Formations: sandstone, shale, limestone, gravel, clay	From	To
CLAY + SAND	0 ft	16 ft
BROKEN STONE	16	17
SANDSTONE	17	37
LIGHT SHALE SOFT	37	39
RED SHALE	39	67
WATER IN STONE		
30' 8" 5" CASING LINER BELOW		
SANDSTONE		

SKETCH SHOWING LOCATION

Locate in reference to numbered state highways, street intersections, county roads, etc.

LOCATION 11 ON FIGURE



DRILLING FIRM BERN SCHUSTER DATE 1-16-76

ADDRESS ELYRIA O. SIGNED B Schuster

25

*If additional space is needed to complete well log, use next consecutive numbered form.

WELL LOG AND DRILLING REPORT

ORIGINAL

NO CARBON PAPER NECESSARY— SELF-TRANSCRIBING

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
65 S. Front St., Rm. 815 Phone (614) 469-2646
Columbus, Ohio 43215

428835

County LORAIN Township CARLISLE Section of Township

Owner PRODUCTION HOMES INC. BUILDER Address

Location of property SOUTH OF 21100 WEST RIVER RD CARLISLE TOWNSHIP

CONSTRUCTION DETAILS

Casing diameter 8" Length of casing 20'

Type of screen Length of screen

Type of pump SUBMERSIBLE

Capacity of pump 5 GPM

Depth of pump setting 48'

Date of completion OCT 28 1972

BAILING OR PUMPING TEST
(Specify one by circling)

Test Rate 1 G.P.M. Duration of test hrs

Drawdown 50' ft. Date OCT 28 1972

Static level-depth to water 12' ft.

Quality (clear, cloudy, taste, odor) CLEAR

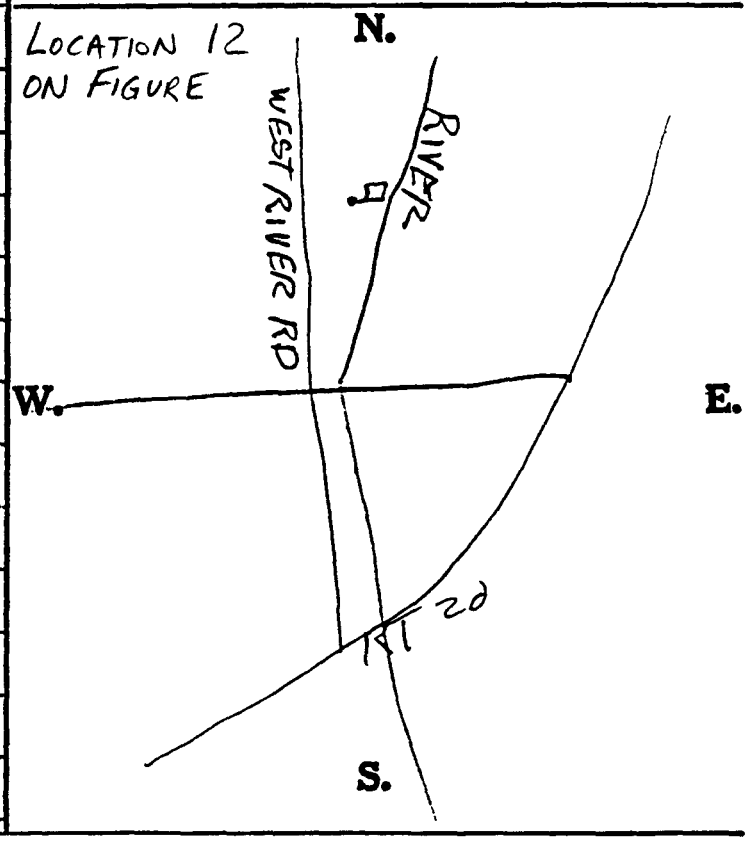
Pump installed by ED ROBERTS

WELL LOG*

Formations Sandstone, shale, limestone, gravel and clay	From	To
BROWN CLAY	0 Feet	8 Ft.
BROWN SAND STONE	8	15'
SHALE STONE SOFT	15	18
SANDSTONE GRAY	18	28
RED CLAY	28	52
RED SHALE	52	55'
WATER AT 18'		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



Drilling Firm ED ROBERTS WELL DRILLING Date NOV 4 1972

Address 18358 WEST RIVER RD COLUMBIA STA, OHIO 44028 Signed [illegible]

26

*If additional space is needed to complete well log, use next consecutive numbered form.

WELL LOG AND DRILLING REPORT

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
1562 W. First Avenue
Columbus, Ohio

PLEASE USE PENCIL OR TYPEWRITER. DO NOT USE INK.

No. 247564

County LORAIN Township ~~ELYRIA~~ Carlisle Section of Township

Owner WALTER KEITH Address 1401 LINWOOD ST ELYRIA

Location of property 1401 LINWOOD ST 1/4 MILE WEST OF RT #57 OFF FULLER RD

CONSTRUCTION DETAILS

Casing diameter 5 3/8 Length of casing 23 1/2

Type of screen — Length of screen

Type of pump —

Capacity of pump

Depth of pump setting

Date of completion 7-14-60

BAILING OR PUMPING TEST

Pumping rate 3 G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity

Static level—depth to water 11 ft.

Pump installed by

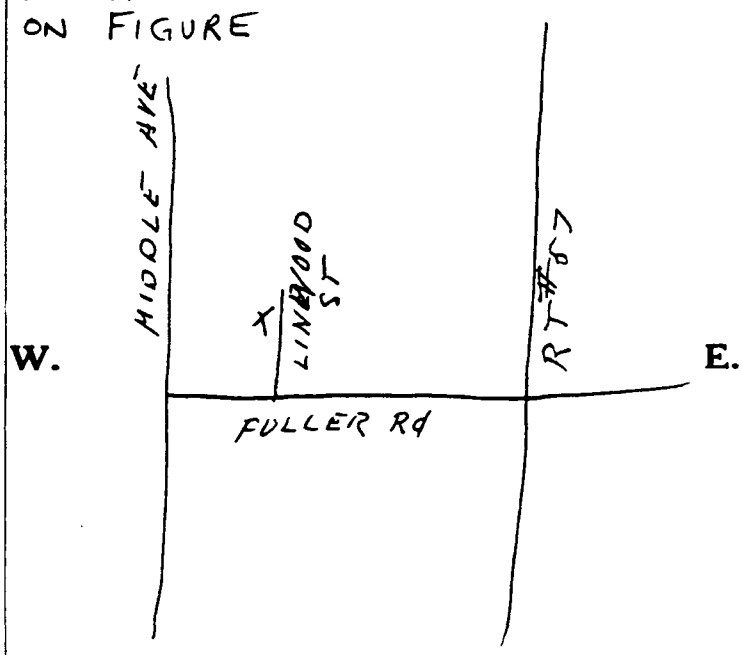
WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY	0 Feet	12 Ft.
SAND	12	22
SANDSTONE	22	56
WATER IN SANDSTONE		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 13 ON FIGURE



See reverse side for instructions

Drilling Firm BERN SCHUSTER Date 7-14-60

Address ELYRIA O Signed B. Schuster

(111)

WELL LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
1500 Dublin Road
Columbus, Ohio

No. 176760

County Lorain Township ~~Elyria~~ Carlisle Section of Township South east

Owner Walter Christman Address 630 State street

Location of property South middle ave 1 mile South of Elyria

CONSTRUCTION DETAILS

Casing diameter 6 Length of casing 23½'

Type of screen — Length of screen —

Type of pump Shallow well

Capacity of pump 10 G P m

Depth of pump setting 33'

Date of completion 6/25/57

BAILING OR PUMPING TEST

Pumping rate 8 G.P.M. Duration of test 8 hrs.

Drawdown 35 ft. Date 6/25/57

Developed capacity 5 G P m

Static level—depth to water 10' ft.

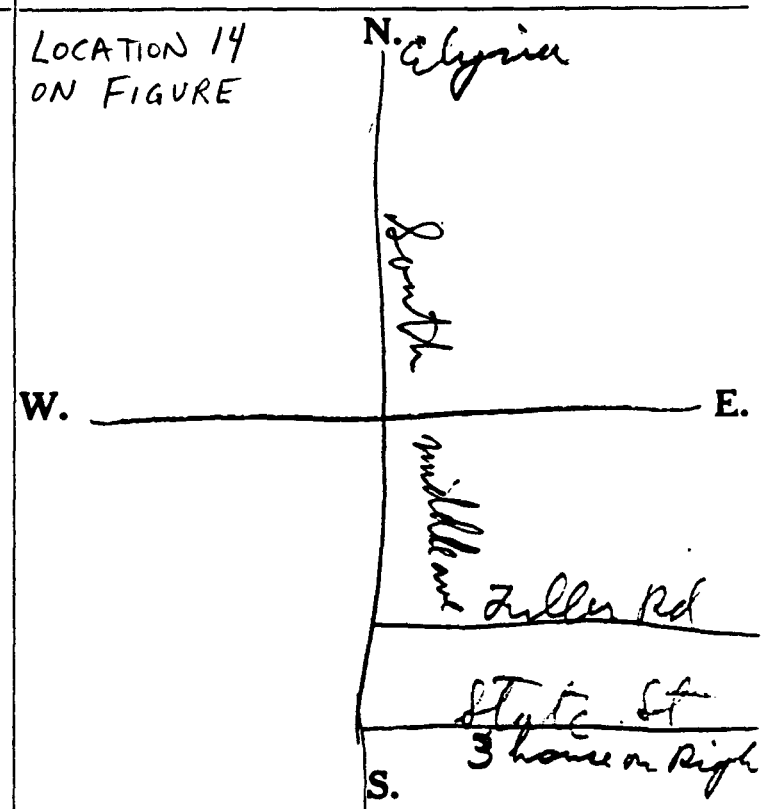
Pump installed by Owner

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
	0 Feet	9 Ft.
Clay		
Gray Clay	9	16
Gravel	16	20
Sand + Clay	20	23½
Stone	23½	70'
water 29'		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm J. Garrick Date 6/25/57

Address R D Elyria O Signed J. Garrick

(112)

WELL LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

Nº 126876

County Lorain Township ~~Elyria~~ Carlisle Section of Township or Lot Number South Sect

Owner Mr Degraphenreed Address 126 Wayne St S. Middle ave

Location of property 1 mile south of Elyria on south middle ave Colored sect

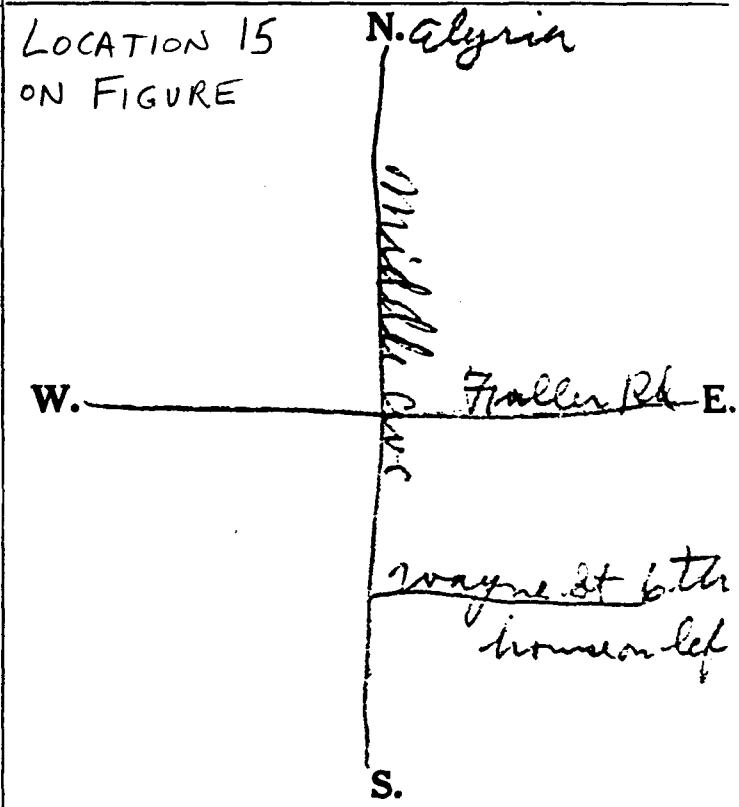
CONSTRUCTION DETAILS		PUMPING TEST	
Casing diameter 6	Length of casing 22	Pumping rate 15 G.P.M.	Duration of test 8 hrs
Type of screen —	Length of screen —	Drawdown 20 ft.	Date Aug 28/55
Type of pump Shallow		Developed capacity 15 GPM	
Capacity of pump 8 GPM		Static level—depth to water 12' ft	
Depth of pump setting 30'		Pump installed by Owner	

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
	0 Feet	~~10~~ Ft.
Clay		
Clay & sand	10	18
Gravel	18	22
Stone	22	40'
water 36'		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm [illegible] Date Aug 28/55

Address R.D. Elyria Signed [illegible]

113

WELL LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
1500 Dublin Road
Columbus, Ohio

(8) LOCATED

No. 191457

8

47 8

County LORAIN Township CARLISLE Section of Township

Owner MR SCHILLING Address ELYRIA O

Location of property ON MURRAY RIDGE Rd ACCROSS FROM ALBRECHT Rd

CONSTRUCTION DETAILS

Casing diameter 6" Length of casing 32

Type of screen NONE Length of screen —

Type of pump —

Capacity of pump —

Depth of pump setting —

Date of completion 12-13-56

BAILING OR PUMPING TEST

Pumping rate 10 G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity 10 GPM

Static level—depth to water 17 ft.

Pump installed by

WELL LOG

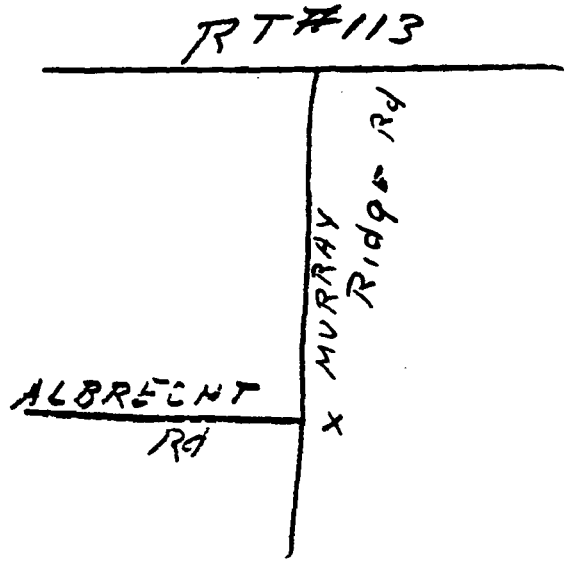
Formations Sandstone, shale, limestone, gravel and clay	From	To
GRAVEL	0 Feet	15 Ft.
CLAY	15	20
SAND	20	31
SANDSTONE	31	54

(4)

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 16 ON FIGURE



See reverse side for instructions

Drilling Firm B SCHUSTER Date 12-13-56

Address 1404 EAST AVE ELYRIA O Signed Bernard Schuster

8

WELL LOG AND DRILLING REPORT

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

LOCATED

No. 79357

47 County Lorain 3 Township West Carlisle Section of Township or Lot Number 21

Owner Kasper Foundry Address Kasper Foundry Rt 20

Location of property Rt 20 just outside of City limits across from County Garage

CONSTRUCTION DETAILS

Casing diameter 6 Length of casing 42'

Type of screen — Length of screen —

Type of pump

Capacity of pump

Depth of pump setting 35'

PUMPING TEST

Pumping rate 8/4 G.P.M. Duration of test 24 hrs.

Drawdown 4 ft. Date Oct 19-50

Developed capacity 8 G p m

Static level—depth to water 25 ft ft.

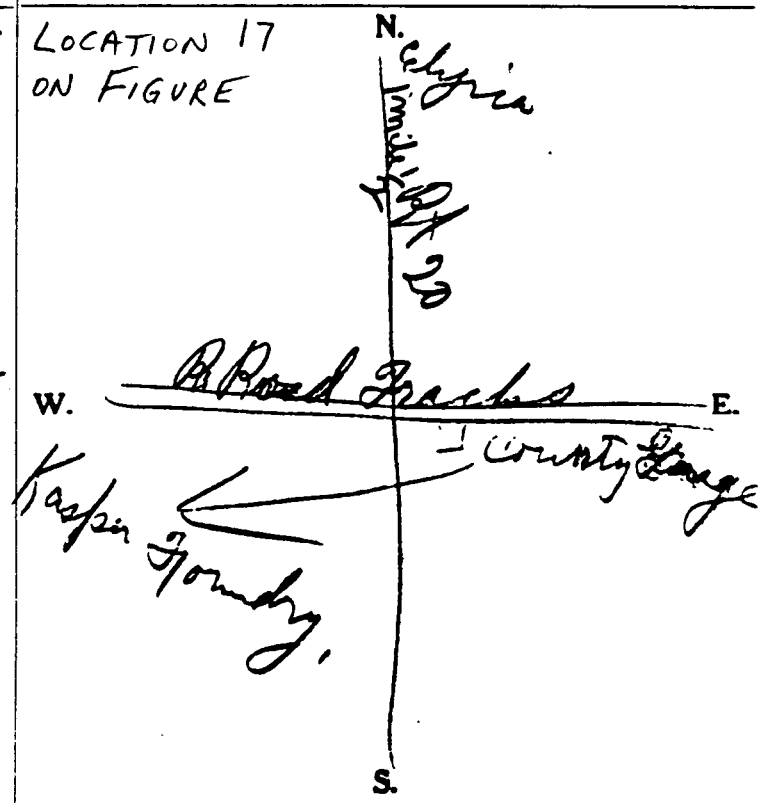
Pump installed by Owner

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
Clay	0 Feet	18 Ft.
Sand	18	20
Clay & Sand	20	42
Gravel	42	49
water at 42'		
3		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm J. Yarnich Date Oct 19. 1950

Address R D 3 West Rivers Rd Signed J. Yarnich

21

WELL LOG AND DRILLING REPORT

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

(27) LOCATED No. 91941

47 County LORAIN 8 Township CARLISLE Section of Township or Lot Number 27

Owner JIM WISEMAN Address ELYRIA, O

Location of property CORNER NELSON & OAK

CONSTRUCTION DETAILS	PUMPING TEST
Casing diameter 5 5/8 Length of casing 20	Pumping rate — G.P.M. Duration of test ... hrs.
Type of screen — Length of screen —	Drawdown ... ft. Date ...
Type of pump ...	Developed capacity ...
Capacity of pump ...	Static level—depth to water 15 ft.
Depth of pump setting ...	Pump installed by ...

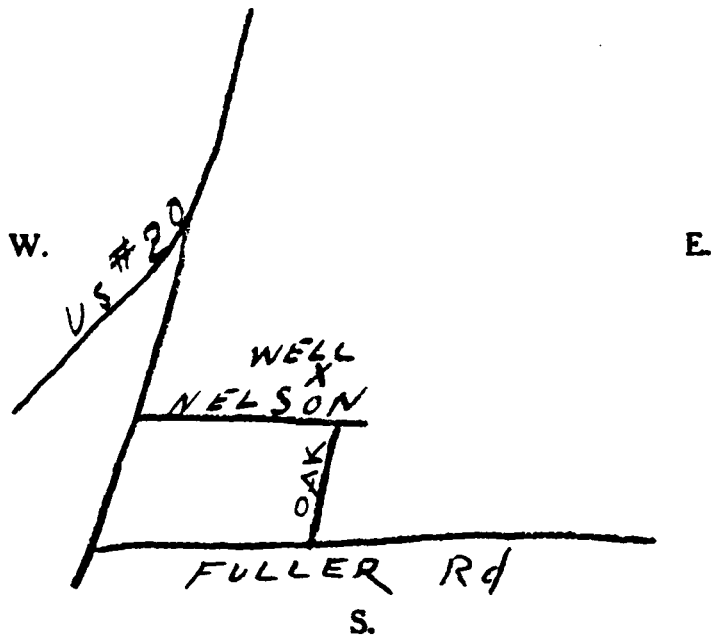
WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY	0 Feet	16 Ft.
SAND	16	19
SANDSTONE	19	40
4		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 18 ON FIGURE



See reverse side for instructions

Drilling Firm L SCHUSTER & SON Date 10-2-52

Address ELYRIA, O Signed B Schuster

27

ELL LOG AND DRILLING REPORT

ORIGINAL

28

LOCATED

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

№ 163334

County 47 LORAIN Township 8 CARLISLE Section of Township or Lot Number 28

Owner MARGARET JONES Address LINWOOD ST ELYRIA, O

Location of property ON LINWOOD ST 500 FT NORTH OF FULLER Rd

CONSTRUCTION DETAILS

Casing diameter 6 Length of casing 15

Type of screen — Length of screen —

Type of pump —

Capacity of pump

Depth of pump setting

PUMPING TEST

Pumping rate — G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity

Static level—depth to water 11 ft.

Pump installed by

WELL LOG

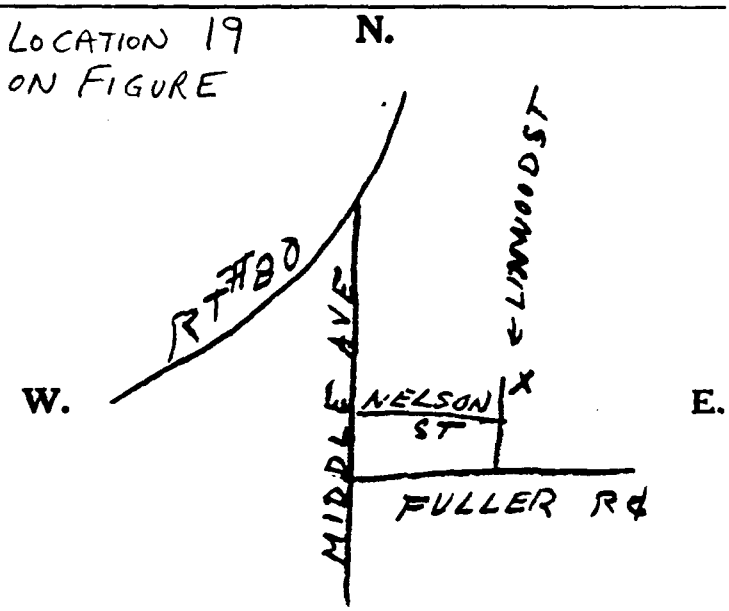
Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY	0 Feet	11 Ft.
SAND	11	15
SANDSTONE	15	40

4

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 19 ON FIGURE



See reverse side for instructions

Drilling Firm L SCHUSTER & SON Date 11-5-55

Address ELYRIA O Signed B Schuster

28

WELL LOG AND DRILLING REPORT

30 LOCATED ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

№ 104058

47 County LORAIN 8 Township CARLISLE Section of Township or Lot Number 30

Owner H. OLIVER Address OAK ST. ELYRIA, O

Location of property ON OAK ST OFF FULLER Rd

CONSTRUCTION DETAILS

Casing diameter 5 5/8 Length of casing 26-6

Type of screen — Length of screen —

Type of pump —

Capacity of pump

Depth of pump setting

PUMPING TEST

Pumping rate — G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity

Static level—depth to water 14 ft.

Pump installed by

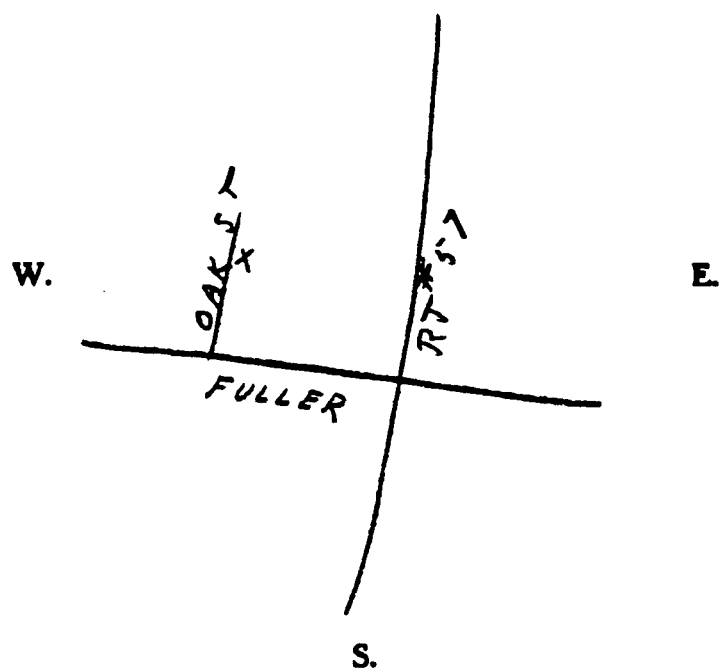
WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY	0 Feet	15 Ft.
SAND	15	25
SANDSTONE	25	44
4		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 20 ON FIGURE



See reverse side for instructions

Drilling Firm L SCHUSTER & SON Date 1-31-53

Address ELYRIA O. Signed B. Schuster

30

WELL LOG AND DRILLING REPORT

State of Ohio
OHIO WATER RESOURCES BOARD
Department of Public Works
553 E. Broad St., Columbus 15, Ohio

(31) LOCATED

No. 47098

47 County LORAIN 8 Township CARLISLE Section of Township or Lot Number 31

Owner WM SPENSER #602 Address WOOD ST ELYRIA, O

Location of property ON FULLER Rd OFF RT # 57

CONSTRUCTION DETAILS

Casing diameter 5 5/8 Length of casing 17-6

Type of screen — Length of screen

Type of pump —

Capacity of pump

Depth of pump setting

PUMPING TEST

Pumping rate — G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity

Static level of completed well 6 ft.

Pump installed by

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
CLAY	0 Feet	14 Ft.
SAND	14	17
SANDSTONE	17	51

4

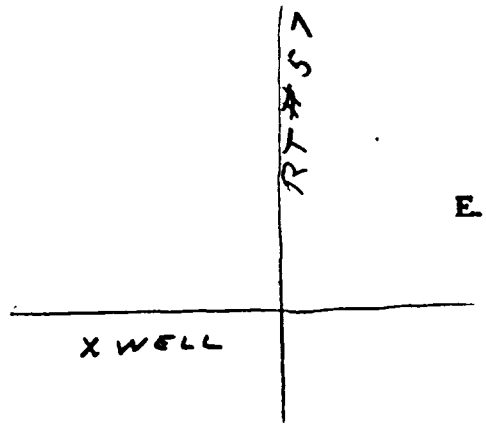
SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.

LOCATION 2 ON FIGURE

N.

ELYRIA



W. E.

S.

See reverse side for instructions

Drilling Firm L SCHUSTER & SON Date 5-15-51

Address ELYRIA, O. Signed B. Schuster

31

APPENDIX L

RESIDENTIAL WELL INVENTORY

RESIDENTIAL WELL INVENTORY RECORDS

A total of 71 residences within a one-half mile radius of the site were inventoried to collect information concerning the existence of wells. All 71 residences are currently using municipal water. Three residences have existing wells that are not in use, and one residence has an existing cistern that is not in use. The occupants of 260 Woodford Street and 264 Woodford Street both stated that their next door neighbor has a well. Included in this Appendix are the six water supply inventory sheets for persons stating knowledge of wells on or near their property and a list of the 71 residences inventoried.

WATER SUPPLY INVENTORY SHEET

REPUBLIC STEEL QUARRY SITE

Water Supply User Roberta Allgood

Address 1801 Douglas

Phone No. 323-6456 Supply Site No. 30

Type of Water Supply (Check Type)

Well ( ); Spring ( ); Cistern ( ); Municipal Waterline (X);
Other _____

Water Use (Check Type)

Domestic (X); Agricultural ( ); Industrial ( );
Other _____(Specify Type)

Well Construction Data

Total Depth _____ft. Elevation _____ft. (MSL)

Cased Depth _____ft. Source Aquifer _____

Well Diameter _____in. Flow Rate _____CFS or GPM (Circle)

Well Material _____

Well Elevation _____ft. (MSL) Protected ( ) Yes ( ) No
(top) (If yes, specify type protection)
Date Drilled _____year

Remarks: _____

Static Water Level _____ft.

Well Yield _____CFS or
GPM (Circle)

Treatment Facilities: ( ) Yes; ( ) No (if yes, specify type)

Well Screen: ( ) Yes; ( ) No; Slotted Casing: ( ) yes; ( ) No

Driller's Logs Available: ( ) Yes; ( ) No (if yes, specify supply log)

Name of Driller _____

Remarks: Pump in front yard Pump broken

Well at 755 W. 17th Street. Nolan

Inventoried by: LSM Date 6/4/87

WATER SUPPLY INVENTORY SHEET

REPUBLIC STEEL QUARRY SITE

Water Supply User C. Samuel Charley

Address 720 18th Street

Phone No. 322-2954 Supply Site No. 32

Type of Water Supply (Check Type)

Well ( ); Spring ( ); Cistern ( ); Municipal Waterline (X);
Other _____

Water Use (Check Type)

Domestic (X); Agricultural ( ); Industrial ( );
Other _____(Specify Type)

Well Construction Data

Total Depth 35 ft. Elevation _____ft. (MSL)

Cased Depth 35 ft. Source Aquifer _____

Well Diameter - in. Flow Rate _____CFS or GPM (Circle)

Well Material Steel

Well Elevation (top) _____ft. (MSL) Protected ( ) Yes ( ) No
(If yes, specify type protection)

Date Drilled 5 year

Remarks: _____

Static Water Level 25 ft.

Well Yield -- CFS or GPM (Circle)

Treatment Facilities: ( ) Yes; ( ) No (if yes, specify type)

Well Screen: ( ) Yes; (X) No; Slotted Casing: ( ) yes; ( ) No

Driller's Logs Available: ( ) Yes; ( ) No (if yes, specify supply log)

Name of Driller _____

Remarks: Pump in front yard, never used

Inventoried by: LSM Date 6/4/87

WATER SUPPLY INVENTORY SHEET

REPUBLIC STEEL QUARRY SITE

Water Supply User Leason Nelson

Address 260 Woodford

Phone No. 323-3507 Supply Site No. 35

Type of Water Supply (Check Type)

Well ( ); Spring ( ); Cistern ( ); Municipal Waterline (X);
Other _____

Water Use (Check Type)

Domestic (X); Agricultural ( ); Industrial ( );
Other _____(Specify Type)

Well Construction Data

Total Depth _____ft. Elevation _____ft. (MSL)

Cased Depth _____ft. Source Aquifer _____

Well Diameter _____in. Flow Rate _____CFS or GPM (Circle)

Well Material _____

Well Elevation _____ft. (MSL) Protected ( ) Yes ( ) No
(top) (If yes, specify type protection)
Date Drilled _____year

Remarks: _____

Static Water Level _____ft.

Well Yield _____CFS or GPM (Circle)

Treatment Facilities: ( ) Yes; ( ) No (if yes, specify type)

Well Screen: ( ) Yes; ( ) No; Slotted Casing: ( ) yes; ( ) No

Driller's Logs Available: ( ) Yes; ( ) No (if yes, specify supply log)

Name of Driller _____

Remarks: Says next door neighbor has well

Inventoried by: LSM Date 6/4/87

WATER SUPPLY INVENTORY SHEET

REPUBLIC STEEL QUARRY SITE

Water Supply User Clair White

Address 264 Woodford

Phone No. 322-3282 Supply Site No. 36

Type of Water Supply (Check Type)

Well ( ); Spring ( ); Cistern ( ); Municipal Waterline (X);
Other _____

Water Use (Check Type)

Domestic ( ); Agricultural ( ); Industrial ( );
Other _____(Specify Type)

Well Construction Data

Total Depth _____ft. Elevation _____ft. (MSL)

Cased Depth _____ft. Source Aquifer _____

Well Diameter _____in. Flow Rate _____CFS or GPM (Circle)

Well Material _____

Well Elevation _____ft. (MSL) Protected ( ) Yes ( ) No
(top) (If yes, specify type protection)
Date Drilled _____year

Remarks: _____

Static Water Level _____ft.

Well Yield _____CFS or GPM (Circle)

Treatment Facilities: ( ) Yes; ( ) No (if yes, specify type)

Well Screen: ( ) Yes; ( ) No; Slotted Casing: ( ) yes; ( ) No

Driller's Logs Available: ( ) Yes; ( ) No (if yes, specify supply log)

Name of Driller _____

Remarks: Doesn't Know. Next door neighbor says she has well

Inventoried by: LSM Date 6/4/87

WATER SUPPLY INVENTORY SHEET

REPUBLIC STEEL QUARRY SITE

Water Supply User Mrs. Diedrick

Address 335 11th Street

Phone No. 322-2865 Supply Site No. 66

Type of Water Supply (Check Type)

Well ( ); Spring ( ); Cistern ( ); Municipal Waterline (X);
Other _____

Water Use (Check Type)

Domestic ( ); Agricultural ( ); Industrial ( );
Other _____(Specify Type)

Well Construction Data

Total Depth _____ft. Elevation _____ft. (MSL)

Cased Depth _____ft. Source Aquifer _____

Well Diameter _____in. Flow Rate _____CFS or GPM (Circle)

Well Material _____

Well Elevation _____ft. (MSL) Protected ( ) Yes ( ) No
(top) (If yes, specify type protection)
Date Drilled _____year

Remarks: _____

Static Water Level _____ft.

Well Yield _____CFS or
GPM (Circle)

Treatment Facilities: ( ) Yes; ( ) No (if yes, specify type)

Well Screen: ( ) Yes; ( ) No; Slotted Casing: ( ) yes; ( ) No

Driller's Logs Available: ( ) Yes; ( ) No (if yes, specify supply log)

Name of Driller _____

Remarks: Cistern, No Pump, Not hooked up

Inventoried by: KPH Date 6/5/87

WATER SUPPLY INVENTORY SHEET

REPUBLIC STEEL QUARRY SITE

Water Supply User Thomas Graham

Address 325 12th Street

Phone No. 322-4458 Supply Site No. 67

Type of Water Supply (Check Type)

Well ( ); Spring ( ); Cistern ( ); Municipal Waterline (X);
Other _____

Water Use (Check Type)

Domestic ( ); Agricultural ( ); Industrial ( );
Other _____(Specify Type)

Well Construction Data

Total Depth _____ft. Elevation _____ft. (MSL)

Cased Depth _____ft. Source Aquifer _____

Well Diameter _____in. Flow Rate _____CFS or GPM (Circle)

Well Material _____

Well Elevation _____ft. (MSL) Protected ( ) Yes ( ) No
(top) (If yes, specify type protection)
Date Drilled _____year

Remarks: _____

Static Water Level _____ft.

Well Yield _____CFS or
GPM (Circle)

Treatment Facilities: ( ) Yes; ( ) No (if yes, specify type)

Well Screen: ( ) Yes; ( ) No; Slotted Casing: ( ) yes; ( ) No

Driller's Logs Available: ( ) Yes; ( ) No (if yes, specify supply log)

Name of Driller _____

Remarks: Doesn't Know, has well does not use.

Inventoried by: KPH Date 6/5/87

Water Supply User	Address	Phone #	Supply Site No.
Ken Bucket	1104 West Ave.	322-0571	1
James Quest	1320 West Ave.	323-5868	2
Mrs. Hines	1026 West Ave.	--	3
Mrs. Osborne	1028 West Ave.	--	4
L. Lenninger	930 West Ave.	--	5
Mrs. Whler	800 West Ave.	322-9803	6
Mrs. Loper	707 West Ave.	322-1112	7
Bill Cameron	600 West Ave.	323-2103	8
Lucille Burnett	--	322-3596	9
William Lash	427 West Ave.	322-4178	10
Mrs. Gilbert	--	--	11
Rev. Chas. Hess	627 West Ave.	322-7594	12
--	817 West Ave.	--	13
Charles Howell	833 West Ave.	323-3581	14
Williams	903 West Ave.	322-4406	15
Mrs. Trice	1105 West Ave.	322-3402	16
Mrs. Willis	1135 West Ave.	322-3170	17
Julia Sito	--	322-7438	18
Rick Wilso	1212 Middle	323-4353	19
Ed Przybylsky	1116 Middle	322-0135	20
Mrs. Borgsteadt	1026 Middle	323-9484	21
John Ro. Harbert	934 Middle	323-8162	22
Mrs. Phiel	906 Middle	322-3237	23
John Lund	817 Middle	--	24

Linda Rogers	905 Middle	322-2462	25
M. Burke	1005 Middle	323-6234	26
Verna Beards	1121 Middle	322-0163	27
Tammie Paliotto	1021 A	322-1072	28
Joe Williams	1628 Douglas Ave.	352-6642	29
Bob Holsten	1900 W. River Rd.	322-6615	31
Dan Horton, Sr.	1524 S. River	322-4964	33
Clair Brink	1182 Garden	323-5859	34
Mrs. Baker	4 Woodford	323-1124	37
Diane Ford	168 Irondale	--	38
James Hudgins	132 Irondale	--	39
Drusilla Glover	163 Irondale	--	40
Mrs. Bakos	135 Blake	322-2181	41
M. Schorrs	109 Blake	323-9640	42
MacIntyre	293 W. River	--	43
Mrs. Wilson	251	--	44
Mrs. Brown	221 W. River	322-6750	45
William Iguatz	124 West River	322-8552	46
Michael Geiser	538 3rd St.	--	47
Ruth Hollis	58 Hilltop Dr.(Mobil Home)	322-6041	48
Steve Saley	218 West River	322-0637	49
Alfred Wyatt	262 West River	322-5195	50
Mrs. Ladd	810 Riverside St.	322-9723	51
Debbie Raven	918 Riverside	322-4931	52
Vicki McCartney	1116 Riverside	322-1036	53
Charles W. Roberts	505 West 12th	322-7248	54
Ross	426 West 12th	322-2034	55

Mrs. Firement	423 11th	322-8650	56
Frank Hall	474 W. 11th	322-0145	57
Russell Belim	434 10th	322-2201	58
June Thomas	444 9th	323-1970	59
Don Gralion	932 8th	322-3454	60
Mrs. Roberts	415 Earl St.	322-3579	61
Dan Kuhman	341 7th St	322-2076	62
Charley Frye	337 8th St.	322-0193	63
Mrs. Parker	315 9th St.	323-7672	64
Mrs. Alonge	334 10th St.	322-8514	65
	356 13th St.	--	68
Mrs. Lowler	3335 15th St.	--	69
Wilmer Key	421 W. 16th St.	323-7372	70
Leonard Hill	428 15th St.	322-2699	71

APPENDIX M
CHEMICAL FATE AND TRANSPORT DATA

APPENDIX M
CONTAMINANT PERSISTENCE AND CHEMISTRY

This Appendix contains the data base used to discuss the transport and fate for the chemicals found at the Republic Steel site. These chemical profiles contain information on environmental transport and fate that were used in creating Section 8.0.

M.1 Volatile Organic Compounds

Because of similarities in physical and chemical properties, volatile organic compounds can, with a few exceptions, be treated as a whole. Relatively high mobility in the subsurface environment and volatility from soil or water are the two common characteristics of these compounds. They are expected to be mobile in the environment without substantial sorption to clay or organic matter. Once released to surface water volatile organics will probably volatilize readily. The ultimate fate of most volatile organics is probably atmospheric photolysis or solution photolysis via a naturally occurring sensitizer (Gale 1970, Gaudini and Mackett 1978). The C-1, C-2, and C-3 low molecular weight chlorinated alkanes and alkenes behave in a manner similar to that of ethylbenzene. They are mobile in water and volatilize readily from the water and soil environment. They are not likely to be strongly sorbed. On release to surface water, volatilization will be rapidly accomplished. Their ultimate fate once in the atmosphere is probably attacked by hydroxyl radicals (Cupitt 1980). The main difference between the halogenated compounds and other volatile organics is that the halogenated compounds are likely to degrade in the subsurface environment. Degradation may occur either via biological processes or chemical hydrolysis.

There is considerable chemical evidence that the chlorinated hydrocarbons undergo various degrees of biodegradation by soil bacteria (Wilson and McNabb 1983). Several studies suggest that the mechanisms and rates of degradation are different for the different subclasses of compounds. In contrast to the phenolics whch are readily degraded under both aerobic and anaerobic conditions (Sutton and Barker 1984), the halogenated hydrocarbons appear to be considerably more degradable under anaerobic conditions. Numerous laboratory and field studies have demonstrated similar anaerobic degradation of chlorinated organics in the marine environment and sewage sludge as well as soils (Kobayashi and Rittman 1982, Wilson et al. 1981). The observation of black colored sediments at the Republic Steel site may indicate sulfides present in the sediments as a result of anaerobic conditions in those sediments.

