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Remedial Investigation Report

Waukegan Manufactured Gas and Coke Plant Site
Waukegan, Illinois

(Including Appendices 5-A through 8-C)

Prepared for North Shore Gas Company

Under the Administrative Order on Consent Re: Remedial Investigation and Feasibility Study for the Waukegan Manufactured Gas and Coke Plant Site Waukegan, Illinois

February 1995

Barr
Engineering Company

BARR

Barr Engineering Company
4700 West 77th Street • Minneapolis, MN 55435-4803
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Minneapolis, MN • Hibbing, MN • Duluth, MN • Ann Arbor, MI • Jefferson City, MO

February 5, 1999

Mr. Mike Bellot
U.S. EPA, Region V, SR-6J
Superfund Division
Remedial Response Section #1
77 West Jackson Boulevard
Chicago, IL 60604-3590

Re: Waukegan Manufactured Gas and Coke Plant Site RI/FS
Monthly Progress Report for January 1999

Dear Mr. Bellot:

Enclosed is the monthly progress report for January 1999 for the Remedial Investigation/ Feasibility Study of the Waukegan Manufactured Gas and Coke Plant Site in Waukegan, Illinois. The report is being submitted on behalf of North Shore Gas Company. The report is being submitted pursuant to Section E of Article IX of the September 27, 1990, Administrative Order by Consent between the United States Environmental Protection Agency and the North Shore Gas Company.

Please contact me if you have any questions on the progress report.

Sincerely,

James R. Langseth

JRL/lah
Enclosure
c: Larry Schmitt
Jerry Willman
Bill Andrae
Steve Matuszak
Jerry Picha
Stephen Armstrong
Jerry Maynard
James Campbell
Edward Peterson
Russell Selman
Gretchen Monti
Sean Mulroney
Sue Pastor
202731

Monthly Progress Report
Remedial Investigation/Feasibility Study
Waukegan Manufactured Gas and Coke Plant
February 5, 1999

This report summarizes the work that was completed during January 1999 for the Remedial Investigation/Feasibility Study of the Waukegan Manufactured Gas and Coke Plant Site. This monthly progress report is submitted pursuant to Section E of Article IX of the September 27, 1990, Administrative Order by Consent (AOC) between the United States Environmental Protection Agency (U.S. EPA) and the North Shore Gas Company.

Descriptions of Actions Taken During the Month to Comply With the AOC, Target and Actual Completion Dates for Each Activity, Schedule Deviations, and Proposed Methods of Mitigating Schedule Deviations.

Feasibility Study

- Waitng for U.S. EPA comments on the November 1998 Feasibility Study.

Results of Sampling and Tests Completed During the Month

- No sampling results were submitted.

Difficulties Encountered During the Month and Actions Taken to Rectify Them

- No difficulties were encountered during the month.

Changes in Personnel

- There were no changes in personnel during the month.

BARR

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January 8, 1999

Mr. Mike Bellot
U.S. EPA, Region V, SR-6J
Superfund Division
Remedial Response Section #1
77 West Jackson Boulevard
Chicago, IL 60604-3590

Re: Waukegan Manufactured Gas and Coke Plant Site RI/FS
Monthly Progress Report for December 1998

Dear Mr. Bellot:

Enclosed is the monthly progress report for December 1998 for the Remedial Investigation/ Feasibility Study of the Waukegan Manufactured Gas and Coke Plant Site in Waukegan, Illinois. The report is being submitted on behalf of North Shore Gas Company. The report is being submitted pursuant to Section E of Article IX of the September 27, 1990, Administrative Order by Consent between the United States Environmental Protection Agency and the North Shore Gas Company.

Please contact me if you have any questions on the progress report.

Sincerely,

James R. Langseth

JRL/lah
Enclosure
c: Larry Schmitt
Jerry Willman
Bill Andrae
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Monthly Progress Report
Remedial Investigation/Feasibility Study
Waukegan Manufactured Gas and Coke Plant
January 8, 1999

This report summarizes the work that was completed during December 1998 for the Remedial Investigation/Feasibility Study of the Waukegan Manufactured Gas and Coke Plant Site. This monthly progress report is submitted pursuant to Section E of Article IX of the September 27, 1990, Administrative Order by Consent (AOC) between the United States Environmental Protection Agency (U.S. EPA) and the North Shore Gas Company.

Descriptions of Actions Taken During the Month to Comply With the AOC, Target and Actual Completion Dates for Each Activity, Schedule Deviations, and Proposed Methods of Mitigating Schedule Deviations.

Feasibility Study

- Submitted December 14, 1998, letter to U.S. EPA discussing regulatory issues.

Results of Sampling and Tests Completed During the Month

- No sampling results were submitted.

Difficulties Encountered During the Month and Actions Taken to Rectify Them

- No difficulties were encountered during the month.

Changes in Personnel

- There were no changes in personnel during the month.

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February 16, 1995

Mr. William Bolen
U.S. Environmental Protection Agency
Region V
Waste Management Division
IL/IN Remedial Response Branch
HSRL-6J
77 West Jackson Boulevard
Chicago, IL 60604

Re: Waukegan Manufactured Gas and Coke Plant Site

Dear Mr. Bolen:

At the request of Mr. Patrick Doyle of North Shore Gas, I am submitting one copy of the revised *Remedial Investigation Report, Waukegan Manufactured Gas and Coke Plant Site.* I understand that you will contact me regarding the number of additional copies needed after you have reviewed the changes in this revision. The RI report has been corrected pursuant to the comments transmitted with your January 31, 1995 letter to Patrick Doyle.

In response to comment 3, Appendix 5-C now provides the calculated flows for groundwater entering the site (page 5-C-9). The report text now refers to this appendix to justify the conclusion of insignificant flow entering the site from beneath OMC plant no. 2.

Except for comment 6, the changes to the report for several of the comments were modified in accordance with our discussions on February 6 and 9, 1995. These modifications were confirmed in my February 10, 1995 letter to you. As a result of your instruction on February 14, 1995, the changes to the report for comment 6 were made as stated in your January 31, 1995 transmittal.

If you have any questions, do not hesitate to call.

Yours truly,

James R. Langseth

JRL/mst
Enclosure
c: Isaac Johnson (w/encl.)
Jerry Willman (w/encl.)
Patrick Doyle (w/encl.)
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Margaret Skinner
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Remedial Investigation Report

Waukegan Manufactured Gas and Coke Plant Site
Waukegan, Illinois

(Including Appendices 5-A through 8-C)

Prepared for North Shore Gas Company

Under the Administrative Order on Consent Re: Remedial Investigation and Feasibility Study for the Waukegan Manufactured Gas and Coke Plant Site Waukegan, Illinois

February 1995

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REMEDIAL INVESTIGATION

WAUKEGAN MANUFACTURED GAS AND COKE PLANT SITE

WAUKEGAN, ILLINOIS

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ACRONYM LIST

ANL	Argonne National Laboratories
ATSDR	Agency for Toxic Substance and Disease Registry
BART	Biological Activity Reaction Test
BETX	Benzene, Ethyl benzene, Toluene, Xylenes
BOD	Biochemical Oxygen Demand
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
COD	Chemical Oxygen Demand
CRDL	Contract Required Detection Limit
DNAPL	Dense Nonaqueous-Phase Liquid
EJ&E	Elgin, Joliet, Eastern Railway Company
EPRI	Electric Power Research Institute
ESA	Expanded Study Area
FAWQC	Federal Ambient Water Quality Criteria
FEMA	Federal Emergency Management Agency
FSP	Field Sampling Plan
GAC	Granular-Activated Carbon
GLWQIC	Great Lakes Water Quality Initiative Criteria
GM	General Motors
GPS	Global Positioning System
GRI	Gas Research Institute
ICP	Inductively Coupled Plasma
IDL	Instrument Detection Limit
IDOC	Illinois Department of Conservation
IEPA	Illinois Environmental Protection Agency
ISFM	Illinois State Fire Marshall
IWQS	Illinois Water Quality Standards
LOD	Limit of Detection
MDL	Method Detection Limit
MSL	Mean Sea Level
MVU	Minimum Variance Unbiased

NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NSG	North Shore Gas Company
NSSD	North Shore Sanitary District
OMC	Outboard Marine Corporation
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PSCS	Preliminary Site Characterization Summary
QAM	Quality Assurance Manual
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RPD	Relative Percent Difference
SLAEM	Single Layer Analytic Element Model
SOW	Statement of Work
TCLP	Toxicity Characteristic Leaching Procedure
TM	Technical Memorandum
TOC	Total Organic Carbon
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
WCP	Waukegan Manufactured Gas and Coke Plant

REMEDIAL INVESTIGATION
WAUKEGAN MANUFACTURED GAS AND COKE PLANT SITE
WAUKEGAN, ILLINOIS

SECTION 1.0
INTRODUCTION

1.1 PURPOSE OF REPORT

This report constitutes the Remedial Investigation (RI) Report for the Waukegan Manufactured Gas and Coke Plant (WCP) site in Waukegan, Illinois and fulfills the requirement for an RI Report in Task VI of the October 1991 Remedial Investigation/Feasibility Study (RI/FS) Final Work Plan for the site (Barr, 1991a). This RI Report has been prepared pursuant to Section IX of the September 27, 1990 Administrative Order on Consent between the United States Environmental Protection Agency (U.S. EPA) and North Shore Gas Company (NSG).

The RI Report fulfills the requirements and scope for the RI Report stated in the following documents approved by the U.S. EPA: (1) Statement of Work for Conducting a Remedial Investigation and Feasibility Study at the WCP site; and (2) October 1991 RI/FS Final Work Plan, namely, that the RI Report summarize the results of field activities to characterize the site, sources of contamination, nature and extent of contamination, and the fate and transport of contaminants. This report summarizes background and regional information obtained from local, state, and federal government agencies and other sources of regional information; presents data and summaries of information obtained from previous investigations conducted at or in the immediate vicinity of the site; describes the RI investigation methods and activities; presents the results of field investigation activities; describes the physical characteristics of the site, the nature of contamination at the site, the extent of soil, groundwater, surface water, and sediment contamination at the site, and the environmental fate and transport of contaminants identified at the site; and summarizes the conclusions that may be drawn from the RI data, stating data limitations where appropriate.

The field investigations (Phase I and Phase II) for the RI were conducted in accordance with the documents listed below. These documents were approved by the U.S. EPA on the dates listed.

- Remedial Investigation/Feasibility Study, Final Work Plan, October 24, 1991 (October 1991 WP) - Final U.S. EPA approval on November 15, 1991.

- Final Sampling and Analysis Plan, Volume I: Field Sampling Plan, October 24, 1991 (October 1991 FSP) - Final U.S. EPA approval on November 15, 1991.

- Final Sampling and Analysis Plan, Volume II: Quality Assurance Project Plan, October 24, 1991 (October 1991 QAPP) - Final U.S. EPA approval on January 9, 1992.

- Project Health and Safety Plan - Final U.S. EPA approval on November 15, 1991.

- Remedial Investigation/Feasibility Study, Phase I Technical Memorandum, July 1993 (July 1993 TM) - Final U.S. EPA approval on July 14, 1993.

Site access to begin Phase I of the field investigation for the RI was obtained on February 26, 1992. Site work for the Phase II field investigation began on August 16, 1993.

1.2 REPORT ORGANIZATION

Section 1.0 of the RI Report describes the purpose and intent of the report and its organization. Section 2.0 summarizes background and regional information such as site definition, site ownership, site and adjacent area history, demographic information, land use, climate, regional hydrology and hydrogeology, water use, and ecological features. Section 3.0 summarizes data obtained from previous investigations conducted at or in the immediate vicinity of the site, including data on soil quality, surface water quality, groundwater quality, sediment quality, and geotechnical and hydrogeologic conditions. Section 4.0 describes the RI activities and methods and summarizes results for the soils investigation, hydrogeologic investigation, groundwater quality investigation, surface water quality investigation, surface features investigation, remedial technology evaluation sampling, and quality assurance/quality control review conducted during both phases of the RI investigation. Section 5.0 describes the physical characteristics of the site, including site geology and hydrogeology. Section 6.0 identifies the key chemical parameters to be used in the characterization of contaminant extent and presents the chemical properties of the identified parameters. Section 7.0 characterizes the vertical and lateral extent of key parameters in background soils, ground surface soils, soil stockpile soils, vadose zone soils, groundwater and saturated soils, and surface water and sediment. Section 8.0 presents an evaluation of the environmental fate and transport (i.e., characteristics and migration pathways) of key parameters identified at the site. Section 9.0 presents the summary and conclusions of the RI report and identifies the limitations of the RI data.

In April 1994, a Preliminary Site Characterization Summary (PSCS) was submitted to the U.S. EPA for approval. The purpose of the PSCS was to provide the U.S. EPA with a preliminary transmission of data collected during the RI and previous investigations before data evaluations were complete. The PSCS was approved by the U.S. EPA on May 5, 1994. Sections 3.0 and 4.0 of this RI Report, including accompanying tables and figures, are substantially identical to Sections 3.0 and 4.0 of the PSCS, with minor corrections or clarifications. Section 2.0 of this RI Report is substantially identical to Section 2.0 of the PSCS, except that hydrologic information on Waukegan Harbor and Lake Michigan has been added for the RI and several corrections or clarifications have been provided where appropriate. The appendices which accompanied Sections 2.0 through 4.0 in the PSCS are not published as part of this RI Report. Instead, references to the appropriate appendices of the PSCS are made throughout this report.

SECTION 2.0
SITE SETTING

2.1 SITE BACKGROUND INFORMATION

This section summarizes available background information regarding site ownership, historical development of the site area, industrial activities at and near the site, and waste types potentially associated with site operations.

2.1.1 Site Definition

The WCP site is located in Waukegan, Illinois, approximately 35 miles north of Chicago. The WCP site location is shown on Figure 2.1-1.

A legal description from a real estate appraiser (Real Estate Research Corporation, 1971) identifies the site in the northwest quarter of Section 22, Township 45 North, Range 12 East of the Third Principal Meridian. The site is bounded to the north by Sea Horse Drive (formerly Pershing Road), on the east by Sea Horse Drive (formerly Pershing Road), on the south by Outboard Marine Corporation (OMC) Plant No. 1, and on the west by Waukegan Harbor. The site is generally rectangular in shape, with a total area of approximately 36 acres.

Available information regarding site operations (OMC, 1990a; General Motors Corporation [GM], 1990; NSG, 1990; Elgin, Joliet, Eastern Railway Company [EJ&E], 1990; Duff and Phelps, 1940) indicates that industrial processes and product storage associated with the site industrial facilities were conducted within the property boundaries shown on Figure 2.1-2. Therefore, for the purposes of this report, the word "site" means the area shown on Figure 2.1-2. Where the text directly references the broader Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) meaning of the word "site," the term "CERCLA Site" is used.

2.1.2 Site Ownership

A title search conducted for OMC (OMC, 1990a) indicates that the WCP site was originally owned by Charles H. Coster. In July 1893, the land was acquired by the EJ&E. The railroad company owned the land for the next 34 years. During EJ&E's ownership of the land, Chicago Tie and Timber Company (CT&T) operated a creosote wood-treating plant at the property, beginning in 1908. EJ&E sold the land to William A. Baehr on March 14, 1927. On the same day, the ownership

of this site was transferred to the North Shore Coke and Chemical Company. In 1941, NSG acquired the property, and eventually sold it to the Waukegan Coke Corporation in 1947. The Waukegan Coke Corporation was a wholly owned subsidiary of GM (Moody's, 1949). In less than a year, the plant was sold by the Waukegan Coke Corporation to GM. GM operated the site until 1971 to produce coke for its foundry in Saginaw, Michigan. GM sold 2.814 acres along the southern boundary of the site to OMC in 1969. GM operated the coking facility until OMC purchased the remainder of the site in 1971 (OMC, 1990a). OMC demolished the coking plant structures and filled and leveled the site shortly thereafter. The site is currently owned by OMC. The Waukegan Port District had an ownership interest in the site for a period from October 1988 to February 1991 (Chicago Title Insurance Company, 1991). Table 2.1-1 lists the history of the deed conveyances for the WCP site.

2.1.3 History of Site and Adjacent Areas

The following sections summarize available information regarding the development of the Waukegan Harbor area and commercial/industrial operations at and near the WCP site.

2.1.3.1 Development of Harbor/Peninsula

The development of Waukegan Harbor began with the construction of a breakwater pier in 1854 at the mouth of the Little Fort River, now known as the Waukegan River (Clark, 1968). The north and south breakwaters of the present day harbor were constructed between 1883 and 1885. Three boat slips (Slip Nos. 1, 2, and 3) and the main harbor channel that connected them were constructed by the year 1900 (Clark, 1968); at this time, Slip No. 3 consisted of the northerly extension of the main harbor channel (U.S. Army Corps of Engineers, 1908). By 1932, Slip No. 3 had been extended to the west at its current location (City of Waukegan, 1932). The central slip, Slip No. 2, was filled in 1957 (U.S. EPA, 1981). After the filling of Slip No. 2, the harbor remained generally unchanged until 1991. A new slip (Slip No. 4) was constructed in 1991 at the WCP site on the east side of the main channel and Slip No. 3 was filled. The Slip No. 3 and Slip No. 4 actions were part of the remedy implemented by the Waukegan Harbor Trust (an entity funded by OMC) for the OMC/Waukegan Harbor Superfund site (hereinafter referred to as the Waukegan Harbor Superfund site) that is adjacent to and partially overlaps the WCP site (Section 2.1.3.6).

The peninsula east of Waukegan Harbor has expanded as a result of sand accretion caused by breakwater construction. The Lake Michigan longshore current, which transports sand, flows from north to south along the Waukegan waterfront. Prior to harbor construction, the breakwaters constructed at the north and south sides of the present-day harbor caused sand to accumulate. The

U.S. Engineers Chart of 1888 showed about 400 feet of easterly accretion of land north of the northerly breakwater compared to the shoreline shown on the U.S. Engineers Chart of 1879. The U.S. Engineers Chart of 1900 showed an additional 800 feet of easterly land accretion north of the breakwater (Clark, 1968). The accreted land became a peninsula when Waukegan Harbor was excavated by the year 1900. The harbor and slip excavation materials were likely used as fill for the peninsula. The width of the peninsula has since increased as sand has been deposited along the lake shore. In 1932, the peninsula was approximately 1,400 feet wide in the vicinity of the southern portion of the WCP site (City of Waukegan, 1932). The peninsula is currently approximately 2,000 feet wide in this area.

Historically, Waukegan Harbor has been dredged on a routine basis to maintain its navigability. The U.S. Army Corps of Engineers dredged approximately 30,000 cubic yards of sediments annually from areas near the entrance channel (U.S. EPA, 1981). Slips No. 1 and No. 3 were also dredged periodically (until 1968 and about 1950, respectively) to maintain navigational uses (U.S. EPA, 1981). For the most part, dredging of Waukegan Harbor has not been performed since polychlorinated biphenyls (PCBs) contamination was discovered in the harbor in 1975 (U.S. EPA, 1981). Additional information on Waukegan Harbor and dredging activities is presented in Section 2.2.4.2. The northern portion of the harbor (including the area west of the WCP site) was dredged in 1991 as part of the Waukegan Harbor Superfund site remedy to address PCB contamination (Section 2.1.3.6). The dredging plans left a soil buttress of harbor sediments against the harbor walls. The buttress was generally 20 to 30 feet wide at its top and 30 to 40 feet wide at its base (Canonie, 1989). Dredged sediments were placed in the PCB containment cell now present at the former location of Slip No. 3 (Figure 2.1-2). In addition, funds have been approved for the U.S. Army Corps of Engineers to again dredge other portions of Waukegan Harbor (Waukegan Harbor Citizens Advisory Group, 1993).

2.1.3.2 CT&T Wood-Treating Plant

Based on information obtained from the EJ&E (EJ&E, 1990), the first industrial facility located on the site was the CT&T creosote wood-treating plant. This operation was located on the western portion of the site (Figure 2.1-2) and was operated by CT&T beginning in 1908. The plant consisted of at least four steel creosote storage tanks, a wood-planing building, an overhead steel conveyor system, two creosote-weighing vanes located due east of the storage tanks, and a storage building for the treated railroad ties (EJ&E, 1990; Sanborn, 1917; U.S. Army Corps of Engineers, 1908). The storage building for the finished product and a 250-foot long, 8-foot high concrete retaining wall (connected to the south edge of the storage building) ran parallel to EJ&E railroad side tracks.

Information on the location and configuration of the CT&T wood-treating plant is included in PSCS Appendix 2-A.

Available information indicates that the untreated railroad ties were transported by the conveyor to the treating building, where they were dipped in vats of creosote. The treated ties were likely transferred to the storage building for future distribution by rail or ship. It is not apparent from the existing data how or where the ties were dried. Based on a review of Sanborn Fire Insurance maps, the CT&T wood-treating plant was dismantled sometime after 1917 (Sanborn, 1929).

2.1.3.3 Waukegan Manufactured Gas and Coke Plant

Between 1926 and 1928, a coke oven gas plant was designed and constructed under the direction of the William A. Baehr Organization. This gas plant sold its excess production (i.e., gas that was not used internally) to NSG.

The major structures present on the original gas plant site, as identified from a 1929 Sanborn fire insurance map, are shown on Figure 2.1-2 and listed in Table 2.1-2. Figure 2.1-3 diagrams the manufactured gas and coke production processes used at the WCP site. The processes and facilities are described below.

The original plant included a dock for coal unloading located on the western edge of the site along Waukegan Harbor. Concrete track foundations (for the crane used to unload coal) extended along the western edge of the site. These foundations reportedly extend to a depth of 7 feet below the ground surface and rest on wooden piling (OMC, 1990b).

The western one-third of the site was used for coal storage, from which the coal was transported by drag line and belt conveyors to the coke ovens. The coke ovens consisted of 31 Koppers Company Becker-type ovens, each with a 9.1-ton capacity and an aggregate normal carbonizing capacity of 450 tons per day (Duff and Phelps, 1940). The coke oven battery was supported by more than 500 concrete piles driven to depths of between 12 and 25 feet below the ground surface (Baehr Organization, 1927).

Before the autumn of 1937, some of the gas that was produced was used for underfiring the ovens. This practice limited gas production to 3,100,000 cubic feet per day. After installation of a producer gas plant that supplied the fuel requirements for underfiring the ovens, the daily production was increased to 5,200,000 cubic feet per day. The producer gas that was not used was often blended

with the coke oven gas to obtain the desired BTU content and, subsequently, transmitted to NSG's distribution system (Duff and Phelps, 1940).

Coal tar and ammonia were by-products of the manufactured gas production. The WCP manufactured gas plant included equipment with which gas by-products were extracted and prepared for the market. By-products that were produced and sold include coke, "sulphate" (likely ammonium sulfate), sulfur paste, and tar (Duff and Phelps, 1940). Figure 2.1-2 shows the locations of the by-products building, tar tanks, tar storage tank, and ammonia tank.

In addition to by-product removal, operations at the site included removal of sulfur and naphthalene from the raw gas during gas purification. The gas was treated for sulfur removal on the North Shore Coke and Chemical Company property using equipment owned by NSG. The purified gas was sent by transmission pipelines for ultimate distributions to the NSG service territory (Duff and Phelps, 1940). The gas purification operations used a liquid sulfur removal process (Thylox) and were conducted at the thionizer building (Figure 2.1-2).

An on-site electric steam generating plant that supplied all of the steam and electricity required for plant operations was owned and operated by the North Shore Coke and Chemical Company (Duff and Phelps, 1940). Steam was generated from two boilers located in the boiler house (Figure 2.1-2). The water used to generate the steam was pumped from Waukegan Harbor to the suction well through a 24-inch intake pipe. In addition, a water well was located at the southwest corner of the boiler house and was completed at a depth of approximately 140 feet below the ground surface (Baehr Organization, 1927).

After the transfer of ownership to GM, the primary function of the plant was to supply coke for its foundry in Saginaw, Michigan. During GM's operation of the plant, coke oven gas was produced for internal use only. No gas was sold for off-site use, as NSG had converted to natural gas in 1947. The gas purification facilities and sulfur removal equipment were dismantled by GM because the coke oven gas was only used on-site.

According to a real estate appraisal description (Real Estate Research Corporation, 1971), the coal preparation and coking portion of the plant consisted of a coal-mixing silo, coal preparation building, coke ovens, coke-quenching station, domestic screen station, and coke screen and hammer mill building. The following structures were located in close proximity to or within the by-products building: four cast iron tanks and two gas pumps within the building, a tar tank, two steel cooling towers, and cooling coils. To the south of the by-products building was a small tank farm which

consisted of three horizontal 15,000-gallon steel tanks, one of which was a tar cooker, as well as two vertical tanks (one for ammonia liquor storage and the other for tar storage).

The plant facilities were dismantled at the direction of OMC in approximately 1972. The specifications for demolition of the coke plant facilities provided for the removal of all of the buildings, smoke stacks, equipment, railroad tracks, and ties (OMC, 1972). According to the specifications, bids were to include the removal of all foundations to 12 inches below grade, and the complete removal of the foundations for the coke battery and the two smoke stack bases. Also included in the specifications for the dismantling of the plant was the filling with incombustible rubble and leveling of all depressed areas such as pits and sumps. An office memorandum indicated that it would be necessary to obtain a permit to "dump concrete, brick, etc. into the Lake Michigan Harbor" (OMC, 1990a). The site presently is clear of all above-grade structures from the coking plant, with the exception of the office building in the southeast corner of the site and the tar tank foundation at the south end of the site. There is evidence that many below-grade building foundations and the crane track foundations are also still present at the site.

2.1.3.4 OMC Operations

After the demolition and removal of the coke plant, OMC used the property for various operations and activities. A data processing building was constructed and is currently maintained on the southeastern portion of the property. Between 1973 and 1989, annual burning permits were obtained from the Illinois Environmental Protection Agency (IEPA) for fire prevention and response training for OMC employees. The location of fire training activities is shown on Figure 2.1-2 (Lenzi and Crawford, 1993). During fire-training activities, combustible materials were reportedly contained in 3-foot deep metal pans (Lenzi and Crawford, 1993); available information on burned materials is provided in PSCS Appendix 2-B. The property has also been used for public parking for special events at the Waukegan public beach. During the winter of 1972-1973, snowmobile performance tests were run on a small track in the northern one-third of the property. OMC's engineering department currently performs quality control and durability testing of their products using a tower in the southwest corner of the site (OMC, 1990a).

OMC has also used portions of the site for temporary storage of construction materials and semitrailers. In 1974, the U.S. Army Corps of Engineers contracted for the dredging of sand from Lake Michigan. The sands were placed on the western edge of the site for temporary storage and were tested and found to contain relatively low concentrations of PCBs (OMC, 1990a). Approximately one-half of these dredged spoils are still in place. Between 1977 and 1981, OMC stored waste oil

containing PCBs in two 15,000-gallon aboveground storage tanks; 1978 analyses of the contents of these two tanks (identified as Pydraul 50-E) showed 300 and 180 parts per million PCBs, respectively (OMC, 1990a). OMC also stored gasoline in two 20,000-gallon aboveground storage tanks in the vicinity of the gas producer building during the period between 1977 and 1981. These four tanks have since been removed; containment areas for these tanks are still evident. During the summer of 1979, four enclosed trailers containing 11,000 gallons of waste oil were parked in the north-central portion of the site, approximately 50 feet south of Sea Horse Drive (formerly Pershing Road) (OMC, 1990a). The approximate locations of the above-referenced tanks are shown on Figure 2.1-2.

During the latter part of 1990, the Waukegan Harbor Trust (an entity funded entirely by OMC) began construction of Slip No. 4 to be used for boat servicing. Slip No. 4 is located in the northwestern portion of the site (Figure 2.1-2). The slip was designed to be 375 feet long by 175 feet wide, with a narrowed entrance (Canonie, 1989). Available plans of Slip No. 4 (Canonie, 1990b) indicate that the slip as constructed is approximately 475 feet long. Slip No. 4 replaces the former Slip No. 3, which was located west of Slip No. 4 across Waukegan Harbor. Slip No. 3 has been filled with sediments containing PCB/oil mixtures and will be capped as a remedial action for PCB contamination in the Waukegan Harbor. Slip No. 4 is currently used for the boat-servicing operations of Larsen Marine. Larsen Marine also currently leases a portion of the northern site area for the storage of boats and boat racks.

Slip No. 4, the new slip constructed at the WCP site, includes sheet pile walls and tie-back systems for its north and south walls and a slurry wall at its eastern end. A force main which traversed the area of Slip No. 4 was relocated. Available construction plans for Slip No. 4 are presented in PSCS Appendix 2-B (Canonie, 1989). Designated creosote-contaminated soils (as defined in the Construction Specifications; Canonie, 1990b) excavated from the vicinity of the former CT&T wood-treating plant during construction of Slip No. 4 were placed at the WCP site in a lined cell intended to meet Resource Conservation and Recovery Act (RCRA) waste pile guidelines. Soils not defined as designated contaminated soils were placed adjacent to the southeast face of the pile of U.S. Army Corps of Engineers dredge spoils.

There is currently an aboveground storage tank farm on the southwestern corner of the site that is used in OMC Plant No. 1 product testing operations. There are nine tanks located in this area with a capacity varying from 300 to 20,000 gallons. The stored fuels consist of gasoline, fuel oil, and kerosene (OMC, 1990a). Cabinets located adjacent to the storage tanks are labeled as holding containers of chemicals, including methyl ethyl ketone, xylenes, methanol, and ethyl acetate (Hersemann, 1994). Information available from Sanborn maps (Sanborn, 1949 and 1969) indicates

that four underground oil storage tanks have also been present at the OMC Plant No. 1 facility. The current status of these tanks is unknown. Two underground petroleum storage tanks were also present at the former Falcon Marine facility located immediately southwest of the current OMC Plant No. 1 facility (Illinois State Fire Marshall [ISFM], 1992).

The OMC Plant No. 2 facility is located north of the WCP site (Figure 2.1-2). Based on an underground Tank Notification form submitted to the ISFM, a total of 27 underground storage tanks were located at this facility as of January 1992 (ISFM, 1992). Underground storage tanks at the OMC Plant No. 2 facility have been reportedly used to store gasoline, naphthalene, trichloroethylene, oil, and waste oil (ISFM, 1992). Portions of the foundation of the eastern area of the OMC Plant No. 2 facility reportedly extend to the clayey till (Lenzi and Crawford, 1993) present at a depth of approximately 30 feet below the ground surface.

2.1.3.5 Larsen Marine Operations

The area adjacent to the WCP site near the property's northwest corner (Figure 2.1-2) has long been used by Larsen Marine, a commercial business engaged in boat sales, servicing, repair, refueling, storing, and launching. Larsen Marine formerly used Slip No. 3 for boat access to its services. Before Slip No. 3 was filled as part of the remedy for the Waukegan Harbor Superfund site, Slip No. 4 was constructed in the northwestern portion of the WCP site for use by Larsen Marine's boat-servicing operations. Larsen Marine has also used the northwest quadrant of the WCP site in the past for seasonal boat and boat trailer storage. Larsen Marine currently uses an area east of Slip No. 4 for such storage.

Larsen Marine has been identified as the location of registered underground petroleum storage tanks and as a leaking underground storage tank site (ISFM, 1992). Five tanks were reportedly removed from the Larsen Marine facility in 1991 (ISFM, 1992); information regarding the former tank locations and potential associated environmental impacts was not available.

2.1.3.6 Waukegan Harbor Remedial Action

The Waukegan Harbor Superfund site was placed on the National Priorities List (NPL) in the Federal Register on September 8, 1983 (48 Fed. Reg. 40658). In the Consent Decree entitled "United States of America v. Outboard Marine Corporation" (No. 8808-71), the Waukegan Harbor Superfund site is defined to include: "Slip No. 3 of Waukegan Harbor, the Upper Harbor of Waukegan Harbor and the following areas located on OMC facility property: the North Ditch, Crescent Ditch and Oval

Lagoon, and the Parking Lot." A map showing the area defined as the Waukegan Harbor Superfund site is included in PSCS Appendix 2-B.

PCB contamination was discovered at the Waukegan Harbor Superfund site in 1975 (U.S. EPA, 1981). Between 1948 and 1971, OMC purchased an estimated 8 million pounds of Pydraul (a hydraulic fluid consisting of a PCB/oil mixture) from Monsanto (Ross, et al., 1990). An estimated 900,000 pounds of the PCB/oil mixture used in the hydraulic fluids of die-casting machines escaped into the floor drains and were discharged to Waukegan Harbor (Ross, et al., 1990). U.S. EPA estimates indicate that these discharges resulted in the presence of approximately 300,000 pounds of PCBs in Slip No. 3 and Waukegan Harbor (U.S. EPA, 1991). Additionally, an estimated 700,000 pounds of PCBs were reportedly present on OMC property as a result of discharges to the North Ditch and other areas north of OMC Plant No. 2 (U.S. EPA, 1991).

As part of the Record of Decision for the Waukegan Harbor Superfund site, sediments containing PCB/oil mixtures were dredged from Waukegan Harbor and disposed of in the former Slip No. 3. The portion of the harbor included in the dredging plans (see map, PSCS Appendix 2-B) did not include the sediment buttress retained to protect the stability of the harbor walls. These buttresses extend a minimum of 20 feet out from the west harbor wall and a minimum of 20 or 30 feet out from the east harbor wall (Canonie, 1989). Slip No. 3 has now been filled with the dredged sediments containing PCB/oil mixtures. The former slip has been covered pending consolidation of the filled soils; after the soils have settled, a cap will be completed over the former slip. As discussed in Section 2.1.3.4, Slip No. 4 has been constructed at the WCP site to replace Slip No. 3.

2.1.4 Waste Types Potentially Associated with Site Operations

Coal tar and sludges are composed of hundreds of different compounds including polynuclear aromatic hydrocarbons (PAHs), phenols, and volatile aromatics. Metals and inorganic parameters contained in oils, by-products, and wastes associated with coal tar may also be present. Table 2.1-3 presents a list of chemicals likely to be associated with materials resulting from coking and coal gasification operations (Gas Research Institute [GRI], 1987).

Creosote is produced from a blend of the fractional distillates of coal tar. This blend may be diluted with coal tar or petroleum oil. Creosote typically contains a smaller fraction of pitch (residue remaining after distillation at 355°C) than does coal tar (Lorenz and Gjovik, 1972; Martin, 1949). Creosote is generally less viscous than coke oven coal tar.

PAH and volatile aromatic compounds associated with coal tar and/or creosote are also typically associated with petroleum products that have been stored and used at and near the WCP site.

2.2 REGIONAL CHARACTERIZATION

This section describes the site environment and the regional and local hydrogeologic setting of the area surrounding the WCP site. Information contained in the following discussion was gathered from published reports as identified in the list of references.

2.2.1 Demographic Information

Waukegan is the county seat of Lake County. In 1990, Waukegan had a population of 69,000. Built on a 50-foot bluff overlooking Lake Michigan, Waukegan is primarily a manufacturing community. Industries and industrial facilities located in Waukegan include, but are not limited to, OMC, National Gypsum, Johns-Manville, Dexter Corporation, Commonwealth Edison, EJ&E railroad yards, LaFarge Corporation, North Shore Sanitary District (NSSD), and Abbott Laboratories.

Waukegan is bordered by the city of North Chicago to the south and the city of Zion to the north. Other than Chicago, Waukegan is the only city in Illinois with industrial harbor facilities. It is served by major railroad lines, highways, and expressways. In addition, a municipal airport is located in Waukegan.

2.2.2 Land Use

This section describes: (1) current land use in areas within 1/4 mile of the site; and (2) current land use at the site itself. Figure 2.2-1 shows the current zoning of the site and surrounding areas as defined by the Waukegan zoning map (City of Waukegan, 1988). Land use in the areas north, west, south, and east of the site are described below.

North of the site (across Sea Horse Drive) is OMC Plant No. 2. North of OMC's Plant No. 2, hazardous waste containment cells have been constructed by the Waukegan Harbor Trust for soils and sediments containing PCB/oil mixtures. The soils were excavated from an area north of OMC Plant No. 2, and the sediments (which contain greater than 50 parts per million PCBs) were removed from the North Ditch. Further north of OMC's Plant No. 2 is the NSSD's Waukegan Sewage Treatment Plant.

West of the site is Waukegan Harbor. Waukegan Harbor is utilized by lake-going freighters delivering gypsum to National Gypsum and cement to LaFarge Corporation, two industrial facilities situated on the west side of Waukegan Harbor. In addition, private boats that are used for recreational and fishing purposes have access to Larsen Marine's repair and docking facilities in the northern part of the harbor and to the public marina located in the southwest corner of the harbor.

Waukegan Harbor was dredged in 1991 to remove sediments containing PCBs. The dredging process was designed to leave in place any sediment with PCB concentrations less than 50 parts per million. No dredging standards were set for other constituents of the PCB/oil mixtures. Former Slip No. 3, situated northwest of the Harbor, has been filled with sediments containing oils and PCBs. A slurry wall surrounds the former slip, and a cap has been placed to cover the containment cell.

South of the site is OMC's Plant No. 1. Operations at OMC's Plant No. 1 include the manufacturing and testing of marine motors. An outdoor testing area in the harbor on the west side of the plant is used for long-term running and testing of dock-mounted outboard motors. South of OMC's Plant No. 1 is the City of Waukegan Water Plant, the Waukegan Harbor inlet, a rock breakwater which extends into Lake Michigan, and a 1,000-boat marina (the "New Harbor"). The rock breakwater is used by individuals for recreational shore fishing.

East of the site is Seahorse Drive. Asphalt parking lots and Waukegan Public Beach are situated east of Seahorse Drive. A Lake Michigan public swimming area is situated along the beach southeast of the site. Land use of the beach and swimming area is recreational.

Figure 2.2-2 shows the categories of potential future land use projected for areas surrounding the WCP site by the City of Waukegan in their comprehensive land use plan (City of Waukegan, 1987). The location of the PCB containment cell at the former Slip No. 3 is also indicated on this figure.

Land use on the site itself has historically included commercial/industrial development, various industrial-related uses, and temporary uses (such as boat and trailer storage) of otherwise vacant land. The northwest quadrant of the Site has historically been utilized by Larsen Marine for seasonal boat storage. Also, OMC has historically utilized portions of the site for industrial and commercial purposes. For example, OMC has stored various petroleum and PCB oils on-site. OMC has also conducted fire prevention and response training activities at on-site locations (Figure 2.1-2).

The existing WCP site land use is shown on Figure 2.2-3. Currently, the northwestern portion of the site surrounding Slip No. 4 is utilized by Larsen Marine, a commercial business engaged in boat sales, servicing, repair, refueling, storing, and launching.