Acetone, 2-Butanone, ethylbenzene, methylene chloride, tetrachloroethene and toluene were identified as site related volatile organics at the Republic Steel Quarry. As described above, volatilization is the major transport process for these contaminants.

Ethylbenzene: From the available data it would appear that the principal mechanism for removal of ethylbenzene from the aquatic environment is volatilization. The atmospheric oxidation by hydroxyl radicals of ethylbenzene probably overshadows all other fates. Adsorption on sediments

and suspended solids appears to play a minor role due to the low K_D value. It is not possible to estimate the relative importance of biodegradation in the determination of the fate of ethylbenzene in the aquatic environment.

Methylene Chloride (Dichloromethane): Volatilization is the major transport process for removal of dichloromethane from aquatic systems. Once in the troposphere, dichloromethane is attacked by hydroxyl radicals with the subsequent formation of carbon dioxide, carbon monoxide, and phosgene as principal, initial products. Any unreacted dichloromethane which reaches the stratosphere will undergo photodissociation.

Based on the information reviewed, it appears that neither oxidation nor hydrolysis is an important fate process of dichloromethane in the aquatic environment. Neither adsorption nor bioaccumulation are important transport processes for dichloromethane as shown by the low K_{oc} values.

Tetrachloroethene (Perchloroethylene): Volatilization appears to be the major transport process for removal of tetrachloroethene from aquatic systems. Once in the troposphere, the compound reportedly reacts with hydroxyl radicals which attack the double bond, resulting in the formation of trichloroacetylchloride as the principle product, with phosgene being produced to a lesser extent. The tropospheric lifetime of tetrachloroethene based on its rate of reaction with hydroxyl radicals is reported to be about 10 days. On this basis, it is unlikely that unreacted tetrachloroethene will diffuse upward to the stratosphere.

Based on the information found it does not appear that photodissociation is a significant fate of tetrachloroethene in the aquatic or the atmospheric environment. Oxidation in the aquatic environment does not appear to be significant, although there is evidence of some oxidation of tetrachloroethene in aqueous, closed systems in the presence of sunlight. In addition, hydrolysis, another potential fate process for compounds in the aquatic environment, probably does not occur at a significant rate to be important for tetrachloroethene.

Although volatilization appears to be the most significant transport process, there is some evidence of bioaccumulation of tetrachloroethene in marine organisms. There is, however, no evidence for biomagnification in aquatic food chains. In addition, no evidence was found of selective concentration of tetrachloroethene in marine sediments, thus indicating that adsorption is probably not an important process for this compound.

Toluene: From the available data it appears that the principal mechanism for removal of toluene from the aquatic environment is volatilization. The atmospheric photodestruction of toluene probably subordinates all other fates. Adsorption on sediments and suspended solids probably plays a minor role in the fate of toluene as shown by the low K_{oc} value. The data do not allow the estimation of the relative importance of biodegradation in the determination of the fate of toluene in the aquatic environment.

M.2 Semi-Volatile Organic Compounds

The results of the data summary, which includes theoretical and empirical evidence, suggests that anthracene, fluoranthene and phenanthrene, compounds only sparingly soluble in water (0.045, 0.26 and 1.29 mg/l, respectively), will be adsorbed onto suspended particulates and biota and that their transport will be largely determined by the hydrogeologic conditions of the aquatic system. That portion dissolved in the water column may undergo direct photolysis at a rapid rate. The ultimate fate of the polycyclic aromatic hydrocarbon which accumulate in the sediment is believed to be biodegradation and biotransformation by benthic organisms.

Benzo(a)Anthracene, Benzo(b)Fluoranthene, Benzo(k)Fluoranthene, Chrysene, Pyrene: Benzo(a)anthracene, has been relatively well studied; and in particular, an excellent study conducted by Smith et al. (1978) has been used extensively in this report. The results of the data summary suggest that these compounds will accumulate in the sediment and biota due to their tendency to adsorb strongly onto suspended particulates. Transport, therefore, is largely determined by the hydrogeologic conditions of the aquatic system. A small amount of the polycyclic aromatic hydrocarbons will be dissolved and probably will be degraded by photolysis and, to a lesser degree, by oxidation. The ultimate fate of these compounds is believed to be biodegradation and biotransformation by benthic organisms, including microbes.

Benzo[g,h,i]Perylene, Benzo(a)Pyrene, Dibenzo[a,h]anthracene, Indeno[1,2,3-cd]Pyrene: Very little data specific to benzo[g,h,i]perylene, indeno[1,2,3-cd]pyrene and dibenzo[a,h]anthracene, were found; the aquatic fate of these compounds is inferred from data summarized for benzo(a)pyrene and polycyclic aromatic hydrocarbons in general. The results of the data summary suggest that these compounds, each containing 5 to 6 aromatic rings, are relatively insoluble in water (0.00070 mg/l for benzo[g,h,i]perylene to 0.00053 mg/l for indeno[1,2,3-cd]pyrene) and have relatively high log octanol/water partition coefficients. As a result, they will adsorb onto suspended particulates and biota, and their transport will be largely determined by the hydrogeologic conditions of the aquatic system. That portion dissolved in the water column will probably undergo direct photolysis at a rapid rate. The ultimate fate of these compounds and in particular benzo(a)pyrene is believed to be biodegradation and biotransformation by benthic organisms, although the processes may be very slow.

Phthalate Esters: Dimethyl Phthalate, Dimethyl Phthalate, Di-n-Butyl Phthalate, Di-n-Octyl Phthalate, Bis(2-ethylhexyl)phthalate, butyl benzyl phthalate: Bis(2-ethylhexyl)phthalate is the most well studied of the phthalate esters. For several of the phthalate esters, however, very little specific data were found, and the aquatic fate of these compounds is to a large extent inferred from data for phthalate esters as a group. Although their solubilities vary from sparingly soluble to moderately soluble, they all are probably readily adsorbed onto suspended particulates and biota and under certain conditions, are likely to form a water soluble complex with humic substances. Their transport will largely depend on the hydrogeologic conditions of the aquatic system. Volatilization is not considered to be a

competitive transport process, with the possible exception of bis(2-ethylhexyl)phthalate and butyl benzyl phthalate, having solubilities of 0.4 mg/l and 2 mg/l, respectively.

A variety of organisms have demonstrated the ability to take up and accumulate phthalate esters; this is probably due to the esters and human tissues and organs. Mixed microbial systems can degrade phthalate esters under aerobic conditions. Degradation is generally slower under anaerobic conditions and ceases to be effective for bis(2-ethylhexyl)phthalate. A variety of multicellular organisms have demonstrated the ability to biotransform and eliminate phthalate esters. Hydrolysis will occur in the water column, but it may be too slow to be environmentally significant. Bioaccumulation, biotransformation, hydrolysis, and biodegradation are probably the important processes determining the aquatic fate of phthalate esters.

Phenol: Photooxidation, metal-catalyzed oxidation, and biodegration probably all contribute to the fate of phenol in the aquatic environment. The dominance of any of these destructive pathways depends upon the particular environmental conditions of the aqueous medium but the degradation products are very similar for all fate pathways. The first step usually involves further hydroxylation of the aromatic ring followed by oxidation to a benzoquinone and cleavage of the ring structure. There is a possibility that some of the phenol that is present in surface waters volatilizes into the atmosphere and is rapidly destroyed by oxidation in the troposphere. Neither sorption nor bioaccumulation appear to be important processes in the aquatic fate of phenol.

Pentachlorophenol. Both photolysis and biodegradation appear to be important fate processes in the aquatic environment for pentachlorophenol. Photolytic destruction is probably rapid near the water-surface but as depth increases microbial metabolism assumes greater importance. Photolysis leads to a mixture of chloranilic acid, chlorinated phenols, chlorinated dihydroxybenzene and small non-aromatic compounds. Microbial metabolism produces pentachloroanisole and a mixture of chlorinated phenols. Pentachlorophenol is accumulated by a large number of aquatic organisms depending on the water pH and, in some cases, appears to be bioconcentrated. Although detoxification and depuration involving formation of sulfate ester conjugate has been demonstrated in fish, the accumulation of pentachloroanisole in the fish of a natural aquatic environment has also been documented. Sorption by the organic matter of sediments and soil definitely plays a role in the storage and transport of this pollutant. In a study of a natural freshwater lake, leaf litter and other organic matter in the soil and sediments of the lake's watershed retained relatively high concentrations of pentachlorophenol and its degradation products, and this served as a source for continual pollution of the aquatic ecosystem. Hydrolysis, oxidation, and volatilization do not appear to affect the environmental fate of pentachlorophenol.

M.3 Pesticides/PCBs Compounds

Aroclor 1254: Both volatilization and sorption of Aroclor 1254 may be significant aquatic transport processes based on qualitative and quantitative data. Bioaccumulation is an important aquatic fate process, and

biotransformation may also be significant aquatic fate processes for Aroclor 1254.

M.4 Inorganic Compounds

It should be noted that many inorganic chemicals discussed in this section are natural constituents of soil and groundwater. They have been detected at elevated concentrations in onsite samples compared to background values and will be considered for risks.

Aluminum. Aluminum (Al), a major constituent of clay, is one of the most commonly occurring elements in the earth's crust and often forms compounds with halides and a variety of other compounds (Consideine 1983). It typically acts as an electron acceptor and, having three electrons in its outer shell, usually exists in the +3 valence state.

While aluminum mobility appears to be primarily controlled by absorption, some aluminum-anion complexes are soluble; halides and sulfates form soluble complexes with aluminum (Weast 1974). Conversely, aluminum hydroxide ($Al(OH)_3$ is extremely insoluble and has a strong tendency to chelate with organic molecules of suitable geometry. The dissolution rate of natural aluminum from soil depends on the chemical structure of the soil or clay and the type and position of functional groups of the solute. Di- and tri-carboxylic acids with beta-hydroxy groups dissolve aluminum faster than do other organic acids (Pohlman and McCall 1986). Under low pH conditions, aluminum is soluble an mobile in most environments, including rich organic soils (Brown 1985).

Aluminum is likely to complex with organic or inorganic ligands. Leckie and Stumm (1970) found that aluminum complexes rapidly with phosphate ions, much of the complexed aluminum precipitates out of solution, whereas some forms colloids that do not settle out. Humic materials also complex with aluminum. Steinbert (1980) found that more than 94% of the aluminum existing in solution in hard, mountain stream water was associated with dissolved organic carbon ligands. As pH decreases, aluminum tends to appear in the ionic form because the solubility of complexed aluminum is leached from humic ligands.

Clays sorb aluminum very tightly because aluminum is a natural constituent of the clay lattice. The addition of a base produces no free $Al(OH)_3$ but may cause reincorporation of aluminum into the central octahedral structure of the clay (Marshall 1964). Clays hold aluminum more tightly than does organic matter, and aluminum will tend to partition from organic matter onto clay particles.

Baes et al. (1984) report a Kd for aluminum or 1,500 ml/g. Considering the very low solubility (or insolubility) of aluminum compounds in general and the tenacity of aluminum's adsorption to clays and humic material, we have adopted this value for the EA.

Arsenic. Arsenic (As) has four stable oxidation states: +5, +3, 0, and -3. The oxidized forms, As(V) and As(III), are the most common. The free element As(0) is rarely found, and the reduced form occurs only when the Eh is very low (Callahan et al. 1979). Oxidized arsenic is found in arsenic acid

(H_3AsO_4) and arsenious (H_3AsO_3 or $HAsO_2$) acids, as well as in minerals and dissolved salts. Metal arsenates (AsO_4^{-3}) and arsenite (AsO_3^{-3}) are formed with calcium, magnesium, and other uni- or di-valent cations. Under mildly oxidizing conditions in the pH range from -0.9 to 9.2, $HAsO_2$ is the predominant species. Under more strongly oxidizing conditions, the equilibrium between H_2AsO^{-2} and $HAsO_4^{-2}$ determines the predominant arsenic form. As the Eh of the solution decreases (i.e., as the solution becomes more reducing), As(III) becomes the dominant ion. In the environment, as a solution or soil becomes more anaerobic, arsenate will be reduced to arsenite.

Arsenate can form relatively insoluble complexes with a variety of cations; consequently, its solubility depends on the ionic composition of the water. In general, arsenic will remain at mg/liter levels (Dawson and Sanning 1982; Lemmo et al. 1983). Barium is the cation that produces the least soluble arsenate complex and is likely to control arsenic concentration to very low levels. In the absence of barium, other metal-arsenate complexes may control arsenic transport.

In addition to removal by precipitation of salts, arsenic is removed form solution by adsorbing to iron and aluminum oxides. Adsorption to iron oxide should be favored by low pH levels (Lemmo et al. 1983). Therefore, typical concentrations of arsenic in freshwater are at ug/liter levels (Woolson 1977). Arsenic can also complex with dissolved organic matter having low molecular weight. In an estuarine system, these complexes presumably prevent adsorption and coprecipitation with sediments, thus keeping arsenic in solution (Waslenchuk and Windom 1978).

Arsenic also can undergo redox reactions under conditions found in some soils. In aerated soils, arsenate may be formed while in flooded or nonoxidized soils, arsenite (a more toxic form) may be produced. Biological activity may contribute to the oxidation of As(III) back to As(V), and vice versa (Walsh et al. 1977). The fate of arsenic in soils also depends on the adsorption of arsenic to soil particles. Korte et al. (1976) found that clay content, surface area, and free iron oxide content of soil could be used to predict sorption. Soil pH, however, was not a significant factor. Other researchers have shown that As(V) has a higher adsorption capacity for bauxite, alumina, and carbon than does As(III); carbon is the least adsorptive of the three. Futhermore, adsorption decreases with increasing pH—above 9 for As(III) and above 7 for As(V) (Gupta and Chen 1978).

The environmental behavior of arsenic, including sorption reactions, is dependent upon redox conditions as well as pH. When arsenic binds to oxides, it is rendered immobile. Baes et al. (1984) report a theoretical Kd of 200 ml/g. Baes and Sharp (1983), however, report Kds in the range of 1.9-8.3 ml/g for As(III);l other investigators report Kds in the range of 1.9-18 mg/g (Frost and Griffin 1977). In work with sewage sludge, Gerritse et al. (1982) report ranges of Kd of about 15-30 ml/g for sandy soil. These experimental Kds, which are much lower than the value given by Baes et al. (1984), may more accurately reflect the mobility of arsenic in soils. Therefore, in the EA we have set the Kd for arsenic at 5 ml/g, a value near the lower end of the range of reported values.

Barium. The environmental chemistry of barium (Ba) has not been well studied. Its chemistry can be inferred from a knowledge of its properties, the solubility of its compounds, and the behavior of similar elements.

Barium forms compounds in the +2 oxidation sate. Barium has not been found to form complex ions in water (Cotton and Wilkinson 1972) and the Ba(II) ion is stable under the pH-Eh range of natural systems. $Ba(OH)_2 8H_2O$ will form above pH 12. BaH_2 is stable under reducing conditions over the entire pH range of aquatic systems (Pourbaix 1963).

Barium is not very mobile in soils. In the presence of carbonate or sulfate, $BaCO_3$ or $BaSO_4$ will precipitate. In the presence of carbonate or sulfate, $BaCO_3$ or $BaSO_4$ will precipitate. Barium is also strongly absorbed by clay (Kabatas-Pendias and Pendias 1984). Humic and fulvic acid interactions, which could increase the mobility of the element, have not been found to occur (EPA 1984). Barium can form compounds with acetate, nitrate, chloride, and hydroxide, but when formed, these compounds are very soluble. In soil containing these compounds, barium's mobility is increased. In general, the solubility of barium compounds increases with decreasing pH (EPA 1985a).

Barium is probably associated with suspended particles or sediments in aquatic media. The solubility product of barium carbonate is likely to control barium concentration. In the absence of adsorptive carbonate or clays, barium is likely to remain in solution (EPA 1984).

The mobility of barium in soil is low under oxidizing and acid conditions, and very low under neutral, alkaline, or reducing conditions (Kabatas-Pendias and Pendias 1984). Baes et al. (1984) report a Kd range of about 8-800 mg/g for sandy soils and about 200-2,300 ml/g in sandy loam soils. It is likely that the lower Kd values reported by Baes et al. (1984) overestimate the mobility of barium. We have adopted a Kd of 60 ml/g for the EA, however, to provide a somewhat conservative estimate of mobility.

Beryllium. Beryllium (Be) is a small atom with a crystal radius of 0.31 Angstroms (Callahan et al. 1979). It forms a +2 ion and has a large surface-to-charge density, which dominates its chemistry. Bonding with beryllium tends to be covalent (Cotton and Wilkinson 1972). Because of its small size, anions such as fluoride and hydroxide form very stable compounds with beryllium.

Beryllium hydroxide ($Be(OH)_2$) is formed when soluble beryllium salts are dissolved in water. Beryllium hydroxide is not very soluble in the pH range characteristic of natural waters (Cotton and Wilkinson 1972). In addition, elemental beryllium is only found under strong reducing conditions. In the pH range typical of natural water (4 to 8), $Be(OH)_2$ is the dominant species (Pourbaix 1963), and any soluble beryllium will be found in the form of hydrated ions.

Beryllium is not a well-studied element, but is chemically similar to aluminum, so that parallels between the two elements can be drawn to predict beryllium's fate. Thus, sorption to clay mineral surfaces is expected at low pH. Beryllium is expected to sorb to clay particles in neutral to moderately

acidic surface soils. If beryllium reaches the groundwater, the relatively insoluble $Be(OH)_2$ should form.

Korte et al. (1976) studied the movement of trace elements through soil and found that beryllium transport was related to the clay content, surface area, free iron oxide concentration, and pH. In ten of the eleven soils tested, beryllium had a low to moderate mobility. Gerritse et al. (1982) found that beryllium had a Kd ranging from 100-800 ml/g for sewage sludge equilibrated with sand soils and a Kd ranging from 1,000-2,000 ml/g for sewage sludge equilibrated with sandy loam soil. Baes et al. (1984) report a Kd of 650 ml/g; this value was adopted for the EA.

Cadmium. Cadmium (Cd is found in the +2 oxidation state in the environment (Cotton and Wilkinson 1972). Redox potential has little influence on cadmium speciation in water (Callahan et al. 1979). Rather, the pH of water will tend to control speciation of cadmium through the formation of hydroxides: $CdOH^{+1}$, $Cd(OH)_2(aq)$, $Cd(OH)_3$, and $Cd(OH)_4^{-2}$. The dominant ion will be Cd(II) at pH levels up to 8 (Pourbaix 1963, Moore and Ramamoorthy 1984). Under reducing conditions and in the presence of sulfur, the relatively insoluble cadmium sulfide (CdS) will form. Therefore under anaerobic conditions, CdS will be expected to control cadmium solubility (Callahan et al. 1979).

Organic matter, such as humic acids, fulvic acids, and other natural substances, can influence the speciation of cadmium. Gardiner (1974) found that the amount of cadmium ion in lake water is inversely related to pH and the amount of organic mater present. A cadmium-organic complex was found to bind cadmium at pH levels as low as 3 (Guy and Chakrabart 1976). Water hardness limits the extent of complex formation, and O'Shea and Mancy (1978) reported than an increase in hardness resulted in a decrease in complex formation.

The chemistry of cadmium in natural systems is dominated by the ionic, dissolved form of the metal. In the presence of organic acids, a complex ion may form. As the pH of water increases, cadmium hydroxide forms and may remove some of the cadmium from solution. Carbonate will also precipitate some of the cadmium at very high pH levels.

Cadmium is among the most mobile of the heavy metals, and its mobility depends more on sorption processes than on precipitation reactions (Kabata-Pendias and Pendias 1984). Sorption of cadmium is influenced by the clay (Korte et al. 1976) and metal oxide (Callahan et al. 1979) content of the soil and sediments and is a pH-dependent process that increases with increasing pH (Frost and Griffin 1977). Below pH 6-7, desorption is the dominant process. Huang et al. (1977) found that organic anions enhance sorption even at low pH levels. The organic acids react with cadmium to form an organo-cadmium complex, which can then be sorbed to soil or sediment particles. Nevertheless, cadmium has considerably less affinity for two sludge-treated soils than do copper, zinc, or lead and is thought to be more mobile than those chemicals (Williams et al. 1984).

Cadmium transport in the Mississippi River was found to be related to levels of organic materials and metal oxides (Eisenreich et al. 1980). Clay material

also removes cadmium effectively. Cadmium absorbed to clay, however, is more available for resuspension than cadmium associated with carbonate minerals or precipitated as a solid or with hydrous iron oxide. The presence of phosphate can enhance cadmium removal by processes similar to those discussed above for organic ions (Farrah and Pickering 1977). Sedimentary iron oxide and carbonates are thought to play a key role in removing cadmium from solution.

Despite these potential removal processes, cadmium is a relatively mobile element that tends to remain in solution as the divalent cation. Thus, the Kd for cadmium is relatively small, and we have adopted for the EA a Kd value of 6.5 ml/g, as reported by Baes et al. (1984).

Chromium. Chromium (Cr can be found in oxidation states ranging from -2 to +6. Cr(III) is the most commonly occurring oxidation state, and Cr(VI) is the next most frequently found. Cr(V) and Cr(IV) are unstable intermediates that occur during the reduction of Cr(VI) to Cr(III). The lower oxidation states are only formed under strongly reducing conditions, and of these oxidation states, only Cr(II) is found in aqueous solutions (Cotton and Wilkinson 1972; Moore and Ramamoorthy 1984).

The chemistry of Cr(III) and Cr(VI) is very different. Cr(VI) is quite soluble in aqueous solutions and is found as chromates or dichromates, which tend to form complex ions. Cr(VI) is not sorbed by clays or hydrous metal oxides. Cr(III) tends to react with hydroxide to from $Cr(OH)_3$ and can be sorbed by clays and metal oxides (Callahan et al. 1979).

Cr(III) is the predominant form under the pH and redox conditions commonly found in natural waters. Theoretically, oxidation of Cr(III) to Cr(VI) could occur at redox potentials found in well-aerated soils. Bartlett and Kimble (1976), however, found evidence of oxidation regardless of pH or aeration. Cr(III) tends to form stable complexes with both organic and inorganic anions, and those anions should remove Cr(III) from solution. In addition above pH 5, $Cr(OH)_3$ will precipitate. Below pH 5 the hydrated ion is stable, while above pH 9 soluble hydroxides are formed (NRCC 1976).

Cr(VI) is found as the oxo-anion in water. The anions chromate (CrO_4^{-2}), hydrochromate ($HCrO_4^{-1}$), and dichromate ($(Cr_2)_7^{-2}$) are found at varying pH levels. Chromate is the dominant ionic form in the pH range of natural water. Because of its anionic nature, it will not bind to negatively charged particulate matter, resulting in very mobile Cr(VI) complexes. In the presence of reducing agents, Cr(VI) will be reduced to Cr(III) (NRCC 1976); Schroeder and Lee 1975).

Cr(III) and Cr(VI) also behave differently in soils. Chromium can be absorbed or complexed to soil particles, metal oxides, or organic matter and is therefore rather immobile. Most of the Cr(III) found in soils is in mixed Cr(III) and Fe(III) oxides or in the lattice of minerals, although Cr(III) complexed with organic ligands may stay in solution for over a year (James and Bartlett 1983). Cr(III) is mobilized only in very acidic soil media. Cr(VI), by contrast, is easily mobilized, independent of the soil pH (Kabata-Pendias and Pendias 1984). The adsorption of chromium onto clays is pH-dependent;

Cr(III) adsorption increases as pH increases, whereas Cr(VI) adsorption decreases as pH increases (Griffin et al. 1977).

Soil pH will influence the mobility of the Cr(VI) species. CrO_4^{-2} may behave similarly to other anions, HPO_4^{-2} for example, and form a bridged complex with iron or aluminum oxides or with other positively charged soil constituents. The phosphate bridges are very stable and render HPO_4^{-2} unavailable for use or movement. A parallel also can be drawn with $H_2PO_4^{-1}$, which is also tightly held by soils. On the other hand, $HCrO_4^{-1}$ may behave like HCO_3^{-1} and remain mobile (James and Bartlett 1983b).

Soil pH can also affect the reduction of Cr(VI) to Cr(III). In the presence of reducing organic compounds under aerobic conditions or under reducing conditions in the presence of ferrous or sulfide ions, reduction of Cr(VI) will occur. The reaction is fastest under low pH conditions (Bartlett and Kimble 1976) but was not observed in soils with little organic matter. It is also possible that Cr(III) will be oxidized to Cr(VI). Bartlett and James (1979) found that this oxidation occurred in soils high in manganese oxide. They reported that this reaction was not very efficient—only 7% of the chromium was oxidized—and hypothesized that the remainder forms an insoluble predominant oxidation state under most conditions. Cr(VI), however, is the oxidation state that has been assumed for the purpose of toxicological assessment in the EA because it is considerably more toxic to living organisms.

The chemistry of chromium in soil is complicated by the fact that in a highly oxidized form, chromium is very mobile, whereas in a lower oxidation state, its mobility is very low. Generally, Cr(III) is expected to be predominant form in natural systems. Cr(VI), however, is far more hazardous to humans and biota. Therefore, although the 850 ml/g Kd value for Cr(III) reported by Baes et al. (1984) is probably realistic, a Kd of 20 ml/g is used in the EA to better represent Cr(VI). This value falls within the range of Kd values for Cr(VI) reported by Baes and Sharp (1983), 1.2 to 1,800 ml/g, and by Gerritse et al. (1982), 10-40 ml/g.

<u>Copper</u>. Copper (Cu) can be found in three oxidation states: 0, +1, and +2. Of these three, only the +2 oxidation state is found in aquatic systems. Any Cu(I) compounds that are stable in oxygenated water are insoluble (Cotton an Wilkinson 1972). The factors that influence copper speciation are Eh, pH, inorganic complexing agents, and organic ligands (Jenne 1968).

Copper forms complexes with carbonate, to the extent that most dissolved copper is present as a cupric carbonate complex rather than as the free Cu(II) ion. In polluted environments, copper can also complex with cyanide, amino acids, and humic substances. In the absence of organic complexing agents, hydrolysis and precipitation dominate copper's chemistry in aqueous environments. In unpolluted waters, $Cu_2(OH)_2CO_3$ can form, removing copper from solution. Formation of this mineral, however, is very slow and can be affected by the presence of competing ligands (Callahan et al. 1979).

The interactions of copper with organic materials in natural waters have been studied extensively. Organo-copper interactions result in the increased

solubility of some copper-containing minerals and the subsequent transport of the organocupric complex (Ong et al. 1970, Rashid and Leonard 1973).

Copper's affinity for forming complexes with inorganic and organic ligands is further manifested in the sorption of copper to metal oxides, clays, carbonate materials, and organic matter. Hydrous metal oxides can sorb copper and render it immobile (Jenne 1968). This sorption process is competitive with other metals present and could result in the release of copper. A further release mechanism is found under reducing conditions, that is, the metal oxide could be reduced and thereby release copper.

Clay (Huang et al. 1977) and organic matter (Rashid 1974) can also sorb copper. Adsorption was found to be pH dependent and could be enhanced by the presence of humic materials (Huang et al. 1977). It is well known that copper forms stable complexes with humic and fulvic acids (Shuman and Cromer 1979), Shuman and Woodward 1977, Schnitzer and Skinner 1967). Once the organo-copper anion forms, it can be sorbed to the clay or the oxide surface. As pH increases, this sorption process will effectively remove copper from solution. Ramamoorthy and Rust (1978) found that the sediments provide a sink for organo-copper complexes. Copper was not very mobile in these sediments.

Absorption, precipitation, and organic complexation are also important processes in soils (Kabata-Pendias and Pendias 1984). These processes render copper one of the least mobile metals. The solubility of copper decreases in the pH 7-8 range. Below pH 7, copper hydroxide cations are formed, and above pH 8 anionic complexes are formed. Copper mobility is enhanced when organic compounds, such as fulvic and humic acid, complex with copper.

Gerritse et al. (1982) studied metal sorption on sand loam and sandy soils. They obtained Kds of 92.2 ml/g for sandy loam soils and 41.9 ml/g for sandy soils. Korte et al. (1976), however, found that in all the soils they studied, copper had low mobility. They also found no correlations between copper mobility and soil type, pH, or oxide concentration. Baes and Sharp (1983) report an observed Kd range of 1.4-333 ml/g. We have adopted for the EA the value of 35 ml/g reported by Baes et al. (1984).

Iron. Iron (Fe) is found primarily as compounds in the +2 or +3 valence states. Metallic iron exists in the 0 valence states, as do alloys and carbonyl compounds.

In aquatic media, iron can undergo such chemical reactions as precipitation, speciation, oxidation-reduction, chelation, sorption, and microbially mediated reactions resulting in oxidation, reduction, and precipitation. Steinburg (1980) found that greater than 82% of dissolved iron is chelated with dissolved organic carbon ligands. Specific chemical reactions will depend on the pH and oxidation-reduction potential. Sorption and microbial reactions also depend on pH, concentration, and composition.

Iron is present primarily as Fe(III) in most soils, although Fe(II) may predominate in oxygen-deficient soils. The fate of iron compounds in soils is determined primarily by chemical and microbiological reactions and the capacity of soils to sorb iron-organic complexes. Most of the iron is not

mobile because biological and chemical reactions cause precipitation of iron in soils. Small amounts of iron are transported through the soil in the form of colloidal ferric oxyhyroxides and in solution as iron-organic chelates. However, Griffin et al. (1976) have shown that iron is only moderately mobile in a variety of clays. Anaerobic conditions increase the mobility of iron because Fe(III) is reduced to the more mobile Fe(II) form. Soil pH is one of the important regulators of iron mobility, with lower pH favoring mobility, although Fuller (1978) found that even soluble Fe(II) from landfill leachate migrated "surprisingly slowly" under highly acidic, reducing conditions.

Gerritse et al. (1982) report that iron is relatively immobile, with a Kd of approximately 1,000 ml/g in sandy top soil and 2,500 ml/g in sandy loam top soil. Fuller (1978) reported that clay and iron oxide content were the most important soil characteristics controlling iron attenuation in natural landfill leachate, and that once iron was associated with soil, it resisted flushing or leaching by water (except for a small amount that was chelated). Baes et al. (1984) report a much lower Kd value of 25 ml/g, recognizing the potential of iron to migrate in the form of soluble iron-organic chelates. We selected 25 ml/g as the Kd for use in the EA.

Lead. Lead (Pb) is found in the +2 and +4 oxidation states. The most commonly found form in the environment is Pb(II). Pb(IV) forms only under highly oxidizing conditions and, once formed, precipitates as the oxide PbO_2, which is rarely found under natural conditions. Metallic lead can be formed under reducing or basic conditions when very little sulfur is present (Cotton and Wilkinson 1972).

Lead precipitates in aquatic environments with inorganic ligands, such as OH^{-1}, Cl^{-1}, CO_3, SO_4^{-2}, and HCO_3^{-1}, to form complexes of low solubility. Long and Angino (1977) found that both CO_3-^{2} and Cl^{-1} complexed with lead in the pH range of 6-8. In this same pH range, OH^{-1} will form a soluble led complex (Moore and Ramamoorthy 1984). At pH 6 ionic Pb(II) and PbOH+1 coexist. As the pH increases, $PbOH^{+1}$ will be the dominant soluble iron. However, even small amounts of inorganic carbonate from dissolution of atmospheric CO_2 are sufficient to reduce the solubility of lead to concentrations below those predicted from hydrolysis alone. At pH and Eh ranges typical of natural waters, lead is found in a solid form.

Lead forms soluble complexes with naturally occurring organic acids. Guy and Chakrabarti (1976) found that lead can remain complexed to fulvic acid even at pH 3. In systems with low concentrations of organics, lead would form $PbCO_3$ or $PbSO_4$.

Organo-lead complexes can also enhance the sorption process. Gerritse and Van Driel (1984) found that sorption of organo-lead increases as pH increases. These complexes will sorb to clay particles as well as to soil or sediments (Callahan et al. 1979). Zimdahl and Skogerboe (1977) found that the organic content of soils was by far the most important factor in lead sorption in soils.

While precipitation of lead-inorganic complexes is important, the predominant fate of lead in the environment is sorption to soils and sediments. In

natural water, lead concentrations decrease over time; sorption of lead to both sediments and suspended particulates is the favored process, with clay, hydrous metal oxides, and organic matter influencing this sorption. Carey et al. (1980) found lead concentrated in the surface soils. The absorption of lead in soil is sorbed (Huang et al. 1977). Lead has been found to sorb to hydrous iron and manganese oxides. Thus, in soils or sediments with a high oxide content, sorption will be expected to occur. Korte et al. (1976) found that lead was virtually immobile in all but sandy soils.

As evidenced by the above discussion, lead has been found to be immobile in soil. Under the typical range of Eh and pH conditions found in the environment, lead can be expected to sorb to soils or form insoluble compounds. The 900 ml/g Kd reported by Baes et al. (1984) reflects these results, and we have therefore adopted it for use in the EA.

Magnesium. Most magnesium salts are soluble at pH levels normally found in natural waters, and the magnesium ion is readily transported in surface water, soil, sediment, and groundwater. The extent of magnesium transport in soil is dependent, in part, on the cation exchange capacity of the soil.

Manganese. Manganese (Mn) can occur in all valence states from -3 to +7, although the inorganic chemistry of manganese is dominated by the +2, +4, and +7 valence states. Mn(II) is very common and forms many salts. Most are resistant to oxidation, except for MnO and $Mn(OH)_2$, which can be oxidized. Mn(IV) forms a number of complexes, often by the reduction of Mn(VII) compounds. Mn(VI) (manganese), produced by alkaline oxidation of MnO_2, is unstable in acidic or neutral solutions, disproportionating to permanganate and MnO_2. Permanganates (Mn(VII)) are very strong oxidizing agents and under acidic conditions are usually reduced to Mn(II), MnO_2, manganates or other species, depending on the alkalinity of the solution (Cotton and Wilkinson 1980; Considine 1983).

The solubility of manganese depends upon the pH and Eh of the aquatic environment. Mn(III) and Mn(IV) are only slightly soluble, and as a result, manganese in these states would remain at low concentrations. At neutral pH levels, however, these manganese species can be reduced to Mn(II), which is much more soluble and mobile. Stone and Morgan (1984) found that reduction to Mn(II) is carried out by some organic compounds under neutral conditions. Aromatics were especially effective at manganese reduction and solubilization. Calcium and phosphate were found to inhibit reduction by adsorbing to the manganese oxide surface.

Manganese can be chelated by a variety of organic and inorganic ligands. Small colloids may bind manganese and keep it mobile in natural waters (Laxen et al. 1984). Steinberg (1980) showed that manganese chelates with macromolecular organic compounds, polymeric organics, and oligomeric organic compounds. Manganese showed a tendency to associate with polymeric organics ranging from 5,100 to 5,700 daltons. These ligands tend to keep manganese in solution. Soil-bound manganese can be dissolved by organic acids (Pohlman and McCall 1986). Others, however, report that in general manganese is not strongly complexed to humics (Laxen et al. 1984). Many trace metals may bind to MnO_2 as it precipitates, but the soluble Mn fraction represents

15-95 percent of the total Mn and is not dependent on pH, alkalinity, specific conductivity, or humic substance concentration in water (Laxen et al. 1984).

Manganese that is either naturally occurring in soil or was added to it will exist in the soil in a variety of forms. In contrast to the Laxen et al. study, Sims et al. (1979) found that less than 2 percent was water soluble. Another 13 to 19 percent exists in fractions that are either exchangeable, bound to organics, or bound to iron oxides. The largest fraction of the manganese, 45 percent, was in the reducible fraction. The exact distribution depends on pH: the lower the pH, the more manganese in the water soluble and exchangeable fractions; the higher the pH, the more in the reducible fraction (Sims et al. 1979).

Several studies have looked at mobilization of manganese after sewage sludge application. Sewage sludge was found to increase soil solution concentration of manganese, which appeared to exist mainly as the free ion.

In one study 95 to 98 percent of the total Mn was present as free Mn(II) ion, although high concentrations of sewage sludge (containing high concentrations and quantities of organic material) caused up to 17 percent of the Mn to complex to humic materials (Behel et al. 1983). Gerritse et al. (1982) found manganese very mobile in sandy soil when leached by water or sewage sludge solution but very immobile in sandy loam.

We have adopted for the EA a Kd value of 65 ml/g, which is the value reported by Baes et al. (1984).

<u>Mercury</u>. Mercury (Hg) can be found in three oxidation states in the environment. Elemental mercury is a liquid at ordinary temperatures, but it can also vaporize at these temperatures. Mercurous mercury, Hg(I), is found as Hg_2^{+2} under environmental conditions and does not form hydroxides, oxides, or sulfides. Mercuric mercury, Hg(II), forms stable complexes with common ligands. Some of these complexes are fairly soluble while others are quite insoluble (Callahan et al. 1979). The hydroxide is not found in aquatic systems, but mercuric oxide is found and is soluble. In the presence of sulfide, mercuric sulfa (HgS) will precipitate from solution (Cotton and Wilkinson 1972; Callahan et al. 1979).

Elemental mercury will be the predominant species in moderately oxidizing environment above pH 5. It becomes more soluble in the presence of chloride. Under mildly reducing conditions, HgS, which has an extremely low water solubility, will form (Callahan et al. 1979).

The dominant process controlling mercury in the environment is sorption to particulates or sediments. The binding capacity of the sediment is related to its organic content (i.e., sorption rates are highest in soils and sands with high organic content); pH does not affect the sorption process. Desorption does not occur readily. Therefore, once mercury reaches the sediment, it remains there (Ramamoorthy and Rust 1976).

Mercury's behavior in soils depends on the soil environment. In a study of the binding of trace metals to eleven soils, mercury was found to be

moderately to highly mobile (Korte et al. 1976). In reviewing the literature on mercury in soil, Kabata-Pendias and Pendias (1984) found studies on the sorption of mercury to soils showing that mercury formed strong bonds if it was added to soils as anion, cations, or elemental mercury. They also reported that organo-mercury complexes dominated the speciation. The clay content of soils did not significantly affect sorption. Theoretical work of MacNaughton and James (1974) predicted that adsorption of inorganic mercury on the inorganic oxide components of sediment will be very small. Precipitation of $Hg(OH)_2$ was found to occur in neutral or slightly alkaline soils.

Mercury has a high vapor pressure, and in the metallic form, it can volatilize from soils and the aquatic environment (Callahan et al. 1979; Kabata-Pendias and Pendias 1984). The rate of volatilization of mercury and its inorganic compounds from aquatic systems decreases in the order Hg > Hg_2Cl_2 > HgCl > HgS > HgO). In soils, volatilization was found to increase with temperature and alkalinity.

In view of the relatively high mobility of mercury, Baes et al (1984) have reported a Kd of 10 mg/g, which we have adopted for use in the EA. The Kd is also supported by Korte et al. (1976), who found mercury to be moderately to highly mobile.

Nickel. Nickel (Ni) is found in the +2 oxidation state in the environment. Nickel forms complexes with hydroxide, nitrate, sulfate, and humic and fulvic acids. These complexes are moderately soluble and, when the pH is below 9, can maintain nickel ion concentrations above 60 ug/liter. Nickel hydroxide or carbonate will precipitate from solution if the pH is above 9 (Cotton and Wilkinson 1972; Callahan et al. 1979). Humic materials also complex with nickel to form soluble complexes. Solutions of humic acid and nickel carbonate showed that nickel was solubilized due to complexation with the humic material (Rashid and Leonard 1973). The nickel-humic complex is stable enough to inhibit the precipitation of nickel hydroxide, carbonate, or sulfide (Callahan et al. 1979).

Nickel can be incorporated into the crystal lattice of precipitating iron and manganese oxides and organic matter. Gibbs (1973) found that much of the nickel in several river waters was associated with suspended particles or co-precipitated with iron or manganese oxides. Iron oxide forms a stronger complex with nickel than does manganese oxide (Kabata-Pendias and Pendias 1984). Nickel may also isomorphously substitute for other metals in carbonate metals (Callahan et al. 1979). Clay is also a good sorbent for nickel, removing nickel or hindering its transport in soils (Korte et al. 1976). Solid organic matter sorbs nickel in both soils and sediments. The organo-nickel complex is stable under basic conditions, and nickel sorption to peat (a substrate with a very high organic acid content) has been shown to be very strong (Gosset et al. 1986). Hydrous iron oxides attract nickel from organic matter, especially under acidic conditions.

There are few controls on the mobility of nickel in the environment. Nickel can complex with commonly occurring inorganic ligands; however, these complexes are fairly soluble. Organic matter can complex with nickel, increasing the mobility of nickel. Solid organic matter can sorb nickel, as

can metal oxides and clay. Nickel can form covalent bonds to organic ligands, increasing their retardation in organic soils (Tyler and McBride 1982).

Nickel appears to be only moderately retarded in its movement through soil. In studies of the migration of metal through soil, nickel was found to be evenly distributed throughout the column (Schirado et al. 1986). In studies of sewage sludge and the leachability of metals, Holtzclaw et al. (1978) and Brown et al. (1983) found that nickel's mobility was similar to that of zinc and cadmium. This finding was further substantiated by Tyler and McBride (1982). Baes et al. (1984) reported a Kd of 150 ml/g for nickel. This value appears to overestimate the significance of nickel sorption to clays and other types of soil. In view of the reported experimental evidence, the Kd for nickel is probably closer to that of cadmium and zinc and is therefore set at 40 ml/g in the EA.

Silver. Silver (Ag) can be found in the +1, +2, or +3 oxidation states, and the dominant oxidation state is Ag(I). The environmental chemistry of silver is governed primarily by the solubility of its salts. Under the Eh-pH conditions commonly found in aquatic systems, metallic silver can be formed (Pourbaix 1963). Silver metal has a very low solubility and can therefore exert control on the concentration of soluble silver (Callahan et al. 1979). Various silver salts can also control silver's solution concentration.

It is possible to find cations or anions of silver. These however, do not seem to aid in mobilizing silver in soils. At pH greater than 4, silver is generally immobile (Kabata-Pendias and Pendias 1984). Sorption to manganese oxide exerts a major control on silver mobility. Ferric oxides and clays can also sorb silver, but to a lesser extent (Kharka et al. 1968). In experiments by Anderson et al. (1973) and Dyck (1968), silver sorption to manganese and iron oxides was related to pH and occurred rapidly. In the competition between manganese and iron oxides, manganese oxide was found to dominate. Complexation or sorption with humic materials results in high levels of silver in surface soils (Kabata-Pendias and Pendias 1984). In the presence of soil organic matter, silver mobility is fairly low. When various exchangeable cations were present, silver mobility increased only when H^+ was the competing cation. This type of interaction would occur at low pH (Khan et al. 1982).

Silver mobility was determined using a thermodynamic equilibrium model (MINTEQ) (Brown et al. 1986). The results of the modeling showed that nearly all the silver present in groundwater was precipitated. Under reducing conditions in the presence of sulfide, Ag_2S would precipitate. As the Eh was raised to oxidizing conditions, bisulfide (HS^{-1}) was found to keep Ag concentrations very low.

Gerritse et al. (1982) report a Kd of 10,000 ml/g for silver in both anaerobically digested sewage sludge and aerated sewage sludge. When the sludge solutions were placed in sandy loam or sandy soils, the Kds for silver were reported as 250 ml/g and 100 ml/g, respectively. When inorganic solutions were equilibrated with sandy loam or sandy soils, the Kds were approximately 1,000 ml/g and 750 ml/g, respectively. Baes et al. (1984) report a Kd of 45 ml/g. Based on the environmental chemistry of silver, it is likely that the distribution coefficient is large (i.e., most silver is

associated with soil or precipitated from water). As a conservative estimate, however, the 45 ml/g Kd value given by Baes et al. (1984) was adopted for the EA.

Sodium. Sodium (Na) is found in the +1 oxidation state in the environment. Because of the ease of the removal of its single outer shell electron, sodium is exclusively monovalent in its compounds, which are electrovalent. Sodium ranks sixth among the elements occurring in the earth's crust, with an average of 2.9 percent Na in igneous rocks. Sodium metal does not occur in nature because of its great chemistry reactivity (Merck 1976).

Like the other alkali metals, sodium forms compounds with virtually all the anions, organic as well as inorganic. Sodium compounds are remarkable for their great variety, and for the fact that the reactivity of sodium bicarbonate with many metallic oxides permits the preparation of many compounds that are unstable in aqueous solution. Sodium reduces most metal oxides to the elemental state and also reduces metallic chlorides (Considine 1983).

In their evaluation of the potential of clay minerals for attenuating landfill leachate, Griffen et al. (1976) found that sodium attenuation was relatively low, only 15.4 percent. The attenuation of sodium follows the general order of cation replaceability in soils: Li^+ Na^+ K^+ Cs^+. Studies comparing the exchange of mono-, di-, and trivalent bound (Bolt and Bruggenwert 1976).

The Kd for sodium was given as 0.25 ml/g by Baes et al. (1984); we have assigned a somewhat lower value, 0.01 ml/g, as the representative Kd for the EA.

Vanadium. The environmental chemistry of vanadium (V) is very complicated. Vanadium can be found in solution in one of four oxidation states: V(II), V(III), V(IV) (found as VO^{+2}), V(V) (found as VO_2^{+1}). In addition, vanadium is found as an anion, depending on its oxidation state and concentration (Macara 1980).

The vanadium ion, V(II), is stable under reducing conditions and low pH. Because it is not commonly found in aquatic or soil systems, it will not be discussed further. The vanadic form, V(III), is found under mildly oxidizing or reducing conditions. At pH 2.2, it is found as VOH^{-1}, and as the pH increases, V_2O_3 is formed and precipitates from solution. V(III) can be oxidized to form V(IV) or the vanadyl oxidation state. The most common form of the vanadyl ion is VO^{+2}. It is stable under oxidizing conditions over a wide pH range. Above pH 2, vanadyl oxidation begins to polymerize and then precipitate from solution. V(V) has the most complex aqueous chemistry of all. Below pH 2, VO_2^{+1} is found. As the pH increases, V_2O_5 will precipitate only if the vanadium concentration is on the millimolar level. At lower concentrations, an oxo-anion will form. These anions probably control the fate of vanadium in the environment (Kustin and Macara 1982)

Vanadium is relatively mobile in neutral and alkaline soils, as can be seen from the above discussion. V(V) is more soluble and hence more mobile than V(IV) or V(III) (Vinogradov 1959).

In studies of ten different soils, Fuller (1978) found that vanadium was readily leached from soil columns to which it was sorbed as an anion. The behavior of vanadate is probably similar to that of phosphate, which is adsorbed to ferric oxides and clays (Kustin and Macara 1982). Korte et al. (1976) found that sorption of vanadium was correlated with clay, free ion oxides, and surface area of the soil. The authors also found pH to be a major factor in controlling vanadium's mobility.

It can be concluded from the above discussion that vanadium is likely to be fairly mobile in the subsurface environment. Under oxidizing conditions, the vanadate ion will be likely to be sorbed onto soil. This is the reversible process, and therefore vanadate can be expected to be leached through the soil column. Because the behavior of vanadium in soils is not widely studied, no experimental Kd could be found in the literature. Baes et al. (1984) derived for vanadium a Kd of 1.00 ml/g, which we have adopted for the EA. This value does not consider the presence of organic carbon. Naturally occurring organic acids have been found to complex with vanadium (E 1985 and references therein). It is possible that these interactions may increase the mobility of vanadium; however, in studies of the influence of organic matter on vanadium mobility, Gerritse et al. (1982) found vanadium to have Kds ranging from 35 ml/g to 5,040 ml/g.

Zinc. Zinc (Zn) is found in the +2 oxidation state in the environment. It can be found as a hydrated ion, a metal-organic complex, or a metal-inorganic complex in water. The redox potential does not affect zinc speciation directly; instead, it affects the ligands with which zinc may react (Cotton and Wilkinson 1972, Callahan et al. 1979)

Zinc can form precipitates in aquatic systems. In reducing environments, zinc sulfide is formed and controls zinc's mobility. Zinc can react with hydroxide to form $Zn(OH)_2$. Zinc oxide can also be found, though it is stable under higher oxidizing conditions than the hydroxide (Pourbaix 1963). In the pH range characteristic of natural waters, both $Zn(OH)_2$ and $ZnCO_3$ can form. Of the two solids, hydroxide formation is favored kinetically (Callahan et al. 1979).

Zinc can form complexes with humic and fulvic acids, and the formation of these complexes can increase its solubility (Ong et al. 1970, Rashid and Leonard 1973). Guy and Chakrabarti (1976) found that these complexes could keep zinc bound but dissolved to a pH as low as 3. These results imply that while zinc may precipitate from solution, the sediments may not by the ultimate sink for zinc, especially in areas where there are high concentrations of dissolved organic acids.

Hydrous metal oxides, clays, and organic mater can all sorb zinc. Iron oxides and phosphates were found to remove zinc from the Vesdie River, trapping it in the sediments (Honba et al. 1983). In addition to sorption, co-precipitation of zinc with hydrous oxides has been found to occur. This process can take place when reduced iron or manganese oxides are oxidized. As the new solids are formed, they can trap various ions into their crystal lattice (Callahan et al. 1979).

The soil chemistry of zinc is governed by the pH of the soil. In acidic soils, zinc adsorption is related to cation exchange sites, while in alkaline processes adsorption will be influenced by organic ligands. Cation exchange processes will be influenced by the type of cations moving through the soil. This implies that when there are mobile metals, competition for the binding sites will occur, and zinc may be mobilized. In more alkaline soils, zinc can form an organo-zinc complex, which would also increase the metal's mobility (Kabata-Pendias and Pendias 1984).

Metal oxides also influence zinc's mobility in soils. Zinc was found to be highly associated with oxides. Clay is also capable of sorbing zinc. Soils that contain high levels of calcium and phosphorus immobilize the metal (Kabata-Pendias and Pendias 1984).

Zinc's mobility is influenced by soil type. Clays and metal oxides will retard mobility. Gerritse et al. (1982) report a Kd of 939 ml/g in sandy loam soil and 12.7 ml/g in sandy soils. Korte et al. (1976) do not report Kd values; their results, however support this range in zinc mobility. Zinc mobility was correlated to pH, clay, surface area, and free ion oxide concentration. Baes and Sharp (1983) report a range in Kds of 0.1 and 8,000 ml/g. The average Kd reported by Baes et al. (1984), 40 ml/g, is the value we have adopted for the EA.

APPENDIX N
CHEMICAL TOXICOLOGICAL PROFILES

BARIUM

INTRODUCTION

Barium is a reactive metal which exists in nature as a number of salts such as barium sulfate and barium carbonate (EPA 1984). These mineral forms are relatively insoluble in water. Barium salts are used for drilling mud, pigments and as an x-ray contrast medium (EPA 1987a). Barium is abundant in nature and can be found in plant and animal tissues (Goyer 1986).

TOXICOKINETICS

In experimental animals, barium absorption varies with the species of animal, the compound tested, the age of the animal, and the dietary composition (EPA 1987a). Soluble barium compounds are absorbed and small amounts are retained in the body. Insoluble barium compounds are adsorbed only minimally (Goyer 1986). Barium was found to distribute widely in the mouse but was principally found in the bone (Dencker et al. 1976). In humans, barium is primarily excreted via the feces (Tipton et al. 1966).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Barium carbonate and more soluble barium compounds are quite toxic to humans following oral exposure. Doses of barium carbonate and barium chloride of 57 mg/kg and 12 mg/kg, respectively, were fatal when ingested by humans. Toxic effects of ingestion include gastroenteritis, muscular paralysis, hypertension, cardiotoxicity including ventricular fibrillation, and damage to the central nervous system (Perry et al. 1983). Inhalation of barium sulfate or barium carbonate dust causes baritosis, a benign pneumoconiosis, in occupationally exposed workers. This effect is reversible upon cessation of exposure (Goyer 1986).

The chronic toxicity of barium has been studied in rats and mice. The only adverse effect identified was a significant increase in blood pressure in rats given drinking water containing 100 ppm barium in one study. No effect on blood pressure was seen in an epidemiological study of the effects on humans of elevated barium concentrations in drinking water (EPA 1984).

No data were available in the literature reviewed concerning the carcinogenicity of barium in humans. Rats and mice exposed to 5 mg/liter barium acetate in the drinking water for a lifetime did not develop statistically significant elevations in tumor incidences. However, the dose administered was low and below acceptable intakes (EPA 1984).

Only limited data are available concerning the genotoxicity of barium compounds. Barium chloride was reported negative in a bacterial mutagenicity assay and in an in vitro test system for error induction in DNA transcription (EPA 1984).

Inhalation exposure of male rats to barium carbonate dust produced decreased numbers of spermatozoids, a decreased percentage of motile sperm forms, and increased fetal mortality following mating of treated males with untreated females. Exposure of female rats lead to ovarian follicle atresia, increased mortality in subsequent litters and a general underdevelopment of newborn pups. No information on teratogenic effects was found in the literature reviewed (EPA 1984).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Using the EPA Carcinogen Assessment Group's criteria for evaluating the weight of the evidence of carcinogenicity in humans (EPA 1986a), the EPA Office of Environmental Criteria and Assessment has determined that barium is most appropriately classified in Group D--Not Classified (EPA 1984). This category applies to agents with inadequate animal evidence of carcinogenicity.

EPA (1987b) derived an oral reference dose (RfD) for barium on a weight of evidence from various epidemiological (Brenniman et al. 1981) and animal (Schroeder and Mitchener 1975a,b; Tardiff et al. 1980; Perry et al. 1983) studies. However, the primary study on which the RfD was based was the study by Perry et al. (1983). These authors exposed weanling rats to barium at 1, 10 or 100 ppm in drinking water for up to 16 months (average daily barium doses of 0.051, 0.51 and 5.1 mg/kg, respectively). There were no signs of toxicity at any barium dose level. Systolic blood pressure measurements revealed no increase in pressure in animals exposed to 1 ppm for 16 months, an increase of 4 mm Hg ($p<0.01$) in animals exposed to 10 ppm for 16 months, and an increase in systolic pressure of 16 mm Hg ($p<0.001$) in animals exposed to 100 ppm barium (5.1 mg/kg/day) for 16 months (EPA 1987b). Using a lowest-observed-adverse-effect level (LOAEL) based on increased blood pressure of 5.1 mg/kg/day and an uncertainty factor of 100, an oral RfD of 0.05 mg/kg/day was derived. It was noted by EPA (1987b) that the rats in this study were maintained in a special contaminant-free environment and fed a diet designed to reduce exposure to trace metals; consequently, it was suggested that the restricted intake of certain beneficial metals (e.g., Ca and K) may have predisposed the test animals to the hypertensive effects of barium.

EPA (1976) has established a maximum contaminant level (MCL) drinking water standard of 1 mg/liter for barium. The Ambient Water Quality Criterion (AWQC) derived for the protection of human health from barium ingested through drinking water and aquatic organism consumption is also 1 mg/liter (EPA 1986). The EPA Office of Drinking Water (EPA 1985) proposed a maximum contaminant level goal (MCLG) for barium based on a study by Perry et al. (1983) in which rats were exposed to 1, 10, or 100 ppm barium in drinking water for 1 to 16 months. Based on an RfD of 0.05 mg/kg/day and factoring in data on human exposure from other sources (0.7 mg/day via diet and 0 mg/day via air), EPA (1985) recommended a maximum contaminant level goal of 1.5 mg/liter.

EPA (1984) determined an acceptable chronic intake (AIC) of 3.6 mg/day (0.05 mg/kg/day) for oral exposure to barium based on the LOAEL of 5.1 mg/kg/day identified from the Perry et al. (1983) study. An inhalation AIC was determined based on the acceptable subchronic intake (AIS) calculated from a study by Taresenko et al. (1977) in which exposure of male rats to 0.8 mg/m^3 barium resulted in no observed toxic effects.

The inhalation AIS of 0.098 mg/day with an additional uncertainty factor of 10 resulted in an AIC of 0.01 mg/day, which is equivalent to 0.14 lg/kg/day.

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommended a time-weighted average threshold limit value of 0.5 mg/m^3 for soluble compounds of barium and 10 mg/m^3 for barium sulfate as a nuisance dust.

SUMMARY OF BARIUM CRITERIA

EPA carcinogen classification	Group D
Oral RfD	0.05 mg/kg/day
MCL	1 mg/liter
Proposed MCLG	1.5 mg/liter
Inhalation AIC	0.14 lg/kg/day
AWQC:	
Ingestion of water and aquatic organisms	1 mg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of Threshold Limit Values and Biological Exposure Indices. 5th Ed. Cincinnati, Ohio

BRENNIMAN, G.R., KOJOLA, W.H., LEVY, P.S., CARNOW, B.W., and NAMEKATA, T. 1981. High barium levels in public drinking water and its association with elevated blood pressure. Arch. Environ. Health. 36(1): 28-32. As cited in EPA 1987b

DENCKER, L., NILSSON, A., RONNBACK, C., and WALINDER, G. 1976. Uptake and retention of 133Ba and 140Ba-140La in mouse tissue. Acta Radiol. 15:273-287 (As cited in EPA 1985a)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1976. National Interim Primary Drinking Water Regulations. Office of Drinking Water, Washington, D.C. EPA 570/9-76-003 (As cited in EPA 1985a)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Barium. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-021

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985. National primary drinking water regulations, synthetic organic chemicals, inorganic chemicals and microorganisms; proposed rule. Fed. Reg. 50:46936-47002 (November 13, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Guidelines for carcinogen risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Quality Criteria for Water 1986. Office of Water Regulations and Standards, Standards Branch, Washington, D.C. May 1, 1986. EPA 440/5-86-001

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Health Advisory for Barium. Office of Drinking Water, Washington, D.C. March 31, 1987

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987b. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. Cincinnati, Ohio. Revised September 30, 1987

GOYER, R.A. 1986. Toxic Effects of Metals. In: Casarett and Doull's Toxicology: The Basic Science of Poisons, 3rd Ed., Klaasen, C.D., Amdur, M.D., and Doull, J. (eds.), Macmillan Publishing Co., New York, Toronto, and London. pp. 623-624

PERRY, H.M., KOPP, S.J., ERLANGER, M.W., and PERRY, E.F. 1983. Cardiovascular effects of chronic barium ingestion. In: Hemphill, D.D., ed. Trace substances in Environmental Health - XVII. Proceedings of the University of Missouri's 17th Annual Conference on Trace Substances in Environmental Health. University of Missouri Press, Columbia, Missouri (As cited in EPA 1984, 1985, 1987b)

SCHROEDER, H.A. and MITCHENER, M. 1975b. Life-term effects of mercury, methyl mercury and nine other trace metals on mice. J. Nutr. 105:452-458. As cited in EPA 1987b

SCHROEDER, H.A. and MITCHENER, M. 1975a. Life-term studies in rats: Effects of aluminum, barium, beryllium and tungsten. J. Nutr. 105:421-427. As cited in EPA 1987b

TARASENKO, M., PROMIN, O., and SILAYEV, A. 1977. Barium compounds as industrial poisons (an experimental study). J. Hyg. Epidemiol. Microbiol. Immunol. 21:361 (As cited in EPA 1984)

TARDIFF, R.G., ROBINSON, M., and ULMER, N.S. 1980. Subchronic oral toxicity of BaC12 in rats. J. Environ. Pathol. Toxicol. 4:267-275. As cited in EPA 1987b

TIPTON, R.H., STEWART, P.L., and MARTIN, P.G. 1966. Trace elements in diets and excreta. Health Phys. 12:1683-1689 (As cited in EPA 1985a)

BERYLLIUM

INTRODUCTION

Beryllium is hard, brittle, grey-white metal with atomic number 4 and an atomic weight of 9 g/mole. It has complicated coordination chemistry and can form complexes, oxycarboxylates, and chelates with a variety of materials. Beryllium is the lightest structural metal and has many uses in the space and nuclear programs as well as in industry. Coal combustion is probably the largest source of environmental beryllium contamination (EPA 1986a).

PHARMACOKINETICS

Beryllium is not well absorbed following exposure by any route. After inhalation exposure, beryllium is retained in the lungs and only slowly cleared. Once in the bloodstream, a colloidal beryllium complex is formed which may be deposited in the liver, spleen or bone marrow. A soluble beryllium complex may also be formed which can be deposited in the bone or excreted in the urine (Hammond and Beliles 1980). Tissue analysis from people occupationally exposed to beryllium indicates that concentrations are the highest in the bone, liver and kidney (EPA 1986a). Unabsorbed beryllium is excreted primarily in the feces (IARC 1980).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

A number of studies have shown that beryllium and several beryllium compounds are carcinogenic in experimental animals resulting primarily in lung and/or bone tumors when given by injection, intratracheal administration, or inhalation. Several epidemiological studies have suggested that occupational exposure to beryllium may result in an increased lung cancer risk though the data are inconclusive. No neoplasms were observed following beryllium exposure by the oral or dermal routes (EPA 1986a). Based on an overall consideration of the available data, the International Agency for Research on Cancer (IARC 1980) concluded that beryllium is probably carcinogenic to humans.

Acute respiratory effects due to beryllium exposure include rhinitis, pharyngitis, tracheobronchitis, and acute pneumonitis. Dermal exposure to soluble beryllium compounds can cause contact dermatitis, ulceration and granulomas (Hammond and Beliles 1980). Ocular effects include conjunctivitis and corneal ulceration from splash burns. The most common clinical symptoms caused by chronic beryllium exposure are granulomatous lung inflammation, with accompanying cough, chest pain, and general weakness (IARC 1980, EPA 1986a). Chronic skin lesions sometimes appear after a long latent period in conjunction with the pulmonary effects. The disease may also develop in people exposed to minimal amounts of beryllium such as those handling beryllium worker's clothes or living near a plant (Hammond and Beliles 1980). Systemic effects from beryllium exposure may include right heart enlargement with accompanying cardiac failure, liver and spleen enlargement, cyanosis, digital clubbing, and kidney stone development.

Beryllium compounds have not been shown to cause mutations in bacteria, but positive results have been obtained in mammalian cell test systems. Certain compounds have been observed to enhance cell transformation, and induce chromosomal abnormalities and possibly SCEs (EPA 1986a). Positive results have also been reported in tests for DNA damage in vitro (IARC 1980).

Only limited data on the potential reproductive or teratogenic effects of beryllium have been reported. One study in rats, failed to demonstrate any effect of a single intratracheal administration of beryllium on the fertility of males or females or on pregnancy (Barlow and Sullivan 1982). No defects were noted in chick embryos exposed to beryllium sulfate (Shepard 1986).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Beryllium has been previously classified by EPA in Group B1--Probable Human Carcinogen (EPA 1986d, 1987a). This category applies to agents for which there is limited evidence of carcinogenicity in humans from epidemiologic studies (EPA 1986d).

The Carcinogen Assessment Group (CAG) has previously calculated a human carcinogen potency factor ($q1^*$) of 8.4 $(mg/kg/day)^{-1}$ for inhalation exposure to beryllium (EPA 1986a). Data from an epidemiological study by Wagoner et al. (1980) and the industrial hygiene reviews by NIOSH (1972) and Eisenbud and Lisson (1983), were used to calculate the cancer risk associated with exposure to air contaminated with beryllium. The incremental lifetime cancer risk associated with 1 lg/m^3 beryllium in the air was estimated to be $2.4x10^{-3}$, which is equivalent to a cancer potency factor of 8.4 $(mg/kg/day)^{-1}$. EPA believes that this risk derived from the epidemiological data may be more relevant for estimating the risks associated with inhalation exposure to mixtures of beryllium compounds likely to be present in ambient air than those risks derived from the animal bioassays which are, in general, significantly higher. This is because the human data are based on exposure to the insoluble beryllium compounds likely to be found in the air and not on exposure to the soluble compounds used in the animal tests (EPA 1986a).

More recently, an inhalation cancer potency factor of 4.86 $(mg/kg/day)^{-1}$ has been derived by CAG and reported by EPA (1986d), 1987a). The basis for this potency factor has not been reported.

An inter-office work group of EPA (1987b) is currently reevaluating the weight-of-evidence classification and cancer potency factor for beryllium. This pending review does not necessarily imply that beryllium is a carcinogen. A risk assessment summary will be included in EPA's Integrated Risk Information System when the review has been completed (EPA 1987b).

In its Ambient Water Quality Criteria Document for beryllium, EPA (1980) established a criteria of 3.7 ng/liter for the protection of human health from the potential carcinogenic effects of exposure to beryllium through the ingestion of water and aquatic organisms. EPA (1980, 1986a) has also derived an adjusted criterion of 3.9 ng/liter for the protection of human health from beryllium ingested only through drinking water. These criteria correspond to an estimated lifetime incremental cancer risk of

10^{-6}. The criterion for a 10^{-6} excess lifetime cancer risk from ingestion of aquatic organisms alone is 64.1 ng/liter. The assumption that beryllium is carcinogenic after oral administration can be questioned in light of the fact that the results on oral studies designed to test this assumption are either negative or uncertain (EPA 1980). The risk assessment performed by EPA (1980) was based on the results of Schroeder and Mitchner (1975) which showed a statistically insignificant excess in grossly-observed tumors of all sites in male rats continuously exposed to beryllium at 5 ppm in the drinking water.

EPA (1986c, 1987b) also established an oral Risk Reference Dose (RfD) for beryllium based on the data of Schroeder and Mitchner (1975) for noncarcinogenic endpoints of beryllium toxicity. In this study, 52 weanling Long-Evans rats of each sex received 0 or 5 ppm (0.54 mg/kg bw/day) beryllium sulfate in drinking water for a lifetime. No adverse effects were seen in the dosed rats. Based on this no-observed-adverse-effect level (NOAEL) and an uncertainty factor of 100, an RfD of 0.005 mg/kg/day was established. The RfD is the currently accepted toxicity value for oral exposure. This RfD has been verified by the RfD Work Group of the Risk Assessment Forum and a low confidence rating has been assigned to the value (EPA 1986c, 1987b).

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommends a time-weighted average Threshold Limit Value (TLV) of 0.002 mg/m^3 for beryllium because of the serious consequences of beryllium disease and uncertainty as to the minimal concentrations which have caused illness.

SUMMARY OF BERYLLIUM CRITERIA

EPA carcinogen classification (inhalation)	Review Pending
Inhalation carcinogenic potency factor ($q1^*$)	Review Pending
Oral RfD	0.005 mg/kg/day
AWQC (10^{-6} estimated lifetime cancer risk)	
Ingestion of water and aquatic organisms	3.7 ng/liter
Ingestion of water	3.9 ng/liter
Ingestion of aquatic organisms	64.1 ng/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

BARLOW, S.M., and SULLIVAN, F.M. 1982. Reproductive Hazards of Industrial Chemicals. An Evaluation of Animals and Human Data. Academic press, pp. 119-125

EISENBUD, M., and LISSON, J. 1983. Epidemiological aspects of beryllium-induced nonmalignant lung disease: A 20-year update. JOM J. Occop. Med. 25:198

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Beryllium. Criteria and Standards Division. Washington, D.C. EPA 440/5-80-024. NTIS PB81-117350

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Health Assessment Document for Beryllium. Review Draft. Office of Health and Environmental Assessment, Washington, D.C. EPA 600/8-84-026B. April 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Guidelines for carcinogenic risk assessment. Fed. Reg. 51:33992-34003. September 24

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986c. Second Set of Verified Reference Doses. Memo from the Office of Health and Environmental Assessment to the RfD Work Group. May 14, 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986d. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response, Washington, D.C. October 1986. EPA 540/1-86-060

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Memo from Sandra Lee (Program Manager, Regional Support Team, Toxics Integration Branch to Addresses. Subject: Updated Reference Dose and Cancer Potency Numbers for Use in Risk Assessments. Office of Solid Waste and Emergency Response. Washington, D.C. October 1987. 19 pp. (Sandra Lee: (202)382-4307)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987b. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. Cincinnati, Ohio Revised September 30, 1987

HAMMOND, P.B., and BELILES, R.P. 1980. Metals. In: Casarett and Doull's Toxicology: The Basic Science of Poisons, 2nd Ed., Doull, J., Klaassen, C.D., and Amdur, M.O. (eds.), Macmillan Publishing Co., New York, Toronto, and London. pp. 438-439

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1980. Some Metals and Metallic Compounds. Vol. 23: IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. World Health Organization, Lyon, France. Pp. 143-204

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1972. Occupational Exposure to Beryllium. HSM 72-10268. Washington, D.C. (As cited in EPA 1984)

SCHROEDER, H.A., AND MITCHNER, M. 1975. Life-term studies in rats: Effects of aluminum, barium, beryllium, and tungsten. J. Nutr. 105:421-421. (As cited in EPA 1984, 1987b)

SHEPARD, T.A. 1986. Catalog of Teratogenic Agents, 5th Ed., Johns Hopkins University Press, Baltimore and London, p. 186

WAGONER, J.K., INFANTE, P.F., and BAYLISS, D.L. 1980. Beryllium: An etiologic agent in the induction of lung cancer, neoplastic respiratory disease, and heart disease among industrially exposed workers. Environ. Res. 21:15-34. (As cited in EPA 1984)

CHROMIUM

INTRODUCTION

Chromium (Cr) is a steel-grey lustrous metal with the atomic number 24 and an atomic weight of 52 g/mole. It can have a valence of 2, 3, or 6. Chromium is used in stainless and alloy steels, in corrosion-resistant products, in pigments, and as a tanning agent for leather.

TOXICOKINETICS

Chromium absorption and distribution are influenced by the particular oxidation state and the water solubility of the compound. In general, gastrointestinal absorption of trivalent chromium (Cr III) is low. Hexavalent chromium (Cr VI) and organic complexes of Cr III are more readily absorbed. Cr VI crosses membranes much more rapidly than Cr III. The spleen and kidneys have been shown to have the highest tissue concentrations following intravenous doses of Cr III or doses of either Cr III or Cr VI in the drinking water (EPA 1987a). The chromium concentration in human tissues has been shown to decrease with age except for the lung, in which chromium concentrations increase with age possibly because of the deposition and retention of insoluble chromium-containing particles inhaled from the environment (EPA 1984a). Chromium metabolism is not well understood. Excretion is primarily through the urine (EPA 1987a).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Chromium is an essential nutrient for normal glucose metabolism, and low level exposure to chromium compounds has not been found to result in systemic toxicity. However, hexavalent chromium (Cr VI) compounds are strong oxidizing agents, a characteristic that explains much of their irritating and toxic properties (EPA 1980). Chronic inhalation of dust or air containing Cr VI in the form of chromic acid or as soluble salts may cause respiratory problems including irritation, perforated or ulcerated nasal septa, and decreased spirometric values. Studies of acute exposure of humans and animals using a variety of routes of administration have indicated that soluble Cr VI and trivalent chromium (Cr III) compounds can produce kidney and liver damage, although the dose levels employed were relatively high. From the evidence available from both human case reports and animal studies, it is uncertain whether the kidneys and liver may be target organs following chronic exposure to chromium compounds. Dermal exposure to chromic acid or chromium VI salts may cause contact dermatitis, sensitivity, and ulceration of the skin (EPA 1984a).

Epidemiological studies of worker populations have clearly established that inhaled Cr VI is a human carcinogen, with the respiratory passages and the lungs as target organs. Convincing evidence for carcinogenicity of Cr VI compounds in animals is not available, except for the induction of sarcomas at the sites of implantation or injection of certain chromium VI salts and chromium trioxide (EPA 1980, 1984a).

Neither chromium III nor chromium VI compounds have been shown to be carcinogenic by the oral route. Rats administered chromium III oxide at doses

up to 5% of their diet for two years had no increase in tumor rates over control animals (Ivankovic and Preussmann 1975 as cited in EPA 1984a). Dogs given Cr VI as potassium chromate at concentrations of 0.45 to 11.2 mg/liter in drinking water for 4 years had no observed adverse effects (Anwar et al. 1961 as cited in EPA 1984a).

Chromium has been shown to have genotoxic effects *in vivo* and *in vitro*. Compounds containing Cr VI species have been shown to induce mutations in bacteria, morphologic changes in mammalian fetal cells, cytogenetic effects in mammalian bone marrow cells, gene conversion in yeast, chromosomal damage in cultured human lymphocytes and enhanced transformation frequencies in mammalian cells. Positive results with Cr III have been difficult to obtain, possibly because of its slight uptake by cells under most conditions. Recent data concerning the genotoxic effects of Cr III suggest that it can interact with DNA and that pure Cr III can cause chromosomal abnormalities (EPA 1984a).

Certain chromium salts have been shown to be teratogenic and embryotoxic in mice and hamsters following intravenous or intraperitoneal injection. Testicular degeneration in rabbits exposed to either Cr III or Cr VI by intraperitoneal injection has also been reported (EPA 1984a).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

The health risks posed by airborne chromium III and chromium VI have been reviewed in considerable detail by EPA (1984a, 1984b, 1984c). Studies on the carcinogenicity of chromium compounds were earlier reviewed by the International Agency for Research on Cancer (1980). A risk assessment for exposure to airborne chromium VI was included in the health assessment document by EPA (1984b). The following summary is based in part on these reviews and risk assessments, augmented by review of key primary papers.

EPA (1984b, 1987b) based its quantitative risk assessment for inhaled hexavalent chromium on an unpublished study by Mancuso (1975). This study, although limited, was judged to be more adequate for risk assessment than three other studies (conducted in Norway, Sweden, and the USSR) which suffered from deficiencies in measurement of exposure, statistical power, and reporting. Mancuso's study showed excess risks of lung cancer in workers exposed to chromates between 1931 and 1937 and followed until 1974. Lung cancer risks increased with duration of exposure and with age. Estimates of cumulative exposure to soluble, insoluble, and total chromium were derived from a single set of industrial hygiene measurements taken in 1949. Smoking habits of the workers were not determined or discussed.

To construct dose-response relationships, EPA (1984b) converted all exposure data into average lifetime ambient concentrations. This is equivalent to assuming that exposure to chromium at any time during life leads to the same increase in lifetime risk of lung cancer. The data were fitted to a dose-response relationship of the Weibull type, in which cancer risk is assumed to be proportional to age raised to the kth power and to a second order polynominal ($ad + bd^2$) in dose d. Fitting the data to observed estimates of age-specific cancer risk and average exposure of the chromate workers, EPA estimated that k was approximately 1.9 and both the linear and quadratic terms in d were significant. At low doses, the term ad dominates the risk calculations, and for lifetime exposure the "unit risk" was calculated to be

1.2×10^{-2} $(\lg/m^3)^{-1}$. However, because of small sample size (only 35 observed lung cancer deaths distributed over 9 age-exposure classes), the statistical uncertainty of this estimate was very high (standard deviation = 7 x mean). Expressed in terms of total intake, the inhalation cancer potency factor was calculated as 41 $(mg/kg/day)^{-1}$ (EPA 1984b, 1987b).

EPA suggested that the assumptions made about exposure and the failure to control for smoking might have led to overestimation of risk by a factor of up to 4. The assumption that risk would be proportional to average lifetime exposure introduces additional uncertainties. More important, the linear extrapolation of the dose-response relationship estimated for highly exposed workers to predict risks of the general population exposure to concentrations about 10^5 times lower is likely to be very conservative. Finally, the unit risk estimate is directly applicable only to persons exposed to chromium compounds similar to those involved in the study by Mancuso. On the basis of a survey performed by Bourne and Yee (1950) at the bichromate-producing plant that served as the basis of the Mancuso (1975) study, EPA (1984b) stated that trivalent and hexavalent chromium compounds were present in the ratio 6:1, so that the unit risk for hexavalent chromium might be 7 times higher than that estimated for total chromium. Overall, therefore, EPA's estimate of the unit risk for exposure to chromium in ambient air must be characterized as extremely uncertain (primarily because of statistical uncertainty and uncertainty in measuring exposure) and probably very conservative (primarily because of the wide range of extrapolation, but also because of assumptions about exposure and failure to control for smoking).

Based on exposure via inhalation, the IARC (1982) classified Cr VI as Group 1, human carcinogen. The evidence for the carcinogenicity of Cr III compounds was judged to be inadequate. However, IARC (1980) concluded that the epidemiological data do not allow elucidation of the relative contributions to carcinogenic risk of Cr III or Cr VI or of soluble versus insoluble compounds. EPA classified inhaled Cr VI as Group A--Human Carcinogen and inhaled Cr III as Group D--Not Classified (EPA 1984b, 1984c, 1987b). Ingested chromium compounds were classified as Group D (EPA 1984d, 1987a).

Hexavalent chromium's potent carcinogenic effects when inhaled make calculation of subchronic or chronic allowable intakes by inhalation for noncarcinogenic endpoints of toxicity inappropriate (EPA 1984b). For trivalent chromium, a chronic allowable intake (AIC) by inhalation of 0.0051 mg/kg/day was calculated in the Health Effects Assessment for Trivalent Chromium (EPA 1984c). This number was derived from a TLV. The studies used for derivation of the TLV involved workers exposed to chromium dusts and fumes (ACGIH 1986).

For oral exposure to Cr VI, a subchronic allowable intake (AIS) of 0.025 mg/kg/day was derived in the Health Effects Assessment for Hexavalent Chromium (EPA 1984b). The AIS was based on a one-year study in which rats were exposed to 0-25 mg/liter Cr VI as potassium chromate in drinking water. Increased tissue concentrations of chromium, but no adverse health effects were reported at the highest dose (Mackenzie et al. 1958 as cited in EPA 1984b). An oral chronic allowable intake (AIC) of 0.005 mg/kg/day was derived from the same study, with application of an additional safety factor of 5 to adjust for less than lifetime exposure (EPA 1984b).

EPA (1987b) has derived an oral reference dose (RfD) for chromium VI based on a study by MacKenzie et al. (1958). In this study, groups of eight male and eight female Sprague-Dawley rats were supplied with drinking water containing 0-11 ppm (0-11 mg/liter) hexavalent chromium (as K_2CrO_4) for 1 year. The control group (10/sex) received distilled water. A second experiment involved three groups of 12 males and 9 female rats. One group was given 25 ppm (25 mg/liter) chromium (as K_2CrO_4); a second received 25 ppm chromium in the form of chromic chloride; and the controls again received distilled water. No significant adverse effects were seen on appearance, weight gain, or food consumption, and there were no pathologic changes in the blood or other tissues in any treatment group. The rats receiving 25 ppm of chromium (as K_2CrO_4) showed an approximate 20% reduction in water consumption. This dose corresponds to 2.4 mg chromium(VI)/kg/day based on actual body weight and water consumption data. Using a NOAEL (no-observed-adverse-effect level) of 2.4 mg Cr(VI)/kg/day and an uncertainty factor of 500, an oral reference of $5x10^{-3}$ mg/kg/day was derived (EPA 1987b).

For oral exposure to Cr III, a subchronic allowable intake of 14 mg/kg/day was established based on a study by Ivankovic and Preussmann (1975). Rats were fed Cr III as chromium oxide at 2% and 5% of the diet for 90 days. A NOAEL of 5% Cr III was suggested, which corresponds to 1,399 mg/kg/day based on measured food consumption and body weight. Slightly depressed spleen and liver weights were reported.

For chronic oral exposure to Cr III, the EPA (1987b) derived an oral reference dose (RfD) of 1 mg/kg/day based on the Ivankovic and Preussman (1975) study. Rats were fed chromic oxide baked in bread at dietary levels of 0, 1, 2, or 5%, 5 days/week for 600 feedings (840 total days). No effects due to chromic oxide treatment were observed at any dose levels. Using a NOEL of 1,468 mg/kg/day (dose that corresponds to 5% chromic oxide in diet 5 days/week for 600 feedings) and an uncertainty factor and modifying factor of 100 and 10, respectively, an oral RfD of 1 mg/kg/day was derived (EPA 1987b). The uncertainty factor of 100 was used to account for both interhuman and interspecies variability. The modifying factor of 10 was used to account for uncertainty in the NOEL.

The interim MCL for total chromium under the National Interim Primary Drinking Water Regulations is 0.05 mg/liter. A proposed maximum contaminant level goal (MCLG) of 0.12 mg/liter is proposed for total chromium, based on an adjusted allowable daily intake (AADI) of 0.17 mg/liter with data on human exposure by other routes factored in (0.10 mg/day via the diet and 0 mg/day via air) (EPA 1985). A reference dose (RfD) for total chromium of $5x10^{-3}$ mg/kg/day can be derived based on the Office of Drinking Water (ODW) analysis.