The western portion of the site has been used for stockpiling dredged material from the lake or harbor and stockpiling soil from the excavation of Slip No. 4. Slip No. 4 was placed through the former CT&T wood-treating facility. Selected soils from the excavation of Slip No. 4 were designated for containment in a membrane-lined cell within a fenced area immediately south of Slip No. 4. The criteria for selecting these soils included prior agreement between OMC and the U.S. EPA on the areas from which the soils would be taken, a carcinogenic PAH concentration exceeding 6 parts per million, and on-site observation and selection of soils by a representative of the U.S. EPA.

The southeast portion of the site is currently occupied by OMC's data building, administration building, parking lots, and lawn space.

Until about 1990, the central and eastern portions of the site were routinely utilized by the City of Waukegan as public vehicle parking areas during beach-front festivals.

2.2.3 Climate

Waukegan has a typical continental climate characterized by frequent changes in temperature, wind direction, cloud cover and humidity. Because the eastern edge of Waukegan is bounded by Lake Michigan, inland lake breezes can cool the air along the lake shore by 10°F to 15°F in the summer and can warm the air by as much as 20°F in the winter (U.S. Department of Agriculture Soil Conservation Service, 1970). Table 2.2-1 summarizes temperature and precipitation data for the Waukegan area.

The total annual average precipitation for the Waukegan area is approximately 33 inches (rainfall plus snowfall converted to inches of water), with the majority of precipitation occurring in the months of April through September. The annual snowfall of about 37 inches (measured as inches of snow) typically occurs during the months of December through March. Winds are primarily from the west to northwest during the colder months and from the west to southwest during the warmer months (Hey and Philippi, undated). The temperature reaches or exceeds 90°F about 13 days a year on average, and drops to 32°F or below about 135 to 140 days a year on average (U.S. Department of Agriculture Soil Conservation Service, 1970).

Data for 1992 and 1993 are specifically included in Table 2.2-1 as they document weather conditions during the remedial investigation. In general, temperatures reported for 1992 and 1993 were warmer than the corresponding average normal monthly temperatures. Precipitation reported for 1992 is less than the long-term average of 33 inches, while available data for 1993 show greater total precipitation than the long-term monthly averages for the same period.

2.2.4 Surface Water

2.2.4.1 Lake Michigan

The shore of Lake Michigan is located approximately 600 to 800 feet east of the eastern boundary of the WCP site.

2.2.4.1.1 Physical Characteristics

Lake Michigan has a surface area of 22,400 square miles, with a mean depth of 276 feet and a volume of 1,170 cubic miles. The watershed contributing to Lake Michigan includes portions of Wisconsin, Illinois, and Michigan, covering 45,500 square miles, or twice the area of the lake surface. Lake Michigan has two outlets: a natural outlet through the Straits of Mackinac on the north end of the lake and through the Illinois Waterway near Chicago. Lake Michigan is the third largest of the Great Lakes and the only one entirely located within the United States.

The Lake Michigan beach east of the site is a sand beach built up from the sand carried by the littoral drift and trapped by breakwaters. The beach slope is gradual, approximately 100 horizontal to 1 vertical. The lake reaches depths of approximately 20 feet at locations 2,500 feet east of the lake shore. Reported depth soundings in Lake Michigan are included in PSCS Appendix 2-C.

2.2.4.1.2 Annual Water Level Cycle

The water surface elevation of Lake Michigan varies daily and annually, and is affected by hydrologic and atmospheric conditions. The water level in Lake Michigan is controlled by two outlets from the lake: one at the north end of the lake through the Straits of Mackinac and the second at the south end of the lake through the Illinois Waterway.

Water levels in Lake Michigan typically vary about 1 foot in elevation between annual low and high measurements. Water levels in Lake Michigan tend to be highest during the months of June,

July and August, with the maximum for the year generally occurring in July. Lake levels begin to drop toward the end of the year, and the lowest water levels occur during the winter months of January, February, and March. The annual water level cycle is illustrated on Figure 2.2-4. Table 2.2-2 presents long-term monthly lake level averages for the period from 1979 through 1988, along with monthly lake level data for 1992 and 1993 (National Oceanic and Atmospheric Administration [NOAA], 1989; U.S. Army Corps of Engineers, 1993a).

The long-term average water surface elevation is 579.37 feet above mean sea level (MSL); the maximum recorded water level is 582.16 feet MSL in 1986, and the minimum water level is 576.72 feet MSL in 1965, based on mean sea level according to the National Geodetic Vertical Datum 1929 adjustment. During 1993, the water level measured hourly at Milwaukee varied 0.86 foot during the year, with daily variations averaging 0.12 foot with maximum and minimum daily fluctuations of 0.49 and 0.04 foot, respectively.

The Federal Emergency Management Agency (FEMA) has published 100-year near-shore, high-water levels for Lake Michigan as a part of the National Flood Insurance Program. The 100-year flood elevation for Waukegan Harbor is reported to be 584.0 feet MSL (City of Waukegan Engineering Department, 1994).

Factors influencing the water level of the lake include precipitation, evaporation, groundwater levels, natural changes in the outlet channels from the lake, surface water inflow from rain, and snowmelt from the surrounding watershed. Periodic fluctuations in the water level are strongly influenced by barometric pressure, winds, and seiches. These fluctuations tend to be highly variable both temporally and spatially.

2.2.4.1.3 Hydrologic Budget

The NOAA maintains historical records of hydrologic data recorded from the Great Lakes (NOAA, 1983). This information can be used to compute the hydrologic budget of the Great Lakes on a long-term basis.

Table 2.2-3 summarizes the hydrologic budget for Lake Michigan based on the records of NOAA. The net basin supply is the sum of surface water inflows and precipitation on the lake, less evaporation. The net basin supply of 38,400,000 acre-feet per year represents the volume of water flowing out of the lake and being withdrawn from the lake for consumptive uses.

The hydraulic residence time of Lake Michigan is computed to be 103 years, based on the lake volume and the net basin supply. Hydraulic residence time is the period of time required to replace the volume of the lake at average outflow rates.

2.2.4.1.4 Other Phenomena

Seiches. Seiches are hydrodynamic instabilities in lakes caused by atmospheric conditions. A seiche creates periodic oscillations in lake levels that are similar to tides, but are not influenced by the moon. Lunar tides exist in the Great Lakes, but the changes in lake levels due to tides are very small. Since Lake Michigan is longest in a north-south direction, lunar tides effects are smaller than would be seen in an east west orientated Great Lake like Lake Superior.

Two different types of seiches occur in Lake Michigan, surface seiches, and internal seiche waves. Surface seiches are caused by strong winds pushing water to one side of the lake and the reaction of the water to the forces of gravity. The response of the lake to surface seiches are small compared to internal seiches. Internal seiches occur in stratified lakes in response to wind and atmospheric conditions. The denser hypolimnion is set in motion by steady winds and atmospheric pressure differences which causes the hypolimnion to oscillate in the direction of the wind for a period of time after the disturbance.

Wind Effect. Winds are primarily responsible for the lake water currents in the Great Lakes (Lick, 1976). The lake currents are important in the transport of suspended and dissolved materials throughout the lake by convection, advection, and turbulent diffusion. The transfer of energy from wind to the lake is dependent on the strength of the wind, the length of the fetch, and the sheltering of the water surface from the wind by shoreline characteristics. The wind impacts the lake differently in deeper portions of the lake than near the shoreline. Waves created by winds react to the bottom as they approach the shoreline causing a mixing of the near-shore waters.

Longshore Currents. Longshore currents are shoreline influences of waves meeting the shoreline of a lake or ocean at an oblique angle to the shoreline. These currents are important in the erosion of beach materials, and in the transport of these materials throughout the lake. The velocity of longshore currents are dependent on incidence angle of the waves, the height of the wave, and the slope of the bottom of the lake in the breaker zone. The longshore currents in Lake Michigan in Kewaunee County, Wisconsin have been measured to range to 1.4 feet per second (0.435 meters per second) (Lee, 1975). Based on theoretical equations for longshore current velocities and wave characteristics of Lake Michigan, longshore current velocities could exceed 2.5 feet per second

(0.75 meters per second) along the westerly shore of Lake Michigan near Waukegan. As evidenced by the littoral transport of beach materials in the area, longshore currents in Lake Michigan near Waukegan generally flow from north to south.

Beach Accretion Rate. The erosion and deposition of shoreline materials due to longshore currents in Lake Michigan is responsible for the build up of beach materials near Waukegan Harbor. The existing breakwater near the harbor entrance is considered to be the anchor for shoreline materials north of Waukegan Harbor (Chrzastowski, 1991). In addition to holding the existing shore in place, the breakwater also causes the deposition of littoral material transported by longshore currents.

The natural-state littoral transport of materials in Lake Michigan is estimated to be 100,000 cubic yards per year (Chrzastowski, 1991), although structures such as the breakwater at Waukegan Harbor reduce this value. Based on comparisons of historical shorelines of the Waukegan Beach, the beach has extended further into the lake by an average of 10 to 15 feet per year between 1958 and 1990.

2.2.4.2 Waukegan Harbor

Waukegan Harbor consists of an entrance channel oriented from east to west, a main channel oriented from north to south, Slip No. 1 on the western side of the main channel, and Slip No. 4 on the eastern side of the main channel (Figures 2.1-1 and 2.1-2). A marina area located south of Waukegan Harbor (i.e., south of the southern breakwater of the Waukegan Harbor entrance channel) is referred to as the "new harbor."

Waukegan Harbor is an industrial and commercial harbor and is adjacent to the western boundary of the WCP site. Lake-going freighters deliver raw materials such as cement and gypsum at Slip No. 1 located on the west side of the harbor. Approximately 75 ships per year use the harbor during the ice-free period, typically from March through December (Walker, 1994). Outboard motor performance testing is conducted by OMC in the harbor off the western end of OMC Plant No. 1. OMC also uses the harbor as a lake access point for boats operated during motor testing. Private boats use the harbor to reach the Larsen Marine repair and docking facilities at the northern end of the main channel and in Slip No. 4. A public marina is located in the southwest corner of Waukegan Harbor.

The harbor must be dredged periodically in order to maintain access to the harbor for freighters, barges, and private boats. Waukegan Harbor has been dredged regularly since it was constructed. According to U.S. Army Corps of Engineers records, the harbor was dredged on a nearly annual basis from 1918 through 1939. The record shows infrequent dredging through the 1940s and 1950s, then annual dredging from 1960 through 1969. Since then, dredging has occurred in 1974, 1975, 1976, 1977, 1979, 1982, 1984, 1985, 1988, 1990, 1991, and 1993 (U.S. Army Corps of Engineers, 1993b). Various portions of the inner harbor were dredged up through the 1960s, and again in 1985. All the other U.S. Army Corps of Engineers dredging projects in the 1970s and 1980s have been for dredging in the outer harbor, which lies east of the south pier of the harbor.

Other entities have also been involved in dredging the harbor. For instance, in 1958, the City of Waukegan dredged the marina area in the angle at the southwest corner of the harbor (Waukegan, 1958).

The northern 1,100 feet of the harbor (see PSCS Appendix 2-B) was dredged in 1991 as part of the Waukegan Harbor PCB remedial action. Immediately to the south, including the entrance to Slip No. 1, is an area commonly called "no man's land" because it lies between the Waukegan Harbor dredging and the limits of U.S. Army Corps of Engineers dredging projects. When the U.S. Army Corps of Engineers has received approval for a plan for disposing of dredged harbor sediments, they will dredge the inner harbor. Private interests are said to be considering dredging "no man's land" and Slip No. 1 (Walker, 1994).

2.2.4.2.1 Watershed

The watershed draining to Waukegan Harbor, shown on Figure 2.2-5, is 300 acres (0.47 square mile) in area. From the standpoint of evaluating generation of runoff, the land use of the watershed is primarily commercial/industrial with significant areas of railroad and highway right-of-way and lesser areas of open and urban residential areas. The area adjacent to the harbor is relatively flat with unpaved surfaces, while the area near the city is highly impervious due to extensive development.

Water reaches the harbor by storm sewer as well as by overland flow. Municipal storm sewers and private storm sewers discharge to the harbor (PSCS Appendix 2-D). Part of the downtown area of Waukegan drains to the harbor by storm sewer. A former storm sewer which discharged water from OMC Plant No. 2 to Slip No. 3 is believed to have been the primary source of PCB/oil mixtures discharged to the harbor (U.S. EPA, 1981). This storm sewer was rerouted during the Waukegan Harbor Superfund site remedial action and now discharges to the North Ditch. In the early 1980s,

oil observed in the south end of the harbor was believed to have resulted from releases of oil at EJ&E railroad tracks located west of the harbor (Bleck, 1993). The oil washed through the Madison Street sewer system to Waukegan Harbor (Bleck, 1993).

2.2.4.2.2 Hydrologic Budget

Flows to and from the harbor include stormwater, groundwater, permitted discharges, and exchanges with Lake Michigan.

Stormwater Discharges. Stormwater inflows to the harbor are estimated to be approximately 350 acre-feet per year based on 14 inches annual runoff over the 300-acre watershed (Hey and Associates, 1993). The average annual rainstorm is 0.27 inches over a duration of 5.7 hours and the average period between rainfall events is 72 hours (U.S. EPA, 1983). The 100-year, 24-hour precipitation is 6.4 inches, and the two-year, 24-hour event is 2.8 inches (Hey and Associates, 1993).

Groundwater Inflows. Groundwater flows to Waukegan Harbor from the peninsula on the east and the landward side on the west. No estimate of the average annual volume of the total flow is available.

Lake Exchanges. A study performed by Argonne National Laboratories (ANL) in 1979 (Harrison, 1979) found average currents in and out of the harbor sufficient to flush the volume of water in the harbor in about 4 days. On two occasions during the 92 day study, currents were large enough to conclude that the harbor can flush in 24 hours or less. The study results support the idea that a two-layer flow system commonly exists in the harbor channel. The two-layer flow system is one in which flow at the harbor surface is in one direction, while flow at the harbor bottom is in the opposite direction, resulting in a reciprocal exchange of water between the lake and harbor. The ANL study found this reciprocal exchange often occurs in response to the wind, and that both instantaneous and daily average water level changes appeared to be less significant than wind in exchanging water between the lake and harbor.

In addition to the study of harbor currents, the ANL research included a dye study to assess harbor flows and water quality sampling to observe the effect of these flows on water quality. The dye study indicated that the harbor flushed in 8 days. The water quality study showed concentration decreases that correlated with a large inflow of water along the harbor bottom.

Periodic changes in the water level of Lake Michigan apparently contribute only modestly to the exchange of water with Waukegan Harbor. These water level changes may affect the hydraulic residence time of the harbor. The ANL study indicated that large water level changes, of about 3 feet, could produce harbor flushing of some importance. The water level of the harbor was measured on a continuous basis between October 28 and November 7, 1993. The continuous water level measurements indicate that the typical change in the average daily water level is 0.5 foot. During a single day, water levels were measured to vary by nearly 1 foot between maximum and minimum levels. Over the two-week monitoring period, the water level in Waukegan Harbor rose and fell nearly 2 feet.

Other Flows. Potential discharges from industrial activities to Waukegan Harbor include noncontact cooling water and other permitted discharges under the NPDES program. OMC has eight permitted discharges to Waukegan Harbor, with a maximum combined discharge of 3.9 mgd (4,400 acre-feet per year).

Water is withdrawn from Waukegan Harbor for use by OMC for noncontact cooling water. Based on their NPDES permit, OMC may withdraw up to 2.4 mgd (2,680 acre-feet per year) from the harbor.

2.2.4.3 Hydrologic Impact of Lake Michigan on Waukegan Harbor

Lake Michigan impacts Waukegan Harbor in several ways. Most significantly, the nearly continual exchange of water between the lake and harbor prevents stagnation of the harbor water. This is especially important in terms of the water quality of the harbor. The lake also influences the harbor by direct waves entering the harbor through the entrance channel causing mixing throughout all or part of the harbor.

In addition to the physical forces of nature acting on the harbor, the influence of the boat and ship traffic in the harbor causes mixing and movement of water in and out of the harbor.

2.2.4.4 Hydrologic Impact of Harbor on Lake Michigan

The total inflow of water to the harbor from all sources, other than from the lake, totals less than 0.01 percent of the total inflow to the lake. Due to the small size of the contributing watershed and surface area of the harbor, Waukegan Harbor has a very small influence on the total inflow of water to Lake Michigan.

2.2.4.5 Rivers and Streams

The Waukegan River, located approximately 3,000 feet southwest of the site, discharges to Lake Michigan (Figure 2.1-1). The Waukegan River is the only river located within a 1-mile radius of the site.

A constructed drainage channel known as the North Ditch is present north of OMC Plant No. 2, approximately 1,500 feet north of the WCP site. The North Ditch flows to the east and discharges to Lake Michigan. The North Ditch outlet is intermittently blocked by sand deposition along the lake shore.

The NSSD sewage treatment plant, located north of the North Ditch, discharges to Lake Michigan via the North Ditch during periods of peak flow rates, such as during very heavy rain storms. The plant has a maximum capacity of 38 million gallons per day. If the plant's detention ponds are filled to capacity and influent exceeds plant capacity, the excess flow is filtered, chlorinated, and discharged to the North Ditch. The excess flow is monitored for water quality during such events (Hey and Associates, undated).

2.2.5 Regional Hydrogeologic Setting

2.2.5.1 Geology

Waukegan is located in a glaciated area of northeastern Illinois. The region is characterized by a series of north-south trending morainal ridges and intervening alluvial deposits that form the valley floors. Glacial deposits are interbedded with alluvial deposits associated with sedimentation and erosional processes related to Lake Michigan and its fluctuating water levels over the past 10,000 to 12,000 years (Reinertsen, et al., 1981).

The WCP site is located on a flat-lying peninsula, which is separated from the mainland by Waukegan Harbor. The peninsula is bounded on the south and east by Lake Michigan and on the west by Waukegan Harbor. The peninsula lies at an average elevation of approximately 585 feet MSL.

Waukegan Harbor is a manmade structure constructed in the late nineteenth and early twentieth centuries. Prior to construction of the harbor, the area located east of the original shoreline (i.e., the site location) was composed of a complex series of natural and manmade inlets and islands. Portions of the site and much of the site vicinity were filled and reclaimed.

Surficial deposits in the vicinity of the site consist of shallow-water, near-shore lake sediments (beach, bar, spit, delta, lacustrine, and other marsh deposits) of the Dolton Member of the Equality Formation. These deposits are predominantly medium-grained sand with gravel. Underlying the Equality Formation is a relatively thick unit of mostly gray clay and sandy clayey till with some pebbles and cobbles; this glacial deposit is termed the Wadsworth Till Member of the Wedron Formation. The total depth of unconsolidated deposits in the region is reported to be between 50 feet and 200 feet (Lineback, 1979; Hughes, et al., 1966).

Underlying the unconsolidated deposits are the dolomitic (Silurian) Racine, Waukesha, Joliet, Kankakee, and Edgewood Formations. The bedrock topography is complex, having been eroded prior to and during the last glaciation. Bedrock valleys are present in the Waukegan area, several with total relief of more than 100 feet. Most of these valleys trend west to east. Below the dolomite lie Ordovician rocks, including: the Maquoketa Shale Group; the Galena-Platteville Formation limestone and dolomites; the Ancell Formation (St. Peter Sandstone); and the Prairie du Chien Formation (Willman, et al., 1967).

2.2.5.2 Hydrogeology

Sand and gravel deposits within surficial glacial materials are used for groundwater production in some areas of northeastern Illinois. Where such deposits are thick and relatively continuous, pumping rates as high as 1,000 gpm are possible (Hughes, et al., 1966).

Bedrock units form three major aquifer systems in northeastern Illinois. The uppermost shallow bedrock aquifer consists of the Silurian dolomites. The underlying Maquoketa Group shales hydraulically separate the Silurian aquifer from deeper units. The shallow bedrock aquifer is recharged through the glacial deposits and is generally in hydraulic connection with the glacial deposits and major surface water features.

The deeper aquifer systems include the Cambrian-Ordovician aquifer and the Mt. Simon Aquifer. These hydrogeologic units are recharged where they outcrop or where they immediately underlie the glacial deposits. In general, the recharge areas are located to the north and west of Waukegan. The deeper units may also receive some recharge through the Maquoketa Group.

Regionally, groundwater generally occurs under unconfined conditions in surficial unconsolidated deposits and under confined conditions in the upper bedrock aquifer. Lake Michigan

acts as a major regional discharge zone for groundwater. Therefore, groundwater flow in both surficial unconsolidated deposits and bedrock units in the region would typically be toward the lake.

2.2.6 Water Use

Lake Michigan is the source of drinking water in the Waukegan area. The City of Waukegan waterworks is located approximately 1,000 feet south of the WCP site, and the water supply intake is in Lake Michigan approximately 6,500 feet southeast of the site. A backup intake is in Lake Michigan approximately 3,100 feet southeast of the site. The backup intake has not been used since the new intake was constructed in 1967. A third intake, which would draw water from Waukegan Harbor about 1,000 feet south of the site, would not be used except in extreme emergency, such as failure of the other two intakes (Chess, 1993). This intake has reportedly been used only on one occasion, in association with maintenance work (Chess, 1993). The locations of the intakes are identified on maps included in PSCS Appendix 2-D. Water well survey data from 1992 indicate that no active private drinking water wells are located within 1 mile of the site (Barr, 1992a).

As discussed in Section 2.1.3.3, available records indicate that a water well was located at the southwest corner of the boiler house and was completed in the bedrock at a depth of approximately 140 feet below the ground surface (Baehr Organization, 1927). Records of this well's abandonment are not available. The potential for downward migration of dissolved parameters through the well from the sand aquifer to the bedrock aquifer is limited because of the upward hydraulic gradient across the till between the bedrock and sand aquifers. However, the potential for downward migration of undissolved contaminants may not be limited by this upward hydraulic gradient.

2.2.7 Ecological Features

The WCP site is located in a commercial/industrial/recreational area along Lake Michigan. Industrial, commercial, and residential development in the surrounding area has virtually eliminated most of the natural areas. The most significant remaining ecological features in the vicinity of the site include Lake Michigan, Waukegan Beach, and the Illinois Beach State Park. The shoreline of Lake Michigan, including a portion of Waukegan Beach, is located east of the site across Sea Horse Drive. Illinois Beach State Park is located approximately 1.5 miles north of the site. The locations of these ecological features are shown on Figure 2.2-4.

2.2.7.1 Lake Michigan

Lake Michigan provides a diversity of aquatic habitat and supports an important commercial and sport fishery. Yellow perch and bloaters are harvested commercially. The Lake Michigan sport-fishing catch consists primarily of yellow perch; chinook and coho salmon; and steelhead, brown, and lake trout. Two state threatened fish species, the longnose sucker and the lake whitefish, have been reported in Lake Michigan between Zion and Waukegan. The last sightings of these species were in 1985 for the longnose sucker and in 1991 for the lake whitefish (Hey and Associates, 1993).

In the Waukegan Harbor area (Figure 2.2-4), sport fish and other fish species are present in both the new harbor area and the Old North Harbor (Trudeau, 1993; Pfister, 1994). No published information is available on impacts to fish populations in the Waukegan Harbor area (Hey and Associates, 1993). However, current fishing advisories posted at the Waukegan Harbor (based on PCB data from fish sampling) state that "the Department of Public Health advises that no fish from Waukegan Harbor Old North Harbor be consumed" (Pfister, 1994). In evaluating loss of fish habitat, the Waukegan Remedial Action Plan Final Report concludes that, because the Old North Harbor portion of Waukegan Harbor is "a man-made structure which was constructed for industrial purposes, its value for wildlife and fish habitat is limited" (Hey and Associates, 1993). Factors that limit this portion of the harbor's value as a habitat include: regular industrial boat traffic that stirs up and muddies the harbor waters; dredging operations that disturb harbor sediments and affect surface water quality; and the lack of cover provided by the deep, vertical harbor walls (Trudeau, 1993).

The Illinois Department of Conservation (IDOC) has been stocking salmon and trout into Lake Michigan near the Waukegan Harbor area since 1957 (Hey and Associates, 1993). The stocked fish are released into the new harbor area just south of the Waukegan Harbor's southern breakwater (Figure 2.2-4). The salmon and trout migrate back to the release site during the spawning season of each year.

2.2.7.2 Waukegan Beach

Waukegan Beach is a sand and dune area east of the site that is used primarily for recreational purposes (i.e., beachcombing, swimming, picnicking, etc.). The beach extends north along the shoreline of Lake Michigan to Illinois Beach State Park. In the past, the City of Waukegan would periodically grade the beach to enhance the recreational opportunities, resulting in a disturbance to the sand dune communities. The City has discontinued grading of the beach, thus allowing for the partial redevelopment of the dune communities (Murphy, 1991).

The IDOC has stated that several endangered, threatened, or rare bird species have nested or attempted to nest at Waukegan Beach (IDOC, 1992). The bird species include the following: common tern, piping plover, ring-billed gull, Brewer's blackbird, and yellow-crowned night heron. None of these species are currently known to nest adjacent to the site (IDOC, 1992). There is a common tern nesting site near the Commonwealth Edison Waukegan Power Plant (Hey and Associates, 1993), which is located approximately 1.5 miles north of the site. This is the only known common tern nesting colony in Illinois (Hey and Associates, 1993).

Three threatened or endangered plant species have been found at the Waukegan Beach between the northern harbor breakwater and the sewage treatment plant (IDOC, 1992). These plant species consist of American sea rocket (state-threatened), seaside spurge (state-endangered), and American beachgrass (state-endangered). Sea rocket and seaside spurge are adapted to sand pocket habitats and are likely only to be found as primary successional species of the upper reaches of a bare sand habitat (Glosser, 1992). Beachgrass (also known as marram grass) may occur as high as the foredune just beyond the upper reaches of the beach sand habitat, but is not likely to occur further inland (Glosser, 1992).

A naturalist with the IDOC has recently confirmed the presence of the American beachgrass on Waukegan Beach opposite the site (Wright, 1993). She also stated that there exists suitable habitat for other rare plant species (including sea rocket and seaside spurge), even though no other rare plant species were observed during her cursory survey (Wright, 1993).

Wetland vegetation communities are scattered throughout the Waukegan Beach area along Lake Michigan and are typically characterized by creeping juniper and nodding wild rye (Hey and Associates, 1993). A small wetland area dominated by rushes has begun to develop along the eastern edge of the parking lot at Waukegan North Beach (Wright, 1993).

2.2.7.3 Illinois Beach State Park

Illinois Beach State Park is a 4,160-acre natural area that is situated along the shore of Lake Michigan. The park contains a diversity of habitat, including cattail marshes, sand prairies, and savannas. An avian ecological survey conducted in 1981 recorded 116 bird species within the park, and 91 of these species were believed to be nesting within the boundaries of the park (Hickman and Neal, 1981). Other animals observed at the park include 28 species of mammals, 14 species of reptiles, and 9 species of amphibians (Hey and Associates, 1993).

State-listed threatened and plant species that have been recorded in the Illinois Beach State Park are provided in Table 2.2-3. The list includes twelve endangered plant species, two threatened plant species, three endangered bird species, and two threatened bird species. Six federally listed threatened or endangered species that could potentially inhabit the park are also listed in Table 2.2-3.

SECTION 3.0
PREVIOUS INVESTIGATIONS

3.1 WAUKEGAN HARBOR PCB INVESTIGATIONS

The Waukegan Harbor Superfund site (Section 2.1.3.6) has been the focus of studies addressing PCB contamination. As discussed below, several studies have been completed that provide relevant information for the Waukegan Harbor area. The studies addressed in this section relate to the extent of PCB contamination and geologic/hydrogeologic conditions at the Waukegan Harbor Superfund site. Studies related to the Waukegan Harbor Superfund site remedy are discussed in Section 3.2.

A hydrogeologic investigation and PCB contamination study was conducted in 1979 and 1980 at the North Ditch area located north of the WCP site. The work was conducted by JRB Associates, Inc. and Warzyn Engineering, Inc. The objectives of the study were to investigate groundwater flow conditions in the vicinity of the North Ditch, to determine if aquifers in the study area were affected by PCBs that had been discharged to the North Ditch, and to determine if PCBs had been released via groundwater to Lake Michigan. The results of the investigation are presented in the following documents: Technical and Witnessing Case Support, Hydrogeological Study of Groundwater - Final Report (JRB Associates [JRB], 1981); Hydrogeologic Investigation, Outboard Marine Corporation, Waukegan Illinois (Warzyn Engineering, Inc., 1979); and Subsurface Investigation, North Ditch Area, Outboard Marine Corporation, Waukegan Illinois (Warzyn Engineering, Inc., 1980).

The first phase of the Waukegan Harbor PCB investigation involved placing 15 soil borings, all of which were completed as monitoring wells or piezometers. The second phase of the hydrogeologic investigation consisted of placing 44 soil borings, installing 5 additional groundwater monitoring wells and two additional piezometers, and taking 20 sediment cores from the North Ditch. PSCS Appendix 3-A includes the following information from this investigation: soil boring, piezometer, and monitoring well locations; boring logs; soil coring logs; monitoring well logs; results of baildown hydraulic conductivity tests; and water level measurements. Summary tables of PCB concentrations in soil and groundwater samples collected from the North Ditch area are available in the JRB Associates (1981) report.

3.2 INVESTIGATIONS RELATED TO WAUKEGAN HARBOR PCB REMEDY

3.2.1 North Ditch Area Investigation

In 1989, Canonie Environmental, Inc. placed 22 soil borings and two deep bedrock piezometers in the area of the North Ditch and OMC Plant No. 2 as part of the design for the PCB remediation. The soil borings were placed to provide geotechnical data for the placement of the east and west slurry wall containment cells (PSCS Appendix 2-B). The investigative work was conducted at generally the same time as the investigation for Slip No. 4 was being conducted (see Section 3.2.2). Six of the soil borings placed during the investigation were placed along the alignment of the North Ditch to provide geotechnical information relating to the planned excavation of sands in this area. PSCS Appendix 3-A includes the following information from this investigation: soil boring and piezometer locations; boring logs; and piezometer logs.

Piezometers L-1 and L-2B were screened in the Silurian Dolomite bedrock aquifer to determine the hydrostatic pressure in the bedrock and evaluate vertical gradients. The hydraulic gradient across the clayey till was reported to be in an upward direction at Piezometer L-1 and a downward direction at Piezometer L-2B (Canonie, 1989). Locations and construction logs for these piezometers are provided in PSCS Appendix 3-A.

Falling head hydraulic conductivity tests were performed at several soil borings to assess the hydraulic conductivity of the till underlying the containment cells to be constructed as part of the Waukegan Harbor Superfund site remedy. In addition, grain size distribution data were used to estimate hydraulic conductivity of sands overlying the till. PSCS Appendix 3-A includes boring locations and available results for these tests (Canonie, 1989).

3.2.2 New Slip Soil and Groundwater Investigations

In 1989, Canonie Environmental, Inc. conducted a soil investigation for the construction of Slip No. 4 (the new slip) for the boat servicing facility. The results of the investigation were contained in the Draft Data Summary Report - New Slip Soil Investigation (Canonie, 1990a). The investigation consisted of a four-phase soil boring program and the installation of two nests of monitoring wells. Samples collected from soil borings and monitoring wells were submitted for chemical analysis of semivolatiles and PCBs.

Additional soil investigations were performed in the area of Slip No. 4 by Canonie Environmental, Inc. in November and December 1990 and January 1991 (Canonie, 1991). These investigations were performed to provide additional information for: (1) delineating areas of contaminated soils to be placed in the designated soil stockpile following excavation of Slip No. 4; and (2) providing information on soil quality in areas affected by the extension of the slip toward the east.

Boring and well locations, boring logs, and monitoring well logs for these investigations are presented in PSCS Appendix 3-A. Soil quality data are in PSCS Appendix 3-B. PSCS Appendix 3-C presents groundwater quality data.

3.3 IEPA SOIL INVESTIGATION

In June of 1989, the IEPA collected and analyzed a total of eleven soil samples from eight soil borings located on or near the WCP site. The samples were collected at depths of 6 feet or less below the ground surface and analyzed for phenols, PAHs, volatile organic compounds (VOCs), pesticides, and metals (IEPA, undated). PSCS Appendix 3-D identifies sampling locations and includes results of soil sample analyses.

3.4 OMC TEST TRENCHING

In early 1990, three test trenches approximately 3.5 feet in depth were dug on property currently occupied by Larsen Marine, north and northeast of the location of Slip No. 4. Information regarding the exact locations of these test trenches is not currently available. A 1-foot thick seam of coal fill was seen below approximately 8 inches of topsoil in a test trench in the Larsen boat storage area, approximately 135 feet south of Sea Horse Drive. The material below the coal was characterized as clean sand (OMC, 1990b). OMC dug a test trench at the northeast corner of the site along the anticipated alignment of the new sanitary sewer force main. The trenching was videotaped and showed no evidence of oily substances in the soil (OMC, 1990b).

3.5 WAUKEGAN HARBOR AREA SEDIMENT INVESTIGATIONS

Several sediment investigations have been conducted in and/or near the Waukegan Harbor (Armstrong, 1980; Norby, 1981; Ross, et al., 1990; Risatti, et al., 1990; Canonie, 1991; Hey and Associates, 1993). Some of the sediment samples analyzed for these studies have been collected from the harbor in the vicinity of the WCP site. In general, the sediment samples collected during these studies were primarily analyzed to provide information relating to PCBs. The following sections

provide a brief summary of the results from previous sediment investigations in the Waukegan Harbor area. Data reported for sediment samples collected from areas of the Waukegan Harbor that were dredged as part of the Waukegan Harbor Superfund site remedy are not representative of current conditions.

3.5.1 1978 Waukegan Harbor and Lake Michigan Study

In 1978, Armstrong (1980) conducted a study in Waukegan Harbor and the southern basin of Lake Michigan to determine the types and concentrations of PCBs in the surface sediments. Sediment samples were collected from Waukegan Harbor, the near-shore area adjacent to the Harbor, and the open lake area of Lake Michigan. PCB concentrations in the Waukegan Harbor ranged from 8 to 3,600 parts per million, with the highest concentrations in the north end of the harbor.

3.5.2 1979 Illinois Beach Nourishment Study

A study was conducted in 1979 near Great Lakes Naval Training Center and Waukegan harbors to evaluate the potential of near-shore sediments for providing beach nourishment material (Norby, 1981). Two sediment cores collected south of the mouth of the Waukegan Harbor were analyzed for seven pesticides; PCBs; and 30 major, minor, and trace elements. The results of the inorganic analysis indicated that elemental concentrations in the sediment samples collected near the Waukegan Harbor are typical of concentrations in sediment from other areas of Lake Michigan (Norby, 1981).

3.5.3 1986 Waukegan Harbor Study

Ross, et al. (1990) conducted an investigation of the sediments in Waukegan Harbor in 1986. The purpose of the study was to assess the ecotoxicological hazard of the sediments. Sediment samples were collected from 24 sites within the Harbor, including Slip Nos. 1 and 3, the north harbor, and the harbor channel. The sediment samples were analyzed for total PCBs. In addition, the following toxicity testing was performed:

- Acute bioassays, using sediment elutriate and luminescent bacterium, green algae, and a free-living nematode.

- In situ and laboratory bioassays, assessing protozoan community structure.

- Phytotoxicity assays, using duckweed, millet, and lettuce plants, and direct sediment testing.

The study recommended further investigation to assess ecotoxicological risks associated with PCBs and other contaminants.

3.5.4 1987 Waukegan Harbor Study

As a follow-up to the 1986 study summarized in the above section, Risatti, et al. (1990) conducted another sediment investigation in 1987 at the Waukegan Harbor. The objectives of this study were to determine the concentrations of other contaminants (i.e., in addition to PCBs) in Waukegan Harbor sediments and to reevaluate the toxicity of the sediments. Sediment samples were collected from 23 sites within the Harbor and analyzed for oil and grease and 22 major, minor, and trace elements. In addition, two sediment samples collected from Slip No. 3 were analyzed for priority pollutants. Elutriates from the sediment samples were used to determine biological response to contamination with the following toxicity tests:

- Luminescent inhibition of a marine bacterium.
- Photosynthetic inhibition of a green algae.
- Developmental inhibition of a nematode.

Sampling locations and analytical results from this investigation are provided in PSCS Appendix 3-E. Oil and grease concentrations ranged from 0.3 percent to 5.19 percent, with the highest concentrations occurring in Slip No. 3 and in the areas immediately outside the slip. Sediments in the harbor were found to have high concentrations of cadmium, copper, manganese, lead, zinc, and iron. The highest concentrations of priority pollutant metals were found in the samples collected at the head of Slip No. 1 and immediately outside of Slip No. 3. In addition, priority pollutants detected in the sediment samples collected from Slip No. 3 include carcinogenic PAHs (at individual concentrations of up to 23 mg/kg), noncarcinogenic PAHs (at individual concentrations of up to 64 mg/kg), PCBs (at individual concentrations of up to 22 mg/kg), and total xylenes (at a concentration of 4.7 mg/kg in one sample) (Risatti, et al., 1990). An analysis of variance of the results of the toxicity tests identified high toxicity areas located at the head of Slip No. 3 and approximately half way between Slip No. 1 and Slip No. 3. Areas of low toxicity were identified in Slip No. 3, at the mouth of Slip No. 1, and along the eastern edge of the Harbor near the northern boundary of the OMC Plant No. 1 facility (Risatti, et al., 1990).

3.5.5 1990 Waukegan Harbor Area Study

As part of the Waukegan Remedial Action Plan (RAP), the IEPA collected sediment samples in 1990 from five sites within the Waukegan Harbor, one site south of Waukegan Harbor, and one site near the Waukegan North Beach (Hey and Associates, 1993). The samples were analyzed for metals, cyanide, nutrients, chemical oxygen demand (COD), volatile solids, semivolatile organic compounds, organochlorine pesticides, and PCBs. Sampling locations and analytical data from this investigation are provided in PSCS Appendix 3-E.

The analytical results for the sediment samples were compared with guidelines for the pollution classification of Great Lakes harbor sediments. Analytical data for samples from the following locations showed one or more parameters classified as signifying "heavy pollution": the upper harbor; Slip No. 1; the central harbor; the entrance channel; and the new harbor. Samples collected from locations at the marina in the southwest portion of Waukegan Harbor and at the North Beach were classified as nonpolluted for all parameters (Hey and Associates, 1993). Sediment samples from Waukegan Harbor showed one or more of the following parameters that were classified as signifying "heavily polluted" conditions: PCBs; cadmium; copper; lead; manganese; and zinc.