SUMMARY

Chromium is an essential micronutrient and is not toxic in trace quantities. High levels of soluble Cr VI and Cr III produce kidney and liver damage. Chronic inhalation exposure may lead to respiratory system damage. Epidemiological studies of workers exposed to Cr VI via inhalation demonstrate that it is a human carcinogen. EPA's (1984b) quantitative risk assessment is based upon a single study of a cohort of workers exposed over a six-year period and followed for approximately 40 years. Smoking habits were not considered in the study. Assumptions and extrapolations included in the calculations lead to

a very wide range of uncertainty in the risk factor. The relative carcinogenic potency of Cr III has not been demonstrated. A reference dose of 1 mg/kg/day has been established for oral exposure to Cr III. An oral reference dose of 0.005 mg/kg/day was derived for Cr VI.

Summary of Chromium Criteria

EPA carcinogen classification:	
Chromium VI, inhalation	Group A
Chromium III, inhalation	Group D
Chromium VI or chromium III, ingestion	Group D
Inhalation carcinogenic potency factor (CrVI)	41 $(mg/kg/day)^{-1}$
Inhalation AIC (Cr III)	0.0051 mg/kg/day
Oral RfD:	
Cr III	1 mg/kg/day
Cr VI	$5x10^{-3}$ mg/kg/day
Oral AIC (Cr VI)	0.005 mg/kg/day
Maximum Contaminant Level (MCL) (total Cr)	0.05 mg/liter
Proposed MCLG (total Cr)	0.12 mg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. Cincinnati, Ohio

ANWAR, R.A., LONGHAM, R.F., HOPPERT, C.A., ALFREDSON, B.V., and BYERRUM, R.V. 1961. Chronic toxicity studies III. Chronic toxicity of cadmium and chromium in dogs. Arch. Environ. Health 3:456-460

BOURNE, H.G., and YEE, H.T. 1950. Occupational cancer in a chromate plant. Indus. Med. Surg. 19:563-567

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Chromium. Office of Water Regulations and Standards. Washington, D.C. EPA 440/5-80-035

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984a. Health Assessment Document for Chromium. Environmental Criteria and Assessment Office. Research Triangle Park, N.C. EPA 600/8-83-014F

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984b. Health Effects Assessment for Hexavalent Chromium. Environmental Criteria and Assessment Office. Cincinnati, Ohio. EPA 540/1-86-019

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984c. Health Effects Assessment for Trivalent Chromium. Environmental Criteria and Assessment Office. Cincinnati, Ohio. EPA 540/1-86-035

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984d. Draft Health Advisory for Chromium. Office of Drinking Water. Washington, D.C. September 30 draft

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985. National primary drinking water regulations; synthetic organic chemicals, inorganic chemicals and microorganisms; proposed rule. Fed. Reg. 50:46936-47025. (November 13)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Second Set of Verified Reference Doses. Memo from the Office of Health and Environmental Assessment to the RfD Workshop. May 14, 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Draft Health Advisory for Chromium. Office of Drinking Water, Washington, D.C. March 31, 1987

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987b. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Cincinnati, Ohio. Revised September 30, 1987

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1982. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Suppl. 4. World Health Organization, Lyon, France. Pp. 133-135

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1980. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Vol. 23: Some metals and metallic compounds. World Health Organization, Lyon, France. Pp. 205-323

IVANKOVIC, S. and PREUSSMANN, R. 1975. Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats. Food Cosmet. Toxicol. 13:347-351 (As cited in EPA 1984c, 1987b)

MACKENZIE, R.D., BYERRUM, R.V., DECKER C.F., HOPPERT, C.A., and LONGHAM, F.L. 1958. Chronic toxicity studies II. Hexavalent and trivalent chromium administered in drinking water to rats. Arch. Ind. Health 18:232-234

MANCUSO, T.F. 1975. International Conference on Heavy Metals in the Environment. Toronto, Canada. (As cited in EPA 1987b)

COPPER

INTRODUCTION

Copper is a reddish colored metal with the atomic number 29 and an atomic weight of 63.5 g/mole. It is widely used as a structural metal, particularly when high electrical and thermal conductivity are required. Copper salts are used as fungicides, in ceramics, and for electroplating, and have a wide variety of other industrial uses (ACGIH 1986).

TOXICOKINETICS

Copper can be absorbed following dermal, oral, or inhalation exposure. Absorption of the metal is controlled by a homeostatic mechanism and therefore it does not tend to bioaccumulate. Elimination of copper occurs primarily through fecal excretion (EPA 1985b).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Copper is an essential element in human nutrition. A daily copper intake of 2 mg is considered to be adequate for health and normal copper metabolism. The normal daily adult intake of copper from food in the U.S. is reported to range from 2 to 4 mg per day. The reported average intake of copper in young children is 1.5 mg per day; the minimum dietary requirement is 0.10 lg/kg body weight per day (EPA 1985a).

Toxic effects resulting from acute over-exposure to copper in laboratory animals and humans include gastrointestinal disturbances, hemolytic anemia, renal damage, liver damage, and glucose-6-phosphate dehydrogenase inhibition. Limited data are available on the chronic toxicity of copper; however, chronic over-exposure may cause anemia. Efficient homeostatic mechanisms generally protect mammals from the adverse effects of dietary copper excess. In humans, individuals with Wilson's disease are at additional risk from the toxic effects of copper. Wilson's disease is an inborn error of copper metabolism in which copper accumulates in the liver, brain, and kidney, resulting in hemolytic anemia, neurological abnormalities, and corneal opacities. In addition, individuals with glucose-6-phosphate dehydrogenase deficiency are likely to be at increased risk to the toxic effects of copper (EPA 1985a).

Ingestion of copper salts by humans can cause salivation, gastrointestinal irritation, nausea, vomiting, gastric pain, hemorrhagic gastritis, and diarrhea. Dermal exposure to copper salts can produce skin irritation and eczema. Ocular contact with copper salts may produce conjunctivitis and corneal lesions. Inhalation of dusts and mists of copper salts may result in irritation of the mucous membranes and pharynx, as well as ulceration and perforation of the nasal septum. A condition similar to metal fume fever has been observed in workers exposed by inhalation to metallic copper dust at concentrations of approximately 0.1 mg/m^3. Metal fume fever is characterized by short-term chills, fever, aching muscles, dryness of throat and mouth, and headache. Extensive industrial experience with copper-welding operations and copper-metal refining suggest that no adverse effects result from exposure to copper fumes at concentrations of up to 0.4 mg Cu/m^3 (ACGIH 1986).

Copper compounds have generally provided negative results in microbial mutation assays. Copper sulfate was observed to increase the frequency of recessive lethal mutations in D. melanogaster at high concentrations. Equivocal results have been obtained from carcinogenicity studies. Administration of copper compounds to mice by subcutaneous injection has been reported to induce tumor formation. Orally-administered copper compounds were not found to increase tumor incidence in several studies (EPA 1985a). There is little evidence in the literature to suggest that copper has a teratogenic effect in either animals or humans (EPA 1980) Copper salts administered to pregnant hamsters by intraperitoneal injection on day eight of gestation resulted in a high proportion of embryos with edema and cardiovascular defects (Shepard 1986).

The health effects of copper in man and animals are reviewed in more detail by EPA (1980, 1984, 1985b).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

The International Agency for Research on Cancer (IARC) has not evaluated the carcinogenic potential of copper. Applying the criteria for carcinogenicity as proposed by EPA's Carcinogen Assessment Group, the EPA Office of Environmental Criteria and Assessment has determined that copper is most appropriately classified in Group D--Not Classified. This category applies to chemical agents for which there is inadequate evidence of carcinogenicity in animals and humans (EPA 1984, 1986).

EPA (1985a) has proposed a maximum contaminant level goal (MCLG) of 1.3 mg/liter for drinking water. This value is based on the observation that copper exposure at high levels may cause gastrointestinal disturbances and other acute toxic effects at oral doses greater than 5.3 mg.

EPA has established an ambient water quality criterion (AWQC) for copper of 1 mg/liter. This level is based on organoleptic data for controlling taste and odor (EPA 1980). It should be noted that organoleptic data have no demonstrated relationship to adverse human health effects. Copper is included in the National Secondary Drinking Water Regulations as a secondary standard of 1.0 mg/liter based upon taste and odor.

The World Health Organization (WHO) has not proposed a guideline for copper based upon health effects; however they have proposed a guideline value of 1 mg/liter based upon the ability of copper to stain laundry and plumbing fixtures at concentrations above 1 mg/liter (EPA 1985a).

In the Health Effects Assessment for copper (EPA 1984), an acceptable chronic oral intake (AIC) of 2.6×10^{-2} mg/day was derived. This value was based on the human lowest-observed-adverse effect level (LOAEL) of 5.3 mg/day and by applying an uncertainty factor of two. Assuming a person weighs 70 kg, an AIC of 2.6 mg/day corresponds to a value of 3.7×10^{-2} mg/kg/day. EPA also derived an acceptable chronic inhalation intake (AIC) of 71 mg/day for copper mists and dusts in the same document. EPA (1984) used the American Conference of Governmental Industrial Hygienists (ACGIH) recommended time-weighted average threshold limit value (TLV) of 1 mg/m^3 (copper dust or mist) to derive the AIC for inhalation exposure to copper. Assuming a 70 kg person, an inhalation reference dose (RfD) of 1.0×10^{-2} mg/kg/day can be derived (0.71 mg/day x 1/70 kg). A reference concentration can also be derived by dividing

0.71 mg/day by the inhalation rate for the average person (20 m^3 in a 24-hour day). The reference concentration for airborne copper is 36 lg/m^3. ACGIH also recommends a time-weighted average TLV of 0.2 mg/m^3 for copper fume.

SUMMARY OF COPPER CRITERIA

EPA carcinogen classification	Group D
Proposed MCLG	1.3 mg/liter
Oral AIC	3.7×10^{-2} mg/kg/day
Inhalation AIC	1.0×10^{-2} mg/kg/day
AWQC	1 mg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Copper. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C. October 1980. EPA 440/5-80-036

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Copper. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-025

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. National primary drinking water regulations; synthetic organic chemicals, inorganic chemicals and microorganisms; proposed rule. 40 CFR Part 141. Fed. Reg. 50:46967-47025 (November 13, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. Drinking Water Criteria Document for Copper (Final Draft). Environmental Criteria and Assessment Office, Cincinnati, Ohio. March 1985. EPA 600/X-84-190-1. NTIS Publ. No. PB86-118239

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Guidelines for carcinogenic risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

SHEPARD, T.A. 1986. Catalog of Teratogenic Agents, 5th Ed., Johns Hopkins Press, Baltimore and London, p. 394

LEAD

INTRODUCTION

Elemental lead is heavy, ductile, and bluish-white in color, with the atomic number 82 and an atomic weight of 207 g/mole. It is used widely in industry because of its softness, resistance to corrosion and radiation, and high density. Lead is also used as a paint pigment, in solders, and in storage batteries.

TOXICOKINETICS

Absorption of lead from the gastrointestinal tract is estimated at 10-15%. For adult humans, the deposition rate of particulate airborne lead is 30-50%, and essentially all of the lead deposited is absorbed. Respiratory uptake by children appears to be greater on a body weight basis. More than 99% of blood lead in humans is associated with the erythrocytes, but it is the very small fraction of lead transported in plasma and extracellular fluid that provides lead to the various body organs. Lead is stored in the body in bone, kidney, and liver, where it may remain for long periods of time. Lead is primarily excreted by the kidneys into the urine, and lesser amounts are eliminated by biliary excretion (EPA 1984a).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

The following information has been summarized from EPA (1984a). Lead has diverse biological effects in humans and animals. Its effects are seen at the subcellular level of structures and processes as well as at the overall level of general functioning of the body. Considerable data exist on the effects of lead exposure in humans, but the effects are generally related to blood lead levels rather than to estimated exposure.

A major problem associated with lead exposure is the ubiquitous nature of the compound. Unlike most other contaminants for which exposure may be related to a specific route or situation, substantial background lead exposure occurs, primarily through food. This background exposure must be considered when additional significant exposure routes are identified.

The major toxic effects caused by exposure to lead are alterations in the hematopoietic and nervous systems. Anemia caused by lead exposure has the following pathogenesis. Heme synthesis is inhibited by the effects of lead on a number of steps in the biosynthetic pathway. Specifically, lead stimulates delta-aminolevulinic acid synthetase (ALA-S) and therefore increases the production of delta-aminolevulinic acid dehydrase (ALA-D) and therefore decreases the production of porphyrobilinogen from ALA; and finally, lead inhibits the incorporation of iron into protoporphyrin to form heme. No threshold has been identified for this effect on heme production. Decreased heme production results in decreased hemoglobin production and anemia. Decreased heme production can also have deleterious effects on other heme-containing proteins, such as cytochrome P450, which detoxify certain chemicals in the body. Impaired heme synthesis has been reported in adults at levels of less than 30 lg/dl lead in the blood (EPA 1984a).

Two types of neurotoxic effects are associated with exposure to lead. Levels of lead in the blood (PbB) of over 80 lg/dl in children and over 100 lg/dl in sensitive adults can cause severe, irreversible brain damage, encephalopathy, and possibly death. Persons with these high levels may be asymptomatic or show only slight signs of intoxication, but rapid deterioration can occur. In children, permanent learning disabilities are seen at these levels, even if there are no overt signs of lead poisoning (EPA 1984a).

Other adverse effects are associated with exposure to low levels of lead. Slow nerve conduction in peripheral nerves has been seen in adults at 30-40 lg/dl blood lead level (PbB); altered testicular function was observed in men with PbB levels as low as 40-50 lg/dl; and renal dysfunction has been associated with PbB levels as low as 40 lg/dl (EPA 1984a).

Conflicting evidence is available for the genotoxicity of lead and lead compounds. Lead salts have not been shown to be mutagenic in bacteria or fungi, but they have been reported to induce mutations in vascular plants. Certain compounds induce chromosome abnormalities in plants but not in cultured mammalian cells. Positive results have bee obtained in a cell transformation assay. *In vivo* studies of lead salts produce conflicting results. Chromosomal aberrations have been induced in bone marrow of rats and mice and in cultured peripheral lymphocytes obtained from monkeys. Cytogenetic studies with people exposed to lead have produced positive results in approximately half the reports (IARC 1982).

Decreased fertility and fetotoxic effects have been reported in laboratory rodents exposed to lead, but these effects may have been related to deficiencies of other trace metals in these studies. Lead exposure has been associated with spontaneous abortions, premature delivery, and early membrane rupture in humans; however, reliable exposure estimates are lacking in most cases (EPA 1984b). Skeletal malformations after lead injection have been reported in rats, mice and hamsters (Leonard et al. 1984).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Oral ingestion of certain lead salts (lead acetate, lead phosphate, lead subacetate) have been associated with increased renal tumor frequency in rats (EPA 1985a), but no quantitative estimate of excess cancer risk has been performed by the Carcinogen Assessment Group of EPA. Applying the criteria described in EPA's Guidelines for Carcinogenic Risk Assessment (EPA 1986), these lead salts have been classified by EPA (1985b) in Group B2--Probable Human Carcinogen. This category applies to agents for which there is inadequate evidence from human studies and sufficient evidence from animal studies. However, EPA (1985b) also has noted that the available data provide an insufficient basis on which to regulate lead acetate, lead phosphate, and lead subacetate as human carcinogens. Dosages that induced kidney tumors in rats were very high (beyond the lethal dose in humans), and several extensive epidemiology studies have not shown an association between lead exposure and increased incidences of tumors in occupationally exposed workers (EPA 1985b).

The interim maximum contaminant level (MCL) for drinking water and the ambient water quality criterion are both 50 lg/liter (EPA 1980, CFR 1984). In deriving

the ambient water quality criterion, EPA determined that consumption of water contaminated with 50 lg/liter would increase PbB levels to around 15 lg/dl in children. If the population average was 15 lg/dl, the Centers for Disease Control (CDC) calculated that 99% of all children would have a PbB level of less than 30 lg/dl. This was based on a CDC definition of "lead toxicity" in a child as a PbB level greater than or equal to 30 lg/dl and an erythrocyte protoporphyrin (EP) level greater than or equal to 50 lg/dl. Based on this calculation, EPA determined that the present drinking water standard was acceptable as an upper limit. However, based primarily on the new information suggesting that neurological impairment may occur in children at PbB levels of less than 30 lg/dl, CDC has revised its criteria for lead toxicity to PbB levels greater than or equal to 25 lg/dl and EP levels greater than or equal to 35 lg/dl (CDC 1985).

A drinking water maximum contaminant level goal (MCLG) of 20 lg/liter (.02 mg/liter) has been proposed by the EPA Office of Drinking Water (ODW). The proposed MCLG is based upon the health effects of lead in infants and pregnant women as a sensitive subpopulation (EPA 1985b). Blood levels above 15 lg/dl were identified as the level of concern, and fetuses and infants under 2 years of age are the sensitive subpopulation. In order to protect the fetus, it was considered advisable to limit the blood lead level in women of child-bearing age to between 15 and 20 lg/dl since studies indicate that the ratio of fetal/maternal blood lead values in close to 1:1 (Hubermont et al. 1978 as cited in EPA 1985a). An absorption constant of 0.16 was identified as the ratio of blood lead in infants to lead intake in the diet (Ryu et al. 1983 as cited in EPA 1985b). An oral risk reference dose (RfD) of $6x10^{-4}$ mg/kg/day can be derived based on the ODW analysis (0.02 mg/liter x 2 liter/day x 1/70 kg).

The Clean Air Act National Ambient Air Quality Standard for lead is 1.5 lg/m^3. This standard is currently being evaluated for revision (EPA 1985c).

Acceptable intakes for chronic or subchronic periods of exposure were not calculated for either inhalation or oral ingestion in the Health Effects Assessment Document (EPA 1984b) because the general population is already accruing unavoidable background exposures through food, water, and dust. Any significant increase above background exposure would represent a cause for concern.

At present, human health criteria for lead in soil have not been established in the United States. The United Kingdom Directorate of the Environment has developed a tentative guideline of 550 ppm for lead in soil in residential areas (Smith 1981). Vernon Houk of the Centers for Disease Control has been quoted as indicating that levels of lead in soil of 300-400 ppm are acceptable based on studies of childhood lead poisoning (Mielke et al. 1984).

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommends a time-weighted average Threshold Limit Value (TLV) of 0.15 mg/m^3 lead in air.

SUMMARY OF LEAD CRITERIA

Interim MCL	50 lg/liter
Proposed MCLG	20 lg/liter

Oral RfD (based on ODW analysis)	6×10^{-4} mg/kg/day
National Ambient Air Quality Standard	1.5 lg/m^3

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

CENTERS FOR DISEASE CONTROL (CDC). 1985. Preventing Lead Poisoning in Young Children. Public Health Service, Chronic Disease Division, Atlanta, Georgia. July 1985

CODE OF FEDERAL REGULATIONS (CFR). 1984. 40 CFR 141, Environmental Protection Agency. National Interim Primary Drinking Water Regulations. U.S. Government Printing Office, Washington, D.C.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984a. Air Quality Criteria for Lead. Environmental Criteria and Assessment Office, Research Triangle Park, North Carolina. External Review Draft. September 1984. EPA 600/8-83-028B

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984b. Health Effects Assessment for Lead. Environmental Criteria and Assessment Office. Cincinnati, Ohio. EPA 540/1-86-055

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. Draft Health Advisory for Lead. Office of Drinking Water. Washington, D.C. September 30, 1985

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. National primary drinking water regulation; synthetic organic chemicals, inorganic chemicals and microorganisms; proposed rule. Fed. Reg. 50:46936-47025 (November 13, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985c. Draft air quality criteria document for lead: Notice of a corrigendum to the second external review draft. Fed. Reg. 50:14289-14294 (April 11, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985d. Water quality criteria; notice of final ambient water quality criteria documents. Fed. Reg. 50:30784-30796 (July 29, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Guidelines for carcinogenic risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

HUBERMONT, G., BUCHET, J.P., ROELS, H., and LAUWERYS, R. 1978. Placental transfer of lead, mercury and cadmium in women living in a rural area: importance of drinking water in lead exposure. Int. Occup. Environ. Health 41:117-124 (As cited in EPA 1984b)

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1982. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Supplement 4: Chemicals, Industrial Processes and Industries Associated with Cancer in Humans. World Health Organization, Lyon, France. Pp. 149-150

LEONARD, A., GERBER, G.B., JACQUET, P., and LAUWERYS, R.R. 1984. Mutagenicity, Carcinogenicity, and Teratogenicity of Industrially Used Metals. In Kirsch-Volders, M., ed. Mutagenicity, Carcinogenicity, and Teratogenicity of Industrial Pollutants. Plenum Press, New York. Pp. 59-126

MIELKE, H.W., BLAKE, B., BURROUGHS, S., and HASSINGER, N. 1984. Urban lead levels in Minneapolis: The case of the Hmong children. Environ. Rev. 34:64-76 (As cited in EPA 1984b)

RYU, J.E., ZIEGLER, E.E., NELSON, F.E., and FOMON, S.J. 1983. Dietary intake of lead and blood lead concentration in early infancy. Am. J. Dis. Child. 137:886-891 (As cited in EPA 1984b)

SMITH, M.A. 1981. Tentative Guidelines for Acceptable Concentrations of Contaminants in Soils. Department of the Environment, United Kingdom

MANGANESE

INTRODUCTION

Elemental manganese is a grey-white metal resembling iron, with the atomic number 25 and an atomic weight of 55 g/mole. It is a highly reactive metal and can be present in seven oxidation states. Manganese is often used as an alloy to impart hardness.

TOXICOKINETICS

Manganese is absorbed at low levels following oral or inhalation exposure. Gastrointestinal absorption is controlled by homeostatic mechanisms and influenced by many factors including age, dose and availability in the diet, and interactions with other metals or other dietary constituents. It does not tend to bioaccumulate in body tissues. Elimination is primarily through fecal excretion (EPA 1984a).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Manganese is an essential trace element for many animal species although there are no well-defined occurrences of manganese deficiency in humans. Manganese deficiency in rodents is associated with skeletal abnormalities, impaired growth, ataxia of the newborn, and defects in lipid and carbohydrate metabolism (EPA 1984a).

The toxic effects of chronic manganese exposure have been studied primarily in workers who have inhaled manganese-containing dust (EPA 1984a). Exposure to high levels of manganese causes pneumonitis in exposed workers. Chronic exposure has also been associated with manganism, a progressive neurological disease similar to Parkinson's disease, manifested by speech disturbances, a masklike, face, tremors, difficulties in walking, and sexual disturbances (EPA 1984a). Although exposure in the cases of manganism reported by EPA (1984a) was by inhalation, some of the manganese that is inhaled can be removed by mucociliary clearance and consequently swallowed (EPA 1984a) and then becomes available for absorption from the gastrointestinal tract. Once case study reported apparent manganism associated with extremely high levels of manganese in a drinking water well, further suggesting that ingestion, as well as inhalation, is an important route of exposure (Kawamura et al. 1941). Chronic exposure to manganese also casus increases production of erythrocytes, with consequent increases in hemoglobin values and erythrocyte counts.

Certain manganese compounds have been shown to be mutagenic in a variety of bacterial tests. Manganese chloride and potassium permanganate have been shown to cause chromosomal aberrations in mouse mammary carcinomal cells. Manganese was moderately effective in enhancing viral transformation of Syrian hamster embryo cells (EPA 1984a,b).

There is no evidence that orally administered manganese is carcinogenic for humans or laboratory animals. Intramuscular injection of manganese acetylacetonate has been reported to increase injection-site sarcomas, while injection of other manganese compounds has not increased tumor incidences. Injection of manganese dusts, along with either nickel subsulfide or

benzo[a]pyrene, has been shown to depress tumorigenesis caused by these compounds (EPA 1984a).

Manganese exposure has not been associated with teratogenic effects; it has been associated with depressed reproductive performance in both humans and laboratory animals. A relationship between manganese toxicity and impotency in humans has been reported. Increased incidences of stillbirths and spontaneous abortions in the wives of workers occupationally exposed to manganese have also been reported. In laboratory rodents, retardation of reproductive development and reduced fertility have been seen (EPA 1984a).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Using the EPA Carcinogen Assessment Group's criteria for evaluating the weight of the evidence for carcinogenicity in humans (EPA 1986a), the EPA Office of Environmental Criteria and Assessment has determined that manganese is most appropriately classified in Group D--Not Classified. This category applies to chemical agents for which there is inadequate evidence of carcinogenicity in animals and humans.

EPA (1984b) has established acceptable levels for chronic intake (AIC) for manganese for both the oral and inhalation exposure routes. The derivation of the oral AIC was based upon studies by Leung et al. (1981) and Lai et al. (1982) in which rats were exposed up until 120 days of age to drinking water containing 0, 1, 10, or 20 mg/ml manganese chloride. No adverse effects were observed in rats receiving drinking water containing 1 mg/ml manganese corresponding to a dose of 22 mg/kg/day. Based on these results, and AIC is calculated by multiplying the animal dose by 70 kg (assumed weight of an adult human) and dividing by an uncertainty factor of 100. The resultant AIC is 15.4 mg/day (2.2×10^{-1} mg/kg/day).

The inhalation AIC established by EPA (1984b) was based upon a review of epidemiological data and a determination of an adverse effect threshold for manganese in humans of 300 lg/m^3. An AIC of 21 lg/day is derived by assuming the average person inhales 10 m^3 of air during the workday and by expanding exposure from 5 to 7 days/week. An uncertainty factor of 100 was also applied. Assuming an adult weighs 70 kg, the inhalation AIC of 21 lg/day corresponds to a value of 0.3 lg/kg/day (or 3×10^{-4} mg/kg/day).

EPA (1986b) has established an Ambient Water Quality criterion (AWQC) for manganese of 50 lg/liter based on organoleptic data for controlling taste and odor. It should be noted that organoleptic data have no demonstrated relationship to adverse human health effects.

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommends a ceiling limit of 5 mg/m^3 for manganese dust.

SUMMARY OF MANGANESE CRITERIA

EPA carcinogen classification	Group D
Oral AIC	2.2×10^{-1} mg/kg/day
Inhalation AIC	3.0×10^{-4} mg/kg/day
AWQC	50 lg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984a. Health Assessment Document for Manganese. Environmental Criteria and Assessment Office, Environmental Protection Agency, Cincinnati, Ohio. Final Report. August 1984. EPA 600/8-83-013F

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984b. Health Effects Assessment for Manganese (and Compounds). Environmental Criteria and Assessment Office, Washington, D.C. EPA 540/1-86-057

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Guidelines for carcinogen risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Quality Criteria for Water 1986. Office of Water Regulations and Standards, Standards Branch, Washington, D.C. May 1, 1986. EPA 440/5-86-001

KAWAMURA, R., IKUTA, H., FUKUZUMI, S., et al. 1941. Intoxication by manganese in well water. Kitasato Arch. Exp. Med. 18:145-19 (As cited in EPA 1984b)

LAI, J.C.K., LEUNG, T.K.C., and LIM, L. 1982. Activities of the mitochondrial NAD-linked isocitric dehydrogenase in different regions of the rat brain. Changes in aging and the effect of chronic manganese chloride administration. Gerontology 28:81-85. (As cited in EPA 1984b)

LEUNG, T.K.C., LAI, J.C.K., and LIM, L. 1981. The regional distribution of monoamine oxidase activities towards different substrates: Effects in rat brain of chronic administration of manganese chloride and of aging. J. Neurochem. 36:2037-2043. (As cited in EPA 1984b)

MERCURY

INTRODUCTION

Elemental mercury is a silvery, heavy liquid with atomic number 80 and an atomic weight of 200.6 g/mole. It is present in the environment in its elemental form, in univalent (mercurous) and divalent (mercuric) inorganic states, and in numerous organic forms. Mercury has many industrial uses because of its unique properties as the only heavy metal in the liquid state. Metallic mercury is used as a cathode in the electrolytic preparation of chlorine and caustic soda, in electrical appliances, dental amalgams, catalysts, and in pulp and paper manufacture (EPA 1987a).

PHARMACOKINETICS

Elemental and inorganic mercury are poorly absorbed from the gastrointestinal tract (less than 15%) and easily absorbed by inhalation (approximately 80%) in humans. Organic mercury is almost completely absorbed from the gut and is assumed to be well absorbed via inhalation (EPA 1984). The extent of dermal absorption is not precisely known, but alkyl mercury is probably well absorbed. Organic mercury is metabolized to inorganic mercury in human tissues. Distribution of organic mercury is primarily to the kidney. Elimination is by biliary excretion and in the urine (EPA 1980).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Mercury has long been recognized as one of the more toxic metals. The toxicity of mercury depends to some extent on its form. Irrespective of the chemical form, the major target organs for mercury toxicity are the central nervous system (CNS) and the kidney. Mercury has been shown to have adverse neurological effects in humans. Organic mercury compounds are generally more neurotoxic than inorganic mercury. In addition, the different forms of mercury can cause somewhat different neurotoxic effects initially, although both will elicit the same effects at higher doses (Hammond and Beliles 1980).

Classical symptoms of elemental mercury vapor intoxication are mental disturbances, objective tremors, and gingivitis, which have been observed following chronic occupational exposure to average air concentrations of 0.1-0.2 mg/m^3 mercury (EPA 1984). The CNS appears to be the primary target of organic mercury intoxication. Primary lesions include destruction of cortical cerebral neurons and damage to the Purkinje cells and granular layer of the cerebellum. Clinical symptoms suggest damage to peripheral nerves, but histopathological documentation is lacking. Clinical symptoms include paresthesia, loss of sensation in the extremities, ataxia, constriction of the visual field, and hearing impairment (WHO 1976). CNS lesions similar to those in humans, proteinuria and morphological kidney changes have been reported in animals exposed to mercury (Koller 1979, EPA 1987a).

The kidney is the primary target organ for inorganic divalent mercury. Massive oral doses in humans lead to anuria followed by polyuria and finally to a recovery of normal renal function. Chronic low dose industrial exposure has been shown to result in proteinuria which, if severe, can lead to hypoproteinemia with edema. Methyl mercury does not appear to be nephrotoxic (Hammond and Beliles 1980).

Methylmercury chloride fed in the diet at 15 ppm induced renal adenomas and adenocarcinomas in male mice after 53 weeks of exposure. No tumors were induced in female mice at this dose level or in males or females fed at a 30 ppm dose level. However, the authors of this report noted that all animals receiving the high dose died due to neurotoxicity by week 26 (Mitsumori et al. 1981). Mercuric chloride and methylmercury chloride administered to mice in the drinking water did not induce tumors over a lifetime, but the doses used in these tests were very low and did not approach maximally tolerated doses (Schroeder and Mitchener 1975). Phenylmercuric acetate administered to mice by gavage early in life followed by administration in the diet for the next 18 months did not result in tumor formation (Innes et al. 1969).

Both inorganic and organic mercury compounds have been reported to be genotoxic in eukaryotic systems. In all test systems, organic mercury compounds appear to be more potent than inorganic compounds. The most notable effect is the production of C-mitosis which can result in aneuploidy and polyploidy. Observations on plants suggest that organic mercury may also act directly on genetic material producing chromosome fragmentation and somatic mutations. Evidence for the production of structural chromosomal anomalies in mammalian systems is not conclusive. Elevated levels of chromosomal abnormalities in lymphocytes of occupationally exposed people have been reported, but the authors have noted that the effects seen may have been due to other chemicals to which the workers were concomitantly exposed (Leonard et al. 1984).

Several investigators have reported embryotoxic and teratogenic effects in experimental animals treated with organic mercury. The most common findings are neurological effects, but skeletal malformations including cleft palate and jaw and facial defects have been reported in mice, hamsters and dogs. Genitourinary malformations have been reported in rats (Leonard et al. 1984). Brain damage, but not anatomical defects, has been reported in humans exposed prenatally to organic mercury. These epidemiological studies may not have been sensitive enough to detect possible teratogenic effects of organic mercury in human populations (EPA 1984).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Limited data are available regarding the carcinogenic potential of mercury in humans or animals. Applying the criteria for evaluation of the overall weight of evidence of carcinogenicity to humans proposed by the Carcinogen Assessment Group (EPA 1986a), the EPA (1984) has determined that mercury is most appropriately classified in Group D--Not Classified.

The interim drinking water maximum contaminant level (MCL) for mercury is 2 lg/liter. A maximum contaminant level goal (MCLG) of 3 lg/liter has been proposed (EPA 1985a).

EPA (1986b) has previously derived an oral reference dose (RfD) for inorganic mercury of 0.002 mg/kg/day based on a study in which rats were exposed to mercury (as mercuric acetate) in the diet (Fitzhugh et al. 1950). A lowest-observed-adverse-effect level (LOAEL) of 2 mg/kg/day was identified based on the presence of morphological changes in the kidney (EPA 1986b). EPA (1987b) has since revised the oral RfD; the revised value is 1.4×10^{-3} mg/kg/day. The basis for this change was not reported (EPA 1987b).

A reference dose for methyl mercury of 0.0003 mg/kg/day was developed by EPA based on several studies reporting human poisonings. A blood level of 200 ng mercury/ml of blood, equivalent to 3 lg/kg/day, was identified as the LOAEL from these studies. The earliest detected effects were CNS effects such as ataxia and paresthesia (EPA 1986b).

EPA's Office of Drinking Water has developed a draft lifetime health advisory of 1.1 lg/liter. The advisory is based on a study by Druet et al. (1978) that reported proteinuria in rats exposed to 0.1 mg/kg/day mercuric chloride by subcutaneous injection for 12 weeks. A no-observed-adverse-effect level (NOAEL) of 0.05 mg/kg/day was identified, from which a human allowable intake of 11 lg/day was derived. Factoring in the assumed daily relative source contribution from water of 20% results in a safe drinking water concentration of 2.2 lg/day, or 1.1 lg/liter for an adult consuming 2 liters of water per day. The health advisory assumes that most of the mercury in drinking water is in the inorganic form (EPA 1987a).

The EPA Environmental Criteria and Assessment Office (EPA 1984) calculated oral and inhalation allowable intakes for organic and inorganic forms of mercury. For inorganic mercury, the oral allowable intakes are derived from the study by Fitzhugh et al. (1950) discussed previously. For both the oral subchronic allowable intake (AIS) and the oral chronic allowable intake (AIC), the animal LOAEL of 2 mg/kg/day was extrapolated to 2 lg/kg/day for humans by using a safety factor of 1000. The inhalation AIS of 0.51 lg/kg/day was extrapolated from the threshold limit value (TLV) for mercury vapor. The inhalation AIC of 0.051 lg/kg/day was derived by applying an additional safety factor of 10 to the AIS (EPA 1984).

For organic mercury, both the oral AIS and the oral AIC of 0.28 lg/kg/day were based on data from an outbreak of mercury poisoning in Niigata, Japan. Miettinen (1973) estimated that an intake of 200 lg/day of organic mercury corresponded to a blood level of 200 ng/ml blood, which was estimated to be a threshold level for the development of neurological symptoms (EPA 1984). The inhalation AIS and AIC of 0.1 lg/kg/day were derived from the TLV (EPA 1984).

The EPA Office of Water Regulations and Standards has developed an Ambient Water Quality Criterion (AWQC) for the protection of human health from the toxic effects of mercury ingested through consumption of contaminated water and aquatic organisms of 144 ng/liter and a criterion of 146 ng/liter for the effects of mercury ingested through consumption of aquatic organisms alone (EPA 1985b). EPA has also derived an adjusted criterion of 10 lg/liter based on the effects of mercury ingested through drinking water alone (EPA 1986c).

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommends a time-weighted average Threshold Limit Value (TLV) of 0.01 mg mercury based on the severity of the CNS effects from absorption of alkyl mercury compounds.

SUMMARY OF INORGANIC MERCURY CRITERIA

EPA carcinogen classification	Group D
Interim MCL	2 lg/liter

Proposed MCLG	3 lg/liter
Oral RfD	1.4×10^{-3} mg/kg/day
Lifetime HA (draft)	1.1 lg/liter
AIS and AIC (oral)	2 lg/kg/day
AIS (inhalation)	0.51 lg/kg/day
AIC (inhalation)	0.051 lg/kg/day
Ambient Water Quality Criteria (AWQC) (10^{-6} estimated lifetime cancer risk)	
Ingestion of water and aquatic organisms	144 ng/liter
Ingestion of aquatic organisms	146 ng/liter
Ingestion of water	10 lg/liter

SUMMARY OF ORGANIC MERCURY CRITERIA

EPA Carcinogen classification	Group D
RfD, verified	0.3 lg/kg/day
AIS and AIC (oral)	0.28 lg/kg/day
AIS and AIC (inhalation)	0.1 lg/kg/day

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

DRUET, P., DRUET, E., POTDEVIN, F., and SAPIN, C. 1978. Immune type glomerulonephritis induced by $HgCl_2$ in the Brown-Norway rat. Ann. Immunol. 129:777-792

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Mercury. Office of Water Regulations and Standards. Washington, D.C. EPA 440/5-80-053

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Mercury. Environmental Criteria and Assessment Office. Cincinnati, Ohio. EPA 540/1-86-042

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. National Primary Drinking Water Regulations; Synthetic Organic Chemicals, Inorganic Chemicals, and Microorganisms; Proposed Rule. Fed. Reg. 50:46936-47025

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. Water quality criteria; notice of final ambient water quality criteria documents. Fed. Reg. 50:30784-30796. (July 29, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Guidelines for carcinogenic risk assessment. Fed. Reg. 51:33992-34003, September 24, 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Integrated Risk Information System (IRIS) Chemical Files. November 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986c. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response, Washington, D.C. EPA 540/1-86-060. October 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Draft Health Advisory for Mercury. Office of Drinking Water. Washington, D.C. September 30, Draft

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987b. Memo from Sandra Lee (Program Manager, Regional Support Team, Toxics Integration Branch) to Addresses. Subject: Updated Reference Dose and Cancer Potency Numbers for Use in Risk Assessments. Office of Solid Waste and Emergency Response. Washington, D.C. October 1987. 19 pp. (Sandra Lee: (202) 382-4307

FITZHUGH, O., NELSON, A., LAUG, E., and KUNZE, F. 1950. Chronic oral toxicities of mercuric-phenyl and mercuric salts. Arch. Ind. Hyg. Occup. Med. 2:433-441

HAMMOND, P.B., and BELILES, R.P. 1980. Metals. In: Casarett and Doull's Toxicology: The Basic Science of Poisons, 2nd Ed., Doull, J., Klaassen, C.D., and Amdur, M.O. (eds.), Macmillan Publishing Co., New York, Toronto, and London. pp. 421-428

INNES, J.R.M., ULLAND, B.M., VALERIO, M.G., PETRUCELLI, L., FISHBEIN, L., HART, E.R., PALLOTA, A.J., BATES, R.R., FALK, H.L., GART, J.J., KLEIN, M., MITCHELL, I., and PETERS, J. 1969. Bioassay of pesticides and industrial chemicals for tumorigenicity in mice: A preliminary note. J. Natl. Cancer Inst. 42:1101-1114

KOLLER, L. 1979. Methylmercury toxicity, model no. 158. In: Jones, T.C., Hackel, D.B., and Migaki, G., eds. Handbook: Animal Models of Human Disease. Registry of Comparative Pathology, Armed Forces Institute of Pathology, Washington, D.C.

LEONARD, A., GERBER, G.B., JACQUET, P., and LAUWERYS, R.R 1984. Mutagenicity, Carcinogenicity and Teratogenicity of Industrially Used Metals. In: Mutagenicity, Carcinogenicity and Teratogenicity of Industrial Pollutants. Kirsch-Volders, M. (eds.), Plenum Press, New York and London, pp. 59-126

MIETTINEN, J.K. 1973. Absorption and elimination of dietary mercury (Hg^{2+}) and methylmercury in man. In Miller, M., and Clarkson, T., eds. Mercury, Mercurials and Mercaptans. , Charles C. Thomas, Springfield, Illinois

SCHROEDER, H.A., and MITCHENER, M. 1975. Life-term effects of mercury, methylmercury and nine other trace metals on mice. J. Nutr. 105:452-458

WORLD HEALTH ORGANIZATION (WHO). 1976. Environmental Health Criteria, Mercury. Geneva

NICKEL

INTRODUCTION

Nickel is a lustrous white, hard metal with atomic number 28 and an atomic weight of 58.7 g/mole. It is used in welding, in electroplating, in storage batteries, and in numerous high temperature and corrosion-resistant alloys. Relatively large amounts occur naturally in vegetables, legumes, and grains (EPA 1980, 1986b).