3.5.6 1991 New Slip Area Study

A sediment investigation was conducted in 1991 in conjunction with the investigation and construction of Slip No. 4 (the new slip) at the WCP site (Canonie, 1991). Sediment samples were collected from three sites in the northern end of the harbor along the east harbor wall, which correspond with the mouth of Slip No. 4. The samples were analyzed for volatile and semivolatile organic compounds and metals. Sampling location information and analytical data from this investigation are provided in PSCS Appendix 3-E.

Phenolic compounds and PAHs were detected in the semivolatile analyses of sediment samples collected from the harbor. VOCs detected in the samples consist of methylene chloride, acetone, benzene, toluene, total xylenes, and 2-butanone. The following metals were also detected in at least one of the sediment samples: arsenic, chromium, copper, iron, lead, mercury, nickel, selenium, and zinc.

3.5.7 1992 IEPA Sediment Sampling

In April 1992, the IEPA collected sediment samples from three locations near intakes for the water treatment plant: one in Waukegan Harbor, near the emergency intake; one from Lake Michigan, near the back-up intake; and one from Lake Michigan, near the main intake (Hey and Associates, 1993). Analyzed parameters and analytical results are provided in PSCS Appendix 3-E.

PCBs and several metals were detected in the sediment samples collected near intakes for the water treatment plant. The highest concentrations of these contaminants were detected in the samples collected from the Waukegan Harbor channel near the emergency intake.

3.6 WAUKEGAN HARBOR AREA SURFACE WATER INVESTIGATIONS

3.6.1 Lake Michigan Water Quality Testing

Since 1977, the Illinois portion of Lake Michigan has been monitored under the terms of a cooperative agreement between the City of Chicago and the IEPA (IEPA, 1993). The North Shore lake survey portion of this sampling program includes one sampling location located approximately 1/2 mile east-southeast of the entrance to Waukegan Harbor. Reported analytical data for this location (Station 7N) are provided in PSCS Appendix 3-E. The annual mean data for inorganic, organic, and biological parameters reported for samples collected from Station 7N typically show values within one standard deviation of the corresponding values for the 10 North Shore lake survey sampling stations (PSCS Appendix 3-E).

3.6.2 1990 Waukegan Harbor Area Study

As part of the Waukegan RAP, the IEPA collected surface water samples in 1990 from five sites within the Waukegan Harbor, one site near the new harbor, and one site near the Waukegan North Beach (Hey and Associates, 1993). Analyzed parameters and analytical data from this investigation are provided in PSCS Appendix 3-E. The reported data show no metal concentrations exceeding surface water quality standards; referenced surface water quality standards were reportedly exceeded by samples from all seven locations for total phosphorus, total ammonia, and sulfate (Hey and Associates, 1993).

3.6.3 1991 New Slip Area Study

Surface water samples were collected in 1991 in conjunction with the investigation and construction of Slip No. 4 (the new slip) at the WCP site (Canonie, 1991). Surface water samples were collected on one or more occasions from two locations in the northern portion of Waukegan Harbor and from three locations within Slip No. 4. The samples were analyzed for volatile and semivolatile organic compounds and metals. Sampling location information and analytical data from this investigation are provided in PSCS Appendix 3-E. The reported data show detectable concentrations of phenolic compounds and PAHs in one or more water samples collected from Slip No. 4. These parameters were not detected in samples from the upper harbor outside of the mouth of Slip No. 4 or in the last sample (June 1991) collected from within Slip No. 4. Various VOCs and metals were detected in one or more of the surface water samples (Canonie, 1991).

3.6.4 Waukegan Water Treatment Plant Surface Water Sampling

Raw water samples are collected and analyzed on an annual basis from the intakes of the Waukegan Water Treatment Plant. Available information about analyzed parameters, analytical data, and sampling locations for the years 1973, 1975 to 1988, and 1990 to 1992 are included in PSCS Appendix 3-E. The available data show no detected occurrences of organic analytes in raw water samples.

In 1988, additional water samples were collected in response to taste and odor problems reported for water from the Waukegan Water Treatment Plant. The sampling locations, analyzed parameters, and analytical results for this investigation are provided in PSCS Appendix 3-E. The data show detectable concentrations of benzene, toluene, and/or xylenes for samples collected from areas within Waukegan Harbor. The highest concentrations of these compounds were reported for the sample collected from the area west of OMC Plant No. 1 (PSCS Appendix 3-E).

SECTION 4.0
REMEDIAL INVESTIGATION ACTIVITIES

The WCP RI consisted of a soils investigation, a hydrogeologic investigation, a groundwater quality investigation, a surface water quality investigation, an environmental features survey, remedial technology evaluation sampling, and a quality assurance/quality control review of analytical data. The objectives of these activities were to characterize the lateral and vertical extent of soil contamination, characterize the soil quality and lithology of the soil stockpiles, characterize the site geology and stratigraphy, evaluate hydraulic characteristics of the sand unit, assess groundwater quality downgradient of identified source areas, characterize the site's groundwater flow regime, characterize surface water quality in the vicinity of the site, characterize the geotechnical properties of the till and sand units for use in the development of remedial alternatives, and provide site-specific data needed to evaluate potential treatment technologies for remedial alternatives.

Remedial investigation activities at the site were conducted in two phases; the first in February through April 1992, the second in August through December 1993. The results of the Phase I investigation were used to refine the design of the Phase II investigation. Phase I involved, in part, a preliminary delineation of the lateral extent of shallow soil contamination using test trenching. On-site soil samples were collected from test trenches, surficial soil borings, and soil borings. Selected soil samples were analyzed to provide a preliminary characterization of soil contaminants. The test trenches were also used to investigate the presence of foundations at former facility structure locations. Surficial soil samples from off-site locations were also collected and analyzed to assess background soil quality. Phase I included the installation of on-site monitoring wells and piezometers to make a preliminary determination of groundwater flow directions at the site and guide the selection of further monitoring well locations and analytical parameters for Phase II. Slug tests were performed at the Phase I monitoring wells to provide initial estimates of aquifer hydraulic conductivity and groundwater samples were collected and analyzed to provide an initial assessment of groundwater quality. During Phase I, on-site and off-site ecological features were evaluated.

The Phase II investigation involved placing soil borings in areas of identified contamination (based on the Phase I test trenching program) to evaluate the vertical and lateral extent of soil contamination, sampling and analysis of soils for chemical constituents, sampling and analysis of soils for geotechnical parameters, installing additional monitoring wells, permeability testing, groundwater and surface water sampling and analysis, and sampling and analysis of soil and groundwater for evaluating remedial technologies.

Prior to beginning remedial investigation activities, potential chemicals of concern were identified for the site (October 1991 RI/FS Final Work Plan). These chemicals of concern consisted of the inorganic and volatile/semivolatile organic compounds typically associated with manufactured gas and coking operations (Table 2.1-3), inorganic and volatile/semivolatile organic compounds associated with creosoting operations (Section 2.1.3.2), PCB and semivolatile organic compounds associated with OMC operations adjacent to the site (Section 3.1), and volatile/semivolatile organic compounds potentially associated with fuel and oil storage areas (Section 2.1.3.4). During the first phase of RI field activities, groundwater samples were analyzed for the full-scan list of parameters in Table 4.0-1 (metals, cyanide, VOCs, PAHs, phenols, pesticides, and PCBs), and soil samples were analyzed for either the full-scan list of analytical parameters in Table 4.0-1 or the Phase I list of parameters in Table 4.0-2 (metals, cyanide, VOCs, PAHs, and phenols). Based on the results of the first phase of sampling, as documented in the July 1993 TM, PCBs and several other parameters were removed from the list of potential chemicals of concern. The shorter lists of parameters for the second phase of the soil and groundwater investigations are shown in Tables 4.0-3 and 4.0-4, respectively. Selected water and soil samples were also submitted for analyses of the general chemistry and remediation evaluation analytical parameters identified in Tables 4.0-4 and 4.0-5, respectively.

For those Phase II water and soil samples submitted for analysis of the semivolatiles in Tables 4.0-3 and 4.0-4, the laboratory was requested to report estimated concentrations below the contract required detection limit (CRDL), but above the method detection limit (MDL), and to indicate when the criteria for reporting estimate concentrations below the CRDL was not met. If the criteria were met and there were no estimated detections below the CRDL, the detection limits for these parameters are reported in the data summary tables as the MDLs.

The following sections of the report describe the field activities conducted during the RI, summarize the objective of each activity, describe the methods used to collect the data, and present the data for each field activity.

4.1 SOILS INVESTIGATION

The soils investigation conducted during the RI consisted of background soil sampling, surficial soil sampling, ground surface soil sampling, test trench excavation and sampling, soil boring placement and sampling, and designated soil stockpile sampling. This section of the report describes the objectives and methods of each of these soil sampling activities.

4.1.1 Background Soil Sampling

The objectives of the background soil sampling were to:

- Characterize the typical background concentrations of chemical constituents in soils in the surrounding industrial area.

- Characterize the typical background concentrations of chemical constituents in soils in local areas thought to be unaffected by industrial activities. These locations were selected by the U.S. EPA.

Eight background soil samples (BS-01 through BS-08) were collected from the locations shown on Figure 4.1-1 during the first phase of RI field activities. Background Soil Samples BS-01 through BS-04 were selected by the U.S. EPA to represent locations thought to be unaffected by industrial activities. These locations were adjusted by U.S. EPA personnel in the field prior to sampling. Background Soil Samples BS-05 through BS-08 were selected to characterize soil quality in the surrounding industrial area.

At each location, a sample was collected from a depth interval of 2 to 4 feet below the ground surface. The samples were collected using hollow-stem auger drilling techniques and split-spoon barrel sampling techniques. The procedures used for soil boring advancement, equipment decontamination, soil cuttings disposal, logging, soil classification, geologic and analytical soil sample collection and handling, and field screening are described in detail in Sections 3.1, 3.5, and 3.6 of the October 1991 FSP. In some cases, where the volume of soil in the split-spoon barrel was not sufficient to fill all of the sample containers, it was necessary to collect soil from the auger flights as well as from the split-spoon barrel. The logs for the borings are in PSCS Appendix 4-A. The field screening results for the samples are summarized in Table 4.1-1 and on the logs in PSCS Appendix 4-A.

Where possible, the background soil sample locations were tied to the site orthogonal grid system and surveyed relative to mean sea level datum. Survey notes are in PSCS Appendix 4-B.

Each background soil sample was analyzed for the full-scan parameter list in Table 4.0-1. Samples submitted for analysis are summarized in Table 4.1-2. The analytical methods used and the quality control sampling plan that was followed are described in detail in the October 1991 QAPP. The analytical results are presented in Tables 4.1-3 through 4.1-6. The tables report the data for the project-specific parameters listed in Tables 3.4-3 and 3.4-4 of the QAPP.

During the second phase of the investigation, ground surface soil samples were collected at the locations of Background Soil Samples BS-01, BS-02, and BS-04. These samples were collected as part of the ground surface soil sampling conducted to characterize on- and off-site surface soil quality for use in direct-contact/ingestion scenarios in baseline risk assessment evaluations. The ground surface soil sampling is discussed in Section 4.1.3.

4.1.2 Surficial Soil Sampling

In order to characterize near-surface soil quality across the site, a series of 19 surficial soil samples (SC-01, SC-02, and SS-01 through SS-17) were collected at the locations shown on Figure 4.1-2 during the first phase of RI field activities. The locations of Samples SS-01 through SS-17 were selected to address areas of the site where potential source areas had not been identified and where other sampling efforts were not planned as part of the first phase of the RI. The locations of the 1989 IEPA soil samples, which were also collected at shallow depths, are also shown on Figure 4.1-2. Surficial Soil Samples SC-01 and SC-02 were collected at the location of two former industrial ponds identified from aerial photographs (Figure 2.1-2).

At each location, a sample was collected from a depth interval of 2 to 4 feet below the ground surface. The samples were collected using hollow-stem auger drilling techniques and split-spoon barrel sampling techniques. The procedures used for soil boring advancement, equipment decontamination, soil cuttings disposal, logging, soil classification, geologic and analytical soil sample collection and handling, and field screening are described in detail in Section 3.2, 3.5, and 3.6 of the October 1991 FSP. In some cases, where the volume of soil in the split-spoon barrel was not sufficient to fill all of the sample containers, it was necessary to collect soil from the auger flights as well as from the split-spoon barrel. The logs for the borings are in PSCS Appendix 4-A. The field screening results for the samples are summarized in Table 4.1-1 and on the logs in PSCS Appendix 4-A.

The surficial soil sample locations were tied to the site orthogonal grid system and surveyed relative to mean sea level datum. Survey notes are in PSCS Appendix 4-B.

Each surficial soil sample was analyzed for the full-scan parameter list in Table 4.0-1. Samples submitted for analysis are summarized in Table 4.1-2. The analytical methods used and the quality control sampling plan that was followed are described in detail in the October 1991 QAPP. The analytical results are presented in Tables 4.1-7 through 4.1-10. The tables report the data for the project-specific parameters listed in Tables 3.4-3 and 3.4-4 of the QAPP.

4.1.3 Ground Surface Soil Sampling

During the second phase of the investigation, ground surface soil samples were collected to characterize soil quality for the depth interval of 0 to 6 inches below the ground surface at 14 on-site locations and at 3 off-site locations. The data from these samples are to be used for direct-contact/ ingestion scenarios in baseline risk assessment evaluations. The location of Sample GS-07 was selected because a small patch of blue soil is present at that location. All other on-site locations were selected to evenly cover the unpaved areas of the site. The locations of Samples GS-01, GS-02, and GS-04 were selected to coincide with the locations of Background Soil Samples BS-01, BS-02, and BS-04, respectively. The locations of the on-site and off-site ground surface soil samples are shown on Figures 4.1-2 and 4.1-1, respectively.

Ground surface soil samples were collected with a stainless steel trowel in accordance with the sample collection and handling procedures defined in Attachments 1 through 3 of the October 1991 FSP. The samples were classified and screened in the field according to the procedures described in Attachment 4 of the October 1991 FSP, Attachment 8 of the July 1993 TM, and Appendix B of the October 1991 FSP. Sample descriptions are in PSCS Appendix 4-A. Field screening results are in Table 4.1-1 and on the sample description log in PSCS Appendix 4-A.

All on-site ground surface soil sample locations were tied to the site orthogonal coordinate system and surveyed relative to mean sea level datum. The survey notes are in PSCS Appendix 4-B.

Each ground surface soil sample was analyzed for the Phase II list of parameters in Table 4.0-3. The ground surface soil sample in the vicinity of the former thionizer building and sulfur pile (GS-08) was also analyzed for corrosivity and reactivity. Samples submitted for analysis are summarized in Table 4.1-2. The analytical methods used and the quality control sampling plan that was followed are described in detail in the October 1991 QAPP. The analytical results are presented in Tables 4.1-11 through 4.1-14. The laboratory analytical data packages are in PSCS Appendix 4-C.

4.1.4 Test Trench Sampling

Excavation of test trenches was the primary method used in Phase I to investigate the locations of historical structure foundations and to visually delineate the lateral extent of shallow soil contamination in areas identified as potential source areas (based on the site's operational history). Thirty test trenches were placed during the Phase I investigation at the locations shown on Figure 4.1-3. These locations were selected to coincide with the locations of facility operations and

potential waste placement areas (e.g., ponds). Three test trenches (TT-05, TT-05E, and TT-06) were excavated at the former CT&T wood-treating plant in order to supplement existing data for this area. One of these trenches (TT-06) was excavated west from the former CT&T wood-treating facility location and adjacent to the southernmost portion of Slip No. 4 and was used to characterize the layer of coal fines found along the southern portion of Slip No. 4 (Canonie, 1991).

During the Phase II investigation, seven additional trenches (TT-24 through TT-30) were excavated to collect bulk samples for remedial technology evaluation. The locations of these test trenches are shown on Figure 4.1-3. Test Trenches TT-27 and TT-28 were excavated in the former CT&T wood-treating facility area. Test Trench TT-24 was excavated in the former manufactured gas and coke plant area, and Test Trenches TT-25, TT-26, TT-29 and TT-30 were excavated in the area of the former ponds on the northeastern part of the site.

During the Phase I investigation, test trenches were extended from areas of visible contamination to areas that appeared to be clean (whenever possible). If contaminated zones were encountered in a test trench, an additional trench was placed approximately perpendicular to the original trench in order to further delineate contaminated areas. During the Phase II investigation, test trenches were excavated in specific areas to collect bulk samples of contaminated materials (soil containing soil, soil containing tar, industrial pond deposit) for remedial technology evaluation. Trenches were extended to depths slightly below the water table and were logged and photographed as they were placed. Test trenches were not excavated through or beneath remaining foundations. Excavated materials were placed back into the same trench at the end of the day. Details of the methods used to excavate, log, and survey the test trenches, as well as the procedures used to decontaminate equipment, are described in Section 3.3 of the October 1991 FSP. The test trench logs are in PSCS Appendix 4-D. All test trenches were tied to the site orthogonal coordinate system and surveyed relative to mean sea level datum. Survey notes are in PSCS Appendix 4-B.

Soil samples collected from the test trenches were examined using field screening methods. The field screening methods included field soil classification, visual observations, field oil sheen screening, and field headspace organic vapor screening. Soil pH was also tested during Phase II. The soil sampling procedures and equipment and the field screening methods that were used are described in detail in Attachments 1 and 4 of the October 1991 FSP and Attachment 8 of the July 1993 TM. Field screening results for the soil samples collected from the test trenches are summarized in Table 4.1-1 and presented in the test trench logs in PSCS Appendix 4-D. Soil sample locations are shown on Figure 4.1-3.

Based on the field screening results, soil samples were selected for laboratory analysis. At least one sample was selected for analysis from each distinct area of soil contamination as determined by field observations. One sample was also collected from the coal fines layer found to be present along the southernmost portion of Slip No. 4. Additional soil samples were selected for analysis from areas that appeared to be near the limit of visible contamination and from areas that showed no visible evidence of contamination. Samples that were submitted for laboratory analysis are listed in Table 4.1-2 and are marked on the test trench logs in PSCS Appendix 4-D.

All the samples collected from the test trenches for laboratory analysis during Phase I were analyzed for the PAHs and VOCs listed in Table 4.0-2. Approximately 20 percent of the samples were also analyzed for the phenolic compounds in Table 4.0-2. Samples from trenches located near the thionizer building (TT-03-01, TT-03W-01, TT-08A-01, and TT-10-01) were also analyzed for cyanide and arsenic. One sample of soil with visible coal tar contamination (TT-03W-02) and one sample of visibly contaminated soil from the area of the former CT&T wood-treating facility (TT-06-02) were analyzed for the full-scan target compounds in Table 4.0-1. One sample of the compacted coal fines layer (TT-06-04) was analyzed for the full-scan target compound list in Table 4.0-1 and for the full list of toxicity characteristic constituents using the toxicity characteristic leaching procedure (TCLP). Laboratory analytical methods and quality control sampling procedures that were used are described in detail in the October 1991 QAPP.

During Phase II, Sample TT2503 of industrial pond deposit collected from TT-25 was analyzed for the full-scan list of parameters in Table 4.0-1. Sample TT2502, a sample of fill (furnace slag) from TT-25, was also analyzed for the Phase II inorganic, volatile, semivolatile, and phenolic compounds listed in Table 4.0-3. Samples of tar-saturated sand (below groundwater) from TT-24 (TT2402) , furnace slag (below groundwater) from TT-25 (TT2504), and silty sand fill (above groundwater) from TT-26 (TT2601) were submitted for laboratory analysis using the TCLP methodology. Additional samples were collected from the test trenches for use in the remedial technology evaluation program. These remedial technology evaluation samples and TCLP samples are described in Section 4.6.

Analytical results for the test trench samples are presented in Tables 4.1-15 through 4.1-18. The tables report the data for the project-specific parameters listed in Tables 3.4-3 and 3.4-4 of the October 1991 QAPP.

4.1.5 Soil Boring Sampling

Seventy-eight soil borings were placed during the RI field activities. The objectives of these soil borings were to:

- Obtain soil samples for the characterization of the vertical and lateral extent and nature of soil contamination;
- Obtain soil samples for the characterization of the soil quality and lithology of the soil stockpile;
- Obtain samples for the characterization of site geology and stratigraphy;
- Obtain soil samples for characterization of the geotechnical properties of the sand and till units for use in the development of remedial alternatives;
- Provide additional data for the evaluation of potential treatment technologies for remedial alternatives; and
- Provide geologic information for the placement and design of wells, piezometers, and temporary well points.

This section of the report discusses soil boring placement, soil boring placement methods, and soil boring sample collection and analysis, and presents the results of the sampling.

4.1.5.1 Soil Boring Placement

During Phase I, soil borings were placed for obtaining geologic information and for installing monitoring wells. During Phase II, soil borings were placed for the purposes of delineating the horizontal and vertical extent of contamination associated with former site operations, collecting soil samples for remedial technology evaluation, obtaining geologic information, and installing wells, piezometers, and temporary well points. The locations of soil borings, temporary well point soil borings, and well/piezometer borings are shown on Figures 4.1-4, 4.1-5, and 4.1-6, respectively.

Areas of former site operations include the former manufactured gas and coke plant, the former ponds in the northeastern part of the site, the former coal storage area on the western portion of the

site, the former CT&T wood-treating plant, areas of past and current OMC activities (Section 2.1.3.4), and the soil stockpile located south of Slip No. 4 and east of the harbor wall.

Several transects of borings were placed in the areas of the former manufactured gas and coke plant and former ponds. Each transect had soil borings in areas of greatest visible contamination (based on the results of the Phase I field investigation), at the apparent fringe of contamination, and outside the limits of observed contamination. All of the soil borings in these areas were advanced to the top of the till unit at a depth of approximately 30 feet below the ground surface. Three borings (SB-21, SB-44, and SB-48) were advanced approximately 10 feet into the till unit for collecting samples of the till for geotechnical analysis.

Three soil borings (SB-26 through SB-28) were placed to assist in characterizing the contamination in the area of the former CT&T wood-treating facility. These borings were advanced to the top of the till at a depth of approximately 30 feet. As discussed in Section 3.2 of this report, this area of the site was the object of significant investigative activity by the Waukegan Harbor Trust's contractor prior to the construction of Slip No. 4. Four trenches and more than 80 soil borings were placed in this area of the site during investigations associated with construction of Slip No. 4 (Canonie, 1990a; 1991). Soil quality data (primarily for PAHs and phenolic compounds) were reported for selected soil samples from the trenches and borings. In addition to the Slip No. 4 investigations, the current location of Larsen Marine on the site property was investigated by OMC with test trenches (Section 3.4). The information from these investigations will also be used in the RI for assessing geologic conditions and contaminant characterization in the area of the former CT&T wood-treating facility.

Three soil borings (SB-29 through SB-31) were planned for the purpose of investigating the soil quality and lithology of the on-site soil stockpile. During the preinvestigation survey of soil stockpile soil boring locations, it became evident that a portion of the stockpile had recently been removed for use in grading associated with the Waukegan Harbor Superfund site remedy (Lenzi and Crawford, 1993). Therefore, only two of the soil borings (SB-30 and SB-31) were extended through the soil stockpile. The third soil boring (SB-29) was drilled at its original location and was used to characterize the soil beneath the area formerly covered by stockpile materials. All three borings were extended to the till.

Soil Boring SB-03 was advanced through the till to the top of the bedrock at a final depth of 109 feet below the ground surface. The purpose of this boring was to obtain stratigraphic information for the site from an area thought to be outside of highly contaminated areas.

Three soil borings (SB-51 through SB-53) were placed on the beach east of the site in order to obtain groundwater samples by means of temporary well points. All three of these borings were extended to the till.

Soil Borings SB-54, SB-57, and SB-58 were placed at the locations shown on Figure 4.1-4 in order to collect samples for remedial technology evaluation. These borings extended to depths of 9.0, 22.0, and 10.0 feet, respectively. The samples collected from these borings are discussed in Section 4.6.

Thirty-five soil borings (MW-3S through MW-15S, MW-3D, SB-04 through SB-15, P-101 through P-108, and PW-1) were placed for the installation of wells and piezometers. The advancement methods and sampling of these soil borings differed from those used for the other soil borings and are discussed separately in Section 4.2.1.1, rather than in the following section.

4.1.5.2 Soil Boring Placement Methods

All soil borings, except SB-03, were advanced using hollow-stem auger drilling techniques. The borings were sampled at 2.5-foot intervals using a split-spoon sampler and in accordance with the ASTM D-1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. All of the soil borings, (except for Borings SB-54, SB-57, and SB-58 placed for remedial technology evaluation sampling) were advanced to the top of the till unit. Three soil borings (SB-21, SB-44, and SB-48) were advanced 10 feet into the till unit. One soil boring (SB-03) was advanced through the till unit to the bedrock at a final depth of 109 feet below the ground surface. The boreholes were abandoned with bentonite slurry upon completion, in accordance with the July 1993 TM.

Soil Boring SB-03 was advanced to approximately 6 feet below the ground surface using hollow-stem auger methods. A 4-inch casing was installed and the boring was continued using mud rotary drilling techniques. At a depth of approximately 12 feet below the ground surface, the borehole collapsed. The casing was extended to a depth of 20 feet below the ground surface, and the boring was continued using mud-rotary methods to completion at the top of bedrock at a depth of 109 feet below the ground surface. Although the casing was not seated into the clay unit, the potential for contaminant transfer between the upper sand unit and the bedrock was mitigated by: (1) not extending the borehole into the bedrock (the borehole was terminated in the uppermost foot of bedrock); (2) an effective mud cake preventing loss of drilling fluid, evidenced by borehole stability and by the drilling notes which show no recorded loss of drilling mud at the bedrock contact; and (3) properly abandoning the borehole by pumping grout under pressure through a tremie pipe and

grouting from the bottom of the borehole to the top while maintaining the discharge point of the tremie pipe 3 inches or more below the grout surface.

Each soil boring was logged by an experienced geologist. Soil samples were classified according to ASTM D-2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) as described in PSCS Appendix B of the October 1991 FSP. In addition, field screening (as described in Attachment 4 of the October 1991 FSP and Attachment 8 of the July 1993 TM) was performed on each sample, except for samples from Soil Boring SB-03. The soil boring logs are in PSCS Appendix 4-A. Field screening results are summarized in Table 4.1-1.

The headspace screening data for soil samples collected from Soil Boring SB-03 were not corrected for methane, due to the lack of an activated charcoal filter. The headspace readings noted on the log for SB-03 and Table 4.1-1, therefore, reflect total headspace organic vapor concentrations, i.e., including methane. A significant portion of the headspace readings is believed to represent methane. For example, Soil Boring MW-3D, located adjacent to SB-03, had a total headspace organic vapor reading of 820 parts per million for the depth interval of 26 to 28 feet, but only 160 parts per million when the methane headspace reading was subtracted from the total. Elevated headspace readings were seen within the upper clay unit at the sampling interval of 44 to 46 feet. Again, a significant portion of the reading was believed to represent methane. The remaining headspace concentrations were likely due to the presence of VOCs in the drilling fluid, because the clay samples from this and overlying intervals did not exhibit a product odor, discoloration, or sheen and because the drilling fluid had been in contact with the deep portion of the sand aquifer where samples exhibited moderate product odor and elevated headspace readings. As previously described, the casing was not seated into the clay (as would have been the standard practice) before drilling through the clay. The potential for contaminant transfer between the sand unit and the bedrock underlying the clay was discussed above.

Soil cuttings that were visibly clean and did not register readings on hand-held air quality screening devices when monitored within 3 inches of the surface of the soil were left on the ground in the vicinity of the boring, in accordance with the July 1993 TM. Soil cuttings from off-site boring locations that met these criteria were transported to the site and spread on the ground in the vicinity of Soil Boring SB-40. Soil cuttings and samples that were saturated with oil or tar or visibly contaminated, as well as visibly contaminated protective clothing and equipment or any other items or materials were placed in Department of Transportation-approved 17-H drums, sealed and labeled. The drums were moved to a location directly east of the designated soil stockpile for storage. Drums from the Phase I investigation, which had been placed inside the fence around the designated soil

stockpile, were also moved to this location. The drums rest on wooden supports and are surrounded by a chain link security fence. The location of the fenced area is shown on Figure 4.1-2.

All soil boring locations were tied into the site orthogonal coordinate system and surveyed relative to mean sea level datum. Survey notes are in PSCS Appendix 4-B.

4.1.5.3 Soil Boring Sampling

The soil sample collection objectives were to:

- Collect samples for the characterization of the nature and extent of chemical constituents associated with the former site operations (PAHs, phenolic compounds, BETX, arsenic, cyanide, cadmium, lead, mercury, and selenium) in the soils from the ground surface to the base of the surficial sand unit;

- Determine the stratigraphy of the site; and

- Collect samples for remedial technology evaluation.

In the areas of the former manufactured gas and coke plant, the former CT&T wood-treating plant, and the former ponds, samples from each boring were collected from the following specific intervals for analysis of the Phase II analytical parameters in Table 4.0-3: (1) the depth interval of 2 to 4 feet to assess potential impacts of unsaturated zone soils on groundwater quality; (2) the depth interval of 7 to 9 feet and a depth interval of 17 to 19 feet to assess the vertical extent of contamination below the water table; and (3) the interval just above the contact between the sand unit and the till unit (at depths of approximately 26 to 30 feet) to assess the presence of coal tar and creosote as dense nonaqueous-phase liquids. In some cases, where the nonmethane organic vapor headspace concentration (total organic vapor headspace concentration minus the methane headspace concentration) of a sample that was not visibly contaminated exceeded 100 parts per million, the next interval down was submitted for analysis of BETX. This method of alternating samples was used to minimize the opportunity for volatilization from the sample during the sample collection process. The samples submitted for analysis are summarized in Table 4.1-2 and shown on the logs in PSCS Appendix 4-A. The analytical results for these soil samples are presented in Tables 4.1-19 through 4.1-22.

Soil samples from each of the soil stockpile borings were collected from the following depth intervals for analysis of the full-scan list of parameters in Table 4.0-1: (1) the depth interval of 4.5 to 6.5 feet below the top of the stockpile, (2) the depth interval of 14.5 to 16.5 feet below the top of the soil stockpile, and (3) the depth interval of 2 to 4 feet below the base of the stockpile. Since these borings were extended through the stockpile to the base of the till, analytical samples from beneath the stockpile were also collected from the same sampling intervals described above for analysis of the parameters in Table 4.0-3. Soil samples submitted for analysis are summarized in Table 4.1-2 and shown on the logs in PSCS Appendix 4-A. The analytical results for these samples are presented in Tables 4.1-19 through 4.1-22.

Soil samples from the temporary well point soil borings and Soil Boring SB-03 were submitted for analysis of parameters in Tables 4.0-3 and Table 4.0-2, respectively, if field screening results indicated the presence of soil contamination. The samples submitted for laboratory analysis from these soil borings are listed in Table 4.1-2 and on the soil boring logs in PSCS Appendix 4-A. (Because of the use of drilling mud at Soil Boring SB-03, the sample submitted for analysis was collected from the hollow-stem auger borehole for Monitoring Well MW-3D adjacent to SB-03 instead of from SB-03. For this reason, the sample is identified as MW-3D instead of SB0301).

Several soil samples obtained from the soil borings were also submitted for analysis of the general remediation evaluation analytical parameters listed in Table 4.0-5 or for geotechnical parameters such as grain size distribution, Atterberg limits, porosity, and vertical permeability. These samples and methods are described in Section 4.6.

Soil samples submitted for laboratory analysis of VOCs were collected using brass tube liners (see Attachment 1 of the October 1991 FSP for procedures). All other samples were obtained with a split-spoon barrel sampler in accordance with the procedures outlined in the October 1991 FSP and packaged in clean sample containers. Sample collection and handling procedures are described in Attachments 1 through 3 of the October 1991 FSP. Laboratory analytical methods and quality control procedures are described in the October 1991 QAPP.

4.1.6 Designated Soil Stockpile Sampling

Soil quality data for excavated materials placed in the designated soil stockpile storage area (Figure 4.1-2) are available in reports of investigations performed prior to and during construction of Slip No. 4 (Canonie, 1990a; 1991). Analytical data for the specific, predefined areas of soils that were ultimately placed in the designated soil stockpile are available only for semivolatile organic compounds

(i.e., PAHs and phenolic compounds). Refer to Section 3.0 of this report for details of previous investigations.

In Phase II of the RI, three soil samples were collected from the designated soil stockpile to: (1) provide soil quality data for parameters not assessed in prior investigations; and (2) provide current concentration data for PAHs and phenolic compounds to assess the nature of the "designated" soils as placed.

Soil samples were collected from the designated soil stockpile at the three locations shown on Figure 4.1-2. At each location, a soil sample was collected with a hand auger from a depth of approximately 18 inches below the top of the stockpile. Sample access points created in the stockpile cover were repaired and tested after sampling. The testing showed that no leaks were present in the cover at the sample access points. The procedures used for soil classification, analytical soil sample collection and handling, and field screening are described in detail in Attachments 1 through 4 and Appendix B of the October 1991 FSP and Attachment 8 of the July 1993 TM. Field screening results are summarized in Table 4.1-1. The descriptions of designated soil stockpile samples are in PSCS Appendix 4-A.

Designated soil stockpile sampling locations were tied to the site orthogonal coordinate system and surveyed relative to mean sea level datum. Survey notes are presented in PSCS Appendix 4-B.

Each of the three soil samples was analyzed for parameters in the full-scan parameter list in Table 4.0-1. The analytical methods used and the quality control sampling plan that was followed are described in detail in the October 1991 QAPP. Analytical results are presented in Tables 4.1-23 through 4.1-26.

4.2 HYDROGEOLOGIC INVESTIGATION

The hydrogeologic investigation for the RI consisted of monitoring well piezometer/pumping well installation and development, a well location and elevation survey, water level measurements, precipitation measurements, and hydraulic conductivity testing. The objectives of the hydrogeologic investigation were to provide data that will allow characterization of the site's groundwater flow regime, evaluation of the hydraulic characteristics of the surficial sand aquifer at the site, and assessment of the relationship between groundwater elevations, surface water elevations, and recharge events. The monitoring well locations were chosen to address the needs of the groundwater quality investigation described in Section 4.3, as well as the needs of the hydrogeologic investigation. The

following section presents piezometer and well installation methods and the results of the hydrogeologic investigation.

4.2.1 Well/Piezometer Installation and Development

4.2.1.1 Well/Piezometer Installation

Thirteen water table monitoring wells (MW-3S through MW-15S), 13 deeper monitoring wells (MW-3D through MW-15D), eight piezometers (P-101 through P-108), and one pumping well (PW-1) were installed during the Phase I and II field activities for the RI. One piezometer (P-101) was abandoned during the second phase of the investigation, due to subsequent installation of a monitoring well nest at this location. The locations of these wells and piezometers are shown on Figure 4.1-6. The rationale for the location of each well and piezometer is summarized below.

Water table Wells MW-3S through MW-8S and MW-10S through MW-11S were placed along the perimeter of the site in order to assess the directions of groundwater flow from the site and for use in assessing potential contaminant migration in the groundwater.

Piezometer P-102 was placed in the northeast corner of the site and Piezometers P-103 and P-104 were placed along the center of the site. These piezometers, in conjunction with the water table monitoring wells along the perimeter of the site, were positioned to provide site-wide coverage for groundwater elevation measurements used in the evaluation of groundwater flow directions.

Wells MW-9S and MW-9D were placed immediately adjacent to an area where contamination was observed during the Phase I investigation. The location is near the areas of former ponds at the former manufactured gas and coke plant (Figure 2.1-2). These wells, therefore, provide groundwater quality monitoring points in immediate proximity to potential sources of groundwater contamination. In addition, the wells will help to further delineate groundwater flow patterns.

To provide long-term monitoring installations for key areas east and north of the site, water table Monitoring Wells MW-12S through MW-15S and Piezometer P-105 were placed north and east of the site. The purpose of the wells was to provide off-site groundwater quality data. The wells and piezometer were installed to help further delineate groundwater flow patterns and assess the potential for groundwater flow toward areas north and east of the site.

Wells MW-3S through MW-15S were nested with deeper Monitoring Wells MW-3D through MW-15D. The deeper wells were screened in the interval just above the till. These wells were to provide vertical hydraulic gradient information and to give an indication of groundwater quality and flow directions at the base of the sand aquifer.

Pumping Well PW-1 was installed at the location shown on Figure 4.1-6. Originally, PW-1 was to be installed near Monitoring Well Nest MW-1S/MW-1D. However, the pilot boring for the pumping well encountered oily soils in the saturated zone at that location. A new location for the pumping well was chosen due to potential complications associated with the following factors at the original location: grain size analyses of soil samples for well screen design; collecting representative samples for general assessment of potential groundwater quality; generation of investigation-derived waste; and potential impacts on aquifer testing results. The alternative location for PW-1 near Piezometer P-103 was chosen to address the concerns listed above. Field observations from the pilot boring placed at the alternative location did not indicate the presence of oily soils and showed geologic/hydrogeologic conditions representative of the site as a whole. The alternative location is also near the center of the site and is generally downgradient of likely groundwater contamination source areas. As a result, pumping test results from this location will be relevant to future evaluations of groundwater mass transport and potential remediation. The alternative location for the pumping well was approved by the U.S. EPA in an October 19, 1993 letter.

Piezometers P-106 and P-108 were placed near PW-1 and P-103 to be used as additional observation points during the pumping test (Section 4.2.4).

Piezometer P-107 was installed to aid in evaluation of the effects of the sheet pile wall south of Slip No. 4 on the hydraulic communication between the groundwater and the surface water at the slip.

Monitoring well installation was performed using 6¼-inch (inside diameter) hollow-stem auger drilling techniques. The monitoring wells were constructed as described in Section 3.7 of the October 1991 FSP, except that neat cement grout was used instead of concrete grout in the top 3 feet of the borehole annulus in the Phase I wells. Monitoring wells were constructed in accordance with the Illinois Water Well Construction Code (Chapter I, Subpart 920). To comply with requirements of OMC and the City of Waukegan, wells located on OMC and City of Waukegan property outside the fenced site were finished flush with the ground surface. Monitoring Wells MW-4S and MW-4D were converted to at-grade construction during Phase II. Risers were constructed of 2-inch nominal diameter stainless steel casing.