PHARMACOKINETICS

Nickel compounds can be absorbed following inhalation, ingestion, dermal or parental exposure. The amount absorbed depends on the dose administered and the chemical and physical form of the particular nickel compound. Gastrointestinal absorption also depends on the composition of the total diet; in general, very little of the nickel ingested in food is absorbed. Absorbed nickel is carried by the blood and tissue distribution depends, in part, on the route of exposure and the dose level (EPA 1986b). Rats exposed to nickel had elevated concentrations in the kidney, liver, heart and testes, while calves had increased levels in the pancreas, testes and bone (EPA 1987a). Excretion of unabsorbed nickel is predominantly through the feces and absorbed nickel is eliminated primarily through the urine (EPA 1986b).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

The occurrence of statistically significant excesses of nasal cavity and lung cancers in nickel refinery workers has been demonstrated in a number of epidemiologic studies. Recent studies have also suggested that nickel exposure may result in cancers of the larynx, kidney and prostate (EPA 1986b). The International Agency for Research on Cancer (IARC) has concluded that some forms of nickel are probably carcinogenic to man by inhalation (IARC 1982). However, because simultaneous exposure to several nickel compounds usually occurs in the workplace, it has been difficult to determine which specific compounds are carcinogenic under these conditions.

The Carcinogen Assessment Group (CAG) of the Environmental Protection Agency (EPA 1986b) has estimated unit risks for development of cancer associated with inhalation exposure to nickel refinery dust and nickel subsulfide. CAG based its unit risk estimates on the results of epidemiologic studies of nickel refinery workers. These studies provide comprehensive documentation of the association between inhalation exposure to nickel and excess risk for cancers of the nasal cavities and lungs, and contains the best data currently available for estimation of inhalation unit risks.

Particle sizes of nickel compounds are generally smaller in ambient air than in the occupational environment. Consequently, exposure to these compounds in ambient air in comparison with exposure in the workplace would be likely to result in greater deposition in the lungs than in the nasal cavities. In addition, Pedersen et al. (1973) suggest that the nasal cavity cancers observed among nickel refinery workers are specifically associated with exposure to forms of nickel present in the refineries, but not in ambient air. Accordingly, the rates of lung cancer associated with occupational exposure to

nickel may not be appropriate for estimation of the risks associated with exposure to nickel in the general environment.

Inhalation exposure to nickel carbonyl or nickel subsulfide has been reported to produce lung tumors in laboratory animals. The National Toxicology Program is in the process of conducting inhalation carcinogenesis bioassays with nickel oxide, nickel sulfate and nickel subsulfide, but these studies have not yet been completed. Several nickel salts have been reported to cause localized tumors at the site of injection or implantation (EPA 1986b). There is no evidence that nickel is carcinogenic in humans or animals when ingested, and EPA (1987a) does not consider nickel to be carcinogenic by ingestion.

Nickel-containing compounds have been observed to decrease the fidelity of DNA synthesis and transcription and to increase the frequencies of chromosomal abnormalities, sister chromatid exchanges, and cell transformations in mammalian cells in vitro. Cultured lymphocytes from workers exposed to nickel compounds have been reported to have a higher frequency of chromatid gaps than lymphocytes from unexposed people. However, elevated frequency of other types of chromosomal aberrations or sister chromatid exchanges have not been observed. Certain nickel compounds may induce gene mutations in bacteria and cultured mammalian cells, but evidence for this is limited (EPA 1986b).

Nickel salts are known to produce allergic contact dermatitis in humans upon chronic exposure. In this allergic condition, symptoms may develop in 7 to 10 days following exposure to nickel salts. Nickel dermatitis most frequently develops after several years of continued low exposure (Dean et al. 1986). Once acquired, nickel sensitivity tends to persist. Sensitized subjects may experience allergic reactions at concentrations between 0.5 and 2 lg/ml nickel (Stokinger 1981).

Adverse effects associated with acute exposure in animals include depressed weight gain, hematological effects and increased iron deposition in blood, heart, kidneys, liver, and testes (EPA 1987a). Chronic exposure has been associated with pathological effects on the respiratory, endocrine and cardiovascular systems including asthma, nasal septal perforations, chronic rhinitis and sinusitis, hyperglycemia, decreased circulating prolactin levels, decreased iodine uptake by the thyroid, and vasoconstriction of the coronary vessels (EPA 1986b).

Exposure to nickel has been shown to lead to deleterious reproductive effects in laboratory animals including degenerative changes in the male reproductive tract and decreased numbers of implantations and viable embryos in exposed females. Teratogenic and fetotoxic effects have been observed in the offspring of exposed animals including structural malformations encompassing the skeleton and soft tissues, increases in neonatal death, and low birth weight (EPA 1986b).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Applying the criteria described in EPA's Guidelines for Assessment of Carcinogenic Risk (EPA 1986a), EPA has classified nickel refinery dust and nickel subsulfide by the inhalation exposure route in Group A--Human Carcinogen. This category applies to agents for which there is sufficient evidence to support the causal association between human exposure to these

agents and cancer. Nickel carbonyl, by inhalation, has been classified in Group B2--Probable Human Carcinogen (EPA 1986b). Nickel compounds by the oral exposure route have been classified in Group D--Not Classified, because of the lack of sufficient evidence of carcinogenicity following ingestion (EPA 1984). Further investigation is necessary to delineate the carcinogenic potential of other nickel compounds. Some biochemical and in vitro toxicological data suggest that the nickel ion itself may be carcinogenic and, therefore, all nickel compounds could be potential carcinogens (EPA 1986b).

The Carcinogen Assessment Group (CAG) of EPA (1986b) computed the geometric means of the individual unit risks for nickel refinery dust calculated from four separate epidemiological studies. Based on low and high exposure estimates, the composite unit risk ranged from 1.1×10^{-5} to 4.6×10^{-4} $(\mu g/m^3)^{-1}$, with a midpoint of 2.4×10^{-4} $(\mu g/m^3)^{-1}$. This midpoint value corresponds to a carcinogenic potency factor of 0.84 $(mg/kg/day)^{-1}$. CAG also derived a unit risk estimate for nickel subsulfide based on its estimate for nickel refinery dust. Since nickel refinery dust is roughly 50% nickel subsulfide, the unit risk for dust was multiplied by a factor of two producing a unit risk estimate of 4.8×10^{-4} $(\mu g/m^3)^{-1}$ and a carcinogenic potency factor of 1.7 $(mg/kg/day)^{-1}$ for nickel subsulfide (EPA 1986b). These values may be used as upper bound estimates of cancer risks to nonoccupationally exposed individuals.

EPA (1985, 1987a) developed a lifetime health advisory (HA) for nickel in drinking water based on a 2-year study in rats given nickel in their diet (Ambrose et al. 1976). A disadvantage of this study is that absorption of metals from the gastrointestinal tract may be decreased by the presence of certain dietary constituents (Rabar and Kostial 1981, Foulkes 1984). Based on a number of parameters, this study reported a no-observed-adverse effect level (NOAEL) of 5 mg/kg/day nickel. Taking into consideration the assumed difference in absorption of nickel in food versus water (0.20), a provisional adjusted allowable daily intake (AADI) of 0.350 mg/liter was calculated. After assessing human exposure from the diet and air, a lifetime HA of 0.15 mg/liter was developed for exposure to nickel in drinking water (EPA 1985, 1987a).

In the Health Effects Assessment for nickel, EPA (1984) derived an oral allowable intake chronic (AIC) of 1×10^{-2} mg/kg/day based on the same study (Ambrose et al. 1976) used by the Office of Drinking Water (EPA 1987a) to derive the lifetime HA for exposure from drinking water.

More recently, EPA (1987b) derived an oral reference dose (RfD) for nickel based on the Ambrose et al. (1976) study. In this study, groups of rats were administered nickel in the diet for 2 years at concentrations of either 0, 100, 1000, or 2500 ppm (estimated as 0, 5, 50, and 125 mg Ni/kg bw, respectively). Body weights in the high-dose male and female rats were significantly decreased compared with controls. Body weight was also reduced at 1000 ppm; this reduction was significant for females at week 6 and from week 26 through 104, whereas males showed body weight reductions only at 52 weeks. Groups of female rats on the 1000 or 2500 ppm nickel diets (50 and 125 mg Ni/kg bw) had significantly higher heart-to-body weight ratios and lower liver-to-body weight ratios than controls. No significant effects were reported at 100 ppm (5 mg Ni/kg bw). The dose of 1000 ppm (50 mg Ni/kg bw) represents a LOAEL for this study, whereas, the dose of 100 ppm (5 mg Ni/kg bw) dose is a NOAEL. In this study, 2-year survival was poor, particularly in control rats of both sexes (mortality: 44/50); this has raised some concern about the interpretation

of the results of this study (EPA 1987b). Using a NOAEL of 5 mg/kg/day and an uncertainty factor of 300, and oral RfD for nickel of 2.0×10^{-2} mg/kg/day was derived. A confidence rating of medium was assigned to this value (EPA 1987b).

EPA (1980) established an Ambient Water Quality Criterion (AWQC) of 13.4 lg/liter for the protection of human health from the toxic properties of nickel ingested through water and aquatic organisms, and an AWQC of 100 lg/liter for protection of human health from nickel ingested through aquatic organisms alone. EPA (1980) derived an adjusted AWQC of 15.4 lg/liter based on the effects of nickel ingested through drinking water alone.

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommends time-weighted average Threshold Limit Values (TLV) of 1.0 mg/m3 for nickel metal and insoluble inorganic nickel compounds and 0.1 mg/m3 for soluble nickel compounds.

SUMMARY OF NICKEL CRITERIA

EPA Carcinogen Classification

Nickel refinery dust, inhalation	Group A
Nickel subsulfide, inhalation	Group A
Nickel carbonyl, inhalation	Group B2
Nickel, oral	Group D

Inhalation Carcinogen Potency Factor (q^1*)

Nickel refinery dust	0.84 $(mg/kg/day)^{-1}$
Nickel subsulfide	1.7 $(mg/kg/day)^{-1}$

Oral RfD	0.02 mg/kg/day

AWQC	
Ingestion of water and aquatic organisms	13.4 lg/liter
Ingestion of water	15.4 lg/liter
Ingestion of aquatic organisms	100 lg/liter

REFERENCES

AMBROSE, A.M., LARSON, P.S., BORZELLECA, J.R., and HENNIGAR, G.R. 1976. Long-term toxicologic assessment of nickel in dogs and rats. J. Food Sci. Technol. 13:181-187

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

DEAN, J.H., MURRAY, M.J., and WADE, E.C. 1986. Toxic Responses of the Immune System. In: Casarett and Doull's Toxicology: The Basic Science of Poisons, 3rd Ed., Klaassen, C.D., Amdur, M.O., and Doull, J. (eds.), Macmillan Publishing Co., New York, Toronto and London, pp. 265-266

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Nickel. Office of Drinking Water. Washington, D.C. EPA 440/5-80-060; NTIS PB81-117715

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Nickel. Environmental Criteria and Assessment Office, Cincinnati, Ohio. EPA 540/1-86-018

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985. National primary drinking water regulations; synthetic organic chemicals, inorganic chemicals, and microorganisms; proposed rule. Fed. Reg. 50:46936-47025

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Guidelines for carcinogenic risk assessment. Fed. Reg. 51:33992-34003. (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Health Assessment Document for Nickel and Nickel compounds. Office of Health and Environmental Assessment, Research Triangle Park, N.C. EPA 600/8-83-012FF

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Health Advisory for Nickel. Office for Drinking Water. Washington, D.C. March 31, 1987

FOULKES, E. 1984. Nickel Absorption Studies in Rats. Preliminary Report. (As cited in EPA 1985)

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1982. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Supplement 4. World Health Organization, Lyon, France. pp. 167-170

PEDERSEN, E., HOGETVEIT, A.C., and ANDERSEN, A. 1973. Cancer of respiratory organs among workers at a nickel refinery in Norway. Int. J. Cancer 12:32-41 (As cited in EPA 1985)

RABAR, I., and KOSTIAL, K. 1981. Bioavailability of cadmium in rats fed various diets. Arch. Toxicol. 46:63-66

STOKINGER, H.E. 1981. The Metals. In: Patty's Industrial Hygiene and Toxicology, 3rd Ed., Vol. IIA. Clayton, G.D., and Clayton, F.E. (eds.), John Wiley, New York, pp. 1820-1841

TIN

INTRODUCTION

Tin (Sn) is a soft, white, silvery metal used in commerce primarily as a protective coating (tinplate), as solder, or as an alloy (bronze, brass, and pewter). Tin occurs in the +2 and +4 oxidation states, commonly as oxides or as chlorides, fluoride, sulfate or sulfide. In nature, complex tin sulfides often contain Cu, Pb, Ni, Zn, or other metals. Many of the tin salts, i.e., chlorides, sulfate, and chromate, are readily water soluble.

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

There is no evidence that inorganic tin compounds are carcinogenic or mutagenic. No information was available regarding the mutagenic or teratogenic properties of inorganic tin.

Inhalation of fumes or dust containing tin oxides has caused benign pneumoconiosis in 150 workers in a foundry (Barnes and Stoner 1959 as cited in Stokinger 1981). No clinical symptoms were present; x-rays of workers in another study showed nodular opacities 3-5 mm in size, but there was no evidence of pulmonary fibrosis or silicosis. Microscopic examination of the dust foci showed them to be dense aggregates of dust-laden macrophages surrounding the respiratory bronchioles (Robertson et al. 1961 as cited by Stokinger 1981). In a careful study of 10 workers with benign pneumoconiosis from inhaling fumes and dust from a Chilean tin foundry with measured air-borne concentrations of 8.6-14.9 mg/m^3 tin and 0.021 mg/m^3 Pb and traces amounts of Fe and Zn, it was concluded that SnO_2 fumes were more likely than dust to cause stannosis. Persistent cough and phlegm was reported in 47% of 196 male workers in a tin smelter in England with average airborne concentrations of 1.6 mg/m^3 (Roach 1966 as cited by Stokinger 1981).

The toxicity of tin salts administered orally is difficult to interpert because of the complication of acidity from hydrolysis and accompanying irritation of the gastrointestinal tract. Tin oxides and sulfides, which are not readily hydrolyzed to generate acid in the body, are essentially innocuous by the oral route. When administered parenterally, tin salts are highly toxic. The hydride, SnH_4, has been reported to be more toxic than AsH_3 (arsine) to mice and guinea pigs; the central nervous system is the major target (Paneth and Joachimoglu 1924 as cited by Stokinger 1981).

Subacute rat feeding studies with tin oxides and several salts for periods of 4 or 13 weeks, utilizing various dose levels in the diet, showed no adverse effects of stannic (+4) oxide or stannous (+2) oxide, sulfide, or oleate at dietary levels up to 0.79% tin. Dietary adminstration of 0.3% or higher stannous chloride, orthophosphate, oxalate, and tartrate caused depressed hemoglobin concentrations, decreases in the red cell count and hematocrit, and a decreased level of serum iron (Fe). Serum iron decrements could be replaced by provision of iron salts in the diet. Rats that died after subacute tin administration exhibited signs of diarrhea, paralysis, twitching of the limbs, and internal bleeding in the major organs. Renal tubular injury characterized by degeneration and necrosis of the proximal tubules occurred when rats were administered acute (35 mg/kg i.p.) or subchronic (gavage doses of 20, 100, or

175 mg/kg for 30 days) doses of $NaSn_2F_5$; no other major histomorphological changes were observed.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

The only available criteria for exposure to airborne tin are occupational exposure guidelines. The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommends a time-weighted threshold limit value (TLV) of 2 mg/m^3 for tin (metal and inorganic tin compounds).

The methodology described in EPA's Health Effects Assessment Documents can be used to derive a reference concentration for nonoccupational exposure to tin, based on the TLV. In EPA's approach, the TLV is multiplied by 10 m^3/20 m^3 to adjust for difference in breathing rates betwen occupationally and nonoccupationlly exposed populations and by 5/7 to adjust for the 5 day workweek. This adjusted value is then divided by an uncertainty factor of 100 to account for differences in individual sensitivity to the chemical agent and to account for differences in exposure duration. The value derived from this calculation, 7 mg/m^3, is the reference concentration for environmental exposure to tin.

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. ACGIH, Cincinnati, Ohio

STOKINGER, H.E. 1981. The Metals. In Clayton, G.D., and Clayton, F.E., eds. Patty's Industrial Hygiene and Toxicology. 3rd revised ed., Vol. 2A. John Wiley and Sons, New York. Pp. 1493-2060

VANADIUM

INTRODUCTION

Vanadium is a metal with the atomic number 23 and an atomic weight of 51 g/mole. Vanadium pentoxide is a yellow-to-brown colored crystalline compound which is used as a catalyst, as a photgraphic developer, and as a coating for welding electrodes. Pentavalent vanadium compounds are generally considered to be more toxic than other valence states.

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Numerous incidents of short- and long-term occupational exposures to vanadium, primarily as vanadium pentoxide dust, have been reported. Effects include respiratory tract irritation, including coughing, wheezing, breathing difficulties, bronchitis, and chest pains; eye irritation; possible skin irritation; and greenish black discolorations of the tongue (NIOSH 1977, NAS 1974). An allergic response developed in workers and subjects exposed in experimental studies (NIOSH 1977, NAS 1974). In persons who recover from acute vanadium exposure, persistent bronchitis resembling asthma, as well as dyspnea can occur (NIOSH 1977).

Respiratory changes, similar to those of bronchopneumonia, are the principal toxic effects observed in experimental animals exposed by inhalation to vanadium pentoxide dust (Browning 1969). Other effects include fatty degeneration of the liver and kidneys, hemorrhage, and bone marrow changes (Browning 1969).

No data were found on the potential mutagenicity, teratogenicity or reproductive toxicity of vanadium. The carcinogenic potential of vanadium was tested by administering vanadyl sulfate at 19.8 mg of vanadium/100 g body wt/yr for the lifespan of white Swiss mice. No evidence of carcinogenicity was suggested in this study (Kanisawa and Schroeder 1967 as reported in NIOSH 1977). No other data on the potential carcinogenicity of vanadium were found.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Pazynich (1966 as reported in NIOSH 1977) exposed groups of white rats continuously for 24 hours/day, 7 days/week for 70 days, to vanadium pentoxide at concentrations determined colorimetrically of 0.027 and 0.002 mg/m^3. In the 0.027 mg/m^3 group, morphologic lesions were observed in the liver, kidneys, and lungs. The liver showed acute vascular congestion in the central veins, and granular dystrophy of the hepatic cells. The kidneys showed necrosis, vascular congestion, and focal hemorrhages. No changes were noted in the 0.002 mg/m^3 group.

The only criteria for inhalation exposure to vanadium were occupational exposure guidelines for vanadium pentoxide. The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommends a time-weighted average Threshold Limit Value (TLV) of 0.05 mg/m^3 and NIOSH (1977) recommended 0.05 mg/m^3 as a ceiling limit value not to be exceeded. The latter value was estimated by NIOSH to correspond to a time-weighted average value of

0.01 mg/m^3. Because of the effects seen in the Pazynich (1966) study, and other results reporting lung irritation in workers exposed for 8 hours to 0.06 mg/m^3, the estimated time-weighted average value of 0.01 mg/m^3 is used as the basis for deriving a reference concentration for vanadium in air.

Based on the methodology used by EPA for deriving a reference dose from TLVs, NIOSH-estimated TLV value of 0.01 mg/m^3 is multiplied by $10m^3/20\ m^3$ to adjust for differences in the amount of air breathed by workers in 8 hours (10 m^3) and the average person in 24 hours (20 m^3) and by 5/7 to adjust for the length of the workweek. This adjusted value is then divided by an uncertainty factor of 100 to provide a margin of safety for individuals in the general population who may be especially sensitive to the chemical agent and to compensate for differences between workers and the general population in duration of exposure. These calculations give a reference concentration of 0.036 mg/m^3 for vanadium pentoxide or 0.02 mg/m^3 for vanadium alone.

An oral RfD for vanadium of $5.7x10^{-3}$ mg/kg/day and an inhalation RfD of $5.7x10^{-3}$ mg/kg/day has been derived (EPA 1987).

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

BROWNING, E. 1969. Toxicity of Industrial Metals. 2nd ed. Appleton-Century-Crofts, New York

CLAYTON, G.D., and CLAYTON, F.E., eds. 1981. Patty's Industrial Hygiene and Toxicology. 3rd rev. ed. Volume 2A: Toxicology. Wiley-Interscience, New York. Pp. 2020-2021

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Integrated Risk Information System (IRIS) Chemical Files. November 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Superfund Public Health Evaluation Manual. Office of Emergency of Remedial Response, Washington, D.C. EPA 540/1-86/060. October 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Memo from Sandra Lee (Program Manager, Regional Support Team, Toxics Integration Branch) to Addresses. Subject: Updated Reference Dose and Cancer Potency Numbers for Use in Risk Assessments. Office of Solid Waste and Emergency Response, Washington, D.C. October 1987. 19 pp. (Sandra Lee: (202) 382-4307)

NATIONAL ACADEMY OF SCIENCES (NAS). 1974. Vanadium. Committee on Biological Effects of Atmospheric Pollutants, Division of Medical Sciences, National Research Council. Washington, D.C.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1977. Criteria for a Recommended Standard--Occupational Exposure to Vanadium. DHEW (NIOSH) Publication No. 77-222

STOKINGER, H.E., WAGNER, W.D., MOUNTAIN, J.T., STACKSILL, F.R., DOBROGORSKI, O.J., and DEENAN, R.G. 1953. Unpublished results. Division of Occupational Health, Cincinnati, Ohio (As cited in Clayton and Clayton 1981)

ZINC

INTRODUCTION

Zinc (Zn) is a silvery metal of low to intermediate hardness, atomic number 30 and atomic weight 65.38 g/mole. Primary uses of zinc in industry are as a component of dry cells and other batteries, in electrogalvanizing, and as alloys. Zinc compounds are used therapeutically as topical astringents, antidandruff products, antiseptics, and emetics.

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Zinc is an essential element, and it is present in a number of metalloenzymes, including carbonic anhydrase carboxypeptidase, alcohol dehydrogenase, glutamic dehydrogenase, lactic dehydrogenase, and alkaline phosphatase (Vallee 1959 as cited by Hammond and Beliles 1980). Zinc is necessary for normal growth and development. Human dwarfism and a lack of sexual development have been related to Zn deficiency (Halsted et al. 1974 as cited by Hammond and Beliles 1980).

There is no evidence that zinc is carcinogenic. Studies which have been performed on zinc-containing organics failed to demonstrate teratogenic effects (Stokinger 1981).

Zinc salts of strong acids are astringent and corrosive. Upon ingestion they act as emetics, and they can cause symptoms of fever, nausea, vomiting, stomach cramps and diarrhea.

Zinc chloride is caustic and causes severe and occasionally fatal irritation of the epithelium lining the trachea and bronchi. Acute interstitial fibrosis of the lung occurred in one fatal case following inhalation of $ZnCl_2$ smoke from a smoke generator (Milliken et al. 1963).

Chronic administration of 0.5-34.4 mg zinc oxide per day for periods of 1 month to 1 year failed to produce signs of toxicity in rats

(Drinker et al. 1927 as cited by Stokinger 1981). In another study, 0.1% zinc was tolerated in the diet of rats, but more than 0.5% zinc reduced their capacity to reproduce, and 1% inhibited growth and caused severe anemia and death (Sutton and Nelson 1937 as cited by Stokinger 1981).

Zinc oxide has been implicated as the cause of metal fume fever in industrial situations. Typically, brass foundry workers exposed to fumes containing zinc experience an unusual metallic taste which is accompanied by dryness and irritation of the throat, with coughing and dyspnea, weakness, pains in the muscles and joints, and a high fever which is followed by profuse sweating. Recovery occurs within 24-48 hours after an attack provided exposure is discontinued. Gastrointestinal disturbances and localized dermatitis may also occur after exposure to zinc oxide.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

EPA (1984) derived an inhalation chronic allowable intake (AIC) for zinc of 0.7 mg/day (0.01 mg/kg/day) based on the American Conference of Governmental Industrial Hygienists (ACGIH 1980) recommended time-weighted average Threshold Limit Value (TLV) for zinc chloride of 1 mg/m^3. This TLV was adjusted to account for differences in the likely exposure of worker and nonoccupationally-exposed individuals, and was divided by an uncertainty factor of 10 to protect individuals in the general population who might be especially sensitive to the chemical agent. Dividing this reference dose of 0.7 mg/day by the breathing rate of the average person (20 m^3/day) gives a reference concentration for zinc in air of 35 mg/m^3.

An oral chronic allowable intake of 14.9 mg/day (0.21 mg/kg/day) was derived by EPA (1984) based on the occurrence of anemia and reduced blood copper in some patients receiving therapeutic doses of approximately 150 mg/day zinc for extended periods of time. A safety factor of 10 was used to protect sensitive individuals. This corresponds to a reference dose of 0.2 mg/kg/day for a 70 kg individual.

SUMMARY OF ZINC CRITERIA

EPA Carcinogen Classification	D
Oral AIC	0.21 mg/kg/day
Inhalation AIC	0.01 mg/kg/day

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1980. Documentation of the Threshold Limit Values and Biological Exposure Indices. 4th ed. Cincinnati, Ohio

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Zinc (and Compounds). Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-048

HAMMOND, P.B. and BELILES, R.P. 1980. Metals. In Doull, J., Klaassen, C.D., and Amdur, M.O., eds. Casarett and Doull's Toxicology. 2nd ed. Macmillan Publishing, New York. Pp. 409-467

MILLIKEN, J.A., WAUGH, D., and KADISH, M.E. 1963. Can. J. Med. Assoc. J. 88:36. (As cited in ACGIH 1980)

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1975. Criteria for a Recommended Standard. . . Occupational Exposure to Zinc Oxide. Publication No. 76-104

STOKINGER, H.E. 1981. The Metals. In Clayton, G.D., and Clayton, F.E., eds. Patty's Industrial Hygiene and Toxicology. 3rd revised ed., Vol. 2A. John Wiley and Sons, New York. Pp. 1493-2060

ACETONE

INTRODUCTION

Acetone is a widely used industrial solvent found in paints, varnishes, and lacquers. The rapid evaporation rate of acetone makes it useful for cleaning and drying precision parts.

TOXICOKINETICS

Several studies in humans and animals indicate that acetone is absorbed after either oral or inhalation exposure (EPA 1984). Orally administered acetone is eliminated through the expired air and in the urine (EPA 1984).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Acetone is currently being tested for carcinogenicity by the National Toxicology Program. Prechronic testing of rats and mice exposed to acetone in the drinking water is underway. Previous carcinogenicity bioassays are limited to skin painting studies in which acetone served as a solvent for other compounds. In general, tumors were not induced by acetone alone in these assays.

Acetone was found to be nonmutagenic in microbial assay systems and cell transformation systems. In other studies with acetone, negative results were noted in assays for sister-chromatid exchange, point mutation in mouse lymphoma cells, and DNA binding. Acetone was reported to induce chromosomal aberrations in one study (EPA 1984).

Pertinent data concerning reproductive or teratogenic effects associated with acetone exposure were not located in the literature reviewed.

No changes in clinical chemistry variables or histological changes in the liver, brain, kidneys, lungs, or heart were found in rats exposed to acetone vapors at levels of either 0 or 19,000 ppm for 3 hours/day, 5 days/week for 8 weeks. Narcosis was seen in exposed rats. Slight decreases in organ weights and body weights were observed in rats killed during exposure but not in rats killed 2 weeks after exposure (Bruckner and Peterson 1981). Workers exposed to acetone vapors at levels up to 2150 ppm experienced irritation of mucosal membranes, but did not suffer other significant toxic effects (EPA 1984).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Based on EPA guidelines for the assessment of carcinogenic risk (EPA 1986a), the EPA Environmental Criteria and Assessment Office determined that acetone is most appropriately classified Group D--Not Classified (EPA 1984). This category applies to agents for which there is inadequate evidence of carcinogenicity from human and animal studies.

EPA (1987) has derived an oral reference dose (RfD) based on an 1986 study sponsored by the Office of Solid Waste (EPA 1986b). In this study, acetone was evaluated for potential toxicity following administration by oral gavage for 90 days to groups of albino rats (30/sex/group) at levels of 0, 100, 500 or

2,500 mg/kg/day. Body weights, food consumption, clinical chemistry, hematology, and histopathologic parameters, as well as organ weights and organ-to-body weights ratios, were measured and analyzed. Animals were sacrificed after 30 and 90 days of exposure. No effects were seen at the 100 mg/kg/day dose level throughout the study. Hematological changes were evident in the 2500 mg/kg group at 30 days (males only) and at 90 days in males and females. Statistical analysis of the organ weight and ratio data revealed significantly increased kidney weights for females in the 500 and 2,500 mg/kg groups and increased kidney-to-body and brain weight ratios for males and females in the 2,500 mg/kg groups. Liver weight and liver/body weights ratios were also increased in the 2,500 mg/kg males and females. Histopathologic studies revealed a marked increase in severity in tubular degeneration of the kidneys and hyaline droplet accumulation with increasing doses. This accumulation was significant in the 500 and 2,500 mg/kg males and the 2,500 mg/kg females. Based on these findings, an animal NOEL of 100 mg/kg/day and a LOAEL of 500 mg/kg/day were established. Using the animal NOEL of 100 mg/kg/day and applying an uncertainty factor of 1,000, an oral RfD of 0.1 mg/kg/day (7.0 mg/day for a 70-kg human) for acetone was calculated.

EPA (1984) derived an inhalation acceptable chronic intake (AIC) from the subchronic experiment of Bruckner and Peterson (1981). In this study, rats were exposed to doses up to 19,000 ppm for 3 hours/day for up to 8 weeks. The rats developed narcosis during the treatment period, with a subsequent decrease in body weight. Body weights returned to normal after the end of exposure. A no-observed-adverse-effect level (NOAEL) of 19,000 ppm (45,134 mg/m^3) was established due to the reversible nature of the toxic effects seen. The NOAEL was used to derive an acceptable subchronic intake (AIS) of 2,096 mg/day. Applying an additional uncertainty factor of 10 for derivation of an AIC from a study lasting less than a lifetime produced an AIC of 210 mg/day, which is equivalent to 3 mg/kg/day.

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommended a time-weighted average threshold limit value of 750 ppm (1,780 mg/m^3) for occupational exposure to acetone. The National Institute of Occupational Safety and Health (NIOSH 1978) recommended an exposure limit of 250 ppm for acetone.

SUMMARY OF ACETONE CRITERIA

EPA carcinogen classification	Group D
Oral RfD	0.1 mg/kg/day
Inhalation AIC	3.0 mg/kg/day

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

BRUCKNER, J.V., and PETERSON, R.G. 1981. Evaluation of toluene and acetone inhalant abuse. II. Model development and toxicology. Toxicol. Appl. Pharmacol. 61:302-312 (As cited in EPA 1984)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Acetone. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-016

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Guidelines for carcinogen risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Ninety-day gavage study in albino rats using acetone. Office of Solid Waste, Washington, D.C. As cited in EPA 1987

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Cincinnati, Ohio. Revised September 30, 1987

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1978. Criteria for a Recommended Standard--Occupational Exposure to Ketones. Washington, D.C. DHEW (NIOSH) Publication No. 78-173

DI-n-BUTYL PHTHALATE

INTRODUCTION

Di-n-butyl phthalate (DBP) is a phthalate ester commonly used as a plasticizer and in the production of polyvinyl chloride (PVC) resins (EPA 1980).

PHARMACOKINETICS

The phthalic acid esters and/or their metabolites are readily absorbed from the gastrointestinal tract, intraperitoneal cavity, and the lungs and distributed to various organs and tissues. The esters are excreted primarily in urine and feces (EPA 1980).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

There are no reports that DBP is carcinogenic in animals or humans. However, DBP was reported to be mutagenic in a bacterial test system (Seed 1982). Reduced fetal weight, resorptions, and dose-related musculoskeletal abnormalities were observed among fetuses from rats and mice exposed to very high doses of DBP during gestation (Shiota and Nishimura 1982).

The acute toxicity for laboratory animals by most routes of administration is very low. Oral, inhalation, and intraperitoneal LD_{50} values of 8,000 mg/kg, 7,900 mg/m^3, and 3,050 mg/kg, respectively, have been reported for the rat (EPA 1980). Smith (1953) fed male Sprague-Dawley rats diets containing 0, 0.01, 0.05, 0.25, and 1.25% di-n-butyl phthalate for 1 year. At the highest di-n-butyl phthalate concentration, one-half of all rats died during the first week of exposure.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Applying the carcinogen risk guidelines established by the Carcinogen Assessment Group of EPA (EPA 1986), di-n-butyl phthalate is most appropriately classified in Group D--Not Classified. This category applies to agents for which there is inadequate evidence of carcinogenicity in animals.

EPA (1987) calculated an oral risk reference dose (RfD) of 0.1 mg/kg/day for di-n-butyl phthalate based on a study by Smith (1953). In this study, male Sprague-Dawley rats in groups of 10 were fed diets containing 0, 0.01%, 0.05%, 0.25%, or 1.25% dibutyl phthalate for a period of 1 year. One-half of all rats receiving the highest dibutyl phthalate concentration (1.25% of diet, or 600 mg/kg/day) died during the first week of exposure. The remaining animals survived the study with no apparent adverse effects. There was no effect of treatment on gross patholgoy or hematology. While it was stated that several organs were sectioned and stained, no histopathology evaluation was reported. Using a NOAEL of 125 mg/kg/day (0.25% dibutyl phthalate in diet) and an uncertaintly factor of 1,000, an oral reference dose (RfD) of 0.1 mg/kg/day was derived (EPA 1987).

EPA (1980) also determined an ambient water quality criterion (AWQC) of 34.1

mg/liter for the protection of human health from the toxic properties of di-n-butyl phthalate ingested through water.

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) has recommended a time-weighted average threshold limit value (TLV) of 5 mg/m^3 for occupational exposure to di-n-butyl phthalate.

SUMMARY OF DI-n-BUTYL PHTHALATE

EPA carcinogen classification	Group D
RfD	0.1 mg/kg/day
AWQC	34.1 mg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Phthalate Esters. Office of Water Regulations and Standards, Washington, D.C. October 1980. EPA 440/5-80-067

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Guidelines for carcinogen risk assessment. Fed. Reg. 51:33992-34002 (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Cincinnati, Ohio. Revised September 30, 1987

SEED, J.L. 1982. Mutagenic activity of phthalate esters in bacterial liquid suspension assays. Environ. Health Perspect. 45:111-114

SHIOTA, K., and NISHIMURA, H. 1982. Teratogenicity of di(2-ethylhexyl) phthalate (DEHP) and di-n-butyl phthalate (DBP) in mice. Environ. Health Perspect. 45:65-70

SMITH, C.C. 1953. Toxicity of butyl stearate, dibutyl sebacate, dibutyl phthalate, and methoxyethyl oleate. Arch. Ind. Hyg. 7:310 (As cited in EPA 1980, 1987)

DIETHYL PHTHALATE

INTRODUCTION

Diethyl phthalate (DEP) is one of a large family of chemicals, the phthalate esters, widely used as plasticizers in the production of plastic resins. This compound also has non-plasticizer uses in industrial oils and solvents, wetting agents, pesticide carriers, insecticidal sprays, cosmetics, fragrances, and alcohol denaturant. The detection of phthalate esters in vegetation, animals, and minerals, and in areas remote from industrial sites has raised questions about possible natural origins of these compounds (EPA 1980). These compounds also appear to be common analytical laboratory contaminants.

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Athough DEP has not been adequately tested, there are no reports that it is carcinogenic in animals or humans. However, DEP is reported to be mutagenic with or without metabolic activation in bacterial test systems (EPA 1986, Seed 1982). Reduced fetal weight, resorptions, and dose-related musculoskeletal abnormalities were observed among fetuses from rats exposed intraperitoneally to DEP during gestation (EPA 1980). This compound is currently under test in a National Toxicology Program skin-painting carcinogenicity bioassay.

The acute toxicity for laboratory animals by most routes of administration is very low. Oral, inahalation, and intraperitoneal LD_{50} values of 9,000 mg/kg, 7,510 mg/m^3, and 5,058 mg/kg, respectively, have been reported for the rat (NIOSH 1986). No specific lesions attributable to DEP and no unusual incidence of tumors have been reported in chronic feeding studies with rats and dogs. However, decreased efficiency of food utilization and increased relative organ weights were observed in some of the treatment groups (EPA 1980, EPA 1986).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

EPA has recently presented an oral reference dose of 0.8 mg/kg/day (EPA 1987). This is based on a study by Brown et al. (1978), which examined the effects of orally administered diethyl phthalate on rats. This is supported by another study (FRL 1955) in which, rats received 0, 0.5, 2.5, or 5.0% DEP in the diet for 2 years. Red and white blood cell counts, differential white cell counts, hemoglobin, blood sugar, blood nitrogen, and urinalysis results were monitored every 12 weeks. No treatment-related effects on these parameters or on gross organ appearance or histopathology were observed. Growth of animals in the 5% treatment group was significantly depressed, with no corresponding decrease in food intake. Accordingly, a lowest-observed-adverse-effect level (LOAEL) of 5% (2,500 mg/kg/day) and a no-observed-adverse-effect level (NOAEL) of 2.5% (1,250 mg/kg/day) DEP in the diet were identified.

SUMMARY OF DIETHYL PHTHALATE CRITERIA

Reference Dose (RfD)	0.8 mg/kg/day

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values. 5th ed. Cincinnati, Ohio

BROWN, D., BUTTERWORTH, K.R., GAUNT, I.F., GRASSO, P., and GANGOLLI, S. 1978. Short-term oral toxicity study of diethyl phthalate in the rat. Food Cosmet. Toxicol. 16:415-422

FOOD RESEARCH LABORATORIES, INC. (FRL). 1955. Toxicological Studies of Diethyl Phthalate. No. 67567. Long Island City, New York (As cited in EPA 1980, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Phthalate Esters. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C. October 1980. EPA 440/5-80-067

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Verified Reference Doses (RfDs) of the USEPA. The ADI Work Group of the Risk Assessment Forum. Cincinnati, Ohio. January 1986. ECAO-CIN-475

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Cincinnati, Ohio. Revised September 30, 1987

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1986. Registry of Toxic Effects of Chemical Substances. Data Base. Washington, D.C.

SEED, J.L. 1982. Mutagenic activity of phthalate esters in bacterial liquid suspension assays. Environ. Health Perspect. 45:111-114

ETHYLBENZENE

INTRODUCTION

Ethylbenzene (EB) is a clear, colorless, flammable liquid found in gasoline. It is used as a solvent and in the manufacture of styrene and acetophenone. Ethylbenzene is also a constituent of asphalt and naptha.

TOXICOKINETICS

Ethylbenzene is absorbed via inhalation and distributed throughout the body in Harlan-Wistar rats. However, the highest levels were detected in the kidney, lung, adipose tissue, digestive tract, and liver (Chin et al. 1980). Data regarding the absorption of ethylbenzene from the gastrointestinal tract following oral ingestion were not located in the available literature. The elimination of ethylbenzene is primarily through urinary excretion of metabolites (EPA 1984).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

CARCINOGENICITY

Pertinent data on the carcinogenic potential of ethylbenzene were not identified in the available literature.

MUTAGENICITY

Ethylbenzene was found to be nonmutagenic in *Salmonella typhimurium* strains TA98, TA100, TA1535, and TA1537 tested with and without metabolic activation (Florin et al. 1980). Pure ethylbenzene did not increase the frequency of recessive lethals in the *Drosophila* recessive lethal test (Donner et al. 1979).

TERATOGENICITY/REPRODUCTIVE EFFECTS

Hardin et al. (1981) found that ethylbenzene did not elicit embryo toxicity, teratogenicity, or maternal toxicity in New Zealand white rabbits exposed for 6-7 hours/day at 100 or 1,000 ppm (435 or 4,348 mg/m^3) during gestation days 1-24. However, female Wistar or Sprague-Dawley rats exposed to 1,000 ppm ethylbenzene for 6-7 hours/day during gestation days 1-19 had increased liver, kidney, and spleen weights indicating maternal toxicity.

ACUTE/CHRONIC TOXICITY

Wolf et al. (1956) administered a single oral dose of ethylbenzene (in olive oil or corn oil solution) by stomach tube to male and female Wistar-derived rats to determine the acute toxicity of ethylbenzene. The reported LD_{50} for both sexes was 3.5 g/kg bw; systemic toxic effects occurred primarily in the liver and kidney.