The water table wells were installed with 10-foot long stainless steel screens and the deeper wells were installed with 5-foot long stainless steel screens. The water table wells were designed with longer screens in order that groundwater levels in the wells remain within the screened intervals during seasonal fluctuations of the water table. The deeper wells utilized 5-foot long screens because they were not designed to intersect the water table and can, therefore, reliably monitor a more distinct groundwater interval. Well construction methods for the water table wells were designed to account for the limited distance between the ground surface and the top of the screen. Well construction details are summarized in Table 4.2-1. Well construction logs are in PSCS Appendix 4-E.

Piezometer construction was the same as the construction of the monitoring wells, except that the riser and screen were constructed from either 1¼-inch or 2-inch diameter PVC. Piezometers P-102 through P-105 and P-107 were constructed with 10-foot long screens that intersected the water table. Piezometer P-108 was constructed with a 5-foot long screen in a manner similar to the deep monitoring wells. Piezometer P-106 was constructed with a 20-foot long screen that fully penetrates the aquifer. Piezometer construction details are summarized in Table 4.2-1 and shown on the piezometer construction logs in PSCS Appendix 4-E.

The 6-inch diameter Pumping Well PW-1 was installed at the site for use during the pumping test (Section 4.2.4). The location of this well is shown on Figure 4.1-6. Well installation was performed using 12¼-inch hollow-stem drilling techniques to a depth of 29 feet. Below 29 feet, the boring was advanced with 11-inch water rotary drilling techniques. The riser and screen were constructed with 6-inch diameter, Type 304 stainless steel. The screen was 23 feet long with No. 8 (0.008-inch) continuous slots, and had a 3-foot long sump welded to the base. The riser is 10 feet long. Well construction details are summarized in Table 4.2-1 and shown on the well construction log in PSCS Appendix 4-E.

Each boring for the placement of a well or piezometer was sampled at 2½-foot intervals, using a standard split-spoon sampler in accordance with the ASTM D-1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. Deep monitoring wells and piezometers were sampled with a 3-inch diameter California Sampler containing a 3-inch diameter brass liner retained in the base of the sampler. Shallow monitoring wells were sampled with 2-inch diameter standard split-spoon samplers without brass liners. Each boring was logged by an experienced geologist. Soil samples were classified according to ASTM D-2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) as described in Appendix B of the October 1991 FSP. In addition, field screening was performed on each sample, as described in Attachment 4 of the October 1991 FSP and Attachment 8 of the July 1993 TM. Soil samples from intervals for which field

screening results indicated the presence of an oil sheen or nonmethane organic vapor headspace concentrations of 100 parts per million or greater were considered for analysis of parameters in Tables 4.0-2 or 4.0-3. Up to three samples from the borings at each well nest location were submitted for analysis. No soil samples from the monitoring well borings were submitted for analysis if field screening results did not indicate the presence of contamination according to the criteria described above. Soil boring logs for the wells and piezometers are in PSCS Appendix 4-A. Field screening results are summarized in Table 4.1-1. Soil samples submitted for laboratory analysis are summarized in Table 4.1-2.

Soil cuttings, drilling fluids, and other investigation-derived wastes were managed as described in Section 4.1.5.2. All soil cuttings from off-site locations were transported back to the site and managed as described in Section 4.1.5.2.

As noted above, Piezometer P-101 was properly abandoned during the second phase of the investigation because a monitoring well nest was installed in the northwest corner of the site at the location of Piezometer P-101. Abandonment consisted of overdrilling the piezometer and backfilling the borehole with bentonite slurry grout.

4.2.1.2 Well Development

All Phase I and II monitoring wells and piezometers were developed until the temperature, pH, and conductivity of groundwater in the wells were stabilized and the water produced from the wells was clear. Well development stabilization sheets are in PSCS Appendix 4-F.

In addition to developing the Phase I and II monitoring wells and piezometers installed for the RI, several existing monitoring wells located north and east of OMC Plant No. 2 (previously installed by Warzyn; Section 3.1) were developed during the second phase of the RI field activities. These wells are designated as Wells W-2A, W-2B, W-2C, W-4A, W-4B, W-4C, W-5, W-6, W-12, and W-13. Available well construction logs for these wells are in PSCS Appendix 3-A. Available well construction details for these wells are summarized in Table 4.2-1. The locations of these wells are shown on Figure 4.2-1. These wells were developed by means of alternate surging and pumping. Since these wells were only to be used for water level measurements, final development by overpumping and stabilization was not conducted. Well development logs for these wells are in PSCS Appendix 4-F.

Pumping Well PW-1 was developed by alternately surging the well throughout the entire length of the screen with a surge block and pumping with a submersible pump until the produced water was

clear and free of turbidity and sand. Full development of the well was achieved by 10 successive cycles of surging and pumping (removing a total of 5,850 gallons of water), at which point, surging did not produce appreciable quantities of sediment. A step drawdown test was conducted following well development. The procedures and results of the step drawdown test are described in detail in Section 4.2.4.2. The development log for Well PW-1 is in PSCS Appendix 4-F.

During Phase I, the development water was treated on-site using a system consisting of two 55-gallon capacity granular-activated carbon (GAC) adsorbers. The groundwater was containerized at the well location, transported to the treatment area, and pumped into a holding tank. From the holding tank, the groundwater was moved through the treatment unit and discharged to the ground near Test Trench TT-03. Approximately 7,000 gallons were processed during Phase I. Results for influent and effluent samples are shown in Tables 4.6-7 through 4.6-10.

During Phase II, development water was transported from monitoring wells in the same manner as in Phase I. However, electrochemical precipitation and GAC were used in a manner described in Section 4.6.2.7 to treat the water. The 75,000 gallons of water were stored in four 21,000-gallon tanks on-site while disposal arrangements were completed. The water was removed from the site and disposed of by Clean Harbors of Chicago, Inc. on April 4-8, 1994. Clean Harbors treated the water using oxidation/reduction with potassium permanganate and then chemical precipitation prior to discharging the treated water to the Metropolitan Water Reclamation District of Greater Chicago.

4.2.1.3 Water Level Measuring Point Elevation Survey

Elevations were surveyed and tied into a common mean sea level datum at the top of casing and (where applicable) the ground level at the following points: existing and newly installed monitoring wells and piezometers; staff gauges; stilling wells; and selected existing monitoring wells north of OMC Plant No. 2. The casing and riser elevations were surveyed (on the northern side) to the nearest 0.01 foot, and the ground elevation was surveyed to the nearest 0.1 foot. The water level measuring point locations were also tied into the site coordinate system. The horizontal locations with respect to the site grid are intended to be accurate to within 1 foot. Top of casing or measuring point elevations and ground elevations are summarized in Table 4.2-1. Survey notes are in PSCS Appendix 4-B.

4.2.2 Water Level Measurements

During the field activities for the RI, both discrete and continuous water level measurements were made at several water level monitoring points. The water level monitoring network consists of several on-site well nests and piezometers screened within the surficial sand aquifer (MW-1S/MW-1D, MW-3S/MW-3D, MW-4S/MW-4D, MW-5S/MW-5D, MW-6S/MW-6D, MW-7S/MW-7D, MW-8S/MW-8D, MW-9S/MW-9D, MW-10S/MW-10D, MW-11S/MW-11D, P-102, P-103, P-104, P-106, P-107, and P-108); a pumping well (PW-1) screened within the surficial sand aquifer; several off-site monitoring well nests and piezometers screened within the surficial sand aquifer (MW-12S/MW-12D, MW-13S/MW-13D, MW-14S/MW-14D, MW-15S/MW-15D, P-105, W-2A, W-2B, W-2C, W-4A, W-4B, W-4C, W-5, W-6, W-12, and W-13); one monitoring well screened at the contact between the till and underlying bedrock aquifer (Monitoring Well L-2B); two stilling wells to measure surface water levels in Waukegan Harbor (Stilling Well SW-1) and Slip No. 4 (Stilling Well SW-2) and, therefore, in Lake Michigan; two staff gauges to measure surface water levels in the North Ditch north of OMC Plant No. 2 (Staff Gauges SG-1 and SG-2); and one staff gauge (Staff Gauge SG-3) to measure water levels in the ditch located across Sea Horse Drive from the northeast corner of the site.

The locations of the water level monitoring points are shown on Figures 4.1-6, 4.2-1, and 4.2-2. The well construction information for bedrock Monitoring Well L-2B is in PSCS Appendix 3-A and Table 4.2-1.

Discrete Measurements. Measurements were made in Phase I monitoring wells and piezometers on the following dates in 1992: April 7, April 9, April 15, April 21, May 7, and May 27. From April 1993 through April 1994, water level elevations were measured on a monthly basis in the Phase I monitoring wells and piezometers and, after installation or establishment of monitoring points during the Phase II investigation, in the extended monitoring well/piezometer/surface water network. More frequent water level measurements were also made in the extended network during the Phase II investigation. Water level measurements were made on the following dates in 1993: April 15, May 21, June 16, July 19, August 21, September 29, October 30 through November 5, and December 1. Daily measurements taken during the period October 30 through November 5 were conducted as part of the continuous groundwater monitoring for the pumping test. The procedures and equipment used to make water level measurements are described in Section 3.8 of the October 1991 FSP. Water level measurements are summarized in Table 4.2-2. Water level data sheets are in PSCS Appendix 4-G.

Continuous Measurements. Water levels were measured every 10 minutes in 12 of the water level monitoring points from October 30 through November 5, 1993 as part of the continuous

monitoring for the pumping test. Barometric pressure was also recorded. Pumping test details are in Section 4.2.4.3. Continuous measurements were taken at Monitoring Wells MW-1S, MW-1D, MW-9S, MW-9D, MW-10S, MW-10D, Piezometers P-103, P-106, P-107, P-108, and Stilling Wells SW-1 and SW-2. Electronic data loggers equipped with sensitive pressure transducers were used to record water level elevations and barometric pressure. For unknown reasons, the data logger used to record water levels at Piezometer P-107 and Stilling Well SW-2 stopped recording data for about one day. The data logger was replaced when the problem was discovered. The loss of data does not impact the usefulness of the data for the planned purpose of these monitoring points, i.e., evaluating hydraulic communication between the groundwater and the surface water in Slip No. 4. Hydrographs showing the continuous water level measurements and the barometric pressure curve are in PSCS Appendix 4-G.

4.2.3 Daily Precipitation Measurements

Precipitation data were obtained from two on-site rain gauges during the second phase of the RI. The precipitation information, together with the water level measurements, will be used to assess the relationship between groundwater elevations, surface water elevations, and recharge events. The first gauge was installed on August 23, 1993, near the location of Monitoring Wells MW-9S and MW-9D. The second gauge was installed on October 26, 1993, next to Pumping Well PW-1. This gauge was installed to provide precipitation information for the pumping test at the location of Pumping Well PW-1. Measurements were recorded daily when field personnel were on-site by reading the water level inside the gauge with the graduated scale on the gauge. The gauge was emptied immediately following the daily reading. Field logs of precipitation measurements are in PSCS Appendix 4-H. Precipitation measurements are summarized in Table 4.2-3.

4.2.4 Hydraulic Conductivity Testing

Hydraulic conductivity testing at the WCP site included slug tests, a step-drawdown test, a pumping test, and triaxial permeability tests. Slug tests were performed in all monitoring wells and piezometers (except Piezometers P-101, P-102, P-103, and P-104) and Pumping Well PW-1 to estimate the horizontal hydraulic conductivity of the surficial sand aquifer. The step-drawdown test and the pumping test were conducted at Pumping Well PW-1, using Piezometers P-103, P-106, and P-108 as primary observation points. The step-drawdown test was performed to determine an optimal pumping rate that would provide maximum aquifer stress during the pumping test. The pumping test was conducted to provide aquifer data, primarily transmissivity and additional hydraulic conductivity information. Although the pumping test was not expected to provide data on specific yield and the

ratio of vertical to horizontal hydraulic conductivity, the pumping test results were satisfactory for estimating these parameters as well. The triaxial permeability tests were conducted to determine the vertical permeability of the upper portion of the clay till unit that underlies the surficial sand aquifer. Vertical permeability data were also obtained using the triaxial permeability method for several samples of the surficial sand aquifer.

4.2.4.1 Slug Tests

The hydraulic conductivity of the surficial sand aquifer at the site was estimated using slug tests.

Phase I monitoring wells were tested in March 1992. Two slug-out tests were performed at each of the Phase I water table monitoring wells (MW-1S, MW-3S, MW-4S, MW-5S, and MW-6S). Two slug-in and slug-out tests were performed at each of the deep Phase I monitoring wells (MW-1D, MW-3D, MW-4D, MW-5D, and MW-6D).

Phase II monitoring wells were tested in October and November 1993. One slug-in and one slug-out test were performed at each of the Phase II water table and deep monitoring wells and piezometers (MW-7S, MW-7D, MW-8S, MW-9D, MW-10S, MW-10D, MW-11S, MW-11D, MW-12S, MW-12D, MW-13S, MW-13D, MW-14S, MW-14D, MW-15S, MW-15D, P-105, P-106, P-107, P-108, and PW-1).

A description of the slug test procedure and the equipment used is in PSCS Appendix 4-I.

Slug test data were analyzed using the Bouwer and Rice method (Bouwer and Rice, 1976; Bouwer, 1989). To perform this analysis, the digitally recorded data were downloaded to a computer and the time versus drawdown data were plotted with the use of AQTESOLV™ software (Duffield and Rumbaugh, 1989). The AQTESOLV™ plots are in PSCS Appendix 4-I. The portion of the curve thought to represent the response from the aquifer was determined visually for use in the analytical solution for hydraulic conductivity, as described in PSCS Appendix 4-I. The wells were assumed to be partially penetrating. Also, slug-in data were not analyzed for the water table wells (for which the screens intersect the water table) because the data obtained from the slug-in test or wetting phase of the test are not representative of saturated conditions and violate the assumptions of the Bouwer and Rice method. The parameters used in the analyses are summarized in Table 4-I-1 in PSCS Appendix 4-I. Hydraulic conductivity estimates based on the slug-out test results are summarized in

Table 4.2-4. The estimates range in value from 1.1 to 16.3 feet/day (4.0×10^{-4}) to 5.8×10^{-3} cm/sec), with a geometric mean value of 4.7 feet/day (1.7×10^{-3} cm/sec).

4.2.4.2 Step-Drawdown Test

The step-drawdown test was performed on November 3, 1993. Pumping Well PW-1 was pumped at 20 gpm for approximately two hours until the rate of drawdown had decreased to less than 0.1 feet/15 minutes. The well could not sustain a pumping rate of 30 gpm. Accordingly, the pumping rate for the next step was reduced to 25 gpm. Well PW-1 was pumped at 25 gpm for more than an hour until the rate of drawdown had decreased to 0.1 feet/15 minutes. On this basis, a target pumping rate of 25 gpm was selected for the constant rate pumping test.

Water level recovery after the step-drawdown test was monitored for approximately 23 hours. Field methods and results of the analysis of the recovery data are discussed in PSCS Appendix 4-J.

4.2.4.3 Pumping Test

The constant-rate pumping test began on November 4, after the water levels in the aquifer in the vicinity of Well PW-1 had recovered to within 0.03 feet of the level measured prior to the step-drawdown test. Based on the step-drawdown test, a target pumping rate of 25 gpm was chosen to maximize the stress on the aquifer during the constant-rate pumping test in accordance with the test objectives defined in the July 1993 TM. The pumping rate was maintained within 5 percent of the target rate of 25 gpm throughout the pumping phase. After nine hours of pumping, the pumping water level in Pumping Well PW-1 drew down to the pump intake. At this point, the test was terminated. The duration of the pumping phase was within the anticipated range of 8 to 24 hours identified in the July 1993 TM. Field methods and results of the pumping-phase data analysis are discussed in PSCS Appendix 4-J.

Water level recovery after the constant-rate pumping test was monitored for approximately 32 hours. At the end of the recovery monitoring period, water levels in the aquifer were approximately 0.14 foot below the pretest static water level. Results of the analysis of the recovery data are discussed in PSCS Appendix 4-J.

Results of the analyses of the pumping test data are summarized in Table 4.2-5. The results of the pumping test meet the test objective of estimating the hydraulic conductivity of the sand unit, as defined in the July 1993 TM. The mean transmissivity value from the pumping test results is 0.84 ft^2/min (1,200 ft^2/day), which produces a hydraulic conductivity value of 47 ft/day (1.7×10^{-2} cm/sec). This value falls within the expected range for silty sand aquifers (0.4 ft/day to 400 ft/day; Freeze and Cherry, 1979). The pumping test results also provide information for estimating the ratio of vertical to horizontal hydraulic conductivity. The mean ratio of vertical to horizontal hydraulic conductivity is estimated to be 0.24.

4.2.4.4 Triaxial Permeability Testing

Vertical permeability tests were conducted on three samples of the till unit using a triaxial permeameter. At the locations of Soil Borings SB-21, SB-44, and SB-48, the soil borings were advanced at least 10 feet into the till in order to collect these and other geotechnical samples. Samples from the top portion (Sample SB2114), middle portion (Sample SB4815), and bottom portion (Sample SB4415) of this 10-foot interval of the till were tested for permeability using ASTM D-5084 (Hydraulic Conductivity of Saturated Porous Materials, Using a Flex Wall Permeameter). Vertical hydraulic conductivity estimates range from 1.3×10^{-8} to 5.9×10^{-8} cm/sec. The results are presented in Table 4.2-6. Laboratory analytical reports are in PSCS Appendix 4-K.

Four sand samples collected from Soil Borings SB-44 and SB-48 (Samples SB4406, SB4411, SB4806, and SB4812) were tested for vertical permeability in brass liners using ASTM D-2434 (Permeability of Granular Soils, by Constant Head). Estimated vertical permeabilities range from 1.1×10^{-3} to 5.9×10^{-3} cm/sec. The results are presented in Table 4.2-6. Laboratory analytical reports are in PSCS Appendix 4-K.

4.3 GROUNDWATER QUALITY INVESTIGATION

Groundwater quality investigation activities consisted of the collection and analysis of groundwater samples from monitoring wells and temporary well points. The objective of the groundwater quality investigation was to provide information for characterizing the nature and extent of groundwater contamination. The groundwater quality investigation data are used in Sections 7.0 and 8.0 to characterize the nature and extent of groundwater contamination, evaluate the spatial distribution of contaminants in groundwater, and assess groundwater fate and transport to potential downgradient receptors. This section of the report describes the procedures used to collect groundwater samples from monitoring wells and temporary well points, describes the analyses that

were performed on the groundwater samples, and presents the sampling results. Well installation methods and the rationale for selection of well locations at the site are presented in Section 4.2.

4.3.1 Monitoring Well Groundwater Samples

Three groundwater sampling events were conducted as part of the remedial investigation. During the first groundwater sampling event, conducted during the Phase I investigation on April 7 through April 9, 1992, samples were collected from all of the Phase I monitoring wells (MW-1S, MW-1D, MW-3S, MW-3D, MW-4S, MW-4D, MW-5S, MW-5D, MW-6S, and MW-6D). During the second groundwater sampling event, conducted during the Phase II investigation on September 30 through October 1, 1993, samples were collected from all of the Phase II monitoring wells and selected Phase I wells. During the third groundwater sampling event, which was conducted during the Phase II investigation on November 29 through December 2, 1993, samples were collected from all Phase I and II monitoring wells. The locations of all monitoring wells are shown on Figure 4.1-6. The procedures and equipment used for monitoring well stabilization, sample collection, and sample-handling are described in detail in Section 3.9 of the October 1991 FSP and Section 6.4 of the October 1991 QAPP. The specific conductance, temperature, and pH of each sample was recorded in the field. Water purged from each well during stabilization was containerized at the well location, transported to the water treatment area, and pumped into a holding tank. The groundwater in the holding tank was treated in the manner described in Section 4.2.1.2 of this report. The field log data sheets for all three sampling events are in PSCS Appendix 4-L. The field measurements of specific conductance, temperature, and pH are summarized in Tables 4.3-1 and 4.3-2.

The groundwater samples from the first two sampling events were analyzed for the full scan parameter list in Table 4.0-1 in order to establish an initial groundwater quality characterization for each well. After these two events, one sample from each monitoring well had been sampled for semivolatile organic compounds, volatile organic compounds, filtered metals, cyanide, pesticides, and PCBs. The analytical methods for the full scan analyses are described in detail in the October 1991 QAPP and the July 1993 TM. The analytical results are summarized in Tables 4.3-3 through 4.3-10. Analytical data reports are in PSCS Appendix 4-C.

During the third groundwater sampling event, samples were collected from all Phase I and II monitoring wells. These samples were analyzed for ammonia and the inorganic parameters, volatile organic compounds, and semivolatile organic compounds listed in Table 4.0-4. (Samples for metals were filtered.) The samples from Wells MW-7S, MW-8S, MW-10S, MW-11S/11D, MW-12S/12D, MW-13S, MW-14S/14D, and MW-15S/15D were analyzed for trace level PAHs, because PAHs were not

detected in samples from these wells during earlier sampling events. In addition, PAHs and phenolic compounds were extracted and analyzed separately for this sampling event. The analytical methods for the Phase II list of groundwater parameters and the trace level PAHs are described in the October 1991 QAPP and the July 1993 TM. The analytical results for this sampling event are summarized in Tables 4.3-3 through 4.3-5 and 4.3-7 through 4.3-9. Analytical data reports are in PSCS Appendix 4-C.

One sample from each of Monitoring Wells MW-6S, MW-6D, MW-7S, MW-7D, MW-9S, MW-9D, MW-10S, MW-10D, MW-12D, and MW-15S was collected during either the second or third groundwater sampling event for analysis of the general parameters listed in Table 4.0-4. The results of these analyses will be used to help evaluate potential treatment alternatives for groundwater. The analytical methods for these parameters are described in the October 1991 QAPP and the July 1993 TM. The analytical results for these parameters are summarized in Tables 4.3-11 and 4.3-12. Analytical data reports are in PSCS Appendix 4-C.

4.3.2 Temporary Well Point Samples

Groundwater samples were obtained on September 16, 1993 from Soil Borings SB-51 through SB-53 by means of temporary well points. The locations of these borings are shown on Figure 4.1-5. The groundwater quality data from these samples provides information to assess potential chemical migration from the site and to supplement information for assessing historical groundwater flow directions. Temporary well points were used at these locations instead of monitoring wells because these locations are on a public beach, where waves, shifting sands, and public access concerns made monitoring wells infeasible.

The groundwater samples were obtained using the HydroPunch II temporary well point method and hollow-stem auger drilling techniques. Information about the HydroPunch II temporary well point method is in Appendix L of the July 1993 TM. The HydroPunch II tool consisted of a stainless steel driving tool that, once driven beyond the hollow-stem auger to the appropriate sampling depth, was retracted a couple of feet to expose a polypropylene screen. Groundwater which entered the drill rod through the exposed screen was collected by means of a 1-inch diameter PVC bailer which was lowered into the drill rod with a stainless steel wire cord. After the sample was collected, the HydroPunch tool was completely withdrawn from the borehole. The screen and well point remained in the borehole and the borehole was backfilled with bentonite slurry by means of a tremie pipe. Between boreholes, the HydroPunch sampling tool and the PVC bailer were washed in a mixture of detergent and potable water and then rinsed with potable water.

Groundwater samples were obtained from the base of the surficial sand aquifer at Soil Borings SB-51, SB-52 and SB-53. Because the HydroPunch sampling tool is driven out in front of the auger, it was necessary to determine the depth to the till with a pilot boring to ensure that the sampled intervals were located just above the till. The pilot boring was placed near Soil Boring SB-52, the centrally located boring on the beach. The pilot boring was drilled with split-spoon sampling down to the till for lithologic characterization. The groundwater sample for SB-52 was taken from another borehole placed about 10 feet south of the pilot boring. At each HydroPunch sampling location, the borings were drilled and sampled to a depth of approximately 29 feet below ground surface. The HydroPunch tool was then advanced to a depth of about 33 feet below ground surface, so that the interval just above the till was screened and sampled.

Because the screened interval of the temporary well points were not developed, the groundwater samples contained sediment. The groundwater samples were submitted for analysis of ammonia and the inorganic, volatile organic, and semivolatile organic parameters in Table 4.0-4, the same parameters analyzed in the second Phase II groundwater sampling event. Analytical results are presented in Tables 4.3-13 through 4.3-17.

The temporary well point groundwater samples sent for metals analyses were inadvertently not filtered as required by the QAPP. Although the concentrations of metals reported in these samples are not representative of dissolved metals concentrations (because the samples were not filtered and contained sediment) and cannot be directly compared to the dissolved metals concentrations measured in samples from monitoring wells, the results directly address the objective of collecting and analyzing these samples, namely, to provide groundwater quality data for evaluating whether past chemical constituent migration in groundwater may have occurred from the site toward the east.

Field parameters (such as temperature, specific conductance, and pH) are typically used to determine whether a monitoring well has stabilized before sampling. These parameters were not measured prior to sample collection at the temporary well points. Although field parameter evaluations were specified in the QAPP, the rationale for well purging/stabilization criteria established for monitoring wells (i.e., removing water that has been present in the well for an extended time period) does not apply to temporary well point sampling because groundwater samples obtained with the HydroPunch tool are derived directly from the formation. Specific conductance and pH were measured at the laboratory for the temporary well point samples.

4.4 SURFACE WATER QUALITY INVESTIGATION

In order to evaluate the potential impacts on surface water associated with chemical migration from the WCP site, surface water sampling was conducted in Slip No. 4, Waukegan Harbor, and Lake Michigan. Chemical constituents reported in surface water samples are expected to reflect the influence of potential releases from the numerous industrial facilities in the Waukegan Harbor area.

This section of the report describes surface water sampling methods and analytical procedures conducted as part of the RI and presents the results of this sampling.

Surface water samples were collected on August 30 and 31, 1993 from 12 sampling locations in Slip No. 4, Waukegan Harbor, and Lake Michigan. Figure 4.4-1 shows the surface water sampling locations.

Surface water sites were located using a hand-held global positioning system (GPS). The latitude and longitude for each individual site are summarized in the survey notes in PSCS Appendix 4-B.

At each sampling location, the depth was sounded and field parameters, such as temperature, pH, dissolved oxygen (D.O.), oxidation potential (Eh), and specific conductance were measured in situ at approximately 3-foot intervals from the surface to the bottom of the water body. These field parameters were also recorded for the samples submitted for analysis. Depth sounding measurements conformed to the SOP for sounding depths in Appendix M of the July 1993 TM. Temperature, pH, and specific conductance methods conformed to the SOPs in Attachments 5a and 5b of the October 1991 FSP. The measurement of D.O. and Eh was conducted according to the SOPs in PSCS Appendix 4-M. Field data collected from the 3-foot intervals and the samples are summarized in Tables 4.4-1 and 4.4-2, respectively. Field sampling notes are in PSCS Appendix 4-N.

One or more samples were collected at each location for analyses of the PAHs, VOCs, and phenols listed in Table 4.0-4, arsenic (total, +III, +V), total cadmium, total mercury, total selenium, total ammonia, total cyanide, thiocyanate, weak and dissociable cyanide, total suspended solids, oil and grease, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total hardness.

At locations where the depth of the water column was greater than 10 feet, water samples were collected for analysis from two sampling intervals: (1) approximately 2 feet below the surface; and (2) approximately 1½ feet above the bottom of the water body. At locations where the water was less

than 10 feet deep, samples were collected for analysis from an interval approximately 1½ feet above the bottom of the water body. The samples were retrieved using Kemmerer bottles as described in the SOP for surface water sample collection in Appendix M of the July 1993 TM. A 1/2-liter volume stainless steel and teflon Kemmerer bottle was used to collect samples for organic parameters. A 3-liter volume stainless steel and PVC bottle was used to retrieve samples for inorganic parameters. Samples for organic parameters were poured directly into the appropriate sample containers by opening the drain valve on the Kemmerer bottle. Samples for inorganic parameters were first poured into an acrylic composite jug before being transferred to the appropriate sample containers. The acrylic jug had been rinsed three times with sample water prior to the compositing of the Kemmerer volumes. Samples were handled in the manner described in Attachment 8 of the October 1991 FSP. Quality control procedures and laboratory analytical methods are described in the October 1991 QAPP and the July 1993 TM.

Surface water analytical results for all locations are summarized in Tables 4.4-3 through 4.4-6.

4.5 SURFACE ENVIRONMENTAL FEATURES

A survey of surface environmental features and surrounding area was conducted during the first phase of the remedial investigation. Data collection activities for this task consisted of: reviewing available ecological studies; reviewing sediment and surface water data and aerial photographs; obtaining additional information from state and local natural resource agencies; and completing a site reconnaissance.

Surface environmental features of the site currently consist of vegetated and nonvegetated areas. The vegetated areas comprise approximately three-fifths of the areal extent of the site and are either lawn or ruderal old field plant communities. The nonvegetated areas comprise approximately two-fifths of the areal extent of the site and consist of buildings, asphalt, packed gravel, stockpiled contaminated soils, stockpiled dredge spoils, areas formerly covered by stockpiled dredged spoils, and surface water. The approximate areas of surface features are listed in Table 4.5-1. Figure 4.5-1 shows the surface features of the site.

A historical aerial photograph review indicated the presence of a pond in the northeast corner of the site in aerial photographs dated 1939 through 1967. This pond is not evident in photographs dated 1974 through 1991. There are currently no areas of permanent open water (other than Slip No. 4) or wetlands on the site (Barr, 1992b; Hey and Associates, 1992). The remainder of the site land use involved industrial structures, coal stockpiles, and vegetated areas, as apparent in

photographs dated 1939 through 1967. The industrial structures are not evident in photographs dated 1974 through 1991 except for the OMC office building and parking lot situated along the southern and southeastern sides of the site.

The substrate at the site and in the general vicinity of the site is predominantly fill material, primarily fine-grained sand. Fill material was first placed in the area of the site for industrial use development in the early 1900s, and sand accretion has occurred along the lake shore due to breakwater construction (Section 2.1.3.1). Industrial activity dominated the site until at least 1972. Industrial building structures were demolished in approximately 1972 and much of the site has become overgrown with successional weedy plant communities. Other areas of the site have been utilized for buildings and parking lots (CH_2M Hill, 1983).

The ruderal old field plant community is predominantly common annual and perennial roadside grasses and forbs, including several weedy species. A woody component exists in the southern portion of this old field habitat and dominates only in small patches. The woody component of the old field habitat is dominated by cottonwood trees and saplings. Box elder saplings are present but sparse. One red-osier dogwood shrub was observed in the southern portion of the old field habitat. The old field community does provide marginal habitat for a few terrestrial species.

Common invertebrates, small mammals, and birds are likely inhabitants of the project site. For example, spiders, beetles, grasshoppers, mice, and eastern cottontail rabbits are typical occupants of successional vegetation communities. Shorebird species such as gulls and black terns are common to the area. Due to the relative scarcity of vegetation on the site and the amount of human activity in the vicinity, the site likely does not provide exceptional habitat for any particular fauna (CH_2M Hill, 1983). Section 2.2.7.1 summarizes information regarding aquatic wildlife present in Waukegan Harbor and Lake Michigan in the vicinity of the site.

The majority of the old field habitat area exhibits a fairly even grade. Other physical features of this area include nonvegetated strips of land used for vehicular travel and piles of timber, rubble, soil, and brush.

The on-site lawn area is a level surface covered by typical lawn grass, overlain in places by ornamental coniferous and deciduous trees.

On-site areas comprised of buildings, asphalt, packed gravel, and stockpiled contaminated soils provide very limited, if any, suitable habitat for plant and animal species. The stockpiled harbor dredge spoils area has recently been disturbed and is void of vegetation.

The surface water in Slip No. 4 potentially provides an aquatic habitat component to the site, and waterfowl have occasionally been observed at the slip. However, the boat traffic and watercraft servicing at the slip inhibit such uses of the slip. Submergent aquatic vegetation has been observed in this slip. No emergent aquatic vegetation was observed in the slip during the site investigation.

4.6 REMEDIAL TECHNOLOGY EVALUATION SAMPLING

During field activities for the RI, sampling was performed to provide data for the evaluation of selected remedial technologies and potential remedial actions at the site. This remedial technology evaluation sampling consisted of general remediation evaluation sampling for analysis by geotechnical or analytical laboratories and specific remedial technology evaluation sampling for analysis by technology vendors. The following sections of this report describe the sample collection methods for, and present the results of, the general remediation evaluation sampling, describe each of the treatment and containment technologies for which vendor samples were collected, and describe sample collection methods for the vendor samples. The remedial technology evaluation results and vendor technology tests will be used in the evaluation of remedial technologies in the Feasibility Study (FS).

4.6.1 General Remediation Evaluation Sampling

The purpose of the general remediation evaluation sampling and analysis was to collect information that will be useful in evaluating the appropriateness and effectiveness of potential remedies during the FS. General remediation evaluation parameters relate to groundwater flow, contaminant fate and transport, and soil classification and characterization.

Soil samples were collected to determine soil engineering properties and characteristics that will influence remedial alternatives screening of treatment and containment technologies. The general remediation evaluation parameters and corresponding samples submitted for analysis are listed in Table 4.6-1. The sample results and some highlights of the findings are summarized in the presentation of each parameter below. Analytical laboratory reports are in PSCS Appendix 4-C. Geotechnical laboratory reports are in PSCS Appendix 4-K.

- Corrosivity and Reactivity. Soil samples collected from soil boring, ground surface soil sample, and test trench locations near the former thionizer building and sulfur pile were analyzed for corrosivity and reactivity. The majority of the samples were taken from the depth interval of 2 to 4 feet. The hazardous waste characteristic of corrosivity is defined as material having a pH less than 2 or greater than 12.5. Samples were collected from the former industrial pond area (TT2502 and SB0903), the former manufactured gas and coke processing areas (TT2402 and SB3402), and the fill material in the northern part of the site (GS-08, SB2302, and SB2402). The pH in these samples ranged from 4.7 in SB0903 to 8.1 in SB2302. No materials that would be classified as hazardous waste by the characteristic of corrosivity were found in this sampling.

  The hazardous waste characteristic of reactivity, as applied to the WCP site, would pertain to cyanide or sulfide-bearing material that, in the presence of pH conditions between 2 and 12.5, could generate toxic gases, vapors, or fumes in sufficient quantity to present a danger to human health or the environment. Material that releases 250 mg/kg or more cyanide as gas (HCN) when exposed to acidic conditions at a pH of 2 is considered reactive. In order to be reactive, the sample must have an initial total cyanide concentration of more than 250 mg/kg. Seventeen of the general remediation evaluation samples were analyzed for total cyanide. Total cyanide concentrations ranged from 0.15 to 29.4 mg/kg, far below the concentrations at which reactivity might become a concern. Sample results are listed in Table 4.6-2 and reported in PSCS Appendix 4-C.

- Grain Size Distribution. Three samples of the surficial sand unit (SB2106, SB4406, and SB4806) and four samples of the clay till unit (SB2114, SB2115, SB4415, and SB4815) were selected to be representative of the units and areally representative of the site based on the results of the soil classification. Additional samples were submitted to characterize the siltier sands that were present in some borings at the bottom of the sand unit. Samples were also submitted from different depths of the pilot boring for the pumping well in order to determine the slot size for the screen. Soil classifications based on grain size distribution are listed in Table 4.6-3. The clay till unit samples were classified as lean clays, in one case lean clay with sand and a little gravel. The surficial sand unit samples were fine sand to silty sand, sometimes with a little gravel. The grain size distribution tables and curves are in PSCS Appendix 4-K.

- Atterberg Limits. Atterberg limits tests were performed on the four samples of the till unit that were submitted for analysis of grain size distribution. The results from the

Atterberg limits tests are listed in Table 4.6-3 and reported in PSCS Appendix 4-K. The Atterberg limit test results generally had liquid limits near 30 and plastic limits around 15, for plasticity indexes of around 15, indicating these till samples are lean clay.

- Porosity. Three samples of the surficial sand unit (SB2106, SB4406, and SB4806), three samples of the deeper siltier portions of the sand unit (SB2112, SB4411, and SB4812), and four samples of the clay till (SB2114, SB2115, SB4415, and SB4815) were analyzed for porosity. These samples were selected because they were representative of the units and areally representative of the site based on the results of the soil classification. Porosity results are summarized in Table 4.6-3 and reported in PSCS Appendix 4-K. The porosity of the surficial sand unit samples, which were poorly graded fine sand, ranged from 33 to 39 percent, consistent with a medium to dense fine sand. The porosity of the samples from deeper portions of the sand unit ranged from 37 to 41 percent. All these samples were silty sand, so this porosity falls in the range of medium to dense relative densities for silty sand. The porosity of the clay till unit samples were generally about 30 percent, indicating a very dense clay (Hough, 1969).

- Total Organic Carbon. Three samples of the surficial sand (SB2106, SB4406, and SB4806), two samples of siltier portions of the sand unit (SB4411 and SB4812), and three samples from the clay till unit (SB2116, SB4413, and SB4816) were analyzed for total organic carbon (TOC). The samples were representative of the units and areally representative of the site based on the results of the soil classification. These samples were collected outside of areas of visible contamination. TOC results are listed in Table 4.6-2 and reported in PSCS Appendix 4-C. The TOC content of the samples ranged from 2.0 percent to 5.8 percent. Shallower samples (12 to 14 feet deep) were generally around 2 percent TOC, while the sand unit samples from below 25 feet deep all exceeded 4 percent TOC. Till unit samples exceeded 3 percent TOC.

- Cation Exchange Capacity. Three samples of the surficial sand (SB2106, SB4406, and SB4806), two samples of the siltier portions of the sand unit (SB4411 and SB4812), and three samples from the clay till unit (SB2116, SB4413, and SB4816) were analyzed for cation exchange capacity. The samples were representative of the units based on the results of the soil classification and were areally representative of the site. These samples were collected from areas with no visible contamination. Cation exchange capacity results are listed in Table 4.6-2 and reported in PSCS Appendix 4-C. The cation exchange capacities ranged from 0.7 to 9.0 milliequivalent per 100 grams. The sand unit

results were toward the low end of the range, and the till unit results were generally near the high end of the range.

- Vertical Permeability. Three samples of the clay till unit (SB2114, SB4415, and SB4815) were selected for vertical permeability testing. They were selected because they were representative of the unit and were areally representative of the site. Two samples of the surficial sand unit (SB4406 and SB4806) and two samples of the siltier portion of the sand unit (SB4411 and SB4812) were also analyzed for vertical permeability by the geotechnical laboratory. Results are listed in Table 4.6-3 and reported in PSCS Appendix 4-K. The till unit permeabilities range from 3.6×10^{-5} to 8.2×10^{-5} feet per day (1.3×10^{-8} to 2.9×10^{-8} cm/sec). The sand unit permeabilities ranged from 3 to 17 feet per day (2.1×10^{-3} to 1.2×10^{-2} cm/s), with no consistent distinction between the two sand unit and two siltier sand unit permeabilities.

- TCLP. Five soil samples were collected for analysis by TCLP. Two samples were collected from above the groundwater: one from within the northeast pond area (TT2601) and one tarry sample from the former manufactured gas and coke processing area (TT2402). One tarry (TT2401) and one oily (TT2504) sample were collected below groundwater in the former manufactured gas and coke plant processing area. One sample from the compacted coal fines layer in the vicinity of Slip No. 4 (TT0604) was also analyzed by the TCLP method (see Section 4.1.4). Prior to packaging in laboratory containers, TCLP samples were placed in a stainless steel bowl and objects larger than 1/2-inch in size were removed. TCLP results are listed in Table 4.6-4 and reported in PSCS Appendix 4-C. Only one sample had any exceedences of a TCLP regulatory level. The tarry sample from below groundwater (TT2401) was reported to have 0.7 mg/L benzene, which is higher than the 0.5 mg/L benzene regulatory level for TCLP. No other parameters exceeded a TCLP regulatory level. The nearby tarry sample (TT2404) from above the water table was reported to have only 0.18 mg/L benzene. Thus, the presence of tar in a sample does not indicate the sample should be expected to exceed a TCLP regulatory threshold.

  The other categories of material -- oily material, coal, and northeast pond fill -- did not exceed any TCLP regulatory levels.

- Gross Heating Value (BTU/lb) and Oil and Grease. One sample each from the northeast pond area (TT2603), the former manufactured gas and coke plant processing area

(TT2402), and the former industrial pond area (TT2504) was analyzed for gross heating value. Five samples, including those analyzed for gross heating value, were analyzed for oil and grease. Gross heating value and oil and grease results are summarized in Table 4.6-2 and reported in PSCS Appendix 4-C. The gross heating value of the northeast pond area samples (TT2603), was low, only 18 calories per gram. The other two samples, which contained tar, had gross heating values of 2,900 and 3,800 calories per gram (TT2402 and TT2504, respectively).

The oil and grease concentrations ranged from 413 mg/kg for Sample TT2502 to 7,530 mg/kg for Sample TT2504, both from the same test trench, the second having much more visible tar and oil present.

- Flashpoint: One sample from each location that was sampled for gross heating value was analyzed for flashpoint. Flashpoint results are listed in Table 4.6-2 and reported in PSCS Appendix 4-C. Flashpoint results were all "non-ignitable."

- Sulfate, Sulfide, and Iron. Twelve soil samples were collected from various depths at three soil borings (SB-34, SB-35, and SB-44) and submitted for analysis of sulfate, sulfide, and iron. Sulfate, sulfide, and iron were analyzed to help evaluate biological influences that may be present at the site. The samples submitted for analysis are listed in Table 4.6-1. The results are listed in Table 4.6-2 and reported in PSCS Appendix 4-C. The sulfate concentrations ranged from nondetect at 11.5 mg/kg to 2,740 mg/kg. The sulfide concentrations ranged from nondetect at 4.6 mg/kg to 52.8 mg/kg. Iron concentrations ranged from 2,790 mg/kg to 10,800 mg/kg.

- Sulfate-Reducing Bacteria Assay. Thirteen samples were collected from various depths at three soil borings and were submitted for analysis of sulfate-reducing bacteria using visual microscopic examination and the biological activity reaction test (BART) kit. A sterile control was also analyzed to verify the test. The samples collected for sulfur bacteria count are listed in Table 4.6-1. All but one of the samples were also analyzed for sulfate, sulfide, and iron. Results are shown in Table 4.6-5. Sulfate-reducing bacteria were identified in all but three of the samples. The test kit methodology and procedures are described in PSCS Appendix 4-O.

- Molecular Structure. One sample of industrial pond deposit taken from Test Trench TT-25 (Sample TT2506) was analyzed by Fourier transform infrared analysis,

x-ray powder diffraction, and emission spectroscopy in order to determine the material(s) comprising the pond deposit. Fourier transform infrared analysis provides a "fingerprint" for identification of molecular structure. Empirical correlations of vibrating groups with specific observed absorption bands can determine the chemical identification. X-ray powder diffraction uses the x-ray diffraction pattern scattered by the substance to produce a fingerprint of its atomic and molecular structure. Emission spectroscopy qualitatively and quantitatively identifies elements by exciting a sample with a high energy a-c spark across two electrodes to produce spectral bands. The results of these analyses are in PSCS Appendix 4-P. The industrial pond deposit was found to consist principally of magnesium and silicon, with small traces of aluminum, calcium, copper, iron, and manganese.

The soil samples submitted for the above analyses were collected from either soil borings or test trenches. Sampling methods and procedures for soil borings and test trenches were described in Sections 4.1.5 and 4.1.4, respectively. Samples analyzed for permeability and Atterberg Limits were collected with a Shelby tube sampler in accordance with ASTM D-1587 Standard Practice for Thin-Walled Tube Sampling of Soils. Samples analyzed for grain size distribution and porosity were submitted for analysis in either brass liners or Shelby tubes. Samples submitted for analysis of corrosivity, reactivity, TOC, cation exchange capacity, TCLP, oil and grease, gross heating value, flashpoint, sulfate, sulfide, iron, and sulfate reducing bacteria assay were packed in clean sample containers.

The analytical methods for the geotechnical analyses are described in Section 4.2.5 of the October 1991 FSP. The analytical methods for the analytical parameters are described in the October 1991 QAPP and the July 1993 TM. Soil sampling and handling procedures are described in detail in the October 1991 FSP and QAPP.

4.6.2 Technology Evaluation Sampling

Sampling was performed during the RI for evaluation of remedial technologies most likely to be useful for the WCP site. The technology evaluation program is for use in the FS. The technology evaluations can provide site-specific information on the viability of specific technologies and can provide information to supplement literature estimates of the cost of implementing specific technologies. The technology evaluations are not intended to be treatability studies, but may be used to select a particular technology for a treatability study, which would be performed for remedial design.

The FS technology evaluations rely primarily on the soil, groundwater, and contaminant characterization of the RI, review of literature, consultation with vendors and suppliers, and previous experience. That information will be supplemented by the information gained from the specific technology testing performed by vendors.

The July 1993 TM identified four soil treatment technologies, two containment technologies, and one water treatment technology that were considered likely to be suitable for site conditions and for which specific sampling or analysis were programmed. The four soil treatment technologies were bioremediation, thermal desorption, alternative fuel use at a cement kiln, and soil washing. The containment technologies consisted of slurry wall and capping. The water treatment technology was electrochemical precipitation. The samples collected for technology evaluation are summarized in Table 4.6-6.

The following sections of the report describe the nature of the samples selected for each technology and the sample collection methods. An evaluation of remedial technology evaluation results and a discussion of vendor methods and results will be presented in the FS.

4.6.2.1 Bioremediation

Bioremediation is an important technology for treating PAH-contaminated soil and an extensive literature has developed on this subject in recent years. The FS will rely on that literature in evaluating potential bioremediation applications at the site. Samples were collected to allow specific evaluations of soil, should that prove necessary. The potential need for and scope of site-specific bioremediation testing will be defined in the future by the remedy selected for the site. Biological treatment of phenols is a well-demonstrated technology, so no bioremediation-related sampling for phenols was programmed.

A bioremediation soil sample was collected from the saturated zone of Soil Borings SB-34 and SB-40/SB-56 as shown on Figure 4.1-4. These borings are located in an area in which field screening indicated the presence of an oil sheen. Soil Borings SB-23, SB-46, SB-47, and SB-50 were originally programmed for this sampling; however, samples from these borings were not used because field screening indicated minimal presence of oily soil below groundwater at these borings.

Samples were collected from hollow-stem auger flights. The soil was collected from a depth of 7 to 12 feet for Soil Borings SB-40/SB-56 and 7 to 18 feet for Soil Boring SB-34. The soil was collected for intervals below groundwater for which the sheen test indicated oil presence in the samples.

Samples from each location were placed in clean 5-gallon pails. The pails were completely filled with the water-saturated soil to reduce volatilization of organic compounds into the headspace. The pails of soil were emptied into a 55-gallon drum which was rolled to homogenize the soil. The soil was then repacked in five clean 5-gallon pails and archived on-site.

Samples SB3404, SB3408, and SB4005 from these borings were independently submitted for analysis of the parameters in Table 4.0-3. The results for these analyses are shown in Tables 4.1-19 through 4.1-21.

Adequate literature is available for the evaluation of bioremediation for creosote-contaminated soil. However, soil was also collected from the creosote-contaminated area and archived on-site, should any further site-specific studies for bioremediation of creosote contaminated soils be warranted during remedial design. The soil was collected from the saturated zone of Soil Boring SB-58 (location shown on Figure 4.1-4) from a depth of 5 to 10 feet. Two 5-gallon pails of oil-saturated soil were also collected from the creosote area from Test Trench TT-28 (Sample TT2801) at a depth of 5 feet. The location of Test Trench TT-28 is shown on Figure 4.1-3, and the sample collection point is shown on the test trench log in PSCS Appendix 4-D.

Sampling to evaluate factors that influence the effectiveness of bioremediation for groundwater was performed during the groundwater investigation of the RI. These factors include aquifer characteristics, contaminant transport-related parameters, and groundwater chemistry (i.e., general chemistry parameters, such as sulfate, sulfide, chloride, alkalinity, acidity, total hardness, total dissolved solids, TOC, biological oxygen demand, and chemical oxygen demand). The results of the groundwater investigation are presented in Tables 4.3-1 through 4.3-17 of this report.

4.6.2.2 Thermal Desorption

Thermal desorption is an energy-intensive treatment technology that has the potential to reduce soil PAH concentrations. Samples for evaluation of this technology were collected from Test Trench TT-24 (Sample TT2403). Three 5-gallon pails of oil-saturated soil were collected. The location of Test Trench TT-24 is shown on Figure 4.1-3. The sample collection point is shown on the test trench log in PSCS Appendix 4-D. One pail remains on-site as an archive sample, and one pail was sent to Westinghouse Remediation Services, Inc. (Westinghouse), the vendor selected for the thermal desorption and soil washing testing. The third pail of oil-saturated soil will be used in the soil washing study (Section 4.6.2.4).

Two 5-gallon pails of industrial pond deposit containing some oil were collected from Test Trench TT-30 (Sample TT3002). The location of Test Trench TT-30 is shown on Figure 4.1-3. The sample collection point is shown on the test trench log in PSCS Appendix 4-D. One pail remains on-site as an archive sample, and one pail was sent to Westinghouse.

4.6.2.3 Cement Kiln Fuel

Removal and use as an alternative fuel may be an appropriate remedial action for materials that are a significant source of contamination to surrounding soil or groundwater. The data for the RI will be evaluated to determine whether such source materials appear to be present at the site. Removal and use as an alternative fuel can be an effective technology for management of soil containing concentrations of PAHs in the percent range. Soil with high enough PAH concentrations to be considered source material may have enough fuel value to be burned for its heat content. NSG does not own or have access to a coal-fired power plant, so the opportunity to use material from the site as a supplemental fuel is restricted by the availability of commercial capacity. Commercial facilities (i.e., cement kilns) have certain quality requirements and material character requirements that limit the range of acceptable wastes. Samples of material which appeared to be suitable for cement kiln use were collected in order to explore requirements for material character and quality and to obtain approximate cost data for use of coal tar-contaminated soils as an alternative fuel.

Samples for evaluation of this technology were collected from areas of tar-saturated soil. Tar-saturated soil was collected in three 5-gallon pails and two 1-gallon containers and was sent to five cement kiln/fuel blending vendors. One 5-gallon pail of tar-saturated soil remains on-site as an archive sample. Tar-saturated soil was collected from Test Trench TT-24 (Sample TT2401). The location of Test Trench TT-24 is shown on Figure 4.1-3. The sample collection point is shown on the test trench log in PSCS Appendix 4-D.

Two 5-gallon pails containing mixed hard tar and soft tar collected at the ground surface remain archived on-site. The sample collection points for this material are shown on Figure 4.1-3.

4.6.2.4 Soil Washing

Soil washing may prove an attractive technology for treatment of sandy soil containing PAHs. Three 5-gallon pails of oil-saturated soil were collected from Test Trench TT-24 (Sample TT2403). This is the same location as the sample of oil-saturated soil collected for thermal desorption evaluation. The location of Test Trench TT-24 is shown on Figure 4.1-3. The sample collection point is shown on

the test trench log in PSCS Appendix 4-D. One pail remains on-site as an archive sample and the other two pails were sent to Westinghouse, the vendor selected for the soil washing and thermal desorption testing.

4.6.2.5 Slurry Wall

Samples collected for evaluation of slurry wall mix designs included glacial till and sand unit soil. Four 5-gallon pails of soil that was not visibly contaminated were collected from depths of 7 to 24 feet at Soil Boring SB-57. Two Shelby tubes and another smaller core of glacial till remain archived on-site from soil boring samples SB2116, SB4414, and SB4816. Table 4.6-6 shows the slurry wall samples archived on-site.

Clay and additional backfill material will be collected from a local borrow pit for the mix design. Contaminated ground water will be collected after a mix design is complete and long-term permeability testing is ready to begin. The engineering and physical analyses of soil properties described in Section 4.6.1 also relate to the slurry wall technology evaluation. The slurry wall design prepared for the Waukegan Harbor Trust containment cells will be reviewed for relevant information.

4.6.2.6 Capping

Caps can serve a variety of purposes, from limiting infiltration to restricting direct contact, and may take a variety of forms. Suitable forms of cap may range from a RCRA-style multilayer cap system to soil cover and grading. Some forms of capping, such as an asphalt cap, may provide the parking and boat storage surface the current site owners desire, as well as protecting site users by restricting contact with the soils below. An asphalt cap could incorporate site PAH-contaminated soil in the asphalt mix. Synthetic membrane or natural clay caps will also be considered. The cap designs prepared for Waukegan Harbor Trust containment cells will be reviewed for relevant information. Sampling and analysis to be used in evaluation of cap design include: grain size distribution, porosity, and relative density from sampler blow counts during boring placement.

4.6.2.7 Water Treatment

During the Phase I investigation, investigation-derived water was treated on-site using a system consisting of two 55-gallon capacity GAC adsorbers. Grab samples of the untreated water (influent) and the treated water (effluent) were analyzed for the full-scan parameter list in Table 4.0-1. Analytical data for these samples are in Tables 4.6-7 through 4.6-10.

The Phase II water treatment system consisted of electrochemical precipitation to remove arsenic and cyanide and GAC to remove organic compounds. The system was tested in two configurations. In the first configuration, the electrochemical precipitation system was upstream of the GAC and three tests with different operating parameters, such as chemical dosage, were performed. In the second configuration, the GAC was moved to the upstream side. Analytical samples were collected at three locations along the treatment train. All of these samples were analyzed for the phenolic and PAH compounds in Table 4.0-4, arsenic, cyanide (total cyanide and weak and dissociable cyanide), thiocyanate, cadmium, lead, mercury, selenium, and total ammonia. These data will be used to evaluate the potential effectiveness and cost of this technology for remedies involving groundwater pump-out and treatment. Samples submitted for analysis are shown in Table 4.6-6. Sample results from the tests are shown in Tables 4.6-7, 4.6-8, 4.6-9, and 4.6-10.

The water treatment vendor, Andco Environmental Processes, Inc., performed bench scale testing as part of their internal testing program to evaluate the process. Results are presented in Table 4.6-11.

After water treatment, grab samples from each of the four holding tanks were collected to evaluate disposal options for the treated water. The majority of the water collected during the field activities was treated by the same process configuration as Test No. 1. Results of analyses of the treated water are shown in Tables 4.6-12 through 4.6-16.

The analysis of grab samples of treated water showed higher levels of cyanide than the NSSD would accept for a 10,000-gallon per day discharge. The cyanide was suspected to exist as a suspended iron cyanide complex which then could be removed by filtration. Bag filter testing was conducted on treated water to determine if cyanide concentrations could be reduced with a 5, 25, and 50-micron bag filter. Results of analysis of an influent water sample and the filtered water samples are shown in Table 4.6-17. The test showed that filtration did not remove the cyanide.

The electrochemical precipitation system generated a precipitate which was dewatered with a filter press and produced on filter cake. To evaluate disposal alternatives for the filter cake, a sample was submitted for TCLP analysis. Results are shown in Table 4.6-18.

As discussed in Section 4.3, selected groundwater samples were analyzed for general chemistry parameters identified in Table 4.0-4. The results for these analyses are in Tables 4.3-11 and 4.3-12. These parameters will be useful in the evaluation of pump and treat technologies and extraction system design.

4.7 QUALITY CONTROL PROCEDURES

The purpose of a quality control review of analytical data is to determine, through a data validation process, the level of quality and validity of the analytical data. The quality control review process determines the suitability of the analytical data for the intended purposes and to what extent the data meets the project needs and specifications. Section 4.7 summarizes the results of the data review and validation process, including which data quality qualifiers were assigned to the analytical data. A detailed presentation of the quality control review for each laboratory report is included in PSCS Appendix 4-C, immediately in front of the corresponding laboratory report.

4.7.1 Quality Control Methods

Samples collected for chemical analysis were sent to CH_2M Hill laboratories for analysis. The samples were analyzed using methods consistent with the U.S. EPA Contract Laboratory Program (CLP) Statement of Work (SOW). The analytical results received from CH_2M Hill laboratories were reviewed in a manner consistent with the U.S. EPA Laboratory Data Validation Functional Guidelines for Evaluating Organic Analyses (1988) and Inorganic Analyses (1989a).

The overall analytical performance of the laboratory was assessed by monitoring and reviewing laboratory performance indicators. The laboratory performance indicators included sample holding time, laboratory instrument calibrations, laboratory blanks, laboratory control samples, laboratory duplicates, and performance evaluation mixtures. Laboratory internal quality control procedures were followed by CH_2M Hill laboratories. These procedures included initial and ongoing programs of quality assurance performed in accordance with the CH_2M Hill laboratories quality assurance manual (QAM).

Aspects of quality control performance external to the laboratory which were utilized during this project were the collection and analysis of field blanks, trip blanks, and matrix spike and matrix spike duplicate samples. Information derived from the external quality control samples are used to indicate the degree to which sampling procedures, laboratory procedures, and sample characteristics and constituents influenced the data quality. Sample heterogeneity and physical/chemical matrix-related effects influence the accuracy and precision of the sample data.

4.7.1.1 Data Validation

The following sections discuss the elements of the data validation process, quality control sample types, and data qualifiers.

4.7.1.1.1 Data Validation Criteria

Data validation is a process of determining the compliance of analytical data with established criteria and project specifications. During the data validation process, the data are evaluated for precision, accuracy, representativeness, comparability, and completeness. These data quality indicators are evaluated during the data validation process by reviewing the degree of compliance with the acceptance criteria of the following individual data quality elements: holding times; instrument tuning; calibration; blank samples; surrogate recoveries; matrix spike samples; field duplicates; instrument performance; interference check samples; laboratory control samples; and serial dilution samples. Data validation also examines analyte quantitation and overall data assessment. The acceptance criteria for the individual data quality elements are documented in the U.S. EPA data validation guidelines.

Method blanks are composed of distilled or deionized water (intended to be analyte-free water) that is processed and analyzed as a sample to determine the existence and to provide a basis for judging the magnitude of potential contamination introduced during sample preparation and analysis. However, method blanks may not always determine the extent of laboratory contamination that may impact the field samples. This circumstance is more common for volatile organic contaminants such as acetone and methylene chloride.

Field blank samples are collected to identify contamination introduced during sampling procedures, bottle transport, sample storage, and/or laboratory procedures.

Trip blank samples are used to indicate potential contamination due to migration of volatile organic chemicals into the sample shipping containers during sample transport and storage.

Duplicate samples, whether collected in the field or produced in the laboratory by splitting a sample, are analyzed to determine the level of data precision. Data precision is a measure of the reproducibility of field sampling, laboratory analysis, and inherent sample constituent heterogeneity. The resulting differences in the concentrations of a parameter are reported as relative percent difference (RPD) and calculated by:

$$RPD = \frac{|S - D|}{(S + D)/2} \times 100$$

where: S = concentration of sample

D = concentration of duplicate sample

Surrogate spikes (in organic analysis) are compounds that are not expected to be present in environmental samples, but have properties similar to those of the target compounds. Surrogate spikes are added to all samples before extraction or other sample preparation steps. The percent recovery (R%) of a surrogate spike is calculated by the following formula:

$$\%R = (SSR/SA) \times 100$$

where: SSR = quantity measured in spiked sample

SA = quantity of spike added

Matrix spikes consist of target compounds added to a sample before analysis or preparation steps. They are performed to evaluate matrix effects on the data accuracy by the analytical methodology utilized. The matrix spike recoveries can be used to assess the degree of matrix effects that the sample exerts on the analytical methodology's ability to accurately estimate the constituent concentrations. The matrix effects can only be assumed to be present in the associated investigative samples (which have not been spiked), since they are not directly observed and measured. Matrix effects in investigative samples may be highly variable, unpredictable, and limited to an individual sample. Percent recovery for a matrix spike is calculated by the following formula:

$$\%R = \frac{SSR - SR}{SA} \times 100$$

where: SR = quantity measured in unspiked sample

4.7.1.1.2 Data Validation Actions

If, during the data validation process, it is determined that the evaluation acceptance criteria have been exceeded, data qualifiers are assigned to any affected data values in the investigative samples. The U.S. EPA data validation guidelines include a list of the data qualifiers that are to be assigned to sample data as a result of the data validation process.

For this project, six data qualifiers were used in the data summary tables: "U," "B," "J," "a," "c," and "R." A "U" qualifier means the parameter was not detected at the indicated concentration. A "B" qualifier means that the reported value is less than the CRDL, but greater than or equal to the instrument detection limit (IDL). A "J" qualifier has several possible meanings, as described in the paragraph below. The "a" qualifier is used for sums to indicate that one or more "J"-qualified values are included in the sum. A "c" qualifier is assigned to data values that coelute at the quantitated concentration with another analyte. The "UJ" qualifier is defined as follows: "The material was analyzed for but not detected. The associate value is an estimate and may be inaccurate or imprecise" (U.S. EPA, 1988). The "R" qualifier is assigned to data values that have been judged to have serious quality deficiencies and should be considered unusable and rejected.

As previously stated, the data qualifiers assigned to sample data as a result of the U.S. EPA data validation process were defined by U.S. EPA (except for the "a" and "c" qualifiers, which were defined by Barr). Some of the U.S. EPA-defined data qualifiers (such as "J") have different meanings when applied to organic data versus inorganic data. In addition, the same data qualifier ("J" for organic data) is applied for exceedences of different data validation criteria, such as surrogate recovery, matrix spike recovery, calibration factors, or concentrations reported between the MDL and the CRDL. Because of the lack of definitive or unique data validation qualifiers for the many data quality elements, all of the analytical data which have data qualifiers assigned to them were reexamined. Many of the "J" qualifiers were assigned to sample data only because of a quality control criteria exceedence of a selected sample that was spiked or duplicated. The data validation guidelines require that samples associated with the spiked or duplicated sample exceedence be qualified when the quality control criteria for the spiked or duplicated sample are exceeded. In effect, the vast majority of the "J"-qualified data were qualified only due to an exceedence of a quality control criteria in an associated quality control sample and may have no actual data quality defects.

All data without "R" qualifiers (including "J"-qualified data) are considered acceptable and usable. The percent of sample data without an "R" qualifier is calculated to be 99.9 percent.

4.7.1.2 Reporting limits

In order to more fully reflect the information gained from the analysis of the Phase II semivolatile sample data, the Phase II semivolatile data were reported in the data tables with MDL values replacing the CRDL values whenever the sample was reported by the laboratory as nondetected at the CRDL. The MDLs were used in place of the CRDLs only when the laboratory had documented that the MDLs were achievable for each semivolatile parameter for each sample. The laboratory had agreed to document in the case narratives of the laboratory reports any instances when the analytical systems could not detect concentrations down to the MDLs. An example of a situation where this could have occurred would have been spectral interferences that prevented the accurate quantitation down to the MDL concentrations. Based on the case narratives and communications with the laboratory, such spectral interferences from the sample extract constituents did not occur during Phase II of the project. As part of the laboratory deliverables for semivolatile organic data, raw spectral data was provided for review to confirm the lack of spectral interferences in the sample extract. The spectral outputs were examined as part of the data validation process. For all instances where the reported concentration was below CRDL, but above the MDL, the "J" (estimated value) data qualifier was assigned. However, the concentrations between the MDL and the CRDL are reported with a 99 percent confidence level and are considered valid and accurate values.

The laboratory provided the results of the semivolatile organic compound MDL study for water and soil samples which applied to the analysis of the Phase II samples. The MDL study was performed in accordance with the U.S. EPA criteria set forth in 40 CFR Part 136, Appendix B, which pertains to the procedure for the determination of MDLs. The CH_2M Hill semivolatile organic compound MDL study summary for soil and water samples is included in Appendix 4-Q. The specific MDL values for individual sample concentrations were determined by factoring in any sample preparation and analysis variable sample weight used (soil samples), sample percent moisture (soil samples), and sample extract dilutions (both soil and water samples). For water samples, since the volume of water used was constant (1 liter), the only variable used was the dilution of the extract. The MDL calculation for water samples was MDL (from MDL study) in micrograms per liter units, multiplied by the extract dilution used, equals sample-specific MDL in micrograms per liter. This calculation was done for each semivolatile parameter, as appropriate. For soil samples, the sample weight was also constant. Therefore, the only variables applicable to calculating MDLs for soil samples were percent moisture and any dilution of the extract. The calculation for soil sample was MDL (from MDL study) in micrograms per kilogram units, divided by the percent solids (1.0 minus the fraction moisture), then multiplied by the extract dilution used, equals sample-specific MDL in micrograms per kilogram. This calculation was done for each semivolatile parameter, as appropriate.

For the Phase I organic analysis data and the Phase II volatile organic analysis data, many of the concentrations of organic parameter sample data were reported at concentrations less than the CRDLs and qualified with a "J" data qualifier denoting them as estimated values. Reporting these data as estimated values was possible since the laboratory's MDLs for the organic parameters were lower than the reporting limits (CRDLs) listed in the laboratory sample data reports. The MDLs are the minimum concentrations of target analytes measured and reported with a 99 percent confidence level. The MDLs are routinely approximately 10 percent of the reporting limit concentration for the organic target parameters. It is reasonable to expect that for the organic target parameters reported as nondetects in the laboratory reports, the laboratory also did not detect the parameters at concentrations of approximately 10 percent of the CRDLs for the Phase I data. Because serious spectral interferences were not observed in the Phase II samples, it is not likely that any serious spectral interferences existed in the Phase I samples.

4.7.2 Data Validation Results

This section of the report summarizes the data validation results per parameter group for soil and water samples. The individual quality control/quality assurance reports are in PSCS Appendix 4-C.

All investigative sample results for Phase I and II are included in Tables 4.1-3 through 4.1-26, 4.3-1 through 4.3-17, 4.4-2 through 4.4-6, 4.6-2, 4.6-4, and 4.6-7 through 4.6-18. Laboratory data reports are in PSCS Appendix 4-C.

All blank results for Phase I and II are included in Tables 4.7-1 through 4.7-11.

All field duplicate results for Phase I and II are included in Tables 4.7-12 through 4.7-22.

During the data validation process for the Phase II data, it was discovered that the Phase I inorganic data had been evaluated using a different interpretation of the third criteria for duplicate sample analysis. The Phase I inorganic data has been revalidated using the same interpretation as used for the Phase II data. Updated quality control/quality assurance summaries for sample data from Phase I which were revalidated are enclosed in PSCS Appendix 4-C. The difference in validation approaches relates to the Section VI, Duplicate Sample Analysis of the U.S. EPA Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses (1989a), for which the third criterion reads as follows: "A control limit of $\pm$ CRDL ($\pm$ 2 x CRDL) shall be used for the sample values < 5 x CRDL, including the case when only <u>one</u> of the duplicate sample values is < 5 x CRDL."

The correct units of the CRDL criteria when evaluating the differences of the duplicate analysis are concentration units, not percent differences (as was used during Phase I data validation). This resulted in the assignment of unnecessary "J" data qualifiers to numerous Phase I sample data values for several metal parameters.

The overall analytical performance of the laboratory was assessed by monitoring and reviewing laboratory performance indicators for the project Phase I and Phase II analytical data. The laboratory performed at a high level of compliance to the quality control indicators in spite of the complex nature of many of the investigative samples. The laboratory's qualifications, capabilities, and performance all met the analytical needs of this project.

All sample data, as validated, were considered acceptable and usable with the associated data qualifiers except for any "R"-qualified data. The "R" qualifier was used to designate data which were deemed unusable according to the U.S. EPA data validation guidelines criteria.

The number of Phase I and Phase II sample parameter values that have been assigned the "R" data qualifier was 31. The total number of individual Phase I and Phase II sample parameter values was approximately 32,220. The percent of sample data without a "R" qualifier was calculated to be 99.9 percent. Thus the project data quality objective completeness goal of 95 percent usable data was met.

Unless otherwise stated in the following sections, all data validation criteria have been met for the analytical data.

4.7.2.1 Soil Samples

4.7.2.1.1 Soil Samples - Inorganic Parameters

Phase I. Metals calibration, preparation, and field blanks had concentrations of several elements less than the CRDL, but greater than the IDL. All associated sample results with less than five times the blank concentration were qualified as nondetects and assigned the "U" data qualifier.

Laboratory duplicate sample RPD values for some metals elements were beyond the control limits. Results for all affected samples were qualified as estimated and assigned the "J" data qualifier.

Recoveries for some spiked samples were beyond data validation acceptance control limits for antimony, arsenic, cadmium, cyanide, lead, manganese, and selenium. Associated sample results for antimony (SS01, SS06, SS07, SS08, SS09, SS11, SS12, SS14, T03W02, and TT1402) and cyanide (BS07 and BS08) were qualified as unusable and assigned the "R" data qualifier, because the concentrations were less than the IDL. Data validation guidelines require those data for which matrix spike recoveries are less than 30 percent and sample results are less than the IDL to be qualified as unusable. Antimony or cyanide results greater than the IDL were qualified as estimated and assigned the "J" data qualifier. Results for the remaining outlier elements in the associated investigative samples were qualified as estimated and assigned the "J" data qualifier.

A small number of samples were assigned the "J" data qualifier for exceedences in the post digestion spike sample recoveries or the ICP serial dilution criteria.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for metals field duplicate data where there existed two detected values which were not qualified as estimated. Three field duplicates were collected and analyzed. Nineteen RPDs were calculated with a range of 1 to 99 percent and the mean RPD was 40 percent.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for cyanide field duplicate data where there existed two detected values which were not qualified as estimated. Three field duplicates were collected and analyzed. No RPDs qualified for calculation.

Phase II. Some cyanide and mercury data were qualified as not detected and assigned the "U" data qualifier due to calibration and preparation blank concentrations above the IDL.

Laboratory duplicate sample RPD values for some metal elements were beyond the control limits. Results for all affected samples were qualified as estimated and assigned the "J" data qualifier.

Some sample data were assigned the "J" data qualifier due to exceedences of the ICP serial dilution criteria for aluminum, sodium, or barium.

Some sample data were assigned the "J" data qualifier due to exceedences of the sample spike recovery criteria for antimony, arsenic, lead, selenium, or cyanide. The U.S. EPA "R" data qualifier was used to designate data which were deemed unusable by the U.S. EPA data validation guidelines criteria for cyanide and selenium due to low spike recoveries.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for inorganic field duplicate data where there existed two detected values which were not qualified as estimated. Twenty-two field duplicates were collected and analyzed. Forty RPDs were calculated with a range of 1 to 106 percent and the mean RPD of 37 percent.

Overall Phase I and II Inorganic Data Usability -- All sample data, as validated, were considered acceptable and usable, except for "R"-qualified data. The "R" qualifier is used to designate data which were deemed unusable by the U.S. EPA data validation guidelines criteria.

4.7.2.1.2 Soil Samples - Volatile Organic Parameters

Phase I. Some target parameters were found in trace level concentrations in a few of the volatile blanks. Any associated investigative sample concentrations below the appropriate concentrations were qualified as nondetects and assigned the "U" data qualifier.

The recoveries of benzene and toluene from a matrix spike sample were outside the acceptance criteria. The associated samples were qualified with the "J" data qualifier.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. Three field duplicates were collected and analyzed. Two RPDs were calculated (66 and 67 percent).

Phase II. Some data were assigned the "J" data qualifier for surrogate recovery criteria exceedences or continuing calibration criteria exceedences. Many of the surrogate recovery exceedences were beyond the upper range of the recovery criteria. When the surrogate recovery is higher than the acceptance criteria, the consequence is a potential for some volatile parameters to be overestimated by the laboratory analysis.

Several other "J" qualifiers were assigned to data that were associated with a continuing calibration percent difference that was greater than the $\pm$ 25 percent criteria. The continuing calibration exceedences reported were just slightly above the acceptance criteria. The occurrences did not compromise the data quality or usability since the continuing calibration response factors reflect the actual analytical system's current responsiveness to the target parameters and their use results in an accurate quantitation of the samples. This is because the continuing calibration response factors are applied to all samples analyzed during the analytical run.

Some target parameters were found in trace level concentrations in a few of the volatile blanks. Acetone was detected in two of the four laboratory blanks. Methylene chloride was detected in one of the four laboratory blanks. Ethyl benzene was detected in one of the 13 laboratory blanks. Toluene was detected in one of the 13 laboratory blanks. Meta and para xylenes were detected in one of the 13 laboratory blanks. Any associated investigative sample concentrations below the appropriate concentrations were qualified as nondetects and assigned the "U" data qualifier. It is known that some air contaminants, such as methylene chloride and acetone, are not always detected in laboratory blanks since the water used for the laboratory blanks may not have had the same laboratory residence time as the samples. The probability of a sample being contaminated by laboratory air may be considered more or less proportional to the sample or blank residence time, acetone and methylene chloride contamination from the laboratory air may occur without being detected in the laboratory blanks. Therefore, all acetone and methylene sample concentrations should be considered potential false positives unless their presence can be explained by field conditions or other sample constituents.

All sample spike recoveries were within the acceptance criteria, reflecting an accurate analytical system and a lack of sample matrix effects.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. The RPDs ranged from 7.4 to 89.2 percent, with the average calculated as 46.7 percent RPD. This represents a good degree of precision and reproducibility considering the complexity and heterogeneity of the non-native sample constituents.

Overall Phase I and II Volatile Organic Data Usability -- All sample data, as validated, were considered acceptable and usable.

4.7.2.1.3 Soil Samples - Semivolatile Organic Compounds

Phase I. Some data were assigned the "J" data qualifier for initial or continuing calibration criteria exceedences. Any positive sample results associated with the outlier compounds were qualified as estimated and assigned the "J" data qualifier. Low concentrations of bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and 4-methylphenol were reported in some of the blanks. All associated sample results less than five times the blank concentration of phenol or 4-methylphenol were qualified as nondetects and assigned "U." All associated sample results less than 10 times the blank concentration of bis(2-ethylhexyl)phthalate or di-n-butylphthalate were qualified as nondetects and assigned "U."

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. Four field duplicates were collected and analyzed. Seven RPDs were calculated with a range of 17 to 96 percent and the mean RPD of 66 percent.

Phase II. Some data were assigned the "J" data qualifier for surrogate recoveries or continuing calibration criteria exceedences. All of the surrogate recovery exceedences were beyond the upper range of the recovery criteria. When the surrogate recovery is higher than the acceptance criteria, the consequence is a potential for some volatile parameters to be overestimated by the laboratory analysis.

Several other "J" qualifiers were assigned to data that were associated with a continuing calibration percent difference that was greater than the $\pm$ 25 percent criteria. The continuing calibration exceedences reported were just slightly above the acceptance criteria.

All sample spikes were acceptable except for three instances. Two spiked samples had low recoveries for 2,4-dimethylphenol. The recoveries of 2,4-dimethylphenol from the spike sample and the duplicate spike sample were variable. In both cases, one of the two spike samples had all acceptable recoveries while the duplicate spike sample had low recoveries for 2,4-dimethylphenol. However, there are no U.S. EPA CLP matrix spike recovery criteria for 2,4-dimethylphenol, but only laboratory-based criteria. All appropriate samples were assigned the "J" data qualifier for the low spike recoveries.

The third case had some low PAH spike recoveries. Only benzo(g,h,i)-perylene did not have acceptable spike recoveries in either the sample spike or duplicate sample spike. However, there are no U.S. EPA CLP matrix spike recovery criteria for benzo(g,h,i)perylene. The high and variable native sample concentrations of the PAHs may have contributed to the apparent low spike recoveries. The appropriate samples were assigned the "J" data qualifier for benzo(g,h,i)perylene.

Overall, the spiked sample recoveries reflected an accurate analytical system and a general lack of a pattern of matrix effects from the samples.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. The RPDs ranged from 0.0 to 162.3 percent, with the average calculated as 29.1 percent RPD. This represents a good degree of precision and reproducibility considering the complexity and heterogeneity of the non-native sample constituents.

Phase I and II Overall Semivolatile Organic Compounds Usability -- All nonpesticide semivolatile organic data points, as validated, were deemed usable.

4.7.2.1.4 Soil Samples - Pesticides and PCBs

Phase I. For an initial calibration, the percent relative standard deviation criteria was exceeded for methoxychlor. Associated samples were assigned the data qualifier "J" or "UJ."

The overall precision of the analytical data was evaluated by reviewing RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. Two field duplicates were collected and analyzed. The RPDs ranged from 10.2 to 22.6 percent, with the mean calculated as 14.7 percent RPD. This represents a high degree of precision and reproducibility.

Phase II. All pesticide data exhibited a high degree of data quality. No data qualifiers were assigned to the data as a result of the data validation process.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. The RPDs ranged from 10.2 to 22.6 percent, with the mean calculated as 14.7 percent RPD. This represents a high degree of precision and reproducibility.

Phase I and II Overall Pesticide and PCB Usability -- All sample data, as validated, were considered acceptable and usable.

4.7.2.2 Water Samples

4.7.2.2.1 Water Samples - Inorganic Parameters

Phase I. Metals calibration, preparation, and field blanks had concentrations of several elements less than the CRDL, but greater than the IDL. All associated sample results with less than five times the blank concentration were qualified as nondetects and assigned the "U" data qualifier.

Laboratory duplicate sample RPD values for some metals elements were beyond the control limits. Results for all affected samples were qualified as estimated and assigned the "J" data qualifier.