Wolf et al. (1956) also administered ethylbenzene in olive oil by stomach tube 5 days/week for 6 months to groups of 10 female Wistar rats. Doses of 468 and 680 mg/kg caused increased liver and kidney weights and cloudiness and swelling

of hepatocytes and renal tubular epithelium. No effects were observed in rats exposed to 13.6 and 136 mg/kg/day.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Applying the criteria in EPA's guidelines for assessment of carcinogenic risk (EPA 1986), ethylbenzene is most appropriately classified in Group D--Not Classified. This category applies to agents for which there is inadequate evidence of carcinogenicity.

EPA (1985c) proposed a maximum contaminant level goal (MCLG) of 0.68 mg/liter based on the results of the Wolf et al. (1956) study that identified a no-observed-adverse-effect level (NOAEL) of 136 mg/kg/day.

EPA (1987) derived an oral reference dose (RfD) for ethylbenzene based on a study by Wolf et al. (1956). In this study, ethylbenzene was given by gavage to rats 5 days/week for 182 days at doses of 13.6, 136, 408, or 680 mg/kg/day in olive oil. Parameters examined included growth, mortality, appearance and behavior, hematology, body weight, histopatholgy, and bone marrow counts. A LOAEL of 408 mg/kg/day was associated with lesions of the liver and kidney. No effects were observed at 136 mg/kg/day. Using a NOEL of 136 mg/kg/day and an uncertainty factor of 1,000, and oral RfD of 0.1 mg/kg/day was calculated.

EPA (1980b) established an ambient water quality criterion (AWQC) of 1.4 mg/liter for the protection of human health from the toxic properties of ethylbenzene ingested through water and contaminated aquatic organisms.

The American Conference of Governmental Industrial Hygienists (ACGIH 1986) recommended a time-weighted average threshold limit value of 100 ppm (435 mg/m^3) for occupational exposure to ethylbenzene.

SUMMARY OF ETHYLBENZENE CRITERIA

EPA carcinogen classification	Group D
Proposed MCLG	0.68 mg/liter
Oral RfD	0.1 mg/kg/day
AWQC	1.4 mg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

BORDODEJ, Z., and BORDODEJEVA, E. 1970. Biotransformation of ethylbenzene, styrene and alpha-methylstyrene in man. Am. Ind. Hyg. Assoc. J. 31:206-209 (As cited in EPA 1985b)

CHIN, B.H., McKELVEY, J.A., TYLER, T.R., CALISTI, L.J., KOZBELT, S.J., and SULLIVAN, L.J. 1980. Absorption, distribution and excretion of ethylbenzene, ethylcyclohexane and methyl ethylbenzene isomers in rats. Bull. Environ. Contam. Toxicol. 24:477-483 (As cited in EPA 1985a)

DONNER, M., MAKI-PAAKKANEN, J., NORPPA, N., SORSA, M., and VAINIO, H. 1979. Genetic toxicology of xylenes. Mutat. Res. 74:171-172 (As cited in EPA 1985a)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980b. Ambient Water Quality Criteria for Ethylbenzene. Office of Water Regulations and Standards, Washington, D.C. October 1980. EPA 440/5-80-048

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Ethylbenzene. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-008

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. Drinking Water Criteria Document for Ethylbenzene (Final Draft). Office of Drinking Water, Washington, D.C. March 1985. EPA 600/X-84-163-1

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. Draft Health Advisory for Ethylbenzene. Office of Drinking Water, Washington, D.C. September 1985

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985c. National primary drinking water regulations; synthetic organic chemicals, inorganic chemicals and microorganisms. Fed. Reg. 50:46936-47022 (November 13, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Guidelines for carcinogenic risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. Cincinnati, Ohio. Revised September 30, 1987

FLORIN, I., RUTHBERG, L., CURVALL, M., and ENZELL, C.R. 1980. Screening of tobacco smoke constituents for mutagenicity using the Ames test. Toxicology 18:219-232 (As cited in EPA 1985a)

HARDIN, B.D., BOND, G.P., SIKOV, M.R., ANDREW, F.D., BELILES, R.P., and NIEMEIER, R.W. 1981. Testing of selected workplace chemicals for teratogenic potential. Scand. J. Work Environ. Health 7:66-75 (As cited in EPA 1985a)

WOLF, M.A., ROWE, V.K., McCOLLISTER, D.D., HOLLINGSWORTH, R.L., and OYEN, F. 1956. Toxicological studies of certain alkylated benzenes and benzene. Arch. Ind. Health 14:387-398 (As cited in EPA 1985a, 1987)

METHYLENE CHLORIDE

INTRODUCTION

Methylene chloride (dichloromethane) is a solvent that is widely used for a variety of purposes. Approximately 85 percent of the methylene chloride consumed in the United States is lost directly to the environment through dispersive use, largely by evaporation to the atmosphere.

PHARMACOKINETICS

The absorption of ingested methylene chloride is virtually complete. The amount of airborne methylene chloride absorbed increases in direct proportion to its concentration in inspired air, the duration of exposure, and physical activity. Dermal absorption has not been accurately measured. Because of methylene chloride's high solubility in water and lipids, it is probably distributed throughout all body fluids and tissues. It readily crosses the blood-brain barrier. Methylene chloride is metabolized by the liver to carbon monoxide or to formaldehyde and formic acid which are further metabolized to carbon dioxide. The carbon monoxide dissociates at the lung and is eliminated (EPA 1985a).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Acute human exposure to methylene chloride may result in irritation of eyes, skin, and respiratory tract; central nervous system depression; elevated carboxyhemoglobin levels; and circulatory disorders that may be fatal. Chronic exposure of animals may produce renal and hepatic toxicity. There is limited evidence of genotoicity in rodents (EPA 1980).

Methylene chloride has been found positive in the Ames assay without the need for metabolic activation. Results in other tests of genotoxicity were largely negative; those for transformation were mixed. An in vivo screening test for carcinogenicity, induction of lung adenomas in strain A mice, gave suggestive positive results for methylene chloride (EPA 1980).

There have been several chronic studies in which methylene chloride was administered to experimental animals either orally or by inhalation. There is clear evidence for carcinogenicity in the inhalation studies. However, there is only suggestive evidence of a treatment-associated increase in combined hepatocellular carcinomas and neoplastic nodules provided in drinking water studies (EPA 1985a,b).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Applying their criteria for evaluating the overall weight of evidence of carcinogenicity, EPA (1987) has classified methylene chloride in Group B2--Probable Human Carcinogen. It has been concluded by EPA (1985b) that the induction of distant site tumors from inhalation exposure and the borderline significance for induction of tumors in a drinking water study are an adequate basis for concluding that methylene chloride be considered a probable human carcinogen via ingestion as well as inhalation. In its addendum to the health assessment document for dichloromethane (methylene chloride), EPA (1985b)

reported carcinogenic potencies (q_1*) for exposure by inhalation and ingestion to this compound.

EPA (1985b, 1987) derived the q_1* for exposure by inhalation based on the results of a National Toxicology Program (NTP) inhalation bioassay (NTP 1986). In the NTP bioassay, groups of 50 male and 50 female F344/N rats and B3C6F$_1$ mice were exposed by inhalation 6 hours a day, 5 days a week to dichloromethane (methylene chloride) for 102 weeks. The rats were exposed to concentrations of 0, 1,000, 2,000, or 4,000 ppm, and the mice were exposed to 0, 1,000, or 4,000 ppm. Significant increases with dose in the incidence of neoplastic lesions were reported for mammary tumors in male and female rats and for lung and liver tumors in male and female mice. The data set indicating the greatest carcinogenic potency of dichloromethane was for alveolar/bronchiolar or hepatocellular adenomas or carcinomas in female mice, for which the incidences were 5/50, 36/48, and 46/47 for the 0-, 2,000-, and 4,000-ppm groups, respectively. Using the molecular weight of dichloromethane (84.94g), the concentrations in ppm can be equated to concentrations in mg/liter of air (3.5 mg/m^3 = 1 ppm). Assuming that the mice weighed 32 g on average, had a respiratory volume of 0.0407 m^3/day, and completely absorbed the substance, the above dosing schedule would give average daily doses of 1,582 and 3,164 mg/kg/day for the 2,000- and 4,000-ppm groups, respectively. These doses and incidence rates were fitted to the multistate model using the program GLOBAL83 (Howe 1983). After using a correction factor for the difference in the surface area-to-volume ratios between mice and humans, the upper 95th percentile estimate of the carcinogenic potency (q_1*) was 1.4×10^{-2} (mg/kg/day)$^{-1}$.

EPA (1985b, 1987) calculated a q_1* for oral exposure to methylene chloride based on the results of the NTP (1986) inhalation bioassay and on an ingestion bioassay conducted by the National Coffee Association (NCA 1983). Each of these studies have limitations for estimating the risks from ingestion of this compound. Methylene chloride is rapidly absorbed following either inhalation or ingestion. Consequently, use of inhalation data for calculation of cancer risk from oral exposure is justified if lung tumor data are excluded (EPA 1987). A slope factor (cancer potency factor) for oral exposure of 7.5×10^{-3} (mg/kg/day)$^{-1}$ was derived using an arithmetic mean of slope factors derived from the NTP (1986) and National Coffee Association (1983) data (2.6×10^{-3} and 1.2×10^{-2} (mg/kg/day)$^{-1}$, respectively).

Because methylene chloride is rapidly absorbed and systematically distributed following either ingestion or inhalation, use of an inhalation study is one approach for assessing hazards from ingestion exposure. However, exposures via the two routes are likely to lead to different doses reaching individual organs. In particular, an inhalation study may result in a higher degree of exposure to lung tissue and a lesser exposure to tissues in the digestive system. Consequently, NTP findings for liver tumors, but not lung tumors, in mice were used for quantitative estimation of risk (EPA 1985b).

The NCA (1983) drinking water study in mice yielded suggestive but not conclusive evidence of a treatment-related increase in hepatocellular carcinoma and/or adenomas in males. EPA (1985b) used these data to make an upper-bound risk estimate from ingestion exposure. However, it was noted that because the NCA study used doses that were well below the maximum tolerated dose (MTD),

elevated tumor incidences may have been found in other tissues if the study had been conducted nearer to the MTD.

The carcinogenic potency factor derived from results of the NTP (1983) study is based on the incidence of hepatocellular adenomas or carcinomas in female mice (3/50, 16/48, and 40/48 in the control, 2,000 ppm, and 4,000 ppm groups, respectively). Using the appropriate dose-conversion procedures, a q_1* of 2.6×10^{-3} $(mg/kg/day)^{-1}$ was calculated.

In the NCA (1983) study, groups of from 50 to 200 $B6C3F_1$ mice received methylene chloride in drinking water for 24 months. The actual mean daily consumption levels for males and females were similar to the target levels of 60, 125, 185, and 250 mg/kg/day. Two control groups for each sex also were maintained. Significant increases in the incidence of hepatocellular adenomas and/or carcinomas were reported for male mice in the 125 mg/kg/day and 185 mg/kg/day groups, and a borderline significant increase in incidence of these neoplastic lesions was reported in the 250 mg/kg/day group. Using the incidence of hepatocellular adenomas and carcinomas in male mice (24/125, 51/200, 30/100, 31/99, and 35/125 for the control, 60-, 125-, 185-, and 250-mg/kg/day groups, respectively) and the appropriate dose-conversion procedures, a q_1* of 1.21×10^{-2} $(mg/kg/day)^{-1}$ was calculated.

The carcinogenic potencies calculated on the basis of the two mouse studies (NCA 1983, NTP 1986) are comparable. Consequently, EPA (1985b, 1987) recommended use of the mean value of 7.5×10^{-3} $(mg/kg/day)^{-1}$ as the q_1* estimate for oral exposure to methylene chloride.

A risk reference dose (RfD) of 0.06 mg/kg/day for noncarcinogenic effects of methylene chloride following oral exposure has been developed by EPA (1986, 1987). The RfD was derived from a 2-year rat drinking water bioassay (NCA 1982) that identified no-observed-effect levels (NOELS) of 5.85 and 6.47 mg/kg/day for male and female rats, respectively. Liver toxicity was the observed effect, and lowest-observed-effect levels (LOELS) of 52.58 and 58.32 mg/kg/day were reported for males and females, respectively. The study was given a high confidence rating by EPA (1986, 1987) because a large number of animals of both sexes in four dose groups were tested. Many effects were monitored and a good dose-severity relationship was observed. Using NOELs of 5.85 mg/kg/day and 6.47 mg/kg/day and an uncertainty factor of 100, an oral RfD of 0.06 mg/kg/day was derived.

In establishing an ambient water quality criterion for methylene chloride, EPA (1980) considered the end point of carboxyhemoglobin elevation for which the American Conference of Governmental Industrial Hygienists (ACGIH) had set a threshold unit value of 200 ppm. This corresponds to ingestion of drinking water from a source containing 12.4 mg/liter methylene chloride.

However, because the findings for mutagenicity and carcinogenicity were suggestive but inadequate for quantitative risk assessment, EPA adopted for methylene chloride the criterion of 0.19 mg/liter established by CAG for the structurally related substance, chloroform. In light of the information made available since publication of this criterion, it appears that the carcinogenic potencies presented in the addendum to the health assessment document for dichloromethane (EPA 1985b) and summarized in preceding section are more appropriate for estimating risks associated with exposure to this compound.

SUMMARY OF METHYLENE CHLORIDE CRITERIA

EPA carcinogen classification oral and inhalation	Group B2
Oral carcinogenic potency factor (q_1*)	7.5×10^{-3} $(mg/kg/day)^{-1}$
Inhalation carcinogenic potency factor (q_1*)	1.4×10^{-2} $(mg/kg/day)^{-1}$
Risk Reference Dose (for noncarcinogenic effects)	0.06 mg/kg/day
AWQC	12.4 mg/liter

REFERENCES

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Halomethanes. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C. October 1980. EPA 440/5-80-051

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. Health Assessment Document for Dichloromethane. Office of Health and Environmental Assessment, Washington, D.C. February 1985. EPA/600/8-82004F

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. Addendum to the Health Assessment Document for Dichloromethane. Office of Health and Environmental Assessment, Washington, D.C. September 1985. EPA/600/8-82-004F

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Verified Reference Doses (RfDs) of the U.S. EPA (Including Addendum of May 14, 1986). Prepared by the ADI Work Group of the Risk Assessment Forum, Washington, D.C. January 1986. ECAO-CIN-475

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. Cincinnati, Ohio. Revised September 30, 1987

HOWE, R.B. 1983. GLOBAL 83: An experimental program developed for the U.S. Environmental Protection Agency as an update to GLOBAL 82: A Computer Program to Extrapolate Quantal Animal Toxicity Data to Low Doses. (May 1982). K.S. Crump and Co., Inc. Ruston, Louisiana. Unpublished (As cited in EPA 1985b)

NATIONAL COFFEE ASSOCIATION (NCA). 1982. Twenty-four Month Chronic Toxicity and Oncogenicity Study of Methylene Chloride in Rats. Final Report. Prepared by Hazelton Laboratories America, Inc., Vienna, Virginia. August 11, 1982. As cited in EPA 1987

NATIONAL COFFEE ASSOCIATION (NCA). 1983. Twenty-Fourth-Month Oncogenicity Study of Methylene Chloride in Mice. Prepared by Hazleton Laboratories, Inc., Vienna, Virginia. Unpublished. (As cited in EPA 1985b, 1987)

NATIONAL TOXICOLOGY PROGRAM (NTP). 1986. NTP Technical Report on the Toxicology and Carcinogenesis Studies of Dichloromethane in F344/N Rats and B6C3F1 Mice (Inhalation Studies). NTP TR306.

NONCARCINOGENIC AND CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS

INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are a diverse class of compounds consisting of two or more fused aromatic rings. They are formed during the incomplete combustion of materials containing carbon and hydrogen and are ubiquitous in the modern environment. PAHs are commonly found as constituents of coal tar, soots, vehicular exhausts, cigarettte smoke, certain petroleum products, road tar, mineral oils, creosote, and many cooked foods.

PAHs occur in the environment as complex mixtures of many components with varying noncarcinogenic and carcinogenic potencies. Only a few components of these mixtures have been characterized adequately, and only limited information is available on the relative potencies of different compounds. The PAHs can be divided into two classes depending on whether they primarily exhibit carcinogenic or noncarcinogenic effects.

A number of reviews have been prepared on the toxicology of the PAHs. The Environmental Protection Agency (EPA) prepared an Ambient Water Quality Criteria Document on the general class of polynuclear aromatic hydrocarbons (EPA 1980a) and Criteria Documents on several specific PAHs, including acenaphthene, fluoranthene, and naphthalene (EPA 1980b-d). More recently, EPA (1984a-f) prepared Health Effects Assessments for PAHs as a class, for coal tars, and for the individual compounds benzo(a)pyrene [B(a)P], naphthalene, phenanthrene, and pyrene. In addition to the EPA documents, Santodonato et al. (1981) prepared a review and risk assessment of polynuclear aromatic hydrocarbons, and the International Agency for Research on Cancer (IARC) reviewed the toxicity and carcinogenicity of a large number of individual PAHs and PAH-containing mixtures (IARC 1973, 1983, 1984, 1985). The Agency for Toxic Substances and Disease Registry (ATSDR) has published detailed toxicological profiles for benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene, chrysene, and dibenz(a,h)anthracene (ATSDR 1987a-e).

TOXICOKINETICS

PAH absorption following oral exposure is inferred from the demonstrated toxicity of PAHs following ingestion (EPA 1984a). PAHs are highly lipid soluble and readily absorbed from the gastrointestinal tract (EPA 1984). Hecht et al. (1979) reported that approximately 85% 14C-labeled B(a)P was excreted in the feces in rats following administration of B(a)P in peanut oil by gavage. PAH absorption following inhalation exposure is inferred from the demonstrated toxicity of PAHs following inhalation (EPA 1984a). It has been suggested that simultaneous exposure to carcinogenic PAHs such as B(a)P and particulate matter can increase the effective dose of the compound (ATSDR 1987a). PAHs are also absorbed following dermal exposure; 3% of an applied dose of 14C-B(a)P to human skin was absorbed under <u>in vitro</u> conditions (Kao et al. 1985). B(a)P was also found to be absorbed from the skin of mice; after 7 days, 93% of radioactivity was recovered primarily in the feces (Sanders et al. 1986). Absorbed PAHs are rapidly and widely distributed among several tissues and excreted primarily in the feces (ATSDR 1987a-e).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Acute effects from direct contact with PAHs and related materials are limited primarily to phototoxicity. Phototoxicity is caused by exposure to a toxic substance followed by exposure to sunlight. The primary effects are dermatitis--skin reddening, itching, and burning. NIOSH (1977) reviewed the phototoxic effects of exposure to coal tar and found that phototoxicity can result from a single 90-minute exposure to a 1% solution of coal tar. These dermatoses usually disappear when contact with the sensitizer is eliminated.

The polycyclic aromatic hydrocarbons have been shown to cause cytotoxicity in rapidly proliferating cells throughout the body, with the hematopoietic system, lymphoid system, and testes frequently noted as targets (Santodonato et al. 1981). This effect appears to be due to inhibition of DNA replication by the PAHs. Destruction of the sebaceous glands, hyperkeratosis, hyperplasia, and ulceration have been observed in mouse skin following dermal application of the carcinogenic PAHs, with the degree of induced morphological changes appearing to correlate with the carcinogenic activity. However, it does not seem that this dermal toxicity is necessary or sufficient for carcinogenesis (Santodonato et al. 1981). It should be noted that similar types of dermatitis have been observed in workers exposed to such PAH-containing materials as coal tar and mineral oil. The carcinogenic PAHs have also been shown to have an immunosuppressive effect in animals. Again, it is not clear what relationship, if any, this immunosuppression has with carcinogenesis.

Some of the noncarcinogenic PAHs have been shown to cause systemic toxicity, but these effects are generally seen only at rather high doses (Santodonato et al. 1981). For example, slight morphological changes in the livers and kidneys of rats have been reported following oral administration of acenaphthene. Oral administration of naphthalene to rabbits and rats has resulted in cataract formation.

Nonneoplastic lesions are seen in animals exposed to the more potent carcinogenic PAHs only after exposure to levels well above those required to elicit a carcinogenic response. Consequently, carcinogenicity is the toxic effect of greatest public health concern following exposure to materials containing carcinogenic PAHs. A number of the PAHs have been shown to be potent carcinogens, producing tumors both at the site of application and systemically, in several different animal species, when administered by any of a number of routes. Rigdon and Neal (1969) reported gastric tumors, pulmonary adenomas and leukemias in mice fed B(a)P, and intratracheal instillation of a number of PAHs has been shown to cause lung tumors in both mice and hamsters (Santodonato et al. 1981). In addition, IARC (1984, 1985) noted that occupational exposure to coal soot, coal tar and pitch, coal tar fumes, and some impure mineral oils causes cancer in humans at several sites, including the skin, and concluded that there is sufficient evidence that soots, tars, and some mineral oils are carcinogenic in humans. Fractionation procedures have demonstrated that the PAHs are the carcinogenic agents in coal tar.

Not all PAHs have been demonstrated to be carcinogenic in animals, and some carcinogenic PAHs are clearly more potent than others (IARC 1983). A number of factors have been shown to influence the relative carcinogenic potencies of

the PAHs. These include planarity of the molecule, cellular absorption, binding affinity, the presence or absence of a particular molecular structure, and the electron configuration of the molecule (Dipple et al. 1984, Frierson et al. 1986). In addition, genetic differences in the exposed animals, particularly in their ability to produce aryl hydrocarbon hydroxylase (AHH), have been shown to influence carcinogenic potency. Finally, the PAHs are not ultimate carcinogens but must be metabolized before they become biologically activated. A complete description of the complex metabolism of these compounds is beyond the scope of this report, but a detailed review of the factors influencing the carcinogenicity of the PAHs and metabolism of these compounds can be found in Dipple et al. (1984), Santodonato et al. (1981), and Frierson et al. (1986). For purposes of risk assessment, it is sufficient to note that the potencies of different PAHs vary over a wide range and that a number of factors, including factors specific to the chemical, the host animal, and the circumstances of exposure, affect carcinogenic potency.

For practical purposes, the PAHs are often separated into two categories, the "carcinogenic" and the "noncarcinogenic" PAHs. This is a somewhat misleading categorization as many of the "noncarcinogenic" PAHs have been shown to have some, albeit weak, carcinogenic activity, or to act as promoters or cocarcinogens. A more accurate designation would be to differentiate between potent carcinogens, weak carcinogens, and noncarcinogens. Another factor complicating the assessment of risks posed by the PAHs is that they do not occur alone in nature, but occur as complex mixtures containing numerous PAHs of varying carcinogenic potencies. The potential interactions of the individual PAHs present as components of these mixtures must be addressed in attempting to quantify the carcinogenic risks posed by exposure to the mixtures.

The approach adopted by EPA (1980a, 1984a) as the basis for risk assessment is to apply a carcinogenic potency factor calculated from assays on B(a)P to the subclass of carcinogenic PAHs within the mixture that is to be assessed. This approach involves three assumptions: (1) that all carcinogenic PAHs have the same potency as B(a)P; (2) that their effects are additive; and (3) that the noncarcinogenic PAHs do not contribute to the carcinogenic effects of the mixture. Although there is limited empirical evidence to support assumptions (2) and (3), assumption (1) may lead to large overestimates of risk because B(a)P is one of the most potent carcinogens among the PAHs and is usually present only in a small percentage of the total mixture.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

B(a)P is representative of the carcinogenic PAHs and is classified by EPA (1984c) in Group B2--Probable Human Carcinogen based on sufficient evidence of carcinogenicity from animal studies and inadequate evidence from epidemiological studies.

EPA (1980a, 1984a) calculated a value of 11.5 $(mg/kg/day)^{-1}$ as the carcinogenic potency factor (upper bound on lifetime risk) for oral exposure to the carcinogenic PAHs, based on the study of Neal and Rigdon (1967) in which oral administration of B(a)P led to forestomach tumors in mice. EPA (1984a) calculated a cancer potency factor for inhalation of B(a)P based on the study of Thyssen et al. (1981). This assay evaluated the production of respiratory tract tumors in hamsters using B(a)P at concentrations of

2.2-9.5 mg/m^3. The linearized multistage model yielded a carcinogenic potency factor of 6.11 $(mg/kg/day)^{-1}$. Both of these carcinogenic potency factors for B(a)P have been suspended by EPA, however, pending further evaluation and recalcualtion. Furthermore, since very few carcinogenic PAHs are as potent as B(a)P, a relative potency method is being developed and applied to tumor bioassay data for other PAHs that will result in cancer potencies that are much less (up to two orders of magnitude) than that of B(a)P.

EPA's Carcinogen Assessment Group has not reported a risk assessment for dermal exposure to the carcinogenic PAHs. Santodonato et al. (1981) performed risk assessments for both dermal and oral exposure and indicated that B(a)P was more potent when applied dermally than when administered orally. A number of factors may account for this difference in relative potency and a complete derivation of a dermal potency factor is beyond the scope of this profile.

In addition to quantification of the effects of individual PAHs, EPA developed a cancer potency factor for inhalation of coal tar pitch volatiles (EPA 1984b). This study evaluated epidemiological data from exposure of coke oven workers to between 0 and greater than 700 mg/m^3 per month coal tar vapors. The equivalent incremental risk calculated from the study was 3.2 $(mg/kg/day)^{-1}$. Coal tar pitch volatiles were classified in Group A--Human Carcinogen.

IARC (1983) in reviewing the carcinogenicity of the PAHs, indicated those for which there was sufficient, limited, inadequate, or adequate negative evidence of carcinogenicity (Table 1). The more potent carcinogens are almost certainly included within the group for which sufficient evidence of carcinogenicity is available.

Of the noncarcinogenic PAHs, naphthalene has undergone the most extensive toxicity assessment. EPA's Environmental Criteria Assessment Office has developed a reference dose (RfD) for chronic oral exposure to naphthalene of 0.41 mg/kg/day based on the development of ocular lesions in rats (Schmal 1955, as cited in EPA 1986) and occupational data on coke oven workers. This intake level is associated with a concentration in drinking water of 14 mg/liter, assuming a body weight of 70 kg and consumption of 2 liters of water per day.

SUMMARY OF PAH CRITERIA

EPA weight-of-evidence classification for benzo(a)pyrene	B2
Oral carcinogenic potency factor for benzo(a)pyrene (q_1*)[a]	11.5 $(mg/kg/day)^{-1}$
Inhalation carcinogenic potency factor for benzo(a)pyrene (q_1*)[a]	6.1 $(mg/kg/day)^{-1}$
Oral RfD for naphthalene	0.41 mg/kg/day

[a]These potency factors have been suspended by EPA.

TABLE 1

CLASSIFICATION OF PAHs ACCORDING TO EVIDENCE FOR CARCINOGENICITY

Chemicals for which there is sufficient evidence that they are carcinogenic in animals:

Benzo(a)anthracene	7H-Dibenzo(c,g)carbazole
Benzo(b)fluoranthene	Dibenzo(a,e)pyrene
Benzo(j)fluoranthene	Dibenzo(a,h)pyrene
Benzo(k)fluoranthene	Dibenzo(a,i)pyrene
Benzo(a)pyrene	Dibenzo(a,l)pyrene
Dibenzo(a,h)acridine	Indeno(1,2,3-c,d)pyrene
Dibenzo(a,j)acridine	5-Methylchrysene
Dibenzo(a,h)anthracene	

Chemicals for which there is limited evidence that they are carcinogenic in animals:

Anthranthrene	Dibenzo(a,c)anthracene
Benzo(c)acridine	Dibenzo(a,j)anthracene
Carbazole	Dibenzo(a,e)fluoranthene
Chrysene	2-, 3-, 4-, and 6-Methylchrysene
Cyclopenta (c,d)pyrene	2- and 3-Methylfluoranthene

Chemicals for which the evidence is inadequate to assess their carcinogenicity:

Benzo(a)acridine	Coronene
Benzo(g,h,i)fluoranthene	1,4-Dimethylphenanthrene
Benzo(a)fluorene	Fluorene
Benzo(b)fluorene	1-Methylchrysene
Benzo(c)fluorene	1-Methylphenanthrene
Benzo(g,h,i)perylene	Perylene
Benzo(c)phenanthrene	Phenanthrene
Benzo(e)pyrene	Triphenylene

Chemicals for which the available data provide no evidence that they are carcinogenic:

Acenaphthene	Pyrene
Acenaphthylene	
Anthracene	
Dibenzofuran	
Fluoranthene	
2-Methylnaphthalene	
Naphthalene	

SOURCE: IARC 1983, 1984

REFERENCES

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (ATSDR). 1987a. Draft Toxicological Profile for Benzo(a)pyrene. October 1987

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (ATSDR). 1987b. Draft Toxicological Profile for Benz(a)anthracene. October 1987

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (ATSDR). 1987c. Draft Toxicological Profile for Benzo(b)fluoranthene. October 1987

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (ATSDR). 1987d. Draft Toxicological Profile for Chrysene. October 1987

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (ATSDR). 1987a. Draft Toxicological Profile for Dibenz(a,h)anthracene. October 1987

DIPPLE, A., MOSCHEL, R.C., and BIGGER, C.A.H. 1984. Polynuclear aromatic carcinogens. In Searle, C.E. ed. Chemical Carcinogens-Second edition. ACS Monograph 182. American Chemical Society. Washington, D.C.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980a. Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons. Office of Water Regulations and Standards, Washington, D.C. October 1980. EPA 44/5-80-069

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980b. Ambient Water Quality Criteria for Acenaphthene. Office of Water Regulations and Standards, Washington, D.C. October 1980. EPA 440/5-80-015

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980c. Ambient Water Quality Criteria Document for Fluoranthene. Office of Water Regulations and Standards, Washington, D.C. October 1980. EPA 440/5-80-049

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980d. Ambient Water Quality Criteria for Naphthalene. Office of Water Regulations and Standards, Washington, D.C. October 1980. EPA 440/5-80-059

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984a. Health Effects Assessment for Polycyclic Aromatic Hydrocarbons (PAHs). Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-013

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984b. Health Effects Assessment for Coal Tars. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-024

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984c. Health Effects Assessment for Benzo(a)pyrene. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-022

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984d. Health Effects Assessment for Naphthalene. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-014

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984e. Health Effects Assessment for Phenanthrene. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-029

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984f. Health Effects Assessment for Pyrene. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-030

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Health and Environmental Effects Profile for Naphthalene. Environmental Criteria Assessment Office, Cincinnati, OH

FRIERSON, M.R., KLOPMAN, G., and ROSENKRANZ, H.S. 1986. Structure-activity relationships (SARs) among mutagens and carcinogens: A Review. Environ. Mutagen. 8:283-327

HECHT, S.S., GRABOWSKI, W., and GROTH, K. 1979. Analysis of feces for B(a)P after consumption of charcoal-broiled beef by rats and humans. Fd. Cosmet. Toxicol. 17:223-227 (As cited in ATSDR 1987a)

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1973. IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans. Volume 3. Certain Polycyclic Aromatic Hydrocarbons and Heterocyclic Compounds. World Health Organization, Lyon, France.

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1983. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Vol. 32: Polynuclear Aromatic Compounds; Part 1, Chemical, Environmental, and Experimental Data. World Health Organization, Lyon, France

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1984. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Volume 33: Polynuclear Aromatic Compounds, Part 2, Carbon Blacks, Mineral Oils and Some Nitroarenes. World Health Organization, Lyon, France

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1985. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Volume 35: Polynuclear Aromatic Compounds, Part 4, Bitumens, Coal-tar and Derived Products, Shale-oils, and Soots. World Health Organization, Lyon, France

KAO, J.K., PATTERSON, F.K., and HALL, J. 1985. Skin penetration and metabolism of topically applied chemicals in six mammalian species including man: An in vitro study with benzo(a)pyrene and testosterone. Toxicol. Appl. Pharmacol. 81:502-516 (As cited in ATSDR 1987a)

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1977. Criteria for a Recommended Standard-Occupational Exposure to Coal Tar Products. Washington, D.C. DHEW (NIOSH) 78-107

NEAL, J., and RIGDON, R.H. 1967. Gastric tumors in mice fed benzo(a)pyrene:

A quantitative study. Tex. Rep. Biol. Med. 25:553-557

RIGDON, R., and NEAL, J. 1969. Relationship of leukemia to lung and stomach tumors in mice fed benzo(a)pyrene. Proc. Soc. Exp. Biol. Med. 130:146-148

SANDERS, C.L., SKINNER, C., and GELMAN, R.A. 1986. Percutaneous absorption of 7,10 14C-benzo(a)pyrene and 7,12 14C-dimethylbenz(a)anthracene in mice. JEPTO 2:25-34 (As cited in ATSDR 1987a)

SANTODONATO, J., HOWARD, P., and BASU, D. 1981. Health and ecological assessment of polynuclear aromatic hydrocarbons. J. Environ. Pathol. Toxicol. 5:1-364

THYSSEN, J., ALTHOFF, J., KIMMERLE, G., and MOHR, U. 1981. Inhalation studies with benzo(a)pyrene in Syrian golden hamsters. J. Natl. Cancer Int. 66:575-577

PENTACHLOROPHENOL

INTRODUCTION

Pentachlorophenol (PCP) and its sodium salt have been used as insecticides, algicides, herbicides, and fungicides, as well as wood preservatives. Materials treated with PCP include wood products, textiles, paints, adhesives, leather, pulp, paper, and industrial waste systems. Commercial PCP preparations contain impurities that include hexachlorobenzene, polychlorinated dibenzofurans, and polychlorinated dibenzo-p-dioxins. It is difficult to determine the extent to which the toxicity of commercial products is due to PCP or to its toxic impurities. PCP used in comparative studies is usually free of impurities.

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Pentachlorophenol is rapidly absorbed following oral, dermal, or inhalation exposure. Once absorbed, pentachlorophenol is distributed throughout the body, accumulating in the liver, kidneys, brain, spleen, and fat. It is not readily metabolized, since a large portion of the administered dose is excreted unchanged. The major metabolic reactions of pentachlorophenol are glucuronide conjugation and oxidative dechlorination. Elimination is biphasic, with an initial rapid phase followed by a period of much less rapid elimination. After chronic exposure, half-lives of 20 days were reported. The major route of elimination is in urine (EPA 1985a).

Pentachlorophenol is an uncoupler of cellular oxidation and phosphorylation, resulting in an increase in the basic metabolic rate (Gotz et al. 1980). Pentachlorophenol poisoning in humans is characterized by a profuse sweating, often accompanied by fever, weight loss, and gastrointestinal complaints. Liver and kidney involvement have been implicated in cases of fatal poisoning (EPA 1985a).

The major targets of pentachlorophenol toxicity seem to be the liver, kidneys, and central nervous system. In the liver, pentachlorophenol produces pigmentation and increased liver weight and induces hepatic enzymes (Johnson et al. 1973, Schwetz et al. 1978). The major renal effects of purified pentachlorophenol have been reported to be increased kidney weight (Johnson et al. 1973) and pigmentation (Schwetz et al. 1978). Reported effects on the central nervous system have included capillary congestion, chromatolysis of the nerve cells, and diffuse focal areas of perivascular lymphocyte and mononuclear infiltration (McGavack et al. 1941). Commercial pentachlorophenol containing chlorinated dibenzo-p-dioxins and dibenzofurans was more toxic than purified pentachlorophenol in subchronic animal studies (Goldstein et al. 1977).

Pentachlorophenol has not been shown to be carcinogenic (IARC 1982, Schwetz et al. 1978, BRL 1968). It has also produced negative results in an initiation/promotion study (Boutwell and Bosch 1959). NTP (1983) is currently testing technical grade pentachlorophenol and Dowicide EC-7 (pentachlorophenol) for carcinogenic activity. However, results from these studies are not yet available.

A number of teratogenicity studies have failed to clearly establish a teratogenic potential for pentachlorophenol, though fetotoxic effects have been detected (EPA 1985a).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

The International Agency for Research on Cancer (IARC) has classified pentachlorophenol in Group 3--inadequate evidence for carcinogenicity (IARC 1982). The EPA (1984a) classified pentachlorophenol in Group E--no evidence of carcinogenicity in humans.

The EPA Office of Drinking Water proposed a recommended maximum contaminant level (RMCL) of 0.22 mg/liter based on the Schwetz et al. (1978) study. Rats were fed doses of 0, 1, 3, 10, or 30 mg purified pentachlorophenol/kg bw/day for 24 months. At the highest dose level, increased serum glutamic pyruvic transaminase activity and pigmentation of the liver and kidney were observed in both males and females. At a dose of 10 mg/kg/day, pigmentation in the liver and kidney were observed in females but not in males. The dose of 3 mg/kg/day was considered a no-observed-adverse-effect level (NOAEL). The RMCL assumes that 20% of adults' total exposure to pentachlorophenol is attributable to drinking water (EPA 1985b). The EPA Office of Drinking Water issued a draft lifetime Health Advisory of 0.22 mg/liter for pentachlorophenol based on the Schwetz et al. (1978) study. The health advisory employs the same assumptions as the RMCL (EPA 1984b).

SUMMARY OF CRITERIA

EPA carcinogen classification	Group E
Oral AIS	0.03 mg/kg/day
Oral AIC	0.03 mg/kg/day
Proposed RMCL	0.22 mg/liter

RfD 0.03 mg/kg/day

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

BIONETICS RESEARCH LABORATORIES (BRL). 1968. Evaluation of the Carcinogenic, Teratogenic, and Mutagenic Activities of Selected Pesticides and Industrial Chemicals. Vol. 1. Carcinogenic Study. Prepared by BRL, Bethesda, Maryland, under Contract Nos. PH 43-64-57 and PH 43-67-735. Publ. No. NCI-DCCP-CG-1973-1-1. National Cancer Institute, Bethesda, Maryland. NTIS PB-223-159. P. 393

BOUTWELL, R.K., and BOSCH, K.K. 1959. The tumor-promoting action of phenol and related compounds for mouse skin. Cancer Res. 19:413-424

BUTYL BENZYL PHTHALATE

INTRODUCTION

Butyl benzyl phthalate is clear, oily liquid with a slight odor. It is used exclusively as a plasticizer for polyvinyl chloride in the manufacture of vinyl chloride floor tiles; in polyvinyl acetate emulsions used as adhesives for packaging; and as a plasticizer for other polymers including ethyl cellulose, acrylic resins, polyvinyl formal and polyvinyl butyral (Monsanto n.d.).

PHARMACOKINETICS

Very limited data exist on the absorption, metabolism or excretion of butyl benzyl phthalate. However, most phthalates are known to be poorly absorbed from the digestive tract (International Labour Office 1971). In numerous *in vivo* and *in vitro* studies, phthalate esters have been observed to be rapidly metabolized to phthalic acid and a monophthalate (Clayton and Clayton 1981-82). The monophthalate can be excreted unchanged or undergo side-chain hydroxylation at one or several positions (The Chemical Society 1977).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

CARCINOGENICITY

Butyl benzyl phthalate has been tested for carcinogenicity in chronic feeding studies using mice and female rats, and via intraperitoneal injection in male mice (IARC 1982). In female rats, an increased incidence of myelomonocytic leukemia was observed in the high exposure group. No increased tumor incidence was noted for mice (IARC 1982).

MUTAGENICITY

Butyl benzyl phthalate has been found to be nonmutagenic in procaryotic and eucaryotic test systems. In bacterial systems, butyl benzyl phthalate (30 mg/plate) was found to be a nonmutagen in *E. coli*, and negative in recombination repair assays using *E. coli* and *Bacillus subtilis*. It has also been shown to be nonmutagenic to strains of *Salmonella typhimurium* and *Saccharomyces cerevisiae* (with and without metabolic activation). In addition, butyl benzyl phthalate did not induce forward mutations at the TK locus of L5178Y mouse lymphoma cells (IARC 1982)

TERATOGENICITY/REPRODUCTIVE EFFECTS

Butyl benzyl phthalate failed to induce malformations in chicks when injected (0.05 ml) undiluted (0.05 g) into fertilized hens' eggs (Bower et al. 1970)

ACUTE/CHRONIC EFFECTS

The oral LD_{50} values for butyl benzyl phthalate in corn oil in Fischer 344 rats of both sexes have been reported as 2.33 g/kg bw and as 4.17 and 6.16 g/kg bw in $B6C3F_1$ female and male mice, respectively (National Toxicology Program 1981).

Dogs ingesting varying amounts of butyl benzyl phthalate in their diets for 90 days were reported to exhibit no alterations in hematological or urinary parameters and no gross or histopathological effects (Hammond 1981). Male and female rats fed diets containing butyl benzyl phthalate for 14 and 90 days exhibited no evidence of compound-related mortality. Body weight gain in the male and female Fischer 344 rats was depressed after 14 days at doses of 25,000 ppm and greater. In male rats fed 50,000 or 100,000 mg/kg in their diet, testicular degeneration was observed; thymic atrophy was reported in both male and female rats given 100,000 mg/kg. Male rats fed 25,000 mg/kg for 90 days had depressed body weight gain and testicular degeneration. No adverse effects were noted in female rats or mice in either study (National Toxicology Program 1981).