A small number of samples were assigned the "J" data qualifier for exceedences in the post digestion spike sample recoveries or the ICP serial dilution criteria.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for metals field duplicate data where there existed two detected values which were not qualified as estimated. Two field duplicates were collected and analyzed. Nineteen RPDs were calculated with a range of 7 to 98 percent and the mean RPD of 22.4 percent.

Phase II. Some cyanide and mercury data were qualified as not detected and assigned the "U" data qualifier due to calibration and preparation blank concentrations above the IDL.

Laboratory duplicate sample RPD values for some metal elements were beyond the control limits. Results for all affected samples were qualified as estimated and assigned the "J" data qualifier.

Some sample data was assigned the "J" data qualifier due to exceedences of the ICP serial dilution criteria for iron, sodium, or zinc.

Some sample data were assigned the "J" data qualifier due to exceedences of the sample spike recovery criteria for arsenic, cadmium, selenium, cyanide, or thallium.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for cyanide field duplicate data where there existed two detected values which were not qualified as estimated. Two field duplicates were collected and analyzed. Two RPDs were calculated with a range of 6 to 34 percent and the mean RPD of 20 percent.

4.7.2.2.2 Water Samples - Volatile Organic Parameters

Phase I. A small number of samples were assigned the "J" data qualifier for initial calibration criteria exceedences for acetone.

Some target parameters (methylene chloride, acetone, methyl ethyl ketone, and chloroform) were found in trace level concentrations in a few of the volatile blanks. Any associated sample results below the appropriate concentrations were qualified as nondetects and assigned the "U" data qualifier.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated or

nondetected. Two field duplicates were collected and analyzed. Seven RPDs were calculated with a range of 0 to 19 percent and the mean RPD of 9.6 percent.

Phase II. A small number of data values were assigned the "J" data qualifier for initial and continuing calibration criteria exceedences. The occurrences did not compromise the data quality or usability since the continuing calibration response factors reflect the actual analytical system's current responsiveness to the target parameters. Their use results in an accurate quantitation of the samples because the continuing calibration response factors are applied to all samples analyzed during the analytical run.

Some target parameters were found in trace level concentrations in a few of the volatile blanks. Any associated sample results below the appropriate concentrations were qualified as nondetects and flagged with the "U" data qualifier.

All sample spike recoveries were within the acceptance criteria, reflecting an accurate analytical system and a lack of sample matrix effects.

For three groundwater samples from the first Phase II sampling event (September 30 through October 1, 1993), the dilutions required, due to the high concentrations of some volatile target analytes, were performed outside of the sample holding time. Any values from the diluted sample data set were assigned a footnote documenting the holding time exceedence. The samples affected were from locations MW-13D, MW-9D, and MW-8D.

Phase I and II Overall Water Sample Volatile Data Usability -- All sample data, as validated, were considered acceptable and usable.

4.7.2.2.3 Water Samples - Semivolatile Organic Compounds

Phase I. Low concentrations of phenol, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and 4-methylphenol were reported in some of the blanks. All associated sample results less than five times the blank concentration of phenol or 4-methylphenol were qualified as nondetects and flagged U. All associated sample results less than 10 times the blank concentration of bis(2-ethylhexyl)phthalate or di-n-butylphthalate were qualified as nondetects and assigned the "U" data qualifier.

A matrix spike sample had recoveries beyond control limits for phenol. The phenol results for the affected samples were qualified as estimated and assigned the "J" data qualifier.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. Two field duplicates were collected and analyzed. Five RPDs with a range of 0 to 130 percent and mean of 50.2 percent were calculated.

Phase II. All nonpesticide semivolatile organic data exhibited a good degree of data quality overall. No "R" data qualifiers (unusable) were assigned to the data as a result of the data validation process.

Some target parameters were found in trace level concentrations in a few of the semivolatile blanks. Any associated investigative sample concentrations below the appropriate concentrations were qualified as nondetects and assigned the "U" data qualifier.

All surface water sample spikes recoveries met the acceptance criteria. The spike recoveries reflected an accurate analytical system and a general lack of sample matrix effects. One groundwater sample acid fraction spike resulted in high recoveries for phenol and low recoveries for 2,4-dimethylphenol. Associated samples were assigned the "J" data qualifier for the recoveries. One groundwater sample base neutral fraction spike resulted in low recoveries for indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene. Sample MW-7S (December 1, 1993) was assigned the "J" data qualifier for indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene due to the spike recoveries.

Phase I and II Overall Water Sample Semivolatile Data Usability -- All sample data, as validated, were considered acceptable and usable.

4.7.2.2.4 Water Samples - Pesticides and PCBs

Phase I. For a low surrogate recovery event, a small number of samples were assigned the "J" or "UJ" data qualifier.

For low recoveries of g-BHC and heptachlor from a matrix spike, a few "J" or "UJ" data qualifiers were assigned to the associated samples.

The overall precision of the analytical data was evaluated by reviewing the RPDs calculated for field duplicate data where there existed two detected values which were not qualified as estimated. Two field duplicates were collected and analyzed with no data values qualifying for RPD calculation.

Phase II. All pesticide data exhibited a high degree of data quality. No data qualifiers were assigned to the data as a result of the data validation process.

Phase I and II Overall Water Sample Pesticide/PCB Data Usability -- All sample data, as validated, were considered acceptable and usable.

SECTION 5.0
PHYSICAL CHARACTERISTICS OF THE SITE

The RI field activities have provided data for characterizing the geology, hydrogeology, and hydrology of the WCP site. The following sections present evaluations of the RI data relating to the site's physical characteristics. Information from other studies and published sources is incorporated, where appropriate, in the evaluations.

The sections below describe geologic and hydrogeologic conditions at the site, identifying a near-surface sand unit that is the aquifer of interest relative to potential groundwater-related impacts. Groundwater elevation measurements and evaluations of aquifer characteristics are used to assess patterns and rates of groundwater flow within the sand unit aquifer. Groundwater flow modeling is subsequently described, integrating hydrogeologic parameter estimates and providing a representative simulation of on-site and off-site groundwater flow patterns.

5.1 GEOLOGY

Geologic conditions in the vicinity of the WCP site were evaluated based on data from soil borings placed during the RI (Figure 4.1-4), data from borings placed during prior investigations (see Sections 3.1 and 3.2), and published geologic information.

The site geology is characterized by near-surface fill materials that were placed over a fine-grained sand unit. The sand overlies a till unit known as the Wadsworth Till (Lineback, 1979), which in turn overlies dolomitic bedrock formations. Geologic cross sections showing the relationship of the geologic units present in the vicinity of the WCP site were developed for the locations shown on Figure 5.1-1. The geologic cross sections are shown on Figures 5.1-2 and 5.1-3. The characteristics of each unit (as determined from field observations and geotechnical analyses) are described below.

5.1.1 Fill

As described in Section 2.1.3, anthropogenic deposits of fill materials were used to create the peninsula of land that is now present between Lake Michigan and Waukegan Harbor. The peninsula was built beginning in the 1880s, was large enough to accommodate the city water treatment plant and the WCP facility by 1927, and is continuing to expand eastward today. At the WCP site, fill deposits were encountered across the surface of the site and to depths of generally 2 to 12 feet below

the ground surface (Figure 5.1-4). Fill materials were encountered to depths of up to 25 feet below the ground surface in the northeastern portion of the site, possibly due to later filling activities related to the pond that was formerly present in this area. The fill materials typically consist of reworked natural sand deposits with construction/demolition debris and zones of coal, coke, and slag. Demolition debris materials were placed at the WCP site and covered with a thin layer of fill during OMC's demolition of the coke plant facilities in approximately 1972.

5.1.2 Sand Unit

The sand unit underlying the fill is generally 20 to 25 feet thick (Figures 5.1-2 and 5.1-3). The unit consists of a well sorted (i.e., poorly graded) fine to very fine sand with silt contents varying from approximately 5 to 15 percent. Deposits in the deeper portions of the sand unit typically showed slightly finer grain sizes than deposits in the upper portions of the unit. No areal zones of distinctly different lithologies were identified. The sands vary in color from pale brown to very dark gray. Geotechnical analyses of samples collected from the sand unit showed porosity values ranging from 33 percent to 41 percent.

5.1.3 Till

The till underlying the sand unit has been determined to be between 77 and 80 feet thick at locations on-site (Boring SB-03) and off-site (Borings L-1 and L-2B, placed approximately 1,000 feet northwest and northeast of the site, respectively). The till consists of a lean clay with sand and some gravel. At one location (Boring SB-32), the upper 7 feet of the till consists of silt and interbedded silty sand overlying the more typical lean clay. Geotechnical data for samples collected from the till unit are presented in Section 4.6.

The surface of the till (i.e., the contact between the till and the overlying sand unit) is overlain by a thin, discontinuous zone that typically consists of a poorly graded gravel with sand to a silty gravel. Where present, the average thickness of this zone is approximately 0.3 feet. The gravelly zone was encountered in more than half of the borings placed during the RI; the areal distribution of the locations at which this zone was encountered does not suggest any discernible trends or groupings. Because this zone contains high percentages of sand and silt and is discontinuous/thin, potential effects on groundwater flow in the sand unit are negligible; data relevant to this issue are discussed in Section 5.2.1.2.

The surface of the till is irregular, with elevation variations of up to 4 feet identified within specific areas of the site (Figure 5.1-5). The irregularities of the till surface are superimposed on an apparent general trend of decreasing till surface elevation from west to east.

5.1.4 Bedrock

A gray carbonate bedrock unit was identified beneath the till at locations on-site (Boring SB-03) and off-site (Borings L-1 and L-2B, placed approximately 1,000 feet northwest and northeast of the site, respectively). This bedrock unit is part of the Silurian dolomite formations present in Northeastern Illinois (Willman, et al., 1967).

5.2 SITE HYDROGEOLOGY

5.2.1 Hydrogeologic Characteristics

The following characterization of site hydrogeology addresses the unconfined, unconsolidated sand aquifer above the till. The hydrogeologic characterization is based on data collected during the RI, including groundwater and surface water elevation measurements and the results of in situ permeability tests (slug tests and pumping tests). In addition, a computer model of groundwater flow was developed to help refine the site hydrogeologic conceptual model and for future use in assessing potential groundwater remedial actions.

5.2.1.1 Groundwater Flow Directions

Groundwater flow directions were evaluated based on groundwater and surface water elevations measured during the RI, as summarized in Table 4.2-2. Based on the measured data, groundwater occurs at depths of 2.5 to 5 feet below the ground surface at the site. The saturated thickness of the sand aquifer ranges from approximately 22 to 27 feet.

Water table elevation contour maps were developed for 15 groundwater elevation measurement events that were completed between April 1992 and April 1994 (PSCS Appendix 5-A). The individual water table elevation contour maps show a consistent flow pattern that includes a groundwater divide in the eastern portion of the site with flow to the east (toward Lake Michigan) and to the south and west (toward Waukegan Harbor). Figure 5.2-1 shows a representative water table contour map illustrating the October 1993 groundwater level measurements.

The water table elevation contour maps presented in Appendix 5-A show that overall groundwater flow patterns do not change significantly with time, although groundwater elevations may vary by as much as 3 feet in transient response to infiltration events. The consistency shown by the flow patterns indicates that transient effects of infiltration or lake level variations do not alter long-term groundwater flow paths from the WCP site, and that average hydraulic gradients (i.e., average values for water table slopes) will be representative of overall groundwater flow conditions.

The groundwater elevation contour maps indicate horizontal hydraulic gradients in the sand aquifer that range from approximately 0.0018 feet/foot to 0.0031 feet/foot for groundwater flow to the east (toward Lake Michigan), 0.0008 feet/foot to 0.0048 feet/foot for flow to the west (toward Waukegan Harbor), and 0.0005 feet/foot to 0.0008 feet/foot for flow to the south (toward the Waukegan Harbor entrance channel). Consistent with observed conditions, these temporal extremes cannot be sustained by the groundwater flow system for long periods of time. Average hydraulic gradients are representative of overall groundwater flow conditions. Average horizontal hydraulic gradients in the sand aquifer are 0.0026 feet/foot for groundwater flow to the east, 0.0021 feet/foot for groundwater flow to the west, and 0.0006 feet/foot for groundwater flow to the south.

The water table elevation contour maps show steeper hydraulic gradients between the sand unit aquifer and adjacent surface water in the vicinity of Slip No. 4 (i.e., near Piezometer P-107) than in areas near the old harbor walls (i.e., near Wells MW-5S and MW-6S). This situation reflects somewhat less hydraulic communication across the Slip No. 4 sheet pile wall than across the old harbor walls, probably due to: (1) possibly tighter seals between the new sheet pile sections (and between the sheet pile sections and the till) at Slip No. 4 compared to the older sheet pile sections present at the harbor wall; and (2) the reduced depth of water in Slip No. 4 compared to the water depth in the harbor.

The monitoring well network installed at the WCP site includes 14 nests of paired monitoring wells (i.e., a water table well and a base of sand aquifer well placed at the same location). Data from these nested wells were used to assess vertical hydraulic gradients within the sand aquifer and related groundwater flow characteristics. The vertical hydraulic gradients at the monitoring wells nested within the sand aquifer generally indicate a slight downward component of flow. Computed downward vertical hydraulic gradients between the upper and lower wells are generally in the range from 0.0 to 0.006 feet/foot. The downward flow components result from infiltration moving downward into the aquifer. Flow is mostly downward near the groundwater divide and mostly horizontal in other areas.

5.2.1.2 Horizontal Hydraulic Conductivity

Horizontal hydraulic conductivity data for the sand unit aquifer at the site are available from analyses of grain size distributions, evaluation of slug test data, and pumping test data evaluations.

Hydraulic conductivity estimates were previously developed based on grain size distribution data (Canonie, 1989). The reported values for samples of the sand unit aquifer (collected from borings placed at the former Slip No. 3 and at OMC Plant No. 2) ranged from 18 to 40 ft/day (6.4×10^{-3} to 1.4×10^{-2} cm/sec).

Hydraulic conductivity estimates based on the results of RI slug tests are presented in Table 4.2-4. The estimates range from 1.1 to 16.3 feet/day (3.9×10^{-4} to 5.8×10^{-3} cm/sec). The geometric mean of these slug test estimates is 4.7 feet/day (1.7×10^{-3} cm/sec). These values are similar to hydraulic conductivity estimates reported for slug tests of the surficial unconsolidated materials at OMC Plant No. 2, approximately 1,000 feet north of the site (JRB, 1981). Hydraulic conductivity estimates for the OMC Plant No. 2 slug tests showed a geometric mean value of approximately 4 ft/day (1.4×10^{-3} cm/sec).

An evaluation of the spatial distribution of horizontal hydraulic conductivity estimates from slug test results did not yield any identifiable pattern. In addition, no systematic differences in hydraulic conductivity were observed between wells intersecting the gravelly zone at the base of the aquifer and wells at locations in which the gravelly zone was not present. Based on slug test data, hydraulic conductivity values for wells intersecting the gravelly zone (i.e., at 9 of the 14 well nests) range from 1.1 to 13.8 feet/day, with a geometric mean value of 5.4 feet/day. For wells that do not intersect the gravelly zone (i.e., at 5 of the 14 well nests), hydraulic conductivity values range from 4.3 to 12.6 feet/day, with a geometric mean value of 7.3 feet/day. These data variations are relatively minor and indicate that the presence or absence of the gravelly zone at a particular location does not materially affect groundwater flow characteristics in the sand unit aquifer.

The mean hydraulic conductivity value computed from the step drawdown and constant rate pumping tests conducted during the RI at Well PW-1 (Table 4.2-5) is 47 feet/day (1.7×10^{-2} cm/sec). The mean ratio of vertical to horizontal hydraulic conductivity estimated from the pumping test results is 0.24. The mean hydraulic conductivity value from the pumping tests performed at Well PW-1 is approximately six times larger than the geometric mean of the slug test estimates for Well PW-1 and adjacent Piezometer P-108.

The slug test estimates provide information on the relative areal variation of hydraulic conductivity across the site. The pumping test results, however, provide more representative values for the absolute value of the sand unit hydraulic conductivity because pumping tests affect a larger volume of aquifer materials than do slug tests (Walton, 1987). Accordingly, a range of values for horizontal hydraulic conductivity was estimated from: (1) the range (1 to 16 ft/day [3.5×10^{-4} to 5.6×10^{-3} cm/sec]) and overall geometric mean (5 ft/day [2×10^{-3} cm/sec]) of slug test estimates from tests at different locations; and (2) scaling these results by a factor of 6, the ratio of pumping test to slug test results at the location of Well PW-1. Using this approach, the site horizontal hydraulic conductivity is estimated to be within the range of 6 to 96 feet/day (2.1×10^{-3} to 3.4×10^{-2} cm/sec), with a geometric mean value of 30 feet/day (1.1×10^{-2} cm/sec).

A range of horizontal hydraulic conductivity values was also estimated from vertical hydraulic conductivity data for triaxial tests performed on samples from the sand aquifer. The vertical hydraulic conductivity results (Table 4.2-6) were divided by the mean ratio of vertical to horizontal hydraulic conductivity estimated from the pumping test results (i.e., 0.24). On this basis, the horizontal hydraulic conductivity of the sand aquifer is estimated to range between 13 and 70 feet/day, with a geometric mean value of 25 feet/day.

In summary, a hydraulic conductivity value of 30 ft/day (1.1×10^{-2} cm/sec) has been determined to be representative for the sand unit aquifer at the WCP site. This value: (1) emphasizes the pumping test results as being most representative of site hydrogeologic conditions; (2) incorporates slug test data in a quantitative way to address areal variations in hydraulic conductivity at the site; and (3) is consistent with estimates developed based on grain size distribution and laboratory permeability test data.

5.2.1.3 Groundwater Flow Rates

Estimates of linear groundwater velocity in the sand aquifer have been developed using the estimated mean hydraulic conductivity value of 30 feet/day, an average porosity of 0.38 (Table 4.6-3), and the horizontal hydraulic gradients (Section 5.2.1.1). The resulting estimates of groundwater flow rates range from 0.14 feet/day (52 feet/year) to 0.24 feet/day (89 feet/year) and average 0.21 feet/day (77 feet/year) for groundwater flow to the east toward Lake Michigan, range from 0.06 feet/day (23 feet/year) to 0.38 feet/day (138 feet/year) and average 0.17 feet/day (62 feet/year) for groundwater flow to the west toward Waukegan Harbor, and range from 0.04 feet/day (14 feet/year) to 0.06 feet/day (23 feet/year) and average 0.05 feet/day (18 feet/year) for groundwater flow to the south toward the Waukegan Harbor entrance channel.

5.2.1.4 Infiltration Rate

The average infiltration rate for the WCP site was estimated based on local hydrologic data. As there are no developed surface water drainage features on the site, no surface runoff was assumed for the site, and infiltration was estimated as the difference between precipitation and evapotranspiration. In larger watersheds that are drained by streams and rivers, the difference between precipitation and evapotranspiration is expressed as runoff (assuming deep percolation is negligible and assuming no net change in storage over long periods of record). Accordingly, hydrologic data for nearby watersheds were assessed to determine representative values for runoff in the Waukegan area.

Data from the stream flow gaging stations at Buffalo Creek (1968-1983), the Des Plaines River at Russell (1968-1983), and the Des Plaines River near Gurnee (1969-1975) were used in the infiltration calculations (Hey and Philippi, undated). The watersheds and gaging stations used in this analysis are near Waukegan, and the corresponding values for total annual precipitation are similar to values reported for the Waukegan stations (Table 2.2-1). Because of this proximity and similarity, no adjustment was applied to the computed values.

The annual runoff for the 19.6-square mile watershed of Buffalo Creek was computed to be 15 inches. The average annual runoff for the 123-square mile watershed of the Des Plaines River at Russell was computed to be 11 inches. The average annual runoff for the 232-square mile watershed of the Des Plaines River near Gurnee was 13 inches. Thus, representative values for the difference between precipitation and evapotranspiration in the Waukegan area are probably within the range of 11 to 15 inches per year for average precipitation conditions. For the WCP site, this indicates that annual infiltration rates to the sand unit aquifer can be expected to be within the same range of values.

The computed infiltration rate range was found to be consistent with observed groundwater elevations and lake levels (Appendix 5-B), indicating that the computed infiltration rates are representative for the WCP site.

5.2.1.5 Hydraulic Communication Across the Till

The potential for hydraulic communication across the till (i.e., groundwater flow between the sand unit aquifer and the dolomitic bedrock aquifer) was evaluated by comparing values for resistance to flow: (1) horizontally through the sand unit; and (2) vertically through the till.

Hydraulic resistance, expressed for vertical flow paths as the flow distance divided by hydraulic conductivity (Kruseman and deRidder, 1991), was computed by an analogous procedure for horizontal flow paths in the sand unit based on a hydraulic conductivity value of 30 feet/day and a maximum flow distance (from the divide to the harbor or lake) of 900 feet. Hydraulic resistance for vertical flow through the till unit was computed based on a thickness of 80 feet and an average hydraulic conductivity of 6×10^{-5} feet/day (2×10^{-8} cm/sec; Table 4.2-6). The calculations show that resistance to vertical flow through the till is computed to be on the order of 40,000 times the resistance to horizontal flow within the sand unit. Thus, upward or downward flow through the till would be negligible compared to horizontal flow within the sand unit aquifer.

Previous investigations identified an upward gradient between the dolomitic bedrock aquifer and the sand unit aquifer, based on artesian conditions (i.e., a flowing well) at OMC bedrock Piezometer L-1 on the west side of OMC Plant No. 2 (Canonie, 1989). This upward gradient is consistent with regional groundwater flow patterns discussed in Section 2.2.5.2.

Water levels measured during the RI at nested wells located east of OMC Plant No. 2 indicate a downward gradient between Well W-12 (screened in the sand unit) and OMC bedrock Piezometer L-2B (Table 4.2-2). However, the water level data from OMC Piezometer L-2B are considered questionable because: (1) the measured water level in OMC Piezometer L-2B is lower than the surface water elevation of Lake Michigan for the same date, which is not consistent with either the lake's position as a regional groundwater discharge point or the lack of groundwater withdrawals from wells in the Waukegan area (Section 2.2.6); (2) the water level in OMC Piezometer L-2B is inconsistent with the reported artesian (flowing well) conditions at bedrock Piezometer L-1 (Canonie, 1989); and (3) development details for OMC Piezometer L-2B (constructed in 1989) are not available, and the degree of piezometer/aquifer communication is not known.

5.2.2 Groundwater Flow Modeling

Two-dimensional models of groundwater flow were developed to: (1) provide a tool for integrating and evaluating independent estimates of hydraulic parameters such as hydraulic

conductivity and aquifer recharge; and (2) provide a basis for future evaluations of potential groundwater remediation scenarios involving hydraulic controls such as groundwater extraction wells and/or hydraulic barriers. The modeling was also performed to supplement the extensive amount of measured site data for evaluating volumetric discharges of groundwater to Waukegan Harbor and Lake Michigan, and to provide a basis for estimating groundwater flow patterns that existed prior to construction of Slip No. 4.

Groundwater flow models were developed using the Single Layer Analytic Element Model (SLAEM), as summarized in the April 12, 1993 Revised Technical Memorandum addressing proposed modeling for the RI/FS (Barr, 1993c). The SLAEM code, as an analytic element code, was selected as particularly applicable for supplementing evaluations of groundwater flow at the WCP site because the varied nature and geometry of hydrologic influences (e.g., the peninsula, Slip No. 4, harbor and slip walls, slurry walls, and building/parking lot areas) can be accurately portrayed without the limitations imposed by grid patterns necessary for finite element and finite difference models. This flexibility in model geometry is also an advantage for future simulations of remedial features that may be placed at currently undefined locations.

Groundwater modeling was performed for steady-state flow conditions to simulate representative groundwater flow patterns and groundwater elevations. As discussed in Section 5.2.1, the observed groundwater flow patterns do not change significantly in response to groundwater elevations that vary on a transient basis. As a result, steady-state simulations are appropriate for achieving the modeling objectives for the following reasons:

1. Parameter value estimates for hydraulic conductivity (not time-dependent) and average annual recharge (specified as uniform for the simulation period) can be effectively integrated and evaluated without transient simulations; and

2. Simulations of future or past conditions will necessarily require long-term representative values for parameters that will show some transient variations -- such long-term representative values are most effectively assessed using steady-state models.

The setup and assumptions incorporated in the groundwater flow model development are presented in Appendix 5-C. Simulations were performed to provide computed groundwater flow patterns and groundwater elevations representative of conditions observed during the period from September 1993 through February 1994 (i.e., the period when the monitoring well network was complete). Hydrogeologic parameter values were varied within ranges established by data presented

in Section 5.2.1 to provide the most representative simulation. The results, shown on Figure 5.2-2, show:

- Groundwater elevation contours indicative of site groundwater flowing primarily toward the harbor, with groundwater in the easternmost portion of the site flowing toward Lake Michigan -- this pattern is consistent with observed groundwater flow patterns (Appendix 5-A);

- A groundwater divide located in the vicinity of Wells MW-4S, MW-7S, and MW-9S -- this position is consistent with the groundwater divide shown by observed groundwater flow patterns (Appendix 5-A);

- Hydraulic gradients of 0.0019 toward the harbor, 0.0025 toward Lake Michigan, and 0.0007 toward the south -- these values represent good matches for average hydraulic gradient values of 0.0021, 0.0026, and 0.0006, respectively, shown by the observed groundwater flow patterns (Appendix 5-A); and

- Groundwater elevations at the on-site groundwater divide (east of Slip No. 4) of approximately 582.75 feet MSL -- this value is representative of overall conditions for the period from September 1993 through February 1994, since it is about midway between the highest observed value for this period (approximately 583.4 feet MSL, September 1993) and the lowest observed value for this period (approximately 582.2 feet MSL, February 1994).

- In the vicinity of the site directly south of the easternmost building of OMC Plant No. 2, groundwater flow is generally in a southwestern, southern, and southeastern direction. These predicted flow directions correspond well with flow directions indicated by the time averaged observations of observed flow patterns (Appendix 5-C). The small hydraulic gradients in this area are most likely the result of the restriction of flow from north of the site due to the foundation of the eastern-most building acting as a no-flow region of the aquifer. As demonstrated with mass balance calculations in Appendix 5-C, the gradients in this area are principally generated from local infiltration and do not represent significant flow entering the site from beneath OMC Plant No. 2.

Parameter values incorporated in the simulation shown on Figure 5.2-2 include a hydraulic conductivity of 31 ft/day (1×10^{-2} cm/sec) and an infiltration rate of 13.6 inches per year (with zero infiltration in building and pavement areas). Based on the ranges of estimated values established for these parameters in Section 5.2.1, the hydraulic conductivity and infiltration values incorporated in the simulation are mid-range values. Appendix 5-C presents a discussion of model sensitivity to these and other parameter values.

Figure 5.2-3 presents the results of a groundwater flow simulation for assumed conditions prior to the construction of Slip No. 4. Input parameter values for this simulation are the same as those for the simulation described above, with the following exceptions: the sheet pile walls and slurry wall that form the boundary of Slip No. 4 were not included; the sand unit aquifer was assumed to be continuous through the current location of Slip No. 4; and the harbor wall was assumed to be continuous across the area of the current mouth of Slip No. 4. The results of the simulation show a fairly symmetrical flow pattern for conditions prior to construction of Slip No. 4, with the groundwater divide shifted approximately 200 feet to the west compared to the divide location (east of Slip No. 4) that is shown on Figure 5.2-2. The computed groundwater flow rate to the harbor without Slip No. 4 is approximately 10 percent less than the computed flow rate to the harbor in the presence of Slip No. 4.

5.3 SUMMARY

The preceding sections describe geologic conditions at the WCP site, identifying a near-surface unit of approximately 30 feet of fill materials and natural sand deposits overlying a lean clay till. Groundwater at the site occurs in this sand unit within 4 feet of the ground surface. Groundwater elevation measurements indicate a consistent flow pattern within the sand unit aquifer, showing a groundwater divide near the eastern site boundary with flow to the east (toward Lake Michigan) and to the south and west (toward Waukegan Harbor). Hydraulic conductivity estimates from site-specific tests indicate that groundwater flow rates (average linear velocities) are on the order of 60 to 80 feet per year to the east and west and 20 feet per year to the south. Average infiltration rates are estimated to be within the range of 11 to 15 inches per year. A groundwater flow model integrates the hydrogeologic parameter estimates and provides a representative simulation of on-site and off-site groundwater flow patterns.

SECTION 6.0
NATURE OF CONTAMINATION

This section sets the agenda for chemical constituents used in characterizing the extent of contamination at the WCP site (Section 7.0) and summarizes associated chemical constituent properties used to evaluate fate and transport (Section 8.0). Chemical constituents are identified based on measured constituent concentrations, frequency of detection, and constituent toxicity and mobility. Parameters selected for extent of contamination characterization include PAHs, volatile organic compounds, phenolic compounds, and inorganic chemicals. Chemical and physical properties of the identified parameters are summarized in this section to indicate potential fate and transport characteristics.

6.1 IDENTIFICATION OF PARAMETERS FOR EXTENT OF CONTAMINATION CHARACTERIZATION

The key parameters that will be used in the following sections to characterize the extent of soil, groundwater, and surface water contamination in the vicinity of the site are listed in Table 6.1-1. These parameters are associated with on-site operations, by-products, and residuals (Section 2.1) and were selected from a list of potential chemicals of concern identified for the site in the October 1991 RI/FS Final Work Plan according to the procedures documented in the July 1993 TM (Barr, 1993b) after the first phase of the RI. These procedures are presented in Appendix 6-A. PCBs were added to the key parameter list because of their association with on-site operations (Section 2.1.3).

6.2 CHEMICAL AND PHYSICAL PROPERTIES OF IDENTIFIED PARAMETERS

This section presents chemical properties and general transport characteristics of identified parameters in order to aid in the interpretation of data collected during the RI and to provide a basis for assessing potential future remedial scenarios. Chemical property values from the literature for the identified organic and inorganic parameters have been compiled and tabulated as described below. General transport characteristics for the identified parameters are also summarized below, based on information available from published sources. Environmental fate and transport characteristics specific to the WCP site are addressed in Section 8.0.

6.2.1 Organic Chemicals

The organic chemicals listed in Table 6.1-1 include PAHs, BETX compounds, phenolic compounds, and PCBs. Table 6.2-1 presents values for relevant chemical properties of the identified parameters. Values are presented for:

- Molecular weight and solubility (relevant to the maximum potential concentration of a compound in water as derived from a multicomponent or pure nonaqueous source);
- Organic carbon partition coefficient (relevant to a compound's tendency to partition from the dissolved phase and be adsorbed onto organic carbon present in subsurface materials);
- Vapor pressure and Henry's Law constant (relevant to a compound's ability to volatilize from water or soil moisture); and
- Degradation constant and half life (relevant to the susceptibility of a compound to be degraded by biological and other processes).

Of the identified organic compounds of interest, PAHs typically have the lowest solubilities in water and tend to be highly adsorbed onto soil organic carbon. Both coal tar (associated with manufactured gas/coking operations) and creosote (associated with creosoting operations) consist mostly of PAHs. Coal tar is only slightly soluble in water and may be present in soils and groundwater as a separate nonaqueous-phase fluid. Coal tar is more dense than water and may migrate as a separate phase primarily under the influence of gravity. Pockets of concentrated coal tar are likely to be persistent because mixing with groundwater (required for solubilization) and aeration (required for biodegradation) are likely to be limited in the subsurface environment. Creosote has environmental fate and transport properties similar to those described for coal tar, although creosote may be more mobile than coal tar due to its lower viscosity and due to differences in surface tension. The migration of creosote as pure phase microdroplets with advective groundwater flow has also been documented at other creosote sites. The dissolution of chemical constituents contained in coal tar and creosote would be governed primarily by effective solubilities (i.e., as a component of a complex mixture), rather than by organic carbon partition coefficients shown in Table 6.1-2.

BETX and phenolic compounds are much more water soluble than PAH compounds. Due to these high solubilities, dissolution in groundwater is a key determinant of the environmental fate of

BETX and phenolic compounds. This high solubility also explains, in part, the susceptibility of BETX and phenolic compounds to biodegradation. Benzene is the most soluble and mobile of the BETX compounds, while phenol is generally the most soluble and mobile of the phenolic compounds (Table 6.2-1).

PCBs have very low solubilities and high tendencies to adsorb onto soil and are, therefore, considered essentially immobile in groundwater environments.

6.2.2 Inorganic Chemicals

The inorganic chemicals listed in Table 6.1-1 include metals and cyanide. Table 6.2-2 presents values for relevant chemical properties of the identified inorganic parameters. Values are presented primarily for distribution coefficient (relevant to a parameter's tendency to partition from the dissolved phase and be adsorbed onto fine particles and/or organic carbon present in subsurface materials). With the exception of cyanide, inorganic parameters are typically not volatile or degradable. Speciation and complexation for inorganic parameters can vary depending on the chemical's initial form and the ambient environmental conditions.

Arsenic is typically strongly adsorbed by most soils and sediments (EPRI, 1984). Studies of arsenic retention by soil have shown that adsorption is controlled to a large degree by the content of hydrous oxides of iron and aluminum (Jacobs, et al., 1979; Wauchope, 1975; Livesey and Huang, 1981) and solubility is expected to be highly dependent upon redox potential (Eh) and pH conditions.

Cadmium is relatively insoluble at neutral pHs (Hassett and Groenewald, 1986) and is, therefore, expected to be relatively immobile in the environment.

The transport and fate of cyanide in the soil is dependent on the chemical compound containing the cyanide. Metal cyanide complexes are generally insoluble. Cyanide salts (i.e., sodium and potassium) are generally soluble. Available data suggest that cyanide is likely to be a relatively mobile constituent (Agency for Toxic Substance and Disease Registry [ATSDR], 1988).

Lead is strongly retained by soils, having a relatively low mobility in soil under both oxidizing and reducing conditions (Swartzbaugh, et al., 1992).

Several studies suggest that mercury adsorption in soils is controlled primarily by organic material (Hogg, et al., 1978; John, et al., 1975). However, with time, microbial processes may lead to

the formation of elemental mercury, which can be released to water even in the presence of high organic material content (Miller, 1975).

Selenium retention in soil has not been extensively studied. Limited studies indicate that in spite of their anionic nature, Se(IV) and Se(VI) may be adsorbed significantly by soils enriched in hydrous oxides of aluminum and iron or amorphous aluminosilicates (EPRI, 1984).

6.3 CONCLUSIONS

Based on sample analytical data, frequency of detection, and constituent toxicity and mobility, chemical parameters were identified from the following parameter groups for characterizing the extent of contamination: PAHs, VOCs, phenolic compounds, and inorganic chemicals. Physical and chemical properties of these parameters provide a context for the evaluation of the extent of contamination in Section 7.0 and for specific fate and transport evaluations subsequently discussed in Section 8.0.

The compiled literature information indicates that PAHs are likely to be relatively immobile in the environment. Potential PAH migration is limited by the compounds' low solubilities and tendency to be adsorbed onto aquifer solids.

The literature data indicate that benzene is likely to be the most soluble and mobile of the selected VOCs and that phenol is likely to be the most soluble and mobile of the selected phenolic compounds. Benzene and phenol are typically susceptible to degradation in soil/groundwater environments, potentially resulting in concentration reductions during contaminant migration.

The mobility of inorganic chemicals is variable and strongly dependent on factors such as constituent speciation, acidity/alkalinity, and soil/groundwater geochemistry. However, sample analytical data and available literature information indicate that the inorganic chemicals of primary interest at the WCP site are arsenic and cyanide. These constituents, as the most significant of the selected inorganic chemicals, are used in characterizations of the extent of contamination at the WCP site.

SECTION 7.0
EXTENT OF CONTAMINATION

This section describes the extent of contamination at the WCP site. The site data are presented in various forms -- summarized, mapped, or tabulated -- in order to define the extent of contamination. Section 7.1 is an overview of the findings of the extent of contamination review and provides background information for the soil evaluations that follow in Sections 7.3 through 7.6. Section 7.2 presents the extent of contamination for PCBs. Sections 7.3 through 7.6 present the extent of contamination for soil. Section 7.7 addresses groundwater and the associated saturated soil. Section 7.8 presents the data from surface water sampling. The principal observations and conclusions from this extent of contamination review are summarized in Section 7.9.

The parameters evaluated in the extent of contamination discussions for soil, groundwater, and surface water are the PAHs, volatile organic compounds, phenolic compounds, and inorganic chemicals listed in Table 6.1-1. PCBs are addressed separately. Ammonia is included for groundwater and surface water samples, but is not applicable to soils. The samples used to develop the extent of contamination include samples collected during both Phase I and Phase II of the remedial investigation, samples from the IEPA soil investigation, and samples from the Slip No. 4 soil investigation. Data from various other sampling events were also used to assist in the overall extent of contamination evaluation in Section 7.0 and contaminant fate and transport evaluation in Section 8.0. The previous investigations from which data were used are described in Section 3.0. The remedial investigation sampling activities at the WCP site are summarized in Section 4.0. Analytical results for the RI are tabulated in Section 4.0, and the laboratory reports are in PSCS Appendix 4-C. Analytical reports for previous investigations are in PSCS Appendices 3-B through 3-E.

7.1 OVERVIEW

This section provides an overview of the findings of Section 7.0, presents the basis for selecting soil concentrations of significance, and notes the relevance of previously implemented remedies at the WCP site.

7.1.1 Overview of Extent of Contamination

The extent of contamination review led to the observations and conclusions stated below.

7.1.1.1 PCBs

The PCB discussion integrates soil and groundwater data. The investigation found that the areas where PCBs were found were associated with operations involving PCBs that took place after closure of the manufactured gas and coking plant. None of the WCP site samples with detectable concentrations of PCBs exceeded 50 mg/kg.

7.1.1.2 Soil

The discussion of soil investigation results is divided into four sections related to units that may be dealt with independently for risk evaluation or remedy evaluation. The four sections are background soils, ground surface soils at the site, soil stockpiles, and vadose zone. Each section discusses the extent of key chemical parameters (PAHs, phenolic compounds, BETX compounds, and inorganic parameters) in these soil units. Table 7.1-1 summarizes the analytical results and field observations for the RI soil samples.

The background samples (Samples BS-01 through BS-08, GS-01, GS-02, and GS-04) provide information on the character of off-site soils in the general vicinity of the WCP site. The data indicate that, with the exception of phenolic compounds, all key chemical parameters were detected in background soils.

The ground surface soil samples, collected for risk assessment purposes, indicate that samples containing visible or solid residues -- as evidenced by discoloration or material type are also likely to display concentrations of total PAHs greater than 100 mg/kg. The only ground surface sample with a cyanide concentration above 5 mg/kg exhibited a blue tint. The ground surface soil samples with the highest concentrations of total PAHs also have the highest concentrations of inorganic parameters. Arsenic is detected at a maximum concentration of 164 mg/kg, but is detected above 40 mg/kg in only three ground surface soil samples. Cadmium is not detected above a concentration of 3.5 mg/kg. Lead is detected at a concentration of 128 mg/kg in one ground surface soil sample and is otherwise detected at concentrations of less than 100 mg/kg. Mercury is detected at a maximum concentration of 38 mg/kg, but is detected above a concentration of 1 mg/kg in only three samples. Selenium is detected at a maximum concentration of 4.9 mg/kg, but is detected at concentrations of less than 1.3 mg/kg in

all but two ground surface soil samples. Phenolic and BETX compounds are not detected above total concentrations of 0.6 mg/kg and 7µg/kg, respectively.

Soil quality was characterized for two stockpiles at the site: (1) the dredge spoils soil stockpile; and (2) the designated soil stockpile. The dredge spoils soil stockpile appears to contain little or no contamination on the whole, but may contain isolated areas of contamination as evidenced by the PAH concentrations in one sample. The soil samples from the designated soil stockpile contain PAHs, but do not contain phenolic compounds, BETX compounds, or mercury, do not contain arsenic or lead at concentrations above 14.1 mg/kg, and do not contain cadmium, selenium, or cyanide at concentrations greater than 1.4 mg/kg.

Vadose zone soils at the site have concentrations of total PAHs of up to 76,000 mg/kg in the area within the 100 mg/kg total PAH concentration contour on the eastern part of the site and south of Slip No. 4. Benzene and BETX concentrations in this zone are associated with the areas containing PAHs. The highest concentrations of arsenic, cyanide, and selenium in the vadose zone soil are found in the eastern part of the site near the northwest corner of the fence around the OMC data building parking lot. Mercury is found at levels above 1 mg/kg in the eastern part of the site and in a limited area in the northeast corner of the site. Lead and cadmium are generally not present in vadose zone soils at concentrations above 80 mg/kg and 3 mg/kg, respectively.

7.1.1.3 Groundwater

Groundwater and associated saturated soils at the site are divided into two units based on the distinct difference in groundwater and saturated soil quality observed between the two units. The two units are part of the same 25-foot thick saturated unit. The upper 17 feet are referred to as the shallow portion of the sand aquifer, and the bottom 8 feet down to the till aquitard are referred to as the deep portion of the sand aquifer.

The concentrations of phenol, benzene, arsenic, cyanide, and ammonia are at least one order of magnitude and usually two to three orders of magnitude higher in the groundwater in the deep portion of the sand aquifer than in the groundwater in the shallow portion of the sand aquifer. The presence of significantly higher concentrations in the deep portion of the sand aquifer are most likely related to historic site operations, including discharges of the wood-treating plant, the manufactured gas plant, and the coke plant, as well as activities associated with demolition of these facilities by OMC. Given those potential former sources, the chemical constituents now found in the deep portion of the sand aquifer must have passed through the shallow portion of the sand aquifer. Natural processes such as

greater biodegradation in the shallow portion of the aquifer may have contributed to the currently observed stratification of key parameters in soil and groundwater.

7.1.1.4 Surface Water and Sediment

The surface water and sediment contamination distribution section presents the RI and previous investigation surface water data for both Lake Michigan and Waukegan Harbor. Lake Michigan water quality standards for total cadmium are exceeded in several lake water samples. This is a parameter of limited extent and relatively low concentration in the site groundwater. Dredging of the harbor sediments, which is repeated periodically, alters the sediment quality and ecological conditions in the harbor.

7.1.2 Previously Implemented Remedies at the WCP Site

Two remedies have been implemented at the WCP site: a PCB remedy and a soil remedy at Slip No. 4. As described in Section 2.1.3.6, the Waukegan Harbor Superfund site overlaps the west and north sides of the WCP site. A remedy addressing PCB contamination at the Waukegan Harbor Superfund site has been selected, approved, and largely implemented.

A soil remedy has been implemented in the Slip No. 4 area. A soil and groundwater investigation was conducted prior to construction of Slip No. 4. That investigation defined zones of soil that would require removal and separate management during slip construction. The soils from these defined zones were placed in an interim containment cell called the designated soil stockpile. Representatives from the U.S. EPA observed the excavation work and adjusted soil removal depths based on visual observations. The excavation program was designed to properly manage all soils within the limits of the Slip No. 4 tie-back and slurry walls. Excavated soils were placed into the designated soil stockpile (containment cell) or beside the dredge spoils soil stockpile, according to the zone from which the soil was taken. Because this U.S. EPA-approved remedy has already been implemented for the area within the tie-back walls of Slip No. 4, no further evaluation of the soils within this area was performed during this RI.

Sections 2.1.3.4, 3.2.2, and 3.5.6 discuss the Slip No. 4 investigation and construction in more detail. The soil excavation zones are documented and explained in the 1991 Canonie Environmental Data Report on Soil and Water Test Results (Canonie, 1991).

The designated soil stockpile remains on-site, as does the stockpile of the rest of the slip excavation soils.

7.2 DISTRIBUTION OF PCBs

The Waukegan Harbor Superfund site is a PCB site adjacent to the WCP site on the north, and adjacent to and overlapping the WCP site on the west (as presented in Section 2.1.3.6, and shown in PSCS Appendix 2-B). Because of the proximity of the Waukegan Harbor Superfund site to the WCP site and because OMC had stored waste oils containing PCBs on the WCP site (discussed in Section 2.1.3.4), selected samples of WCP site soils were analyzed for PCBs. In order to screen the site as a whole, all the surficial soil samples were analyzed for PCBs. In addition, the first round of samples from all site wells were analyzed for PCBs.

Samples collected from areas on-site in which PCB-containing materials had been stored by OMC were targeted for PCB analysis. These areas included the soil stockpile, which consists of dredge spoils from the harbor and lake and of spoils from excavation of Slip No. 4; a former OMC fuel tank near SB-42; and an area in which trailers with drums of PCB-containing waste oils had been stored. In addition, all designated soil stockpile samples were analyzed for PCBs. None of the soil samples contained PCB concentrations in excess of 50 mg/kg.

Specific areas where PCBs were likely to have been handled by OMC in the past were sampled. The dredge spoils stockpile had been reported to contain up to 1.3 mg/kg PCBs in previous sampling (OMC, 1990a). PCB-1248 was detected at concentrations of less than 2 mg/kg in Soil Sample SB2902 from the soil stockpile area and in Samples SB3003 and SB3007 from the soil stockpile. PCBs were not detected in Surficial Soil Sample SS-16 located south of the soil stockpile or in soil samples from Soil Boring SB-31 in the slip excavation spoils.

Designated Soil Stockpile Sample DS-01 indicated a concentration of 3 mg/kg of PCB-1248. No PCBs were detected in the other two samples from the designated soil stockpile.

Soil Boring 42 was placed in the southern portion of the site at the location of former OMC fuel tanks. PCB-1248 was detected at a concentration of 38 mg/kg in the 2 to 4-foot sample from Soil Boring SB-42.

PCBs were reported in samples from the area of the former OMC waste oil storage trailers in the northern portion of the WCP site. The storage trailers are visible in aerial photographs of the site

from 1977 and 1981. Samples collected in this area included GS-05 and SS-01. Reported PCB concentrations for Ground Surface Soil Sample GS-05 were 20 mg/kg of PCB-1248, 7.9 mg/kg of PCB-1254, and 3.2 mg/kg of PCB-1260. Surficial Soil Sample SS-01 was reported to contain PCB-1248 at 0.2 mg/kg.

The screening of the site as a whole with surficial soil samples (SS) and ground surface soil samples (GS) found PCBs in only a few locations. PCB concentrations of less than 1 mg/kg were detected in the surficial soil samples that were collected from the Larsen Marine area (Samples SS-03 and SS-05). Other instances of PCB detection were associated with former OMC PCB oil storage and are noted above.

The other approach to screening the site for PCBs was analysis of groundwater samples. Of the 28 groundwater samples analyzed for PCBs, only one sample was reported to contain PCBs. A PCB-1248 concentration of 1.1 µg/L was detected in the sample from MW-15S, a water table monitoring well on OMC Plant No. 2 property, upgradient of the WCP site.

It is reasonable to conclude from the soil and groundwater sampling that PCBs are not widespread at the WCP site. Those areas where PCBs were found were associated with storage by OMC of oils containing PCBs. Releases of PCBs by OMC were addressed as part of the Waukegan Harbor Superfund Site remedy, which has been approved and largely implemented.

7.3 BACKGROUND SOIL CHEMICAL CONCENTRATIONS

Eight background soil sample locations were identified in the approved RI/FS final work plan. The objectives of the background soil sampling were to: (1) characterize typical background concentrations of chemical constituents in the surrounding industrial area; and (2) characterize typical background concentrations of chemical constituents in soils in local areas thought to be unaffected by industrial activities.

Three off-site ground surface soil sample locations were identified in the Phase II RI/FS work plan. The locations of Samples GS-01, GS-02, and GS-04 were selected to coincide with the location of Background Soil Samples BS-01, BS-02, and BS-04, respectively. The objectives of off-site ground surface soil sampling were to characterize the soil quality for the 0 to 6-inch depth interval at selected off-site locations (for use in direct-contact/ingestion scenarios in baseline risk assessment evaluations).

Background Sample Locations BS-01 through BS-04 were selected by the U.S. EPA to represent locations thought to be unaffected by industrial activities. These four sample locations were further adjusted by U.S. EPA personnel in the field prior to sampling. Background Sample Locations BS-05 through BS-08 were selected to characterize soil quality in the surrounding industrial area.

After reviewing laboratory analytical data for the background soil samples, the U.S. EPA indicated that Background Soil Sample BS-03 could not be used to characterize soil quality for areas thought to be unaffected by industrial activities. As a result, data from Sample Locations BS-01, BS-02, and BS-04 are used to represent data from U.S. EPA-designated background soil sample locations.

Methods used to collect background soil samples are described in detail in Section 2.2.1.2 of the July 1993 TM (Barr, 1993b). Methods used to collect ground surface soil samples are described in detail in Section 4.1.3. The locations of background soil samples and off-site ground surface soil samples are shown on Figure 4.1-1.

Background soil samples were analyzed for the full-scan parameters listed in Table 4.0-1. Off-site ground surface samples were analyzed for the more focused set of parameters listed in Table 4.0-3. Table 7.3-1 shows chemical constituent concentration ranges for U.S. EPA-designated Background Soil Samples BS-01, BS-02, and BS-04; off-site Ground Surface Samples GS-01, GS-02, and GS-04; and Background Soil Samples BS-01 through BS-08.

Table 7.3-1 also shows the representative upper range background concentrations for key site parameters for all background samples and the upper range background concentrations for the U.S. EPA-designated background samples. As described in Appendix 7-A, the representative upper range background calculations were calculated with the one-sided upper tolerance limit approach, using statistical procedures appropriate to the percentage of detections below the detection limit for each parameter (U.S. EPA, 1989b). The upper tolerance limit approach determines the concentration, below which a specified percentage of the sample population will fall with a specified degree of confidence. For this analysis, both the specified percentage of the population and the specified degree of confidence are 95 percent. Tolerance limits cannot be calculated for parameters that were not detected in any background samples, as there are no appropriate statistical procedures to apply in this case. The data distribution types used for the analysis of all background samples are in Appendix 7-A. The data distribution for the U.S. EPA-designated samples was assumed to be normal.

In this and following sections, the term "background soil samples" will refer to all eight background soil samples and the three off-site ground surface soil samples. All key site soil parameters, except phenolic compounds, are reported as detected in the background soil samples. The key inorganic parameters are arsenic, cyanide, cadmium, lead, mercury, and selenium. Arsenic is detected at concentrations ranging from 2 to 235 mg/kg. It is routinely detected at concentrations of 10 mg/kg or less. Although there is statistical evidence that the arsenic detection at a concentration of 235 mg/kg is an outlier, it cannot be attributed to sampling and analysis error and must therefore be retained in the data set (U.S. EPA, 1989b). The representative upper range background concentration for arsenic is 40 mg/kg, as shown in Table 7.3-1. Cyanide, which was detected in only one sample, has a representative upper range background concentration of 1.5 mg/kg. Cadmium is reported in several samples at concentrations ranging from about 1 mg/kg to 7 mg/kg. The representative upper range background concentration for cadmium is 4.2 mg/kg. Lead is detected in all the background samples, generally at concentrations from 3 mg/kg to 30 mg/kg, but ranging as high as 430 mg/kg. The representative upper range background concentration for lead is 110 mg/kg. Mercury is reported in background samples at concentrations of 0.1 to 1.7 mg/kg and has a representative upper range background concentration of 1.5 mg/kg. Selenium is reported in background samples at concentrations of 0.55 to 0.93 mg/kg and has a representative upper range background concentration of 1.7 mg/kg.

The key volatile organic parameters for the WCP site are BETX compounds. Benzene is reported in one background sample at a concentration of 2 µg/kg and has a representative upper range background concentration of 2.6 µg/kg. Sums of BETX compounds are reported in most of the background samples at concentrations up to 9 µg/kg. The representative upper range background concentration for the sum of BETX compounds is 10.2 µg/kg.

The key semivolatile organic parameters for the WCP site are phenolic compounds (phenol, o-cresol, p-cresol, and 2,4-dimethylphenol) and PAHs. No phenols are reported as detected in the background soil samples. Total PAHs are reported in most background soil samples at concentrations ranging from 0.1 to 19 mg/kg. The representative upper range background concentration for total PAHs is 17.6 mg/kg. Carcinogenic PAHs are also detected in most background soil samples. Reported concentrations range from 0.04 to 10 mg/kg. The representative upper range background concentration for carcinogenic PAHs is 9.1 mg/kg.

PCBs are also reported as detected in background samples at concentrations ranging up to 23 mg/kg.

The background soil samples provide information on the character of off-site soils in the general vicinity of the WCP site. The data indicate that, with the exception of phenolic compounds, all key chemical parameters are detected in background soils.

7.4 GROUND SURFACE SOIL CONTAMINATION DISTRIBUTION

Ground surface soil samples were collected to characterize the 0 to 6-inch depth interval at locations across the site. The data from ground surface soil samples are useful for baseline risk assessment evaluations of direct contact/ingestion scenarios. The ground surface soil sampling and analytical methods are presented in Section 4.1.3. The IEPA soil samples collected in 1989 included one on-site sample (X-107S) in the interval from zero to six inches. The data for that sample are included in this presentation of ground surface soil data.

7.4.1 Semivolatile Organic Compounds

Total PAH and phenolic compounds concentrations reported for the site ground surface soil samples are shown on Figure 7.4-1. The semivolatile organic compound distribution indicates that the predominant surface PAH contamination is in the eastern portion of the site. The samples with total PAH concentrations above 100 mg/kg are GS-15, which contained a slag-like material; GS-08, a black demolition fill mixture; GS-07, the blue-stained sample; and GS-11, which contained clinkers. Sample X-107S was reported to have a concentration of 91 mg/kg total PAHs. Samples GS-03 and GS-05, also in the eastern portion of the site, but not described as having black or blue discoloration or containing slag or cinders are reported to have total PAH concentrations of 27 mg/kg and 4 mg/kg, respectively. As is evident in the vadose zone PAH distribution presentation in Section 7.6 (and on Figure 7.6-1), a more dense sampling pattern of the soil of the eastern part of the site reveals areas of lower total PAH concentration than are seen in Samples GS-07, 08, 11, and 15.

Minimal phenol and total phenolic compound concentrations are present in the ground surface soil samples. Phenol and total phenolic compound concentrations are below 0.6 mg/kg in Samples GS-11 and GS-13, the only two samples in which these compounds were reported.

7.4.2 Volatile Organic Compounds

Low benzene and BETX compound concentrations are reported in three soil samples collected from the eastern portion of the site. Benzene is detected below quantitation limits in all three samples that exhibited positive benzene detections. IEPA Sample X-107S and Samples GS-15 and GS-16, shown on Figure 7.4-1, have BETX compound concentrations of less than 7 µg/kg. No other BETX compound concentrations are detected in ground surface samples.

7.4.3 Inorganic Parameters

The inorganic compound concentrations for ground surface soil samples are shown on Figure 7.4-2. The concentrations of total arsenic, total cyanide, and mercury are generally highest in the east-central and northeastern portions of the site. The total arsenic concentrations reported for ground surface samples ranged from an estimated 1.2 mg/kg at GS-06 to an estimated 164 mg/kg at GS-07. With the exception of Sample GS-07, which is reported to have a cyanide concentration of 388 mg/kg and is discussed below, all of the other cyanide concentrations in ground surface soil samples are reported to be less than 5 mg/kg. Mercury concentrations are reported to range from not detected at 0.02 mg/kg over much of the western half of the site to 38 mg/kg in Sample X-107S. The concentration in IEPA Sample X-107S, 38 mg/kg, is more than three times the next highest concentration, 10.3 mg/kg, at nearby Sample GS-03. The quality assurance/quality control applied to IEPA samples is not known. IEPA samples were not collected or analyzed under a U.S. EPA-approved quality assurance project plan.

Total selenium and cadmium concentrations are reported at concentrations that range up to 4.9 mg/kg in Sample GS-07 and 2.1 mg/kg in Sample X-107S, respectively. Cadmium is detected in only 4 of the ground surface samples, X-107S, GS-05, GS-07, and GS-08, all of which are located in the northeast quadrant of the site.

Lead concentrations are reported ranging from 4.2 mg/kg at GS-14 to 128 mg/kg at GS-11.

Sample GS-07 was collected from a small patch (3 feet by 4 feet in area and 1/2 inch deep) of blue-tinted soil that is uncharacteristic of the surrounding surface soils. This small patch of blue-tinted soil was the only such patch to be observed at the site. Of all of the ground surface soil samples, Sample GS-07 has the highest reported concentrations of total arsenic, total cyanide, and selenium. This blue-tinted soil most likely obtained its color from ferric ferrocyanide ($Fe_4[Fe(CN)_6]_3$), a stable metal complex of cyanide. The Merck Index states that ferrocyanides, i.e., compounds

containing the anion $Fe(CN)_6^{-4}$, have a low order of toxicity because of strong chemical bonding between the cyanide groups and iron.

7.4.4 Summary and Conclusions

The ground surface soil data indicate that those samples containing visible residues or solids (i.e., blue or black staining, slag, clinkers) are also likely to display concentrations of total PAHs greater than 100 mg/kg. The only ground surface sample with a cyanide concentration above 5 mg/kg was marked with a blue tint. The ground surface soil samples with the highest concentrations of total PAHs also have the highest concentrations of inorganic parameters. Arsenic is detected at a maximum concentration of 164 mg/kg, but is detected above 40 mg/kg in only three ground surface soil samples. Cadmium is not detected above a concentration of 3.5 mg/kg. Lead is detected at a concentration of 128 mg/kg in one ground surface soil sample and is otherwise detected at concentrations of less than 100 mg/kg. Mercury is detected at a maximum concentration of 38 mg/kg, but is detected above a concentration of 1 mg/kg in only three samples. Selenium is detected at a maximum concentration of 4.9 mg/kg, but is detected at concentrations of less than 1.3 mg/kg in all but two ground surface soil samples. Phenolic and BETX compounds are not detected above total concentrations of 0.6 mg/kg and 7 µg/kg, respectively.

7.5 SOIL STOCKPILES CONTAMINATION DISTRIBUTION

As discussed in Section 2.0, two soil stockpiles are currently located on the western side of the site. These stockpiles are: (1) the dredge spoils soils stockpile, which contains sediments dredged from Slip No. 4 and the southern and eastern portions of Waukegan Harbor; and (2) the designated soil stockpile, which is a membrane-lined cell containing selected soils originating from the excavation of Slip No. 4. The following sections discuss the analytical results of the soil samples collected from these stockpiles. Soil sampling and analytical methods are presented in Sections 4.1.5 and 4.1.6.

7.5.1 Dredge Spoils Soil Stockpile

The dredge spoils soil stockpile extends approximately 20 feet above the surrounding ground surface in the southwest portion of the site along the harbor wall, as shown on Figure 2.1-2. Soil Borings SB-30 and SB-31 were drilled through, and soil samples collected from, the soil stockpile and the underlying soils. The following discussion presents the extent of soil contamination within the dredge spoils soil stockpile.

7.5.1.1 Semivolatile Organic Compounds

In three of the four samples from the dredge spoils soil stockpile, concentrations of carcinogenic PAHs range from below detection limits to approximately 2 mg/kg and total PAHs range from below detection limits to approximately 6 mg/kg. Sample SB3003 (collected from within the stockpile at a depth of 4.5 to 6.5 feet) is an exception, with the concentration of carcinogenic PAHs at 83 mg/kg and the concentration of total PAHs at 142 mg/kg.

No phenolic compounds are detected.

7.5.1.2 Volatile Organic Compounds

Benzene and BETX compound concentrations are not reported as present in samples collected from the dredge spoils soil stockpile.

7.5.1.3 Inorganic Parameters

Except for a lead concentration of 55 mg/kg in one sample, the total arsenic and lead concentrations reported in soil samples collected from within the dredge spoils soil stockpile are all less than 10 mg/kg.

No total cyanide, cadmium, mercury, or selenium concentrations are reported as present in the samples collected from the dredge spoils soil stockpile.

7.5.2 Designated Soil Stockpile

The designated soil stockpile consists of the soil that the Waukegan Harbor Trust and the U.S. EPA agreed would be excavated and stockpiled in a containment cell as part of the construction of Slip No. 4. Selection of soil to be placed in the cell included criteria such as PAH concentration and the appearance of oiliness.

7.5.2.1 Semivolatile Organic Compounds

Total carcinogenic PAH and total PAH concentrations are reported in all three soil samples collected from the designated soil stockpile. Soil Samples DS-01, DS-02, and DS-03 show total carcinogenic PAH concentrations of 35.3 mg/kg, 33.7 mg/kg, and 87 mg/kg, respectively. Concentrations of total PAHs are reported as 194.1 mg/kg, 221.5 mg/kg, and 207 mg/kg for Soil Samples DS-01, DS-02, and DS-03, respectively. Concentrations of phenolic compounds are all below detection limits.

7.5.2.2 Volatile Organic Compounds

7.5.2.2.1 Benzene/BETX Compounds

Benzene and BETX compound concentrations are not detected above MDLs in the samples collected from the designated soil stockpile.

7.5.2.3 Inorganic Parameters

Total arsenic and lead concentrations reported in soil samples collected from the designated soil stockpile are all 14.1 mg/kg or less. Mercury is not detected in any of the samples. Cadmium, selenium, and cyanide are detected in only one sample (DS-02) at concentrations of 1.4 mg/kg, 0.44 mg/kg, and 0.25 mg/kg, respectively. The selenium and cyanide concentrations in this sample are above the IDL but below the CRDL.

7.5.3 Summary and Conclusions

Except for one sample, total PAHs are not detected at concentrations of greater than 6 mg/kg in soils from the dredge spoils soil stockpile. Cyanide, cadmium, mercury, selenium, phenolic compounds, and BETX compounds are not reported as present. Except for the reported lead concentration in one sample, arsenic and lead are not reported at concentrations above 10 mg/kg in these samples.

The soil samples from the designated soil stockpile exhibit concentrations of total PAHs that range from 194 to 221 mg/kg. Phenolic compounds, BETX compounds, and mercury are not detected. Detected concentrations of arsenic and lead are 14.1 mg/kg or less. Cyanide and selenium are detected in only one sample at a concentration below the CRDL. Cadmium is detected in only one sample.

7.6 VADOSE ZONE SOIL CONTAMINATION DISTRIBUTION

The contamination distribution in soil above the groundwater at a depth of less than 4.5 feet (vadose zone soils) is discussed in this section.

This section presents the data evaluation of the vadose zone soil sampling results and discusses the field observations that are pertinent to the evaluation of the extent of vadose zone soil contamination.

The key parameters that will be used in the following sections to characterize the extent of vadose zone soil contamination in the vicinity of the site are listed in Table 6.1-1. These parameters were identified in the manner described in Section 7.1 and Appendix 6-A.

7.6.1 Semivolatile Organic Compounds

7.6.1.1 PAHs

The distribution of PAH concentrations in vadose zone soils is shown on Figure 7.6-1 for total PAHs and Figure 7.6-2 for carcinogenic PAHs.

In vadose zone soils, concentrations of total PAHs range from less than the detection limit to 76,000 mg/kg. Areas from which samples are reported to have total PAH concentrations of greater than 100 mg/kg consist of one large area on the eastern portion of the site, two smaller areas on the western portion of the site, and two smaller areas on the northeastern part of the site.

The larger area on the eastern portion of the site, shown on Figure 7.6-1, encompasses portions of Test Trenches TT-03W, TT-03, TT-25, TT-08A, TT-0C, TT-10, TT-11, TT-12, TT-23, TT-14, TT-15, TT-18, TT-19W, TT-20, TT-21, TT-24, TT-00D and Soil Borings SB-33, SB-34, SB-40, SB-56, SB-46, SB-55, SB-45 and SB-50. The concentration ranges within this area vary greatly depending on the matrix of the sample. Discrete samples from test trenches and soil borings showing visible contamination of soil or samples containing coal fines or fragments generally exhibit higher concentrations of PAHs. Visibly contaminated soil is encountered in discontinuous patches throughout this larger area of PAH concentrations greater than 100 mg/kg.

Within this larger area of PAH contamination on the eastern portion of the site, the soils are very heterogeneous. Test trenching results reveal a number of areas where demolition debris appears

to have been mixed with, deposited over, and/or interbedded with visible contamination. Visibly contaminated soil is found with demolition debris in Test Trenches TT-01, TT-02, TT-11, TT-12, TT-14, TT-19, TT-20, TT-23, TT-00A, TT-00C, TT-19W, and TT-20. For instance, in TT-12, discrete patches of visibly contaminated soil are mixed with demolition debris such as concrete, reinforcing steel, and pieces of pipe. A similar condition was observed in TT-23. In TT-00C, visibly contaminated soil was found overlying a zone of demolition debris. All of the named test trenches contained contamination mixed with demolition debris. As evidenced by the mixture of demolition debris with visible contamination and the presence of visible contamination overlying demolition debris, the final demolition of the coke plant by OMC (Section 2.1.3.3) apparently enlarged the area impacted by visible contamination.

Generally, visible contamination appears to be confined to the vadose zone within this larger area on the eastern portion of the site. Test Trench TT-00D shows visibly contaminated soil that abruptly terminates at a depth of approximately 4 feet at the groundwater table. Similarly, Test Trenches TT-03W, TT-19, TT-19W, TT-20, and TT-23, all placed to depths ranging from 5 to 7 feet, have discrete zones of visibly contaminated soil, which do not appear to penetrate the underlying material. Only a few test trenches in the eastern area show visible contamination extending to the bottom of the trench at depths ranging from 4 to 6 feet: Test Trenches TT-00C, TT-11, TT-14 and a portion of TT-03 and TT-03W. In these cases, the visible contamination does not terminate at the groundwater table. The relationship between PAH contamination in the saturated zone and groundwater quality is addressed in Section 7.7.

Two smaller areas with total PAH concentrations of greater than 100 mg/kg are located on the western portion of the site near the northeastern and northwestern portion of the designated soil stockpile. Visibly contaminated soil is apparent in Test Trench TT-05, TT-06 and a portion of TT-05E. Test Trench TT-27 shows no visible contamination of the soil within the trench.

On the northeastern portion of the site, Samples TT0102, TT0206, and X-106S show total PAH concentrations either close to or greater than 100 mg/kg. Test Trenches TT-01 and TT-02 contain demolition debris throughout most of the trench and in the area the samples were collected. The concentration of total PAHs in other samples from this area is generally less than 25 mg/kg.

The pattern of carcinogenic PAH distribution in the vadose zone parallels that of the total PAHs, but the carcinogenic PAH concentrations are about an order of magnitude lower.

7.6.1.2 Phenol and Total Phenolic Compounds

The distribution of phenol concentrations in vadose zone soils are shown on Figure 7.6-3.

Except for one visibly contaminated sample, phenol is reported at concentrations of less than 41 mg/kg in vadose zone soils (Figure 7.6-3). The visibly contaminated sample, SB5002, has a reported phenol concentration of nearly 1,000 mg/kg.

Phenol and total phenolic compounds are generally not detected in the soil samples from the vadose zone.

7.6.2 Volatile Organic Compounds

7.6.2.1 Benzene/BETX

Figure 7.6-4 shows the benzene concentrations in vadose zone soils.

On the eastern portion of the site, the highest benzene concentrations reported are 62 mg/kg and 18 mg/kg, reported in Test Trench Samples TT03W02 (from a depth of 3.5 feet) and TT03W01 (from a depth of 4 feet), respectively, and 22 mg/kg in Test Trench Sample TT2303 (from a depth of 4 feet).

As shown on Figure 7.6-4, the area from which vadose zone soils have benzene concentrations of greater than 1 mg/kg lies largely within the area from which vadose zone soils have total PAH concentrations of greater than 100 mg/kg.

The pattern of BETX compound concentrations in vadose zone soils on the eastern portion of the site is very similar to that of benzene. The highest concentrations of BETX compounds (596 mg/kg) is detected in Test Trench Sample TT2303 at a depth of 4 feet below ground surface.

Benzene is generally not detected in vadose zone soil samples collected from the western portion of the site. The highest benzene concentration in the western portion of the site (0.2 mg/kg) is reported in Soil Boring Sample SB2602 in the 0.5 to 4.5-foot interval.

BETX compound concentrations are detected in several vadose zone soil samples collected from the western portion of the site, with the highest concentrations of BETX compounds (less than 5 mg/kg) reported for Samples SB2602 and SB2704.

Benzene and BETX concentrations for vadose zone soil samples collected north of Slip No. 4 are all at or below detection limits. Samples collected from this area during the investigations conducted by Canonie for OMC were not generally submitted for analysis of BETX parameters.

7.6.3 Inorganic Parameters

7.6.3.1 Arsenic

Figure 7.6-5 shows total arsenic concentrations in vadose zone soils. The highest total arsenic concentrations are reported for samples from the eastern portion of the site (Samples TT2503 and TT0701 at concentrations of 1,720 and 1,820 mg/kg, respectively). Arsenic concentrations generally exceed 100 mg/kg in the east-central portion of the site.

All of the reported total arsenic concentrations in vadose zone soil samples from the western portion of the site and north of Slip No. 4 are less than 13 mg/kg, with the exception of Soil Boring Sample SB2602. The total arsenic concentration for Sample SB2602 in the 0.5 to 4.5-foot interval is reported to be 233 mg/kg.

7.6.3.2 Cyanide

Figure 7.6-6 shows total cyanide concentrations for the vadose zone soil samples. The highest total cyanide concentrations are reported for samples collected from the eastern portion of the site. Test Trench Samples TT2503 and TT03W01 and IEPA Sample X-105 have concentrations of 1,390 mg/kg, 956 mg/kg and 556 mg/kg, respectively. These samples are clustered in the east-central portion of the site, near the northwest corner of the OMC data building fence. The cyanide concentrations in all of the other vadose zone soil samples from this depth interval are less than 50 mg/kg.

Total cyanide is either reported at low concentrations or is not detected in vadose zone soil samples from the western portion of the site. Vadose zone soil samples north of Slip No. 4 were not submitted for analysis of total cyanide.

7.6.3.3 Cadmium

Cadmium is detected in vadose zone soil samples in the eastern portion of the site. However, all but one of the reported concentrations in the samples collected from the vadose zone are less than 3 mg/kg. An estimated concentration of 4.4 mg/kg is reported for one sample (TT1402).

Cadmium is generally not detected (at a detection limit of approximately 0.7 mg/kg) in samples from the western portion of the site and north of Slip No. 4.

7.6.3.4 Lead

Only two vadose zone soil samples at the site are reported to have lead concentrations above 80 mg/kg. Test Trench Sample TT2502 (2 feet deep) has a reported lead concentration of 454 mg/kg and Soil Boring Sample SB1602 (2 to 4 feet deep) has an estimated reported lead concentration of 180 mg/kg.

Lead concentrations reported in vadose zone soil samples from the western portion of the site and north of Slip No. 4 are less than 80 mg/kg.

7.6.3.5 Mercury

Mercury concentrations reported for vadose zone soil samples are shown on Figure 7.6-7. The highest mercury concentrations are detected in samples from the eastern portion of the site. The highest mercury concentrations are reported in IEPA Samples X-107 and X-105 at concentrations of 58 mg/kg and 18.2 mg/kg, respectively. RI samples in close proximity to IEPA Sample X-107 have reported concentrations of less than 0.1 mg/kg. The mercury concentrations in RI samples from the eastern portion of the site in close proximity to IEPA Sample X-105 show reported concentrations ranging from less than 1 mg/kg to 8 mg/kg.

Mercury concentrations reported in vadose zone soil samples from the western portion of the site are less than 0.3 mg/kg. Mercury concentrations in the soil samples collected north of Slip No. 4 are below the detection limit of approximately 0.09 mg/kg.

7.6.3.6 Selenium

In vadose zone soil samples from the eastern portion of the site, selenium detections are reported to exceed 1.7 mg/kg in 14 samples located near the northwest corner of the fence around the OMC data building parking lot. Only three detections of selenium are reported to exceed 6 mg/kg. These are 20.4 mg/kg in Soil Boring Sample SB2402, 12.5 mg/kg in Surficial Soil Sample SS-08, and 14.1 mg/kg in IEPA Sample X-106.

Selenium concentrations reported in the vadose zone soil samples from the western portion of the site and north of Slip No. 4 are less than 1.7 mg/kg, except for one sample (SB2902 at 2 mg/kg).

7.6.4 Summary and Conclusions

The field screening and analytical data for vadose zone soil samples indicate the following:

- In vadose zone soils, total PAH concentrations of up to 76,000 mg/kg are present in the eastern and west-central areas of the site within the area delineated by the 100 mg/kg total PAH concentration contour shown on Figure 7.6-1.

- Benzene concentrations above 1 mg/kg are associated with total PAH concentrations of greater than 100 mg/kg.

- Arsenic, cyanide, and selenium are at concentrations above 10 mg/kg, 1 mg/kg, and 1.7 mg/kg, respectively, in samples from the eastern portion of the site. Mercury is detected at concentrations of greater than 1 mg/kg in the east-central portion of the site and a limited area in the northeastern corner of the site. The highest concentrations of these compounds are not directly associated with the highest concentrations of PAHs and benzene.

- Lead and cadmium are generally not present at concentrations above 80 mg/kg and 3 mg/kg, respectively.

7.7 GROUNDWATER AND SATURATED SOIL CONTAMINATION DISTRIBUTION

This section of the RI report presents the magnitude and extent of the key chemical parameters in groundwater and saturated soils (aquifer matrix) at the WCP site. Groundwater and saturated soils are evaluated together in the RI, as the remedial options for aquifer matrix materials are typically evaluated on the basis of groundwater alternatives.

Because a distinct difference in water and soil quality was observed between the shallow and deep portions of the sand aquifer, the groundwater presentation is divided into two sections. The first section discusses the magnitude and extent of key chemical parameters in the shallow portion of the sand aquifer, which extends from the water table (at a depth of approximately 4.5 feet) to a depth of approximately 21.5 feet. The second section discusses the magnitude and extent of these parameters in the deep portion of the sand aquifer, which extends from a depth of approximately 21.5 feet to the top of the till unit (at a depth of approximately 30 feet). The rationale for dividing the sand aquifer into two portions at a depth of approximately 21.5 feet is as follows:

- Groundwater concentrations of most parameters in samples from wells screened in the deeper portion of the aquifer just above the till (top of screen at a depth of 21 feet or below) are orders of magnitude greater than the concentrations in samples from wells screened in the shallow portion of the sand aquifer (bottom of screen at a depth of 17.5 feet or less).

- For the interval of the aquifer for which groundwater data are not available (17.5 feet to 21 feet), phenol concentrations in saturated soil samples were used to make the final determination of which depth to use as the division between the shallow and deep portions of the sand aquifer. Phenol was used because its soil concentrations are generally found to be in equilibrium with its groundwater concentrations. Saturated soil samples collected from the soil sampling intervals of 17 feet to 19 feet and 19.5 feet to 21.5 feet do not indicate frequent detections of elevated phenol concentrations as do the saturated soil samples from the screened portion of the aquifer above the till. Therefore, the interval of the aquifer down to 21.5 feet is ascribed to the shallow portion of the sand aquifer.

In each of the two major sections, the presentation is divided into subsections by parameter group and then by parameter. The discussion for each parameter begins with an evaluation of the groundwater quality data and includes a review of general patterns (as observed using data from the

complete groundwater sampling event, November/December 1993) and data variability (as observed using data from all sampling events). Figures illustrating the horizontal distribution of the chemical parameter in groundwater are used, where appropriate, to aid in the interpretation of the groundwater quality data. The November/December 1993 sampling event, in which samples were collected from the complete set of monitoring wells, was used to construct concentration contours. Next, the text for each parameter discusses the saturated soil quality data for the parameter as it relates to groundwater quality, using the principles of soil-water chemical partitioning to help define the relationship wherever possible.

For most organic compounds, soil-water partitioning is affected in a significant way by two factors: distribution coefficients (related to a contaminant's solubility) and the organic carbon content of soil. Soil-water distribution coefficients are typically estimated for organic compounds by multiplying the organic carbon partition coefficients (Table 6.2-1) by a representative percent TOC measured in saturated soils at the site (2 to 3 percent for soils in the shallow portion of the sand aquifer and 3 to 6 percent for soils in the deep portion of the sand aquifer; Table 4.6-2). In the following discussions, soil-water partitioning theory using the distribution coefficient approach was not applied to benzene in the deep portion of the sand aquifer in the center of the site where benzene concentrations were 100 to 500 times less than those of phenol. In such cases, phenol can effectively compete with benzene for adsorptive sites on the aquifer solids. Such competitive adsorption processes (Luft, 1984) are expected to reduce benzene adsorption, relative to distribution coefficient calculations, in areas of the deeper portion of the sand aquifer where groundwater phenol concentrations are much higher than groundwater benzene concentrations. Competitive adsorption would clearly apply to areas where groundwater phenol concentrations exceed 100,000 µg/L (Figure 7.7-9). Soil-water partitioning theory for benzene was, however, applied in those areas of the site (shallow portion of the sand aquifer on-site and deep and shallow portions of the aquifer downgradient of the site) where benzene and phenol concentrations are more or less similar.