Benzyl butyl phthalate has also been found to inhibit the growth of cultured neonatal rat cerebellar cells in vitro; overt cytotoxic effects were noted at concentrations of 7×10^{-4} M and greater (Kasuya 1980, Teranishi and Kasuya 1980).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Available data inadequate to quantify toxic effects and recommend criteria.

REFERENCES

BOWER, R.K., HABERMAN, S., and MINTON, P.D. 1970. Teratogenic effects in the chick embryo caused by esters of phthalic acid. Pharmacol. Exp. Ther. 171:314-324

THE CHEMICAL SOCIETY. 1977. Foreign Compound Metabolism in Mammals. Volume 4: A Review of the Literature Published during 1974 and 1975. The Chemical Society, London. P. 239

CLAYTON, G.D., and CLAYTON, F.E. 1981-1982. Patty's Industrial Hygiene and Toxicology. Volumes 2A, 2B, 2C: Toxicology. 3rd ed. John Wiley and Sons, New York. P. 2343

HAMMOND, B.G. 1981. Toxicology of butyl benzyl phthalate. Toxicologist 1:114 (Abstract No. 414)

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1982. Monographs on the Evaluation of the Carcinogenic Risks of Chemicals to Humans. Some Industrial Chemicals and Dyestuffs. Volume 29, p. 193

INTERNATIONAL LABOUR OFFICE. 1971. Encyclopedia of Occupational Health and Safety. Vols. I and II. McGraw-Hill Book Co., New York. P. 1059

KASUYA, M. 1980. Toxicology of butylbenzyl phthalate (BBP) and other phthalate esters to nervous tissue in culture. Toxicol. Lett. 6:373-378

MONSANTO COMPANY. No date. Plasticizer and Resin Modifiers. Monsanto Industrial Chemicals Co., St. Louis, Missouri. P. 10

NATIONAL TOXICOLOGY PROGRAM (NTP). 1981. Bioassay of Butyl Benzyl Phthalate for Possible Carcinogenicity. U.S. Department of Health and Human Services, Washington, D.C. DHHS (NIH) Publication No. 80-1769. NTP No. 81-25

TERANISHI, H., and KASUYA, M. 1980. The effects of phthalate esters on fibroblasts in primary culture. Toxicol. Lett. 6:11-15

2-BUTANONE
(METHYL ETHYL KETONE)

INTRODUCTION

Methyl ethyl ketone (MEK, 2-butanone) is a colorless liquid generally used as a solvent for paint, nitrocellulose coatings, and vinyl films. It is also found in cements, adhesives, and cleaning fluids and is used in the manufacture of smokeless powder (Verschueren 1983).

TOXICOKINETICS

Absorption of methyl ethyl ketone from the gastrointestinal tract and from the lungs has been inferred from systemic toxic effects observed following acute oral exposure and acute and subchronic inhalation exposures (Lande et al. 1976).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

Methyl ethyl ketone has not been adequately tested for carcinogenicity and has produced only equivocal evidence of mutagenicity in a few bacterial assays (EPA 1984). Schwetz et al. (1974) reported that methyl ethyl ketone caused retarded fetal development and some teratogenic effects (acaudia, imperforate anus, and brachygnathia) at air concentrations of 3,000 ppm (9,000 mg/m^3).

Cavender et al. (1983) reported elevated serum glutamic pyruvic transaminase (SGPT) activity in female rats exposed via inhalation to 2,500 ppm MEK for 6 hours/day, 5 days/week for 90 days. At the 5,000-ppm exposure level, treated female rats exhibited significant increases in liver weight, liver-to-body weight ratio, and liver-to-brain ratio; significantly decreased SGPT activity; and increased phosphatase, potassium, and glucose levels. Takeuchi et al. (1983) reported slight neurological effects in rats exposed via inhalation to 200 ppm MEK 12 hours/day, 7 days/week after 4 weeks of exposure.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Applying the criteria proposed by the Carcinogen Assessment Group of EPA for evaluating weight of evidence (EPA 1986), methyl ethyl ketone is most appropriately classified in Group D--Not Classified. This category applies to agents for which no data were available regarding carcinogenicity in humans or animals.

EPA (1987a) has determined a risk reference dose (RfD) for methyl ethyl ketone based on a study by LaBelle and Brieger (1955) in which no effects were observed in 25 rats exposed to 235 ppm (693 mg/m^3 or 46 mg/kg/day) methyl ethyl ketone for 7 hours/day, 5 days/week for 12 weeks. Using a no-observed-adverse-effect level (NOAEL) of 235 ppm (46 mg/kg/day) and an uncertainty factor of 1000, an oral RfD of 0.05 mg/kg/day was derived.

The American Conference of Governmental Industrial Hygienists (1986) has recommended a time-weighted average threshold limit value (TLV) of 200 ppm (590 mg/m^3) for occupational exposure to methyl ethyl ketone. NIOSH (1978) has also recommended a time-weighted average threshold limit value of 590 mg/m^3.

EPA (1987b) has derived an an RfD inhalation exposure to methyl ethyl ketone of $5.0x10^{-2}$ mg/kg/day. The study on which this value is based was not reported.

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, Ohio

CANVENDER, F.L., CASEY, H.W., SALEM, H., SWENBERG, J.A., and GARALLA, E.J. 1983. A 90-day vapor inhalation toxicity study of methyl ethyl ketone. Fund. Appl. Toxicol. 3:264-270 (As cited in EPA 1984)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Methyl Ethyl Ketone. Office of Health and Environmental Assessment, Cincinnati, Ohio. September 1984. EPA 540/1-86-003

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Guidelines for carcinogen risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Integrated Risk Information Systems (IRIS). Envrionmental Criteria and Assessment Office. Cincinnati, Ohio. Revised September 30, 1987

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987b. Memo from Sandra Lee (Program Manager, Regional Support Team, Toics Integration Branch) to Addresses. Subject: Updated Reference Dose and Cancer Potency Numbers for Use in Risk Assessments. Office of Solid Waste and Emergency Response. Washington, D.C. October 1987. 19 Pp.

LABELLE, C.W., and BRIEGER, H. 1955. Vapour toxicity of a composite solvent and its principal components. Arch. Ind. Health 12:6523-627 (As cited in EPA 1987)

LANDE, S.S., DURKIN, P.R., CHRISTOPHER, D.H., HOWARD, P.H., and SAXENA, J. 1976. Investigation of Selected Potential Environmental Contaminants: Ketonic Solvents. U.S. Environmental Protection Agency, Washington, D.C. EPA 560/2-76-003 (As cited in EPA 1984)

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1978. Criteria for a Recommended Standard--Occupational Exposure to Ketones. DHEW (NIOSH) Publication No. 78-173

SCHWETZ, B.A., LEONG, B.K.J., and GEHRING, P.J. 1974. Embryo- and fetotoxicity of inhaled carbon tetrachloride, 1,1-dichloroethane and methyl ethyl ketone in rats. Toxicol. Appl. Pharmacol. 28:452-464 (As cited in EPA 1984

TAKEUCHI, Y., ONO, Y., HISANAGA, N., ET AL. 1983. An experimental study of the combined effects of n-hexane and methyl ethyl ketone. Br. J. Ind. Med. 40:199-203 (As cited in EPA 1984)

VERSCHUEREN, K. 1983. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold, New York

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984a. Health Effects Assessment for Pentachlorophenol. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-043

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984b. Draft Health Advisory for Pentachlorophenol. Office of Drinking Water, Washington, D.C. September 30, 1984

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. Drinking Water Criteria Document for Pentachlorophenol. Final Draft. Office of Drinking Water. March 1985. EPA 600X-84-177-1

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. National primary drinking water regulations; synthetic organic chemicals, inorganic chemicals, and microorganisms; proposed rule. Fed. Reg. 50:46936-47025 (November 13, 1985)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Verified Reference Doses (RfDs) of the U.S. EPA. ECAO-CIN-475

GOLDSTEIN, J.A., FRIESEN, M., LINDER, R.E., HICKMAN, P., JHAS, J.R., and BERGMAN, H. 1977. Effects of pentachlorophenol on hepatic drug-metabolizing enzymes and porphyria related to contamination with chlorinated dibenzo-p-dioxins and dibenzofurans. Biochem. Pharmacol. 26:1549-1557

GOTZ, R., SCHWARZ, L.R., and GREIM, H. 1980. Effects of pentachlorophenol and 2,4,6-trichlorophenol on the deposition of sulfobromophthalein and respiration of isolated liver cells. Arch. Toxicol. 44:147-155

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1982. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Supplement 4. Chemicals, Industrial Processes and Industries Associated with Cancer in Humans. World Health Organization, Lyon, France. Pp. 205-206

JOHNSON, R.L., GEHRING, P.J., KOCIBA, R.J., and SCHWETZ, B.A. 1973. Chlorinated dibenzodioxins and pentachlorophenol. Environ. Health Perspect., Exp. Issue No. 5, September. P. 171

McGAVACK, T.H., BOYD, L.J., PICCIONE, F.V., and TERRANOVA, R. 1941. Acute and chronic intoxication with sodium pentachlorophenate in rabbits. J. Ind. Hyg. Toxicol. 23:239

NATIONAL TOXICOLOGY PROGRAM (NTP). 1983. Chemical on Standard Protocol. NTP, Carcinogenesis Testing Program, Bethesda, Maryland. Available for Technical Resources Branch, Carcinogenesis Testing Program, NTP, Landau Bldg., Rm. A306, Bethesda, Maryland 20014

SCHWETZ, B.A., QUAST, J.F., KEELER, P.A., HUMISTON, C.G., and KOCIBA, R.J. 1978. Results of 2-year toxicity and reproduction studies on pentachlorophenol in rats. In Rao, K.R., ed. Pentachlorophenol: Chemistry, Pharmacology and Environmental Toxicology. Plenum Press, New York. P. 301

PHENOL

INTRODUCTION

Phenol is a high-volume industrial chemical that is widely used as an intermediate in the manufacture of other chemicals and is a by-product of combustion and some industrial processes. It is also produced by biological processes, e.g., microbial metabolism in the gut and metabolism of certain drugs in vivo (EPA 1980). It is a component of several over-the-counter medicines for both topical and oral administration.

PHARMACOKINETICS

Phenol is readily absorbed through the gut, by inhalation, and percutaneously. Following absorption, the compound is rapidly distributed systemically. The majority of phenol and its metabolites are excreted rapidly in the urine (EPA 1980).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

The National Cancer Institute (NCI 1980) conducted a subchronic (90-day) study and a carcinogenesis bioassay of phenol administered in drinking water to F344/N rats and $B6C3F^1$ mice. In the subchronic study, doses of 100, 300, 1,000, 2,000, and 10,000 ppm phenol were not associated with mortality or histological changes; rats and mice of both sexes receiving 10,000 ppm consumed less water than animals in the control or other treatment groups, and their body weights decreased. In the 105-week carcinogenesis bioassay, no treatment-related mortality, tumors, or nonneoplastic lesions were reported in rats or mice ingesting water containing 2,500 or 5,000 ppm phenol. A dose-related depression in mean body weight, which was related to decreased water consumption, occurred in both species of rodents.

Phenol exhibited tumor-promoting activity in the mouse skin painting system following initiation with 9,10-dimethyl-1,2-benzanthracene (DMBA) or benzo[a]pyrene (B[a]P), and it exhibited cutaneous carcinogenic activity in a sensitive mouse strain when applied at concentrations that produced repeated skin damage (EPA 1980).

There are no data in the literature on the carcinogenicity of inhaled phenol in experimental animals or humans. The compound is mutagenic in several systems but not in others (NCI 1980). There are no data on its teratogenicity (EPA 1984a).

Signs of acute phenol toxicity in humans and experimental animals are central nervous system depression, collapse, coma, cardiac arrest, and death. Acutely toxic doses can also cause extensive necrosis at the site of exposure (eyes, skin, oropharynx) (EPA 1980).

In a subchronic oral (gavage) study (Dow Chemical Co. 1976), rats received 0, 50, or 100 mg/kg phenol, 5 days/week (adjusted for 7-day exposure to 0, 35.7, or 71.4 mg/kg/day) until 135 or 136 doses were administered. A lowest-observed-adverse-effect level (LOAEL) of 50 mg/kg/day (adjusted for 7-day exposure to 35.7 mg/kg/day) was identified. Some of the animals in this

exposure group reportedly experienced slight kidney damage. However, lack of study details (numbers of animals, incidence figures, specific lesions) in the 1980 EPA document that summarized the study make these results unreliable for interpreting the toxic changes. Subchronic inhalation studies conducted by Deichmann and Witherup (1944) in guinea pigs, rabbits, and rats were inadequately designed (no control groups). Therefore, caution should be used in interpreting the reported pulmonary, myocardial, renal, and hepatic damage as compound induced. The results of other subchronic inhalation studies are difficult to interpret based on the information in secondary sources (EPA 1980, 1984a).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Applying the criteria for overall weight of evidence of carcinogenecity proposed by the Carcinogen Assessment Group of EPA (EPA 1984b), phenol has been classified in Group D--Not Classified (EPA 1984a). This category applies to agents for which there are no data available regarding carcinogenicity in humans or experimental animals.

EPA (1987) has derived an oral reference dose (RfD) based on an unpublished 1945 study by the Dow Chemical Company. In this 1945 study (reference not cited), groups of 10 rats were gavaged with 0, 50, or 100 mg/kg of phenol, 5 days/week (0, 35.7, or 71.4 mg/kg/day on a 7-day basis) until 135 or 136 doses were administered, after which surviving animals were killed for histopathological examination. The animals receiving 71.4 mg/kg/day of phenol showed a marked temporary drop in body weight gain but rapidly recovered. Surviving animals (6/10) in this group showed a very slight amount of cloudy swelling of the liver, while four animals had some kidney damage. In the animals (6/10) that survived treatment with 35.7 mg/kg/day phenol, two showed a slight kidney damage. Mortality was not treatment related. The low dose (35.7 mg/kg/day) was identified by EPA (1987) as the LOAEL for renal and hepatic lesions. Using a LOAEL of 35.7 mg/kg/day and an uncertainty factor of 1,000, an oral RfD of 4.0×10^{-2} mg/kg/day was derived.

An ambient water quality criterion (AWQC) based on organoleptic properties was established at 0.3 mg/liter (EPA 1980). However, it should be noted that there is no demonstrated relationship between organoleptic effects (taste and odor thresholds) and adverse health effects.

An inhalation acceptable intake chronic (AIC) of 1.4 mg/person/day (0.02 mg/kg/day) was recommended by EPA (1984a) based on the threshold limit value of 19 mg/m^3 phenol established by the American Conference of Governmental Industrial Hygienists (ACGIH 1983).

SUMMARY OF PHENOL CRITERIA

EPA carcinogen classification	Group D
Oral reference dose (RfD)	4×10^{-2} mg/kg/day
AIC (inhalation)	1.4 mg/person/day
AWQC	0.3 mg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1983. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1983-1984. Cincinnati, Ohio (As cited in EPA 1984a)

DEICHMANN, W.B., and WITHERUP, S. 1944. Phenol Studies. VI. The acute and comparative toxicity of phenol and o-, m-, and p-cresols for experimental animals. J. Pharmacol. Exp. Ther. 80:233 (As cited in EPA 1980)

DOW CHEMICAL CO. 1976. References and Literature Review Pertaining to Toxicological Properties of Phenol. Toxicol. Res. Lab. (unpublished manuscript) (As cited in EPA 1980)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Phenol. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C. October 1980. EPA 440/5-80-066

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984a. Health Effects Assessment for Phenol. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-007

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984b. Proposed guidelines for carcinogen risk assessment. Fed. Reg. 49:46294-46301 (November 23, 1984)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. Cincinnati, Ohio. Revised September 30, 1987

NATIONAL CANCER INSTITUTE (NCI). 1980. Bioassay of Phenol for Possible Carcinogenicity. CAS No. 108-95-2. NCI Carcinogenesis Technical Report Series No. 203. Washington, D.C. USDHHS Publication No. (NTP) 80-15

TETRACHLOROETHYLENE

Tetrachloroethylene is a moderately volatile liquid with important uses in commercial dry cleaning operations. It is also used in the textile industry in the synthesis of certain fluorocarbons and as a degreaser. Since it is not consumed during its various uses, it is a common contaminant in air, groundwater, and surface water (EPA 1987a).

TOXICOKINETICS

Tetrachloroethylene is readily absorbed through the lungs (IARC 1979) and to some extent from the gastrointestinal tract (EPA 1985a,b). Tetrachloroethylene vapors and liquid can be absorbed through the skin (rate and extent unspecified) (EPA 1985a,b). Only small amounts of tetrachloroethylene (less than 4% of the absorbed dose) are metabolized in humans (IARC 1979). The metabolic pathways of tetrachloroethylene are saturable and may involve an epoxide intermediate (IARC 1979). Metabolic products include trichloroethanol, trichloroacetic acid, and unidentified chlorinated products (IARC 1979). Elimination of unchanged tetrachloroethylene has been reported to be primarily via the lungs (IARC 1979); metabolite excretion is through the urine (EPA 1987a).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

CARCINOGENICITY

In a National Cancer Institute bioassay (1977), a high incidence of hepatocellular carcinoma was observed in both sexes of B6C3F1 mice administered tetrachloroethylene in corn oil by gavage 5 days per week for 78 weeks. Time-weighted average doses were 536 and 1,072 mg/kg bw/day in males and 386 and 772 mg/kg bw/day in females. No conclusion concerning the effects on Osborne-Mendel rats administered 471 to 949 mg/kg by gavage could be made because of high mortality rates and other technical flaws (NCI 1977).

NTP recently reported the results of inhalation studies on tetrachloroethylene (NTP 1986). There was some evidence of carcinogenicity in F344/N rats in which increased incidences of mononuclear cell leukemia were seen in both sexes and increased incidences of renal adenomas and carcinomas (combined) were seen in males only. Significantly increased incidences of hepatocellular carcinomas provided clear evidence of carcinogenicity in B6C3F1 mice of both sexes. Classification of tetrachloroethylene as a carcinogen in the rat is controversial because of questions raised concerning the relevance to man of increased incidences of mononuclear cell leukemia and about the validity of combining renal adenomas and carcinomas to achieve statistical significance (EPA 1987a).

MUTAGENICITY

The majority of mutagenicity studies, with a variety of test systems, revealed little or no evidence of mutagenic activity by tetrachloroethylene (EPA 1985a,b). Cerna and Kypenova (1977, abstract only) reported positive results in plate tests with S. typhimurium and in host-mediated assays (EPA 1985a,b).

TERATOGENICITY/REPRODUCTIVE EFFECTS

The offspring of female rats and mice exposed to tetrachloroethylene at 2,000 mg/m^3 for 7 hours daily on days 6-15 of gestation showed toxic effects, including a decrease in fetal body weight in mice and a small but significant increase in fetal resorption in rats (EPA 1985a,b). Mice also exhibited teratogenic effects, including subcutaneous edema and delayed ossification of skull bones and sternebrae (EPA 1985a,b).

ACUTE/CHRONIC EFFECTS

In mice, the reported oral LD50 values for tetrachloroethylene are 6.4-8 g/kg bw, 8.85, and 10.8 g/kg bw (IARC 1979). In rats, the oral LD50 is 13 g/kg bw (IARC 1979). The inhalation LC50 values in mice and rats with 4-hour inhalation exposures have been reported to be 5,200 ppm (IARC 1979) and 4,000 ppm (EPA 1985a,b), respectively.

The principal toxic effects of tetrachloroethylene in humans and animals from both acute and longer-term exposures include central nervous system (CNS) depression and fatty infiltration of the liver and kidney with concomitant changes in serum enzyme activity levels indicative of tissue damage (EPA 1985a,b).

Central Nervous System Effects

Individuals exposed to concentrations of tetrachloroethylene ranging from 6,258 to 10,600 mg/m^3 experienced lassitude, mental fogginess, and exhilaration, progressing at the higher dose to signs of inebriation (EPA 1980). People exposed to lower doses (136-1,018 mg/m^3) for 5 weeks noted deleterious effects at 678 mg/m^3 but not at 136 mg/m^3 (EPA 1987a). Signs of central nervous system depression and cholinergic stimulation were also observed at concentrations of 1,622 ppm tetrachloroethylene in an animal study in rabbits, monkeys, rats, and guinea pigs (EPA 1980).

Liver and Kidney Effects

Single oral gavage doses of 2,158 mg/kg tetrachloroethylene given to rabbits resulted in an increase in serum lipoprotein levels and serum enzymes (alkaline phosphatase, SGOT, SGPT) which were indicative of liver damage (EPA 1985a,b). Increased total lipid and triglyceride levels were observed in mice exposed to 800 ppm tetrachloroethylene in air for 3 hours (EPA 1985a,b). A dose-related increase in fatty infiltration of the livers of mice was observed following 4-hour inhalation exposures to 200 and 3,000 ppm (EPA 1985a,b).

Rats exposed to 1,600 ppm tetrachloroethylene 7 hours per day, 5 days per week, 18 times over 25 days exhibited central nervous system depression and hepatic and renal hypertrophy. Rats exposed to 230 ppm and 470 ppm tetrachloroethylene, 8 hours a day, 5 days a week, over a period of 7 months, exhibited congestion and swelling of kidneys and liver, respectively (Carpenter 1937 as cited in EPA 1985a,b). Female Sprague-Dawley rats exposed to tetrachloroethylene in air 5 days a week for 12 months at concentrations of 300 or 600 ppm showed liver atrophy, and the high-dose females developed an increased incidence of fluid-filled cysts in the liver (EPA 1980).

Fatty infiltration in the livers of mice was observed following exposures to 200 ppm, 4 hours per day, 5 days per week for 8 months (EPA 1985a,b). A high incidence of toxic nephropathy was seen in mice exposed by gavage to 386 and 1,072 mg/kg tetrachloroethylene for 78 weeks (NCI 1977).

In guinea pigs, a dose-dependent increase in liver weight and fatty infiltration of the liver was observed following exposure 100, 200, or 400 ppm tetrachloroethylene for up to 169 exposures over 236 days (Rowe et al. 1952).

Rabbits showed liver enzyme changes and renal function alterations following 200 to 300 ppm exposures, 4 hours per day, 5 days per week for 9 weeks (Brancaccio et al. 1971, Mazza 1972).

Three of seven men occupationally exposed to tetrachloroethylene at concentrations of 1,890-2,600 mg/m^3 showed evidence of impaired liver function (EPA 1980).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

EPA (1986, 1987c) has previously classified tetrachloroethylene in Group B2--Probable Human Carcinogen. This classification has been questioned by the Science Advisory Board, Halogenated Organics Subcommittee, which has recommended classification in Group C--Possible Human Carcinogen (EPA 1987a). An inter-office work group of EPA (1987b) is currently reviewing the status of tetrachloroethylene as a carcinogen. A risk assessment summary will be included in EPA's IRIS database when the review has been completed (EPA 1987b).

In its Health Assessment Document for tetrachloroethylene, EPA (1985a) reported carcinogenic potency factors ($q1^*$) for exposure to this compound by both ingestion and inhalation. Evaluation of the 1985 NTP data in a draft addendum to the health assessment document supported the quantitative results reported in the 1985 health assessment. The EPA Carcinogen Assessment Group (CAG) derived these values based on the results of the NCI (1977) gavage bioassay for mice cited above. Groups of 50 male and 50 female B6C3F1 mice received various levels of tetrachloroethylene in corn oil by gavage, 5 days per week, for 78 weeks. The time-weighted average doses for this study were 536 or 1,072 mg/kg/day for male mice, and 386 or 772 mg/kg/day for female mice. Control groups of 20 male and 20 female mice were also maintained. All surviving mice were killed at 90 weeks. Highly significant increases in the incidences of hepatocellular carcinomas were observed in treated mice. The incidences for these tumors were 2/20, 32/48, and 27/45 for the control, low-dose, and high-dose male mice, respectively, and 0/20, 19/48, and 19/45 for the control, low-dose, and high-dose female mice, respectively. The dose-response data for female mice were determined to be more reliable, and were therefore used to calculate a carcinogenic potency. Using the linearized multistage model and appropriate scaling factors, an oral carcinogenic potency factor of 5.1×10^{-2} $(mg/kg/day)^{-1}$ was derived. Based on the oral potency factor of 5.1×10^{-2} $(mg/kg/day)^{-1}$, the concentration in drinking water corresponding to a 10^{-6} excess lifetime cancer risk is 0.69 lg/liter. After adjusting for the amount of tetrachloroethylene metabolized after exposure to this compound in air, an inhalation carcinogenic potency factor of 2.5×10^{-1} $(mg/kg/day)^{-1}$ was

calculated, also based on the hepatocellular carcinoma data for female mice. This latter inhalation cancer potency factor has recently been reevaluated by the Toxics Integrations Branch of EPA (1987c). The value of 2.5×10^{-1} $(mg/kg/day)^{-1}$ has been superseded by a $q1^*$ of 3.3×10^{-3} $(mg/kg/day)^{-1}$. This basis for this change was not reported (EPA 1987c). The oral and inhalation cancer risk estimates for tetrachloroethylene are currently undergoing review by an inter-office work group of EPA (1987b).

The EPA Office of Drinking Water developed ten-day, longer-term, and lifetime health advisories (HAs) (EPA 1987a). The ten-day HA derived for a 10-kg child is 2,000 lg/liter. The HA is based on a study in which mice were treated by gavage with doses ranging from 20 to 2,000 mg/kg body weight, 5 days/week for 6 weeks. A no-observed-adverse-effect level (NOAEL) of 20 mg/kg body weight was identified based on significant increases in liver weight at higher doses. The longer-term HAs were also based on this study. Based on the NOAEL of 2 mg/kg body weight, a longer-term HA was derived for the 10-kg child consuming 1 liter of water per day and the 70-kg adult consuming 2 liters of water per day. These values are 1,400 lg/liter and 5,000 lg/liter, respectively.

The EPA (1987a) also derived a DWEL (lifetime HA) for tetrachloroethylene based on its classification as a Group C carcinogen. A DWEL is defined as the medium-specific exposure which is interpreted to be protective for noncarcinogenic end points of toxicity over a lifetime of exposure. A DWEL of 500 lg/liter was determined for a 70-kg adult ingesting 2 liters of water per day, based on the NOAEL of 20 mg/kg body weight established in the study cited above. The lifetime HA is then 10 lg/liter using a relative source
contribution of 20% and an uncertainty factor of 10.

EPA (1987b) derived an oral reference dose RfD for tetrachloroethylene based on an inhalation study by Carpenter (1937). In this study, groups of 24 rats (12/sex) were exposed to 1 of 3 doses by inhalation for 8 hours/day, 5 days/week for 7 months. No significant changes were observed at the low dose of 70 ppm. At 230 ppm, renal congestion and swelling were noted. At 470 ppm, the liver also was congested and exhibited cloudy swelling, which remained for 46 days after termination of exposure. The kidney showed increased secretion, cloudy swelling and desquamation; the spleen was congested and showed an increase in pigment content. Using a NOAEL of 70 ppm (19.4 mg/kg/day) and an uncertainty factor of 1000 (10 for intraspecies variability, 10 for interspecies variability, 10 for subchronic to chronic extrapolation), an oral RfD of 2.0×10^{-2} mg/kg/day was derived. In converting from an inhalation NOAEL to an oral dose of 19.4 mg/kg/day, the following dose conversion factors and assumptions were used: 70 ppm = 475 mg/cu. m x 1 cu. m/hour (assumed ventilation rate) x 8 hours/day x 5 days/7 days x 0.5 (assumed inhalation retention factor)/70 kg (assumed human body weight) = 19.4 mg/kg/day.

SUMMARY OF TETRACHLOROETHYLENE CRITERIA

EPA carcinogen classification	Under Review
Oral carcinogenic potency factor	5.1×10^{-2} (mg/kg/day)$^{-1}$ (Under Review)
Inhalation carcinogenic potency factor	3.3×10^{-3} (mg/kg/day)$^{-1}$ (Under Review)
MCLG (proposed)	0 lg/liter
Health Advisories (HA):	
Ten-Day HA (child)	2,000 lg/liter
Longer-term HA	
Child	1,400 lg/liter
Adult	5,000 lg/liter
Lifetime HA (DWEL)	500 lg/liter
RfD, verified	0.02 mg/kg/day
Drinking water concentration (corresponding to a 10^{-6} excess lifetime cancer risk)	0.69 lg/liter
AWQC (10^{-6} upperbound excess lifetime cancer risk)	0 (0.8 lg/liter)

REFERENCES

BRANCACCIO, A., MAZZA, V., and DiPAOLA, R. 1971. Renal function in experimental tetrachloroethylene poisoning. Folia Med. (Naples) 54:233-237 (As cited in EPA 1985a)

CARPENTER, C.P. 1937. The chronic toxicity of tetrachloroethylene. J. Ind. Hyg. Toxicol. 19:323-336 (As cited in EPA 1987b)

CERNA, M., and KYPENOVA, H. 1977. Mutagenic activity of chloroethylenes analyzed by screening system tests. Mutat. Res. 46:214-215

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Tetrachloroethylene. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C. October 1980. EPA 440/5-80-073

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. National primary drinking water regulations; volatile synthetic organic chemicals; proposed rulemaking. Fed. Reg. 49:24330-24355

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. Health Assessment Document for Tetrachloroethylene (Perchloroethylene). Office of Health and Environmental Assessment, Washington, D.C. July 1985. EPA 600/8-82-005F

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. Drinking Water Criteria Document for Tetrachloroethylene. Office of Drinking Water, Criteria and Standards Division, Washington, D.C. April 1985

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Addendum to the Health Assessment Document for Tetrachloroethylene (Perchloroethylene). External Review Draft. Office of Health and Environmental Assessment. April 1986

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Health Advisory for Tetrachloroethylene. Office of Drinking Water, Washington, D.C. March 31, 1987

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987b. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. Cincinnati, Ohio. Revised September 30, 1987

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987c. Memo from Sandra Lee (Program Manager, Regional Support Team, Toxics Integration Branch) to Addresses. Subject: Updated Reference Dose and Cancer Potency Numbers for Use in Risk Assessments. Office of Solid Waste and Emergency Response. Washington, D.C. October 1987 19 Pp

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC). 1979. IARC Monographs on the Evaluation of the Carcinogenic Risks of Chemicals to Humans. Vol. 20: Some Halogenated Hydrocarbons. World Health Organization, Lyon, France

MAZZA, V. 1972. Enzymatic chnages in experimental tetrachloroethylene poisoning. Folia Med. 55:373-381 (As cited in EPA 1985a)

NATIONAL CANCER INSTITUTE (NCI). 1977. Bioassay of Tetrachloroethylene for Possible Carcinogenicity. CAS No. 127-18-4. NCI Carcinogenesis Technical Report Series No. 13. Washington, D.C. DHEW (NIH) Publication No. 77-813

NATIONAL TOXICOLOGY PROGRAM (NTP). 1986. Toxicology and Carcinogenesis Studies of Tetrachloroethylene (Perchloroethylene) (CAS No. 127-18-4) in F344/N Rats and B6C3F1 Mice (Inhalation Studies). NTP Technical Report Series No. 311. Research Triangle Park, North Carolina. DHEW (NIH) Publication No. 86-2567

ROWE, V.K., McCOLLISTER, D.D., SPENCER, H.C., ADAMS, E.M., and IRISH, D.D. 1952. Vapor toxicity of tetrachloroethylene for laboratory animals and human subjects. AMA Arch. Ind. Hyg. Occup. Med. 5:566-579 (As cited in EPA 1985a)

TOLUENE

INTRODUCTION

Toluene occurs naturally in foods at ppb levels and as a component of petroleum oil. It is used in the production of benzene and other organic solvents and as a solvent for paints, coatings, gums, oils, and resins. It is also used as a gasoline additive to boost octane ratings (EPA 1987).

TOXICOKINETICS

In humans, toluene is absorbed quickly through the respiratory tract; dermal absorption of aqueous toluene is directly related to concentration (EPA 1985a). In rats nd rabbits, gastrointestinal absorption is rapid and almost complete (EPA 1984). Because of its lipophilic nature and low water solubility, toluene is expected to distribute and accumulate in lipid tissue (EPA 1985b). In humans and animals, toluene is excreted via the urine as the metabolite hippuric acid and through pulmonary exhalation as the unchanged compound (EPA 1985a).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

CARCINOGENICITY

A chronic (106-week) oral bioassay of toluene conducted in F344 rats of both sexes resulted in no carcinogenic effects (CIIT 1980 as cited in EPA 1985b). Gross and microscopic examination of tissues and organs revealed no increase in tumor incidences among rats treated at 30, 100, or 300 ppm when compared with controls. However, the highest dose used did not approach the maximum tolerated dose (MTD); therefore, it has been suggested that this bioassay may not have been an adequately test for carcinogenicity (EPA 1985b). Dermal studies suggest that toluene neither initiates nor promotes tumor development (EPA 1987). The National Toxicology Program is currently conducting an inhalation carcinogenicity bioassay in rats and mice (NTP 1987).

MUTAGENICITY

Toluene has been tested for genotoxicity by many investigators using various assays methods and has not been demonstrated to be genotoxic (EPA 1985a).

TERATOGENICITY/REPRODUCTIVE EFFECTS

Toluene administered by gavage to CD-1 mice at 260 mg/kg/day on days 6-15 of gestation produced embryo lethality. Higher doses (430 or 870 mg/kg/day) also caused fetal toxicity and cleft palates (Nawrot and Staples 1979 abstract as cited in EPA 1985b). Inhalation exposure of CFLP mice on days 6-13 of gestation resulted in decreased fetal weight of offspring (EPA 1984). Inhalation exposure of pregnant rats resulted in a significant increase in retardation of skeletal development, but no signs of internal or external malformations (EPA 1987).

ACUTE/CHRONIC EFFECTS

The oral LC50 in rats is between 6,400 and 7,500 mg/kg (EPA 1985b). The LC50 in rabbits is 12.2 g/kg (EPA 1985a). In experimental animals, acute oral and inhalation exposures to toluene result in central nervous system (CNS) depression and histological changes in the lungs, liver, and kidneys (EPA 1985b). In humans, the major acute effects of toluene (375-1,500 mg/m^3) are CNS depression and narcosis (EPA 1985b).

Toxic effects following prolonged exposure of experimental animals to toluene are similar to those seen following acute exposure, predominantly to the CNS, liver, kidneys, and lungs (EPA 1985b). In humans, chronic exposure to toluene vapors at levels of approximately 200 and 800 ppm has been associated with CNS and possibly, peripheral nervous system effects, hepatomegaly, and hepatic and renal function changes (EPA 1985b).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Applying EPA's criteria for evaluating the overall weight of evidence of carcinogenicity to humans (EPA 1986), the EPA Office of Environmental Criteria and ASsessment has determined that toluene is most appropriately classified in Group D--Not Classified (EPA 1984). This category indicates that the evidence for carcinogenicity in animals is inadequate (EPA 1986a).

EPA (1987) has derived an oral risk reference does (RfD) of 0.3 mg/kg/day. The oral RfD is based on a 24-month chronic inhalation study conducted in male and female F344 rats (CIIT 1980). Toluene was administered by inhalation at 30, 100, or 300 ppm to 120 male and female F344 rats, 6 hours/day, 5 days/week. The same number of animals was used as a control. Clinical chemistry, hematology, and urinalysis testing were conducted at 18 and 24 months. All parameters measured at the termination of the study were normal except for a dose-related reduction in hematocrit values in females exposed to 100 and 300 ppm toluene. Based on these findings, a no-observed-adverse-effect level (NOAEL) of 300 ppm (1130 mg/m^3 or 29 mg/kg/day). Using a NOAEL of 29 mg/kg/day and an uncertainty factor of 100, an oral Rfd of 0.3 mg/kg/day was derived. This chronic inhalation study was also used by EPA (1984) in its Health Effects Assessment Document as a basis for deriving an allowable intake for chronic exposure (AIC) by inhalation. By using the NOAEL of 300 ppm (1,130 mg/m^3), adjusting for continuous exposure, and applying an uncertainty factor of 100, an AIC of 1.5 mg/kg/day was calculated.

EPA/s Office of Drinking Water has proposed a maximum contaminant level goal (MCLG) of 2 mg/liter for toluene in drinking water, based on the CIIT (1980) study cited above (EPA 1985b).

The American Conference of Governmental Industrial Hygienists has recommended a time-weighted average threshold limit value of 100 ppm (approximately 435 mg/m^3) for occupational exposure to toluene (ACGIH 1986).

SUMMARY OF TOLUENE CRITERIA

EPA carcinogen classification	Group D
Oral RfD, verified	0.3 mg/kg/day
Inhalation AIC	1.5 mg/kg/day
Proposed MCLG	2 mg/liter

REFERENCES

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. ACGIH, Cincinnati, Ohio.

CHEMICAL INDUSTRY INSTITUTE OF TOXICOLOGY (CIIT). 1980. A twenty-four month inhalation toxicology study in Fischer-344 rate exposed to atmospheric toluene. Executive Summary and Data Tables. October 15, 1980.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1984. Health Effects Assessment for Toluene. Final Draft. Environmental Criteria and Assessment Office, Cincinnati, Ohio. September 1984. EPA 540/1-86-033

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985a. Drinking Water Criteria Document for Toluene. Office of Drinking Water, Washington, D.C. March 1985

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985b. National primary drinking water regulations; synthetic organic chemicals, inorganic chemicals, and microorganisms; proposed rule. Fed. Reg. 50:46936-47025 (November 13, 1985).

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986. Guidelines for carcinogenic risk assessment. Fed. Reg. 51:33992-34003 (September 24, 1986)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office. Cincinnati, Ohio. Revised September 30, 1987

NAWROT, P.S., AND STAPLES, R.E. 1979. Embryo-fetal toxicity and teratogenicity of benzene and toluene in the mouse. Teratology 19:41a (Abstract)

BIS(2-ETHYLHEXYL)PHTHALATE

INTRODUCTION

Bis(2-ethylhexyl)phthalate (di-ethylhexyl phthalate or DEHP) is widely used as a plasticizer, primarily in the production of polyvinyl chloride resins (EPA 1980). Polyvinyl chloride resins are used in construction materials, home furnishings, transportation, apparel, and food and medical packaging materials.

TOXICOKINETICS

The primary route of exposure to DEHP is via inhalation; ingestion of DEHP from surface water and from foods and beverages packaged in polyvinyl chloride products can also occur. DEHP is poorly absorbed through the skin (NIOSH 1985).

DEHP and its metabolites are readily absorbed from the gastrointestinal tract, and lungs. The absorption, distribution, and elimination of DEHP can be influenced by the vehicle in which it is administered (EPA 1980).

Absorbed DEHP is distributed to various organs and tissues in animals and humans, primarily to the lungs, heart, liver, kidney, gonads, and spleen. Excretion of DEHP occurs in urine and feces; excretion into bile also occurs and can increase the amount of DEHP (or metabolites) in the intestine (EPA 1980).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

CARCINOGENICITY

DEHP is reported to be carcinogenic in rats and mice, causing increased incidences of hepatocellular carcinomas or neoplastic nodules following oral administration (NTP 1982). Groups of 50 $B6C3F_1$ mice and 50 F344 rats of each sex were fed diets containing either 0, 3,000, or 6,000 ppm DEHP (mice) or diets containing 0, 6,000, or 12,000 ppm DEHP (rats). The dosing regimen was continuous (7 days/week) over a period of 103 weeks. Upon completion, a 1-2 week nontreatment period was allowed, after which survivors were sacrificed and examined grossly and microscopically. Histopathological analyses were conducted on all animals killed or discovered dead and included approximately 30 of the tissues/organs that are routinely examined according to the NTP rodent carcinogenicity protocol. In male and female mice, a dose-related increase in the incidence of hepatocellular carcinomas was noted. The incidence of hepatocellular carcinomas in low-dose and high-dose male mice was 14/48 and 19/50, respectively. The incidence of hepatocellular carcinomas in low-dose and high-dose female mice was 7/50 and 17/50, respectively. In the study with rats, a significant increase in the incidence of combined neoplastic nodules and hepatocarcinomas was noted in high-dose males (12/49) and high-dose females (13/50).

MUTAGENICITY

The results of dominant lethal experiments in mice suggest that DEHP is mutagenic when injected intraperitoneally (Singh et al. 1974). However, most experiments conducted with microorganisms and mammalian cells have failed to demonstrate genotoxic activity (EPA 1980).

TERATOGENICITY/REPRODUCTIVE EFFECTS

Singh et al. (1972) reported dose-related gross or skeletal abnormalities in mouse fetuses from pregnant females injected intraperitoneally with 5 or 10 ml/kg DEHP. Nikonorow et al. (1973) orally administered 0.34 and 1.70 g/kg/day DEHP to pregnant rats during the gestation period and reported a reduction in fetal weight and increased number of resorptions. Other reproductive effects, including testicular changes in mice and rats, have also been reported (NTP/IRLG 1982).

ACUTE/CHRONIC TOXICITY

DEHP appears to have a relatively low acute toxicity in experimental animals. The oral, intraperitoneal, and intravenous LD_{50} values reported for DEHP in rats are 31 g/kg, 30.7 g/kg, and 0.25 g/kg, respectively. DEHP is poorly absorbed through the skin, and no irritant response or sensitizing potential from dermal application has been noted in experimental animals or humans (NIOSH 1985, NTP/IRLG 1982, EPA 1980).

Chronic exposure to relatively high concentrations of DEHP in the diet can cause retardation of growth and increased liver and kidney weights in experimental animals (NTP/IRLG 1982, EPA 1980).

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

EPA (1986b, 1987c) has previously classified DEHP as a Group B2 carcinogen for both oral and inhalation exposure. This classification applies to those agents for which there is inadequate evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals.

EPA (1986a, 1987a) previously published an oral cancer potency factor for DEHP of 8.36×10^{-3} $(mg/kg/day)^{-1}$. This potency value was derived using data for male mice from the NTP (1982) study. Under conditions of the NTP (1982) investigation, DEHP was a hepatocarcinogen in $B6C3F_1$ mice and F344 rats.

An interoffice work group of EPA (1987b) recently evaluated DEHP for evidence of human carcinogenic potential and confirmed the value listed above (EPA 1988).

EPA (1987b) has recommended an oral reference dose (RfD) of 0.02 mg/kg/day for DEHP. This value was based on a study by Carpenter et al. (1953) in which guinea pigs were fed diets containing 0%, 0.04%, or 0.13% DEHP for 1 year. No treatment-related effects were observed on mortality, body weight, kidney weight, or on gross pathology or histopathology of kidney, liver, lung, spleen, or testes. Statistically significant increases in relative liver weights were observed in both groups of treated females (64 and 19 mg/kg/day). Using

19 mg/kg/day as the lowest-observed-adverse-effect level and a safety factor of 1,000, the RfD of 0.02 mg/kg/day was derived.

EPA (1980) derived an acceptable daily intake (ADI) for DEHP from the results of a chronic ingestion study in rats, guinea pigs, and dogs. Although details of this derivation were not presented, an ADI of 0.6 mg/kg/day (42 mg/day) was calculated. Based on this value, EPA recommended an ambient water quality criterion (AWQC) of 15 mg/liter for protection of human health from the toxic properties of DEHP ingested through water and contaminated aquatic organisms. The AWQC for exposure to DEHP in drinking water alone was 21 mg/liter.

SUMMARY OF DEHP CRITERIA

EPA carcinogen classification	B2
Oral cancer potency factor (q_1*)	8.36×10^{-3} $(mg/kg/day)^{-1}$
RfD	0.02 mg/kg/day
AWQC:	
Ingestion of water and aquatic organisms	15 mg/liter
Ingestion of water	21 mg/liter

REFERENCES

CARPENTER, C.P., WEIL, C.S., and SMYTH, H.F. 1953. Chronic oral toxicity of di(2-ethylhexyl)phthalate for rats, guinea pigs and dogs. Arch. Indust. Hyg. Occup. Med. 8:219-226

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1980. Ambient Water Quality Criteria for Phthalate Esters. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C. October 1980. EPA 40/5-80-067

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986a. Drinking Water Criteria Document of Phthalic Acid Esters (PAEs). Draft. Environmental Protection Agency, ECAO/OHEA, Cincinnati, Ohio. August 1986 (As cited in Salinas 1988)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1986b. Superfund Health Evaluation Manual. Exhibit C-4. Office of Emergency and Remedial Response, Washington, D.C. October 1986. EPA 540/1-86-060

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Health and Environmental Effects Profile for Phthalic Acid Alkyl, Aryl, and Alky/Aryl Esters. Draft. Environmental Protection Agency, ECAO/OHEA, Cincinnati, Ohio. September 1987 (As cited in Salinas 1988)

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987b. Integrated Risk Information System (IRIS). Bis(2-ethylhexyl)phthalate. Environmental Criteria and Assessment Office, Cincinnati, Ohio. Revised September 30, 1987

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987c. Memo from Sandra Lee (Program Manager, Regional Support Team, Toxics Integration Branch) to Addresses. Subject: Updated Reference Dose and Cancer Potency Numbers for Use in Risk Assessments. Office of Solid Waste and Emergency Response, Washington, D.C. October 1987. 19 pp.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1988. Status of RfD and CRAVE Work Group Outputs. Memo from Jacqueline Patterson, Mehtods Evaluation and Development Staff, Environmental Criteria and Assessment Office, Cincinnati, Ohio. January 25, 1988

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1985. Registry of Toxic Effects of Chemical Substances Data Base. Washington, D.C. July 1985

NATIONAL TOXICOLOGY PROGRAM (NTP). 1982. Carcinogenesis Bioassay of Di(2-ethylhexyl)phthalate in F344 Rats and B6C3F$_1$ Mice. Feed Study. NTP Technical Report Series No. 217, U.S. Department of Health and Human Services. NIH Publication No. 82-1773. NTP-80-37

NATIONAL TOXICOLOGY PROGRAM/INTERAGENCY REGULATORY LIAISON GROUP (NTP/IRLG). 1982. The Conference on Phthalates. Environ. Health Perspect. 45:1-153

NIKONOROW, M., ET AL. 1973. Effect of orally administered plasticizers and polyvinyl chloride stabilizers in the rat. Toxicol. Appl. Pharmacol. 26:253 (As cited in EPA 1980)

SALINAS, J.A. 1988. Overview of Risk Assessment Procedures Used in Six Documents on Bis(2-ethylhexyl)phthalate. Unpublished background document to be used at the workshop on risk assessment of DEHP, Bethesda, Maryland, April 19-20, 1988. Prepared by the Eastern Research Group, Arlington, Massachusetts. Work Assignment No. 88-6. Contract 68-02-4404. April 6, 1988. 41 pp.

SINGH, A.R., et al. 1972. Teratogenicity of phthalate esters in rats. J. Pharmacol. Sci. 611 (As cited in EPA 1980)

SINGH, A.R., et al. 1974. Mutagenic and antifertility sensitivities of mice to di-2-ethylhexylphthalate (DEHP) and dimethoxyethyl phthalate (DMED). Toxicol. Appl. Pharmacol. 29:35 (As cited in EPA 1980)

APPENDIX O
MODELS USED FOR ENDANGERMENT ASSESSMENT

APPENDIX O

SEDIMENT/SURFACE WATER EXPOSURE MODEL

INTRODUCTION

In order to assess the potential impacts from contaminated sediments at the Republic Steel site on aquatic life and those who may consume fish from the quarry, a simple screening model was developed. The model develops a relationship between contaminant levels in the sediments and surface water of the site. The model uses sediment chemical concentrations detected during the RI for input to calculate the average annual surface-water concentration. The surface-water concentration is used to assess the risk to aquatic life and to those individuals consuming fish from the pond under a no-action remedial alternative. This model treats the ratios between contaminants in sediment and water as if they were at equilibrium. The actual extent of the approach to equilibrium is currently unknown, however, this model derives concentrations in the water column which are plausible upper bounds.

SEDIMENT/WATER PARTITIONING

The chemical concentration in water (C_W) is derived from the sediment concentration as follows:

$$C_W = C_S / K_D$$

where

C_S = concentration in the on-site sediments (ug/kg), and

K_D = sediment-water equilibrium partition coefficient (ml/g).

The partition coefficient is defined as

$$K_D = (K_{OC})(f_{OC})$$

where

K_{OC} = organic carbon partition coefficient (ml/g), and

f_{OC} = fraction of organic carbon in the sediment, assumed to be 0.12 (12%) for the Republic Steel site, based on the median value of total organic carbon analyses of sediment samples.

Dissolved chemical concentrations in the interstitial water of the sediments are then diluted by the estimate of dilution developed in the following section.

ESTIMATION OF INTERSTITIAL WATER DILUTION

Because fish in the quarry are expected to reside in the upper 30 feet of the water column as described in the text, the dilution factor will be determined by creating a ratio between this 30 foot column of water and the thickness of the interstitial water. For the purposes of the model it is assumed that the sediment is equally distributed over the bottom of the quarry, this is accomplished by calculating an arithmetic mean of available sediment thicknesses. This calculation gives us a thickness of 4 inches. Thus, a dilution factor of 90 is achieved.

ESTIMATION OF FISH TISSUE CONCENTRATION

To estimate concentrations of chemicals in fish tissue, chemicals in the water column calculated in the above section and detected in the preliminary RI are summed and this value is multiplied by available bioconcentration factors (BCFs).

SAMPLE CALCULATION

Sample calculation for estimating surface water concentrations using the sediment/surface water exposure model (for carcinogenic PNAs).

$C_w = C_s/K_d$

C_s = 3,000 ug/kg (ppb) (average concentration)

$K_d = K_{oc} * f_{oc}$

$K_{oc} = 5.5 \times 10^6$ (Mabey, et al., 1982)
f_{oc} = 12% (from this study)
$K_d = 6.6 \times 10^5$

C_w for interstitial water concentration

C_w in ug/l = 4.5×10^{-3}

C_w in surface water = (C_w in interstitial water)(dilution factor of 90)

= 5×10^{-5} ug/l

BCF for cPNA = 920 (Mabey, et al., 1982)

$C_w \times BCF = (5 \times 10^{-5}$ ug/l)(920)
= 4.6×10^{-2} ug/kg
= 4.6×10^{-5} mg/kg concentration in fish

APPENDIX P
CALCULATIONS USED TO PREDICT RISK

SUMMARY OF CALCULATIONS USED TO ESTIMATE CONTAMINANT INTAKES

This appendix provides an explanation of the approached used to calculate human exposures to contaminants present at the site.

INCIDENTAL INGESTION OF CONTAMINATED SOIL

Total contaminant dose ingested over an individual's lifetime is estimated by the equation:

$$TD_i = C_s(F)(L)(DER)(X)(ABS)$$

where

TD_i = total dose ingested over a lifetime in mg;

C_s = chemical concentration in soil in mg/kg;

F = frequency of exposure in days per year;

L = length of exposure in years;

DER = daily exposure rate for incidental soil ingestion in mg/day;

X = conversion factor of 1 kg/10^6 mg; and

ABS = soil ingestion absorption factor.

PNAs are likely to be absorbed relatively strongly to ingested soils and are likely to have a reduced bioavailablility compared with chemicals that are administered orally in an experimental setting in food mash or a solvent medium. An oral absorption factor of 0.15 to 0.45 is used for these compounds.

Using the total lifetimendose calculatd above, the chronic daily intake averaged over a lifetime is calculated by the equation:

$$CDI = TD_i(Y)/(L)(BW)$$

where

CDI = chronic daily intake in mg/kg/day;

Y = coversion factor of 1 year/365 days;

L = lifetime of 70 years; and

BW = body weight in kg.

DERMAL CONTACT WITH CONTAMINATED SOIL

Total contaminant contact with the skin over an individual's lifetimen is estimated by the equation:

$$TD_d = C_s(F)(L)(CR)(A)(X)$$

where

TD_d = total dermal dxposure over a lifetime in mg;

CR = daily soil contact rate in mg/cm^2;

A = skin surface area exposed in cm^2.

The daily dermal exposure averaged over a lifetime is calculated by the equation:

$$ADE = TD_d(Y)/(L)(BW)$$

where

ADE = average dermal exposure in mg/kg/day.

INGESTION OF CONTAMINATED WATER

Chronic daily intake of chemical contamination through ingestion over an individual's lifetime is estimated by the equation:

$$CDI = \frac{(C_w)(IR)(ABS)}{(ABW)}$$

where

C_w = chemical concentration in water (mg/l),

IR = ingestion rate (L/day),

ABS = ingestion absorption factor (%), and

ABW = average body weight (kg).

INGESTION OF CONTAMINATED FISH

Chronic daily intakes of chemicals of potential concern via ingestion of

contaminated fish are estimated as follows:

$$CDI = \frac{(C_F)(FI)(E)(YR)(W)}{(BW)(D)(YL)}$$

where

CDI = chronic daily intake (mg/kg/day),
C_F = chemical concentration in fish (mg/kg),
FI = amount of fish ingested per meal (g/event),
E = number of fish meals per year from the on-site quarry,
YR = years of exposure,
W = conversion factor (kg/1000g),
BW = average body weight (kg),
D = days in the year (365), and
YL = years for which risk is estimated.

APPENDIX Q
TECHNOLOGY SCREENING

TABLE Q-1
IDENTIFICATION OF APPLICABLE SURFACE SOIL
TECHNOLOGIES AND PROCESS OPTIONS
REPUBLIC STEEL QUARRY RI

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
NO ACTION	NONE Leave site as is.	Yes	The NCP requires No Action to be carried through to detailed analysis of alternatives. Health and environmental hazards make this a non-viable option.
ACCESS RESTRICTIONS	USE LIMITATIONS Deed Restrictions: All deeds for property within potentially contaminated areas would include restrictions on use of property.	Yes	Viable alternative for reducing exposure to contaminated soil.
	Site Fencing: Fencing around the site and drainage ditches would be upgraded. All fencing would be maintained as necessary.	Yes	Viable alternative for reducing human exposure to contaminated soils.
	Runoff Monitoring: Collect and analyze storm water and transported soil/sediment runoff to detect changes in runoff quality.	No	Offsite soils not identified as problem.
CONTAINMENT	SURFACE CONTROLS Soil Stabilization. Chemical binders and tacks are sprayed on bare soils or mulches to coat, penetrate and bind together the particles, thus reducing erosion and soil water loss and enhancing plant growth.	No	Short term solution only; does not meet goals of NCP. Prevents erosion, but does not reduce leaching of soil contaminants to saturated zone.
	Revegetation. Establish vegetative cover which will reduce erosion and contribute to the development of a naturally fertile and stable surface environment. Vegetation may be grasses, shrubs, legumes, or trees.	No	Does not significantly reduce contact with contaminated soils.
	Soil Cover. Cover contaminated soils at site with soil and establish vegetative cover to reduce potential for direct contact, erosion, volatilization or dust generation.	Yes	Viable alternative to reduce contact with contaminated soils.
	Surface Sealing. Application of water, emulsions or resins to form erosion resistant surface.	No	This is only a temporary solution. May be applicable during construction phase of other technologies, but as a long-term remedy this technology does not meet NCP goals.

TABLE Q-1 (Page 2 of 6)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
CONTAINMENT (cont'd)	CAPPING		
	Single Layer Cap. Cover contaminated solids with a single layer of low permeability material such as clay, asphalt, or concrete to contain contaminated solids.	Yes	Viable alternative to reduce contact with contaminated soils.
	Multi-layered Cap. Combine several layers of cover materials such as soil, synthetic membrane, and clay to provide erosion and moisture control in addition to containing the soil or sediment.	Yes	Viable alternative to reduce contact with contaminated soils.
	Chemical Sealants/Stabilizers. Application of water dispersible emulsions or resins which form a protective crust over soil.	No	Temporary solution. Does not meet long-term goals of NCP.
	VERTICAL BARRIERS		
	Use of slurry walls, grout curtains, sheet piles or vibrating beam methods to reduce horizontal contaminant migration.	No	Horizontal migration of soil contaminants is not a concern.
	HORIZONTAL BARRIERS		
	Use of block displacement or injection grouting to reduce downward migration of contaminants into saturated zone.	No	Vertical migration of soil contaminants not a concern.
REMOVAL	EXCAVATION/DEMOLITION		
	Mechanical Excavation. Excavate contaminated soil by means of conventional construction equipment such as backhoes, hydraulic excavators, front-end loaders, bulldozers, or hand tools. Larger equipment such as dragline or clamshell excavators may be utilized for deep excavation.	Yes	Viable alternative for removal of contaminated solids.
TREATMENT	DEWATERING		
	Decrease in water content of solid or semi-solid waste by use of various physical processes, such as gravity thickening, centrifuges, belt filter presses, etc., or the use of drying beds to remove excess water.	No	Considered to be a pretreatment step that would be analyzed in conjunction with other technologies.

TABLE Q-1 (Page 3 of 6)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	PRELIMINARY PROCESSING		
	Pretreatment of solid wastes by various methods, such as crushing and grinding, separation of metal by magnetic processes, separation by screening, etc.	No	Considered as a pretreatment alternative, does not remediate solids contamination. May be a necessary step in various other treatment processes.
	PHYSICAL TREATMENT		
	Solvent Leaching. Removal of contaminants soluble in the leaching solvent by flushing with the solvent. The solvent must be treated or disposed.	Yes	Viable technology for removing organics from contaminated soils.
	Critical Fluid Extraction. Extraction of organics from solid wastes by forcing a solvent (generally CO_2) at its critical point through the waste. Organic components are transferred to the solvent. Contaminants are released from the solvent when it is returned to standard conditions.	No	Technology is still in the experimental stages.
	Water Leaching. Removal of water-soluble contaminants from soil by flushing with water. The water must be treated or disposed.	No	Organic contaminants are not readily soluble in water.
	SOLIDIFICATION, FIXATION, AND STABILIZATION		
	Increase in solids content of waste by addition of sorbents, decrease in fluidity of mass by addition of lime or cement, or coating of individual particles or the entire mass in a protective jacket.	No	Considered to be a pretreatment step that would be analyzed in conjunction with other technologies.
	CHEMICAL TREATMENT		
	Neutralization. Neutralization of solid wastes by the application of acids or bases.	No	Multi-contaminant wastes are inappropriate for neutralization due to potential for side reactions. pH extremes are not a concern.
	Oxidation. Chemical oxidation of contaminants by application of oxidizing agents. Generally used to treat organic compounds.	No	Oxidation is difficult to implement in a multi-contaminant situation due to the potential for side reactions, possibly explosive.
	Reduction. Chemical reduction of contaminants by application of reducing agents. Generally used to treat hexavalent chromium and other metals.	No	Reduction is difficult to implement in a multi-contaminant situation due to the potential for side reactions.

TABLE Q-1 (Page 4 of 6)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	Other Chemical Modifications. Chemical modification of contaminants rendering them inert. Treatments include hydrolysis, photolysis, catalysis, and others.	No	The large number of contaminants present would make implementation of these technologies difficult due to differing reactivities and chemical specificity of reagents.
	BIOLOGICAL TREATMENT		
	New Biotechnologies. Use of a controlled reactor utilizing modified micro-organisms selected for their ability to degrade and metabolize specific organic compounds. New biotechnologies include cultured micro-organisms, genetic engineered micro-organisms, and enzyme systems.	No	Can not treat coarse or fine fractions of soil mass; primarily for use on clean sands. Currently in developmental stage.
	Land Treatment. Utilization of the natural biological processes of soils and vegetation for stabilization and destruction of organic wastes. Processes include land farming and spray irrigation.	No	Difficult to obtain administrative approval due to potential for groundwater contamination, large area requirements, and public concern over introduction of NPL site wastes into uncontaminated areas.
	Aerobic Biological Treatment - Composting. Aerobic, thermophilic decomposition of organic solids by micro-organisms. Organic solids are placed in a pile or a reactor vessel and aerated by mechanical turning or by aeration headers buried in the solids.	No	Large volume of organic solids are not present. Most of the contaminated solids consist of soils containing VOC's, BNA's and heavy metals.
	THERMAL TREATMENT		
	Incineration. For a rotary kiln system, waste is injected into a horizontal, rotating, refractory-lined steel cylinder where it is incinerated at temperatures up to 2,000° F. Combustion gases are passed through an afterburner and scrubbed before release. Both conventional, permanent systems and mobile systems are available.	Yes	Viable alternative for treatment of contaminated soils.
	Codisposal Processes. Use of waste mixed with other combustible material as a supplemental fuel source for an existing industry. Includes the use of power generation boilers, cement kilns, lime kilns, and municipal sludge or refuse incinerators.	No	Not applicable to high ash content solids such as contaminated soils.

TABLE Q-1 (Page 5 of 6)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
	Pyrolysis. Thermal liberation of volatile organic compounds in the absence of oxygen. Volatile gases released are burned in an afterburner. Applicable processes are conventional pyrolytic reactor and rotary hearth pyrolyzer.	No	Most of the specific technologies are more applicable to trash, sludges, or liquids.
	IN-SITU TREATMENT		
	Neutralization. Application or injection of substances into the contaminated site to neutralize the pollutants present. Neutralizing agents are waste specific.	No	Multi-contaminant waste would be difficult to neutralize. Technique is not fully developed for use on contaminated soil or buried material.
	Oxidation. Degradation of oxidizable compounds by the addition of oxidizing agents or by the natural action of the soil.	No	Oxidizing agents may cause violent reactions when applied to multi-contaminant systems, and may mobilize metals.
	Reduction. Degradation of reducible compounds by the addition of reducing agents or by the natural action of the soil.	No	Difficult to assess the toxicity and potential mobility of reduction products, particularly in a complex, multi-contaminant system.
	Bioreclamation. Includes surface, subsurface, and bacterial augmentation systems. Degradation of hazardous chemicals by enhancing the biodegradation activity of native soil micro-organisms. Methods include manipulating oxygen, nutrient, and moisture content of the soil. Augmentation involves the addition of commercially available microbial cultures.	No	Low permeability of subsurface strata limits ability to control oxygen, nutrient, and moisture content. Surface bioreclamation alone does not satisfy NCP goals (subsurface waste could leach to groundwater).
	Immobilization. Immobilization of waste constituents within the soil mass by natural soil processes or the addition of immobilizing agents. Three major types of immobilization are sorption, ion exchange, and attentuation.	No	Technology is not fully developed and the long-term stability of immobilizing agent/waste constituent complexes is not known.
	Polymerization. Conversion of organic waste constituents to less mobile polymers by the addition of a catalyst and an activator.	No	Technology is still experimental.

TABLE Q-1 (Page 6 of 6)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT	Photolysis. Degradation of photo-degradable organic constituents utilizing incident solar radiation. Soil generally requires mixing to increase solar exposure.	Yes	Viable technology for treatment of soils contaminated with organics.
	Vitrification. Melting and solidification of the contaminated soil into a glass-like material by passing an electrical current through the soil. Gases omitted during the process are collected and treated.	Yes	Viable alternative for treatment of contaminated soils.
	Soil Vapor Extraction. Application of a vacuum to wells or perforated pipe installed in the vadose zone. This creates an air flow through the soil which will strip VOC's.	No	VOCs not a problem associated with site soils.
DISPOSAL	ONSITE DISPOSAL		
	RCRA Landfill. Permanent storage facility on site, double lined with clay and a synthetic membrane liner and containing a leachate collection/detection system.	Yes	Viable alternative for onsite disposal.
	Vault. Disposal of contaminated solids in a concrete vault on site.	Yes	Viable alternative for onsite disposal.
	Unlined Landfill. Replacement of treated solids into the excavation from which they were taken, covered by a multi-layer cap.	Yes	Viable alternative for materials treated on site.
	OFFSITE DISPOSAL		
	RCRA Landfill. Transport excavated soil or sediment to a RCRA approved landfill. May require dewatering or solidification prior to transport.	Yes	Viable alternative for solid wastes; however, this does not satisfy the goals of SARA.
	LAND APPLICATION Incorporation of low-level solid hazardous wastes into the upper soil horizon where hazardous constituents are degraded by the natural action of the soil.	No	Difficult to obtain administrative approval due to potential for groundwater contamination, large area requirements, and public concern over the introduction of NPL sites wastes into uncontaminated areas.

TABLE Q-2
IDENTIFICATION OF APPLICABLE QUARRY SEDIMENT
TECHNOLOGIES AND PROCESS OPTIONS
REPUBLIC STEEL QUARRY RI

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
NO ACTION	NONE Leave site as is.	Yes	The NCP requires No Action to be carried through to detailed analysis of alternatives. Health and environmental hazards make this a non-viable option.
ACCESS RESTRICTIONS	USE LIMITATIONS Deed Restrictions: All deeds for property within potentially contaminated areas would include restrictions on use of property.	Yes	Viable alternative for reducing fishing and subsequent ingestion of fish.
	Site Fencing: Fencing around the site and drainage ditches would be upgraded. All fencing would be maintained as necessary.	Yes	Viable alternative for reducing fishing and subsequent ingestion of fish.
	Runoff Monitoring: Collect and analyze storm water and transported soil/sediment runoff to detect changes in runoff quality.	No	Offsite sediments not identified as a problem.
CONTAINMENT	HORIZONTAL BARRIERS Placement of a horizontal barrier to prevent fish from contact with sediments.	Yes	Viable technology to prevent uptake of contaminants by fish.
REMOVAL	EXCAVATION		
	Sediment Excavation. Removal of sediments by various methods, such as conventional excavating equipment, or hydraulic or pneumatic dredging equipment.	Yes	Viable alternative for removal of contaminated sediments.
TREATMENT	DEWATERING Decrease in water content of solid or semi-solid waste by use of various physical processes, such as gravity thickening, centrifuges, belt filter presses, etc., or the use of drying beds to remove excess water.	No	Considered to be a pretreatment step that would be analyzed in conjunction with other technologies.

Table Q-2 (Page 2 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	PRELIMINARY PROCESSING		
	Pretreatment of solid wastes by various methods, such as crushing and grinding, separation of metal by magnetic processes, separation by screening, etc.	Yes	Viable alternative for treatment of contaminated sediments.
	PHYSICAL TREATMENT		
	Solvent Leaching. Removal of contaminants soluble in the leaching solvent by flushing with the solvent. The solvent must be treated or disposed.	Yes	Viable alternative for removing organics from contaminated sediments following removal from quarry.
	Critical Fluid Extraction. Extraction of organics from solid wastes by forcing a solvent (generally CO_2) at its critical point through the contaminated solid. Organic components are transferred to the solvent. Contaminants are released from the solvent when it is returned to standard conditions.	No	Technology is still in the experimental stages.
	Water Leaching. Removal of water-soluble contaminants from soil by flushing with water. The water must be treated or disposed.	No	Organic contaminants are not readily soluble in water.
	Vitrification. Melting and solidification of the contaminated soil into a glass-like material by passing an electrical current through the soil. Gases omitted during the process are collected and treated.	Yes	Viable alternative for treatment of contaminated sediments.
	SOLIDIFICATION, FIXATION, AND STABILIZATION		
	Increase in solids content of waste by addition of sorbents, decrease in fluidity of mass by addition of lime or cement, or coating of individual particles or the entire mass in a protective jacket.	No	Considered to be a pretreatment step that would be analyzed in conjunction with other technologies.
	CHEMICAL TREATMENT		
	Neutralization. Neutralization of solid wastes by the application of acids or bases.	No	Multi-contaminant wastes are inappropriate for neutralization due to potential for side reactions. pH extremes are not a concern.
	Oxidation. Chemical oxidation of contaminants by application of oxidizing agents. Generally used to treat organic compounds.	No	Oxidation is difficult to implement in a multi-contaminant situation due to the potential for side reactions, possibly explosive.

Table Q-2 (Page 3 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	Reduction. Chemical reduction of contaminants by application of reducing agents. Generally used to treat hexavalent chromium and other metals.	No	Reduction is difficult to implement in a multi-contaminant situation due to the potential for side reactions.
	Other Chemical Modifications. Chemical modification of contaminants rendering them inert. Treatments include hydrolysis, photolysis, catalysis, and others.	Yes	Viable alternative for treatment of contaminated sediments.
	BIOLOGICAL TREATMENT		
	New Biotechnologies. Use of a controlled reactor utilizing modified micro-organisms selected for their ability to degrade and metabolize specific organic compounds. New biotechnologies include cultured micro-organisms, genetic engineered micro-organisms, and enzyme systems.	Yes	Viable alternative for reduction of organic contamination. Requires sediment removal from quarry.
	Land Treatment. Utilization of the natural biological processes of soils and vegetation for stabilization and destruction of organic contaminants. Processes include land farming and spray irrigation.	No	Difficult to obtain administrative approval due to potential for groundwater contamination, large area requirements, and public concern over introduction of NPL site wastes into uncontaminated areas.
	Aerobic Biological Treatment - Composting. Aerobic, thermophilic decomposition of organic solids by micro-organisms. Organic solids are placed in a pile or a reactor vessel and aerated by mechanical turning or by aeration headers buried in the solids.	No	Large volume of organic solids are not present. Most of the contaminated solids consist of soils containing VOC's, BNA's and heavy metals.
	THERMAL TREATMENT		
	Incineration. For a rotary kiln system, waste is injected into a horizontal, rotating, refractory-lined steel cylinder where it is incinerated at temperatures up to 2,000° F. Combustion gases are passed through an afterburner and scrubbed before release. Both conventional, permanent systems and mobile systems are available.	Yes	Viable alternative for treatment of contaminated sediments.
	Codisposal Processes. Use of waste mixed with other combustible material as a supplemental fuel source for an existing industry. Includes the use of power generation boilers, cement kilns, lime kilns, and municipal sludge or refuse incinerators.	No	Not applicable to high ash content solids such as sediments.

TABLE Q-2 (Page 4 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	Pyrolysis. Thermal liberation of volatile organic compounds in the absence of oxygen. Volatile gases released are burned in an afterburner. Applicable processes are conventional pyrolytic reactor and rotary hearth pyrolyzer.	No	Most of the specific technologies are more applicable to trash, sludges, or liquids.
	IN-SITU TREATMENT		
	Neutralization. Application or injection of substances into the contaminated site to neutralize the pollutants present. Neutralizing agents are waste specific.	No	Multi-contaminant waste would be difficult to neutralize. Technique is not fully developed for use on contaminated soil or buried material.
	Oxidation. Degradation of oxidizable compounds by the addition of oxidizing agents or by the natural action of the soil.	No	Oxidizing agents may cause violent reactions when applied to multi-contaminant systems, and may mobilize metals.
	Reduction. Degradation of reducible compounds by the addition of reducing agents or by the natural action of the soil.	No	Difficult to assess the toxicity and potential mobility of reduction products, particularly in a complex, multi-contaminant system.
	Bioreclamation. Includes surface, subsurface, and bacterial augmentation systems. Degradation of hazardous chemicals by enhancing the biodegradation activity of native soil micro-organisms. Methods include manipulating oxygen, nutrient, and moisture content of the soil. Augmentation involves the addition of commercially available microbial cultures.	No	Low permeability of subsurface strata limits ability to control oxygen, nutrient, and moisture content. Surface bioreclamation alone does not satisfy NCP goals (subsurface waste could leach to groundwater).
	Immobilization. Immobilization of waste constituents within the soil mass by natural soil processes or the addition of immobilizing agents. Three major types of immobilization are sorption, ion exchange, and attentuation.	No	Technology is not fully developed and the long-term stability of immobilizing agent/waste constituent complexes is not known.
	Polymerization. Conversion of organic waste constituents to less mobile polymers by the addition of a catalyst and an activator.	No	Technology is still experimental.

TABLE Q-2 (Page 5 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
DISPOSAL	ONSITE DISPOSAL		
	RCRA Landfill. Permanent storage facility on site, double lined with clay and a synthetic membrane liner and containing a leachate collection/detection system.	Yes	Viable alternative for onsite disposal.
	Vault. Disposal of contaminated solids in a concrete vault on site.	Yes	Viable alternative for onsite disposal.
	Unlined Landfill. Replacement of treated solids into the excavation from which they were taken, covered by a multi-layer cap.	Yes	Viable alternative for materials treated on site.
	OFFSITE DISPOSAL		
	RCRA Landfill. Transport excavated soil or sediment to a RCRA approved landfill. May require dewatering or solidification prior to transport.	Yes	Viable alternative for solid wastes; however, this does not satisfy the goals of SARA.
	LAND APPLICATION Incorporation of low-level solid hazardous wastes into the upper soil horizon where hazardous constituents are degraded by the natural action of the soil.	No	Difficult to obtain administrative approval due to potential for groundwater contamination, large area requirements, and public concern over the introduction of NPL sites wastes into uncontaminated areas.

TABLE Q-3
IDENTIFICATION OF APPLICABLE QUARRY SURFACE WATER
TECHNOLOGIES AND PROCESS OPTIONS
REPUBLIC STEEL QUARRY RI

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
NO ACTION	NONE		
	Leave site as is.	Yes	The NCP requires No Action to be carried through to detailed analysis of alternatives. Health and environmental hazards make this a non-viable option.
ACCESS RESTRICTIONS	USE LIMITATIONS		
	Deed Restrictions. All deeds for property within potentially contaminated areas would include restrictions on use of property.	Yes	Viable technology for reducing fishing and subsequent ingestion of fish.
	Site Fencing. Fencing around the site and drainage ditches would be upgraded. All fencing would be maintained as necessary.	Yes	Viable alternative for reducing fishing and subsequent ingestion of fish.
	Runoff Monitoring. Collect and analyze storm water and sediment runoff to detect changes in runoff quality.	No	Offsite surface water not identified as a problem.
COLLECTION	BULK LIQUID REMOVAL		
	Removal of bulk liquids located in quarry by means, of various physical methods, such as pumps, industrial vacuum, gravity siphon, dredges and bailing.	Yes	Water in quarry may be removed by some method prior to treatment or disposal.
TREATMENT	PHYSICAL TREATMENT		
	Activated Carbon Adsorption. Passage of waste water containing up to 1% organics through a bed of activated carbon. Carbon adsorbs most organics and some metals.	Yes	Viable alternative for water treatment. Will require pretreatment to remove solids from the water.
	Air (or Gas) Stripping. Removal of volatile contaminants from a liquid by percolating air or other gas through the liquid. The volatile components are transferred from the liquid to the gas which is either treated or released to the atmosphere.	No	Uptake of VOCs by fish not a problem.

TABLE Q-3 (Page 2 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	Steam Stripping. Removal of volatile contaminants from water by fractional distillation. Contaminated water enters the top of the distillation column and flows downward as steam rises through the column. Volatile components are transferred from the water to the steam which is either treated or released to the atmosphere.	No	Uptake of VOCs by fish not a problem.
	Critical Fluid Extraction. Extraction of organics from liquid wastes by forcing a solvent (generally CO_2) at its critical point through the waste. Organic components are transferred to the solvent. Contaminants are released from the solvent when it is returned to standard conditions.	No	Still in experimental stage.
	Coagulation and Flocculation. Addition of chemical agents to waste water which cause suspended particulates to aggregate. Improves efficiency of filtration, sedimentation, and flotation processes.	No	No problem associated with suspended solids.
	Flotation. Separation of suspended solids and free and emulsified oil and grease from water by floating them to the surface with gas bubbles and skimming off the froth.	No	No problem associated with suspended solids.
	Cartridge Filtration. Filtration of liquid through replaceable filter cartridges.	No	No problem associated with suspended solids.
	Liquid-Liquid Extraction. Extraction of organics from an aqueous solution by forcing an immiscible organic solvent through the aqueous solution. Organics are transferred to the solvent.	No	Complete removal of organics cannot be achieved and extraction solvents are retained in water.
	Distillation. Concentration of volatile components of a liquid mixture by boiling and collecting and condensing the vapor.	No	Not applicable to complex or variable waste streams.
	Evaporation. Concentration of contaminants in water by evaporating off pure water.	No	Volatile contaminants tend to be evaporated with pure water. Concentrated stream requires further treatment.
	Freeze Crystallization. Removal of dissolved solids from a liquid by freezing and physically separating crystals from the solution. A concentrated contaminant solution is produced.	No	Process is still experimental.

TABLE Q-3 (Page 3 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	Granular Media Filtration. Filtration of liquid through a bed of granular material.	No	Suspended solids are not site problems.
	Molecular Sieves. Passage of waste water over synthetically produced anhydrous metal-alumino-silicates which adsorb contaminant molecules. Uniform and controllable pore-size of the adsorbant allows high selectivity of molecules adsorbed.	No	Molecular sieves are highly selective for molecule size. The surface water contains a wide range of contaminants of various molecular sizes, and thus is not suitable for this treatment.
	Membrane Processes. Separation of components of a mixture or solution by employing some driving force across a barrier membrane which will preferentially pass certain components. These processes produce two streams; one concentrated and one dilute. Specific processes include electrodialysis, reverse osmosis, dialysis, and ultra filtration.	No	Not effective treatment.
	CHEMICAL TREATMENT		
	Precipitation. Precipitation of metals as sulfides, carbonates, phosphates, and hydroxides by the addition of the appropriate precipitant, such as lime.	No	Not applicable to remove contaminants of concern.
	Neutralization. Application of substances into the contaminated water to neutralize the pollutants present. Neutralizing agents are waste specific.	No	Not applicable to remove contaminants of concern.
	Oxidation. Degradation of oxidizable compounds by the addition of oxidizing agents.	No	Not applicable to remove contaminants of concern.
	Reduction. Degradation of reducible compounds by the addition of reducing agents.	No	Not applicable to remove contaminants of concern.
	BIOLOGICAL TREATMENT		
	Aerobic Processes. Waste stream placed in a controlled environment such as a compost pile with the addition of air to aid microbial degradation of organics.	Yes	Applicable for contaminants of concern.

TABLE Q-3 (Page 4 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
TREATMENT (cont'd)	Anaerobic Processes. Waste stream placed in a controlled and enclosed environment such as a digester, to allow microbial degradation in the absence of oxygen.	No	Not a proven technology for treatment of contaminants of concern.
	Facultative Processes.		
	Facultative Ponds. Waste water flows through earthen ponds containing a suspended culture. The ponds are not artificially aerated so that an aerobic zone forms at the top and an anaerobic zone at the bottom. Between these zones is the facultative zone.	No	Temperature is difficult to control due to regional climate.
	New Biotechnologies.		
	Use of cultured or genetically modified micro-organisms selected for their ability to degrade and metabolize specific organic compounds. New biotechnologies include cultured micro-organisms, genetic engineered micro-organisms, and enzyme systems.	Yes	Viable for removal of organics. Would require pretreatment to remove solids and metals.
	THERMAL TREATMENT		
	Incineration Technologies. Thermal destruction by use of a rotary kiln, multiple hearth, plasma arc, fluidized bed, molten salt, infrared or electric arc.	No	Not applicable to destruction of low level organic contaminants in water. Majority of energy would be expended in vaporizing water.
DISPOSAL	STORAGE		
	Surface Impoundments. Storage of liquid or sludge wastes in earthen impoundments. Generally a temporary action.	No	Not a permanent disposal alternative; does not meet goals of NCP.
	Storage in Containers. Storage of liquid waste in tanks, drums, or other containers. Generally a temporary action.	No	Not a permanent disposal alternative; does not meet goals of NCP.

TABLE Q-3 (Page 5 of 5)

General Response Action	Remedial Technology and Process Option	Retained for Further Analysis	Screening Comments
DISPOSAL (cont'd)	WASTE WATER DISCHARGE		
	Discharge to Public Owned Treatment Works. Discharge of low-level aqueous waste to POTWs for treatment.	Yes	Viable technology.
	Discharge to Deep Injection Wells. Disposal of hazardous fluids to the deep subsurface (below the lowermost formation containing an underground source of drinking water) by means of deep (Class I) injection wells.	Yes	Viable technology.
	Discharge to Shallow Wells. Disposal of non-hazardous fluids to the subsurface by means of shallow (Class V) injection wells.	No	Underground Injection Control Program will not permit discharge of treated hazardous materials to shallow groundwater.
	Discharge to Surface Water. Disposal of aqueous waste containing very low levels of contaminants to streams.	Yes	Viable alternative for treated water. Requires compliance with NPDES standards.
	Discharge to RCRA Facility. Discharge to RCRA licensed facility for treatment and disposal.	Yes	Viable alternative.
	LAND APPLICATION Incorporation of low-level liquid hazardous wastes into the upper soil horizon where hazardous constituents are degraded by the natural action of the soil.	No	Difficult to obtain administrative approval due to potential for groundwater contamination, large land area needed, and public concern over the introduction of NPL site wastes into uncontaminated areas.