Soil-water partitioning for inorganic parameters is dependent on several geochemical variables that vary in space and time and cannot be quantified for these discussions. Instead, general observed relationships between concentrations of inorganic parameters in soil and groundwater are described.

In order to provide a framework for the following detailed discussions, the main points and conclusions of the section are summarized here:

- PAH concentrations in saturated soil decrease significantly with depth and detections of PAHs above parts per trillion concentrations in groundwater at the site are limited to

detections of the most mobile PAH compounds in samples from upgradient wells or wells within or immediately adjacent to soils containing PAHs.

- Both inorganic (arsenic and cyanide) and organic (phenol and benzene) parameters are present over a greater extent and at higher concentrations in the groundwater of the deep portion of the sand aquifer than in the shallow portion.

- While phenol is generally not detected in the soils and groundwater of the shallow portion of the sand aquifer, it is present in high concentrations in both the groundwater and saturated soils of the deep portion of the sand aquifer. The soil and groundwater concentrations are in equilibrium with each other, indicating that soil concentrations in the deep portion of the sand aquifer are the result of adsorption of phenol from groundwater.

- For benzene, arsenic, and cyanide, the groundwater concentrations and/or distribution patterns in the shallow portion of the sand aquifer are consistent with expectations for soil-water interactions given the concentrations and distributions of these parameters in the saturated soils of this zone. Benzene concentrations in the shallow portion of the sand aquifer are generally in equilibrium with soil concentrations. The highest groundwater concentrations of arsenic and cyanide are spatially associated with the highest saturated soil concentrations of those compounds.

- For benzene, arsenic, and cyanide, saturated soil concentrations in the deep portion of the sand aquifer are similar to or slightly higher than those in the shallow portion of the sand aquifer, while groundwater concentrations are orders of magnitude higher. However, the observed distribution is inconsistent with what would be observed if vadose zone soils were the current source of these parameters in groundwater of the deep portion of the sand aquifer, namely, soil and groundwater concentrations both decreasing with depth or distance from the source.

- No dense nonaqueous-phase liquid (DNAPL) presence is evident at the site that could account for the observed distribution of key parameters in the groundwater in the deep portion of the sand aquifer.

- Dissolved oxygen and redox potential results indicate that conditions are most likely more aerobic and oxidizing in the shallow portion of the sand aquifer than in the deep

portion. This indication is reasonable considering the likely influx of dissolved oxygen to the shallow portion of the aquifer from infiltrating precipitation.

7.7.1 Shallow Portion of the Sand Aquifer

This section of this chapter discusses the magnitude and extent of key chemical parameters in groundwater and saturated soils in the shallow portion of the sand aquifer at the WCP site. As discussed in the introduction to Section 7.7, the shallow portion of the sand aquifer extends from the water table (at a depth of approximately 4.5 feet) to a depth of approximately 21.5 feet.

Analytical data for groundwater samples collected from the shallow portion of the sand aquifer during the RI are summarized in Tables 4.3-3 through 4.3-6. The monitoring wells in this portion of the sand aquifer are screened across the water table down to depths of 11.5 to 13.5 feet. One well, MW-1S, is screened below the water table between depths of 12.5 feet to 17.5 feet.

Analytical data for the key chemical parameters for soil samples collected during the RI are summarized, together with field screening results, in Table 7.1-1. Analytical data for soil samples collected during previous investigations are presented in PSCS Appendices 3-B and 3-D.

The following subsections of this section discuss the extent and magnitude of semivolatile organic compounds, volatile organic compounds, inorganic parameters, and general chemistry parameters in the groundwater and saturated soils in the shallow portion of the sand aquifer. In general, the groundwater data from the shallow portion of the sand aquifer indicate that key parameters are found at the highest concentrations in the western and/or west-central portions of the site and that concentrations diminish to the north, east, and south. The groundwater concentrations and/or distribution patterns of key parameters in the shallow portion of the sand aquifer are consistent with expectations for soil-water interactions, given the concentrations and distribution of these parameters in the saturated soils of this zone.

7.7.1.1 Semivolatile Organic Compounds

The semivolatile organic compounds to be discussed in the following subsections are phenolic compounds, total PAHs, and carcinogenic PAHs.

7.7.1.1.1 Phenolic Compounds

Groundwater Quality. Only four phenolic compounds are detected in the groundwater samples from the shallow portion of the sand aquifer at the site. These compounds are (in order of generally decreasing concentrations and solubility limits) phenol, p-cresol, o-cresol, and 2,4-dimethylphenol. Because phenol is the most soluble of the four parameters and because it is detected most frequently and at the highest concentrations, it is used as an indicator compound for evaluation of the distribution of phenolic compounds in the shallow portion of the sand aquifer.

Phenol concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-1. The November/December 1993 sampling event is the only sampling event for which samples were collected from the complete set of monitoring wells. Except for concentrations of 22 µg/L and 280 µg/L in samples from Wells MW-7S and MW-6S, respectively, the concentrations of phenol in the November/December samples range from not detected (at a detection limit of 1.3 µg/L) to 6 µg/L.

Phenol is not consistently reported as detected in the samples from any well except MW-6S. At most of the wells, phenol concentrations in samples from different sampling events range from not detected (at a detection limit of 1.3 µg/L) to 6 µg/L. Such variation is typical for laboratory analyses. At one well (MW-7S), the phenol concentrations in samples from different sampling events range from not detected (at a detection limit of 1.3 µg/L) to 22 µg/L. At three of the wells (MW-3S, MW-4S, and MW-5S), the April 1992 samples have reported phenol concentrations that are several times higher than those reported for the November/December 1993 samples. Although such wide variability in results for samples from some wells may be part of site conditions, the November/December sample results are more consistent with the results of samples from other wells and are, therefore, considered to be more representative of overall site conditions.

Saturated Soil Quality/Groundwater Quality Interactions. In order to facilitate the discussion of the relationship between saturated soil quality and groundwater quality in the shallow portion of the sand aquifer, phenol is used as an indicator parameter for evaluation of the distribution of phenolic compounds.

Except for two samples, SB2404 and S-109-1, for which the maximum reported phenol concentrations are 2.6 mg/kg and 1.1 mg/kg, respectively, the phenol concentrations in saturated soil samples from depths of 4.5 to 11.5 feet (the approximate screened interval of the shallow portion of the sand aquifer) do not exceed 1 mg/kg. In most samples from this interval, phenol is not detected

at detection limits of approximately 50 µg/kg. The soil-water distribution coefficient for phenol is approximately 0.5 to 0.8. Since phenol concentrations in the groundwater samples from this interval are generally 6 µg/L or less, soil concentrations of 3 to 4.9 µg/kg, well below the detection limit of about 50 µg/kg, would actually be expected.

Although phenol is not detected in most soil samples from depths of 11.5 to 21.5 feet, there are more detections of phenol at higher concentrations in this interval than in the interval from 4.5 feet to 11.5 feet. In the southeast-central portion of the site (in the vicinity of Soil Borings SB-9, SB-34, SB-35, SB-39, SB-40, SB-45, and SB-46) and along the southern side of Slip No. 4, several soil samples have reported phenol concentrations of greater than 1 mg/kg. Six soil samples, Samples SB0909, SB4508, SB2008, SB2908, SB3015, and S-45-DUP-03, have reported phenol concentrations of 39 mg/kg, 30 mg/kg, 21 mg/kg, 13 mg/kg, 59 mg/kg, and 71 mg/kg, respectively. The appearance of more phenol in the saturated soil matrix of this interval along the southern edge of Slip No. 4 (between Monitoring Wells MW-1S and MW-6S) may also explain the higher concentrations of phenol observed in the groundwater samples from Well MW-6S as compared to the phenol concentrations in samples from Well MW-1S, the nearest upgradient well to MW-6S.

Summary. Phenol and phenolic compounds are either not detected or are detected at low concentrations in the groundwater and saturated soil in the shallow portion of the sand aquifer. Soil and groundwater concentrations measured in samples from this zone are consistent with soil-water partitioning expectations for phenol. Phenol is detected in both sampling events in the samples from only one well, Well MW-6S. Samples from this well have the highest concentrations of phenol reported in the groundwater of the shallow portion of the sand aquifer.

7.7.1.1.2 Total PAHs

Of the identified organic compounds of interest, PAHs typically have the lowest solubilities in water and tend to be highly adsorbed onto soil organic carbon (Table 6.2-1). PAHs are expected to be concentrated in soils and relatively immobile in groundwater.

Groundwater Quality. Two rounds of groundwater samples were collected from each water table monitoring well for analysis of PAHs. If PAHs were not detected in the sample from a well during the first sampling event, a low-level (parts per trillion) PAH analysis was performed on the sample from that well during the second sampling event. Because the April 1992 sample from Monitoring Well MW-4S was suspected to contain sediment, the well was redeveloped before the second sampling event in order to obtain a sample that would be representative of groundwater quality.

Total PAH concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-2. The highest reported concentrations of total PAHs for groundwater in the shallow portion of the sand aquifer are observed in samples from Monitoring Wells MW-1S, MW-4S, MW-6S, and MW-9S in the east-central and west-central portions of the site. In the samples from these wells, total PAH concentrations range from 62 µg/L to 2,400 µg/L. Total PAH concentrations of 10 µg/L to 17 µg/L are reported for the samples from Well MW-11S located upgradient of the site. In samples from all of the other wells located north (MW-3S and MW-15S), east (MW-7S, MW-12S, MW-13S, and MW-14S), and south (MW-5S, MW-8S, and MW-10S) of the central portion of the site, PAH compounds either are not detected or are detected at part-per-trillion concentrations similar to those detected in blank samples.

Because different suites of PAH compounds are detected in the samples from Wells MW-1S, MW-4S, MW-6S, MW-9S, and MW-11S, there does not appear to be a widespread or consistent plume of PAHs in the central portion of the site. Naphthalene is essentially the only PAH compound detected in the samples from Well MW-9S. It is reported at concentrations ranging from 62 µg/L to 2,400 µg/L. In the November/December 1993 sample (the sample collected after redevelopment of the well) from nearby Well MW-4S, naphthalene is not reported as detected. Instead, acenaphthene, acenaphthylene, anthracene, dibenzofuran, fluoranthene, fluorene, phenanthrene, pyrene, and carbazole are detected at concentrations ranging from 2 to 46 µg/L. In the samples from Monitoring Wells MW-1S and MW-6S, naphthalene is detected at concentrations of 300 to 1,800 µg/L and acenaphthene, dibenzofuran, fluorene, 2-methylnaphthalene, and carbazole are detected at concentrations ranging from 9 to 190 µg/L. Phenanthrene is also detected in the sample from Well MW-1S at concentrations of 27 to 40 µg/L. In the samples from Monitoring Well MW-11S, which monitors groundwater upgradient of the site, chrysene, fluoranthene, phenanthrene, and pyrene are detected at concentrations ranging from 2 µg/L to 3 µg/L.

The suites of PAH compounds detected in the samples from the water table wells consist of the most mobile PAH compounds, based on the solubilities and organic carbon partition coefficients listed in Table 6.2-1.

There is little variability in the total PAH concentrations between sampling events, except in the samples from Wells MW-6S and MW-9S. Total PAH concentrations in the samples from Well MW-9S range from 62 µg/L to 2,400 µg/L between sampling events. Total PAH concentrations in the samples from Well MW-6S range from 450 µg/L to 2,000 µg/L between sampling events. Total PAH concentrations in the samples from all other wells are consistent between sampling events.

The April 1992 sample from Well MW-4S and the November/December 1993 sample from Well MW-11S are not considered to be representative of groundwater quality at these locations. The reported concentration of benzo(a)pyrene (3 µg/L) in the sample from Well MW-4S and the reported concentration of benzo(k)fluoranthene (1.7 µg/L) in the sample from Well MW-11S either approach or exceed the solubility limits for these compounds, despite the fact that no visible contamination was observed during the installation of these wells or confirmed by soil sample analyses as described below. The detection of a single parameter at the solubility limit in samples from a single sampling event does not indicate the presence of pure-phase PAHs. Pure-phase PAHs would result in detections of several PAH compounds near solubility limits in samples from several sampling events. Finally, Well 4S was specifically redeveloped during the second phase of the investigation. After redevelopment, benzo(a)pyrene was not detected in the November/December 1993 sample from this well. For these reasons, these specific sample results from Wells 4S and 11S are excluded from the above discussions of PAH distributions in groundwater.

Saturated Soil Quality/Groundwater Quality Interactions. Total PAH concentrations in saturated soil samples from depths of 4.5 to 11.5 feet (the approximate screened interval of the shallow portion of the sand aquifer) exceed 1 mg/kg beneath most of the eastern half of the site and along the southern edge of Slip No. 4. Within these areas, total PAH concentrations in soil samples from this interval exceed 10 mg/kg along Slip No. 4 and in the southeast-central and central portions of the site. The area in which soil samples exceed 10 mg/kg total PAHs is approximately defined by the following soil borings: S-45, S-53, SB-24, SB-09, SB-39, SB-50, SB-41, SB-33, SB-26, S-68, S-62, S-63, SB-28, and SB-29. In the southeast-central portion of the site within the area defined by the above-mentioned borings, only two soil samples from this interval have reported total PAH concentrations in excess of 100 mg/kg. These samples were TT1001 and SB4005 and have reported total PAH concentrations of 920 mg/kg and 2,100 mg/kg, respectively. In the area southeast and along the southern edge of Slip No. 4, within the area defined by the above-mentioned borings, total PAH concentrations exceed 100 mg/kg in 11 samples (SB2704, S-45-01, S-46-01, S-47-01, S-50-01, S-54-01, S-60-01, S-61-01, and S-70-01). In four of these samples (SB2704, S-45-01, S-47-01, and S-50-01) the total PAH concentrations exceed 1,000 mg/kg and range from 1,600 mg/kg to 17,500 mg/kg.

PAHs do not appear to be readily dissolving and migrating from the soils exhibiting elevated total PAH concentrations. Detections of total PAHs in groundwater samples are essentially limited to samples from wells within (MW-1S) or immediately adjacent to (MW-9S and MW-6S) soils exhibiting total PAH concentrations of at least 10 mg/kg.

Total PAH concentrations in the shallow portion of the sand aquifer in soil samples collected from below depths of 11.5 feet decrease significantly in magnitude and extent as compared with those from above 11.5 feet. Below 11.5 feet, limited areas of soils with total PAH concentrations greater than 10 mg/kg are located in a limited portion of the southeast-central portion of the site and adjacent to the southeast corner of Slip No. 4. Only three samples from this interval have reported total PAH concentrations in excess of 100 mg/kg. These samples are SB4508 (105 mg/kg), SB2708 (317 mg/kg), and S-54-02 (5,700 mg/kg).

Summary. As predicted by the solubilities and organic carbon partition coefficients of PAHs, the data indicate that PAHs are concentrated in soils and are relatively immobile in groundwater. The highest reported concentrations of total PAHs for groundwater in the shallow portion of the sand aquifer are observed in samples from Monitoring Wells MW-1S, MW-4S, MW-6S, and MW-9S in the central portion of the site, but because different suites of PAH compounds are detected in the samples from these wells, there does not appear to be a widespread or consistent plume of PAHs in the central portion of the site. In addition, the detections of total PAHs in groundwater samples are essentially limited to detections of the most mobile PAH compounds in samples from wells within or immediately adjacent to soils exhibiting total PAH concentrations of greater than 10 mg/kg.

Total PAH concentrations in the shallow portion of the sand aquifer in soil samples collected from below depths of 11.5 feet decrease significantly in magnitude and extent as compared with those from above 11.5 feet.

7.7.1.1.3 Carcinogenic PAHs

Of the identified PAH compounds of interest, carcinogenic PAHs typically have the lowest solubilities in water and tend to be highly adsorbed onto soil organic carbon (Table 6.2-1). Carcinogenic PAHs are expected to be concentrated in soils and relatively immobile in groundwater.

Groundwater Quality. Total carcinogenic PAH concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-3. The highest reported concentrations of carcinogenic PAHs for groundwater in the shallow portion of the sand aquifer are observed in samples from Monitoring Wells MW-1S and MW-6S. In the samples from these wells, carcinogenic PAH concentrations range from 35 µg/L to 110 µg/L. Carcinogenic PAH concentrations ranging from 2 µg/L to 4 µg/L are reported for the samples from Well MW-4S and Well MW-11S located upgradient of the site. In samples from all of the other wells, carcinogenic PAH

compounds are not detected or are detected at part-per-trillion concentrations similar to those detected in field blanks.

Carbazole, the most mobile of the carcinogenic compounds, is the only carcinogenic compound to be detected in on-site wells (MW-1S, MW-4S, and MW-6S). Chrysene is the only carcinogenic compound detected in the sample from upgradient Well MW-11S.

There is little variability in the total carcinogenic PAH concentrations between sampling events. However, the April 1992 sample from Well MW-4S and the November/December 1993 sample from Well MW-11S are not considered to be representative of groundwater quality at these locations because, as described above, there is reason to believe that sediment was in both samples. These samples are excluded from the above discussion of carcinogenic PAH distribution in groundwater.

Saturated Soil Quality/Groundwater Quality Interactions. Carcinogenic PAH concentrations in saturated soil samples from depths of 4.5 to 11.5 feet (the approximate screened interval of the shallow portion of the sand aquifer) are less extensive and generally an order of magnitude lower than the total PAH concentrations of soils in this interval. Carcinogenic concentrations in excess of 1 mg/kg are limited to samples from Soil Borings SB-24, SB-34, SB-40, and SB-50 in the central portion of the site and to the area adjacent to the southeast corner of Slip No. 4. Only one soil sample in the central portion of the site (SB4005) and five soil samples adjacent to the southeast corner of Slip No. 4 (SB2704, S-50-01, S-47-01, S-45-01, and S-60-01) have reported total carcinogenic PAH concentrations of greater than 100 mg/kg. The carcinogenic PAH concentration of only one sample (S-47-01) exceeds 1,000 mg/kg.

Carcinogenic PAHs do not appear to be readily dissolving and migrating from the soils exhibiting elevated carcinogenic PAH concentrations. Detections of carcinogenic PAHs in groundwater samples are essentially limited to samples from wells within (MW-1S) or in close proximity to (MW-6S) soils exhibiting carcinogenic PAH concentrations of at least 1 mg/kg.

Carcinogenic PAH concentrations in the shallow portion of the sand aquifer in soil samples collected from below depths of 11.5 feet decrease significantly in magnitude and extent as compared to those from above 11.5 feet. Only five samples from depths below 11.5 feet have reported carcinogenic PAH concentrations exceeding 1 mg/kg. These samples were SB3808, SB4508, SB2708, SB2808, and S-116-02 and they have reported carcinogenic concentrations ranging from 1.2 mg/kg to 48 mg/kg. Only two of these samples (SB4508 at 48 mg/kg and SB2708 at 34 mg/kg) had carcinogenic PAH concentrations greater than 10 mg/kg.

Summary. As predicted by solubilities and organic carbon partition coefficients for carcinogenic PAHs, the data indicate that carcinogenic PAHs are concentrated in soils and are relatively immobile in groundwater. The highest reported concentrations of carcinogenic PAHs for groundwater in the shallow portion of the sand aquifer are observed in samples from Monitoring Wells MW-1S and MW-6S. In addition, the detections of carcinogenic PAHs in groundwater samples are essentially limited to detections of the most mobile carcinogenic PAH compound (carbazole) in samples from wells within or immediately adjacent to soils exhibiting carcinogenic PAH concentrations of greater than 1 mg/kg. As shown in Table 6.2-1, carbazole is the most biodegradable of the carcinogenic PAHs. It is also among the least potent of the PAH carcinogens.

Carcinogenic PAH concentrations in the shallow portion of the sand aquifer in soil samples collected from below depths of 11.5 feet decrease significantly in magnitude and extent as compared with those from above 11.5 feet.

7.7.1.2 Volatile Organic Compounds

The volatile organic compounds to be discussed in the following subsections are BETX compounds and other volatile organic compounds, such as acetone, methylene chloride, carbon disulfide, styrene, 1,1-dichloroethane, 1,1,1-trichloroethane, vinyl chloride, 1,2-dichloroethylene, and trichloroethylene.

7.7.1.2.1 BETX Compounds

Because benzene is the most soluble of the BETX compounds and because it is detected most frequently, it is used as an indicator compound for evaluation of the distribution of BETX compounds in the shallow portion of the sand aquifer. Observations about the magnitude or extent of ethyl benzene, toluene, and xylenes are made where necessary.

Groundwater Quality. Benzene concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-4. The pattern depicted by the contours of benzene concentrations is identical to the pattern of BETX concentrations, with the highest concentrations being detected in the western portion of the site.

Benzene is not detected (at a detection limit of 10 µg/L) in any of the samples from the wells on the northern (MW-3S, MW-11S, and MW-15S) and eastern (MW-4S, MW-7S, MW-8S, and MW-12S through MW-14S) sides of the site. Because the laboratory reports concentrations down to

approximately 10 percent of the quantitation limit, it is reasonable to expect that benzene is not present in the samples from these wells at a concentration of approximately 1 µg/L. Benzene is consistently detected in samples from Monitoring Wells MW-1S, MW-5S, MW-6S, and MW-10S at concentrations ranging from 6 µg/L to 70 µg/L. The highest concentrations are detected in samples from Wells MW-5S and MW-6S. BETX concentrations in the samples from these wells range from 6 µg/L to 270 µg/L, with the highest concentrations being detected in the samples from Well MW-6S. Benzene and BETX compounds are reported as detected in the September/October 1993 sample from Well MW-9S at concentrations of 7 µg/L and 101 µg/L, respectively. All four BETX compounds are not reported as detected in the November/December 1993 sample from that well.

The samples from those wells in which benzene is consistently detected (MW-1S, MW-5S, MW-6S, and MW-10S) contain different suites of BETX compounds. Xylenes, benzene, ethyl benzene, and toluene (in the order of decreasing concentrations) are detected at approximately the same percentages in the samples from Wells MW-1S and MW-6S. In the sample from MW-10S, toluene is not detected and the sum of BETX compounds is almost entirely benzene. Benzene is the only BETX compound to be detected in the samples from Well MW-5S. The data suggest that the water quality in the southern portion of the site, especially in the vicinity of Well MW-5S, may be influenced by current activities and features, such as OMC's aboveground storage tank farm for petroleum products located on the southwestern corner of the site. The data for other volatile organic compounds, which will be discussed in the following subsection, also indicate the influence of off-site activities on the water quality in the vicinity of Well MW-5S.

There is some variability in the benzene and BETX concentrations between sampling events. While the concentrations of benzene in the samples from Wells MW-1S and MW-6S remain approximately the same between sampling events, benzene concentrations in samples from Wells MW-5S and MW-10S decrease by more than one-half and disappear in samples from Well MW-9S between sampling events. The variation in BETX concentrations between sampling events is slightly greater than the variation in benzene concentrations. Between sampling events, the sum of BETX concentrations decreases by one-fourth in samples from Well MW-1S and by one-half or more in samples from Wells MW-5S, MW-6S, and MW-10S. The sum of BETX concentrations disappears in the samples from Well MW-9S.

Saturated Soil Quality/Groundwater Quality Interactions. In order to facilitate the discussion of the relationship between saturated soil quality and groundwater quality in the shallow portion of the sand aquifer, benzene is used as an indicator parameter for evaluation of the distribution of BETX compounds.

Except for two samples, TT1001 and SB4005, for which the reported benzene concentrations are 31 mg/kg and 0.68 mg/kg, respectively, the benzene concentrations in saturated soil samples from depths of 4.5 to 11.5 feet (the approximate screened interval of the shallow portion of the sand aquifer) range from 0.0002 mg/kg to 0.0073 mg/kg. Benzene is not detected in many of the soil samples. In those samples from this interval in which benzene is detected, most benzene concentrations do not exceed 0.001 mg/kg. Since the soil-water partition coefficient for benzene is approximately 1 to 1.5, these soil concentrations would be in equilibrium with groundwater concentrations of less than 1 µg/L. As shown on Figure 7.7-4, the reported benzene concentrations in the groundwater samples from this interval are generally not detected (i.e., below 1 µg/L) (Figure 7.7-4). These concentrations correspond with the low benzene concentrations in the saturated soil samples.

Benzene concentrations increase slightly in saturated soil samples collected from depths of 11.5 to 21.5 feet. Benzene concentrations in these samples range from 0.0003 mg/kg to 0.076 mg/kg; most (approximately 85 percent) are below 0.009 mg/kg. One sample (SB4508) has a concentration of 0.31 mg/kg. The highest benzene concentrations in this interval are detected in the southern portion of the site (near Soil Borings SB-10 and SB-45 through SB-50) and adjacent to the southeast corner of Slip No. 4. The higher concentrations of benzene in the saturated soil matrix of these areas may explain the benzene concentrations of greater than 10 µg/L observed in the groundwater samples from Wells MW-10S and MW-1S.

The BETX plume, as defined by benzene concentrations of greater than 10 µg/L, does not appear to be continuous over the western portion of the site between Wells MW-6S and MW-5S, because the suite of BETX compounds detected at each well is different. The concentrations of benzene detected in the samples from Well MW-5S may be attributable to current activities and features, such as OMC's aboveground storage tank farm for petroleum products located in the southwestern corner of the site.

Summary. The pattern depicted by the contours of benzene concentrations obtained from groundwater samples from the shallow portion of the sand aquifer is identical to the pattern of BETX concentrations, with the highest concentrations being detected in the western portion of the site. Benzene is not detected in any of the samples from the wells north and east of the site. Soil and groundwater concentrations measured in samples from the shallow portion of the sand aquifer are generally consistent with soil-water partitioning expectations for benzene. The benzene concentrations which exceed 10 µg/L in groundwater samples from Wells MW-6S and MW-5S probably are not attributable to a single source. Water quality in the vicinity of Well MW-5S may be influenced by off-site activities.

7.7.1.2.2 Other Volatile Organic Compounds

As discussed in Section 6.0, volatile organic compounds other than BETX compounds were not identified as key chemical parameters for the characterization of contamination at the WCP site based on the results of the Phase I RI activities. However, several new monitoring wells were installed during the second phase of the RI and sampled for analysis of the full scan parameter list of volatile organic compounds. For this reason, volatile organic compound data other than BETX compounds obtained from the water table wells screened in the shallow portion of the sand aquifer are discussed here.

Groundwater samples from Wells MW-1S, MW-3S, MW-4S, MW-6S, MW-7S, MW-9S, MW-12S, MW-13S, and MW-14S have reported detections of one or more of the following compounds: acetone, methylene chloride, carbon disulfide, styrene, 1,2-dichloroethylene, and trichloroethylene. The reported concentrations of acetone are 31 µg/L or less. The reported concentrations of all other compounds are less than 8 µg/L. With the exception of one parameter in the samples from one well, these compounds were only detected during one of the two sampling events.

Chlorinated volatile organic compounds are more consistently detected in the samples from Monitoring Wells MW-5S and MW-10S along the southern perimeter of the site and in the samples from Wells MW-11S and MW-15S located upgradient of the site. During both sampling events, 1,1-dichloroethane and 1,1,1-trichloroethane are reported as detected in the samples from Wells MW-5S, MW-10S, and MW-15S. Maximum reported concentrations of 1,1-dichloroethane in the samples from Monitoring Wells MW-5S, MW-10S, and MW-15S are 700 µg/L, 4 µg/L, and 3 µg/L, respectively. The reported concentrations of 1,1,1-trichloroethane in the samples from these wells are 200 µg/L, 18 µg/L, and 3 µg/L, respectively. In one of the samples from Well MW-5S, 1,2-dichloroethane and 1,1-dichloroethylene are also detected at concentrations of 12 µg/L to 20 µg/L.

A different set of chlorinated volatile organic compounds are detected in the samples from upgradient Well MW-11S. These compounds are 1,2-dichloroethylene and vinyl chloride, and they are detected at maximum concentrations of 95 µg/L and 51 µg/L, respectively.

For the following reasons, the chlorinated volatile organic compounds detected in Monitoring Wells MW-5S, MW-10S, MW-11S, and MW-15S are probably related to releases from off-site activities: (1) these compounds are not detected in on-site soils and groundwater and are not associated with historic site operations; and (2) these wells are located either upgradient of the site (MW-11S and

MW-15S) or along the perimeter of the site in the vicinity of OMC's petroleum product storage tanks and solvent storage cabinets located in the southwestern corner of the site (MW-5S and MW-10S).

7.7.1.3 Inorganic Parameters

The inorganic parameters to be discussed in the following subsections are total dissolved arsenic, cyanide, cadmium, lead, mercury, and selenium. The distribution of total dissolved arsenic and cyanide in the groundwater and soils of the shallow portion of the sand aquifer are similar, with higher concentrations located in the east-central, west-central, and north-central portions of the site and decreasing concentrations to the north, east, and south. Total dissolved concentrations of cadmium, lead, mercury, and selenium are low and clearly definable trends are not evident.

7.7.1.3.1 Arsenic

Groundwater Quality. Total dissolved arsenic concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-5.

In general, total dissolved arsenic concentrations in the shallow portion of the sand aquifer are higher in the central and western portions of the site and decrease to the north, east, and south. The highest total dissolved arsenic concentrations are detected in samples from Wells MW-1S, MW-3S, MW-5S, MW-6S, MW-7S, and MW-9S. Except for two samples, the total dissolved arsenic concentrations in the samples from these wells range from 120 µg/L to 390 µg/L. One sample from Well MW-3S has a reported total dissolved arsenic concentration of 1,700 µg/L, and one sample from Well MW-9S has a reported total arsenic concentration of 4,100 µg/L. Significantly lower total dissolved arsenic concentrations (2 µg/L to 90 µg/L) are reported for areas east of the site (Wells MW-12S, MW-13S, and MW-14S), the southeastern and eastern portion of the site (Wells MW-4S, MW-8S, and MW-10S), and areas north of the site (Wells MW-11S and MW-15S).

There is little variability in the total dissolved arsenic concentrations between sampling events. The December 1993 data are generally consistent with data from the first sampling event at each well, with the exception of data for Well MW-3S (134 µg/L for April 1992 compared to 1,700 µg/L for November/December 1993) and Well MW-9S (4,100 µg/L for September/October 1993 compared to 248 µg/L for November/December 1993).

Arsenic speciation analyses were performed on groundwater samples collected in November/December 1993 in order to better address ecological concerns during the risk assessment.

The data indicate that both Arsenic III and Arsenic V are typically present in the samples from the wells in the shallow portion of the sand aquifer. In general, dissolved Arsenic III concentrations are two to six times greater than dissolved Arsenic V concentrations for the groundwater samples with the higher concentrations of total arsenic.

Saturated Soil Quality/Groundwater Quality Interactions. Except for seven samples, the arsenic concentrations in saturated soil samples from depths of 4.5 to 11.5 feet (the approximate screened interval of the shallow portion of the sand aquifer) range from 0.7 mg/kg to 37 mg/kg. Arsenic concentrations above that range are reported for Samples SB0903 (761 mg/kg), TT1001 (318 mg/kg), T08A01 (304 mg/kg), SB3404 (160 mg/kg), SB1704 (156 mg/kg), SB2304 (51 mg/kg), and SB6004 (63 mg/kg). Most of the saturated soil samples from this interval that were collected from the northeastern and east-central portions of the site have reported arsenic concentrations of greater than 10 mg/kg.

Arsenic concentrations decrease in magnitude and extent in the saturated soil samples from below a depth of 11.5 feet in the shallow portion of the sand aquifer. Only three samples from this interval, PW0107 (161 mg/kg), SB3407 (43 mg/kg), and SB3507 (50 mg/kg), have reported arsenic concentrations in excess of 40 mg/kg. The areas in which saturated soil samples have reported arsenic concentrations of greater than 10 mg/kg are limited to the north-central portion of the site near Soil Borings P-107, S-2, and SB-60 and the east-central portion of the site near Soil Borings SB-33, SB-34, SB-09, PW-01, SB-41, and SB-44.

With the exception of the vicinity of Wells MW-5S and MW-6S, where arsenic data for saturated soils are limited (most of the soil samples collected during previous investigations in the vicinity of Slip No. 4 were not analyzed for arsenic), the area of the shallow portion of the sand aquifer in which arsenic concentrations in groundwater exceed 100 µg/L corresponds to the area in which arsenic concentrations in saturated soil exceed 10 mg/kg.

Summary. In general, total dissolved arsenic concentrations in the shallow portion of the sand aquifer are higher in the central and western portions of the site and decrease to the north, east, and south. Most saturated soil samples from the shallow portion of the sand aquifer have reported concentrations below 40 mg/kg. Total dissolved arsenic concentrations decrease in magnitude and extent with depth in the shallow portion of the sand aquifer. With the exception of the vicinity of Wells MW-5S and MW-6S, where arsenic data for saturated soils are limited, the area of the shallow portion of the sand aquifer in which total dissolved arsenic concentrations in groundwater exceed 100 µg/L correspond to the area in which arsenic concentrations in saturated soil exceed 10 mg/kg.

7.7.1.3.2 Cyanide

Groundwater Quality. Total dissolved cyanide concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-6.

In general, total dissolved cyanide concentrations in the shallow portion of the sand aquifer are higher in the north-central, east-central, and west-central portions of the site and decrease to the north, east, and south. The highest total dissolved cyanide concentrations are detected in samples from Wells MW-1S, MW-3S, MW-7S, and MW-9S. The total dissolved cyanide concentrations in the samples from these wells range from 28 µg/L to 651 µg/L. Significantly lower total dissolved cyanide concentrations (not detected [at a detection limit of 1.2 µg/L] to 18 µg/L) are reported for areas east of the site (Wells MW-12S, MW-13S, and MW-14S), the southeastern and eastern portion of the site (Wells MW-4S, MW-8S, and MW-10S), the western portion of the site (MW-5S and MW-6S), and areas north of the site (Wells MW-11S and MW-15S).

There is some variability in the total dissolved cyanide concentrations between sampling events, especially for the wells from which samples with lower concentrations of cyanide were collected. The samples from Wells MW-5S, MW-8S, MW-10S, MW-11S, MW-12S, MW-13S, MW-14S, and MW-15S have reported total dissolved cyanide concentrations of 1 µg/L to 18 µg/L in the first sampling event. Dissolved cyanide is not detected at a concentration of 1.2 µg/L in the second set of samples from all of these wells. The data from wells from which samples with higher concentrations of total dissolved cyanide are detected are more consistent between sampling events.

Analysis of weak acid dissociable cyanide was performed on groundwater samples collected in November/December 1993 because the applicable surface water standard is for weak acid dissociable cyanide. Weak acid dissociable cyanide is only detected in the samples from Wells MW-7S (6 µg/L) and MW-9S (31 µg/L). It is not detected (at a detection limit of 5 µg/L) in any of the other groundwater samples from the shallow portion of the sand aquifer. Except for a small area in the east-central portion of the site, weak acid dissociable cyanide is not present in the groundwater of the shallow portion of the sand aquifer.

Saturated Soil Quality/Groundwater Quality Interactions. Except for three samples, the cyanide concentrations in saturated soil samples from depths of 4.5 to 11.5 feet (the approximate screened interval of the shallow portion of the sand aquifer) are below 10 mg/kg. Cyanide concentrations greater than 10 mg/kg are detected in Samples T08A01 (52 mg/kg), SB3404 (38 mg/kg), and SB6004 (20 mg/kg). Most of the saturated soil samples from this interval that were collected from the

northeastern and east-central portions of the site have reported cyanide concentrations of greater than 1 mg/kg. Cyanide is generally not detected or is detected at concentrations of less than 1 mg/kg outside of these areas.

Cyanide concentrations decrease in magnitude and extent in the saturated soil samples from below a depth of 11.5 feet in the shallow portion of the sand aquifer. Only three samples from this interval have reported cyanide concentrations in excess of 1 mg/kg. Cyanide is otherwise not detected or detected at concentrations below 1 mg/kg in all of the other saturated soil samples from this interval.

With the exception of the vicinity of Well MW-6S, where cyanide data for saturated soils are limited (most of the soil samples collected during previous investigations in the vicinity of Slip No. 4 were not analyzed for cyanide), the area of the shallow portion of the sand aquifer in which total dissolved cyanide concentrations in groundwater exceed 10 µg/L corresponds to the area in which cyanide concentrations in saturated soil exceed 1 mg/kg.

Summary. In general, total dissolved cyanide concentrations in the shallow portion of the sand aquifer are higher in the north-central, east-central, and west-central portions of the site and decreased to the north, east, and south. Except for a small area in the east-central portion of the site, weak acid dissociable cyanide is not present in the groundwater of the shallow portion of the sand aquifer. Most saturated soil samples from the shallow portion of the sand aquifer have cyanide concentrations below 1 mg/kg. Dissolved cyanide concentrations decrease in magnitude and extent with depth in the shallow portion of the sand aquifer. With the exception of the vicinity of Well MW-6S, where cyanide data for saturated soils are limited, the area of the shallow portion of the sand aquifer in which total dissolved cyanide concentrations in groundwater exceed 10 µg/L corresponds to the area in which cyanide concentrations in saturated soil exceed 1 mg/kg.

7.7.1.3.3 Other Inorganic Parameters

Total dissolved cadmium, lead, mercury, and selenium concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-7.

Cadmium. Groundwater analytical data for total dissolved cadmium for samples from the water table wells in the shallow portion of the sand aquifer show reported concentrations ranging from not detected (at a detection limit of approximately 3 µg/L) to 11 µg/L. The first sample from each of Wells MW-3S, MW-6S, MW-9S, and MW-15S has reported detections of cadmium at concentrations

of 3 µg/L, 4 µg/L, 4 µg/L, and 11 µg/L, respectively. Cadmium is not detected in the samples from these wells during the second sampling event and is not detected in any of the samples from the other wells. These data do not suggest a clearly definable areal trend.

In the saturated soils of the shallow portion of the sand aquifer, cadmium is detected in only 14 samples at concentrations of up to 1.7 mg/kg. Only four of those samples have reported detections of greater than 1 mg/kg. Cadmium is not detected (at detection limits of approximately 0.7 mg/kg) in any of the other soil samples from this zone. These data do not suggest a clearly definable areal trend.

Lead. Groundwater analytical data for total dissolved lead for samples from the water table wells in the shallow portion of the sand aquifer show concentrations ranging from not detected (at detection limits of approximately 1 to 2 µg/L) to 3.6 µg/L. One sample from each of Wells MW-3S, MW-6S, and MW-14S and both samples from Well MW-9S have reported detections of dissolved lead at concentrations of 2 µg/L, 3 µg/L, 3 µg/L, 4 µg/L, and 2 µg/L, respectively. Dissolved lead is not detected in any of the samples from the other wells. These data do not suggest a clearly definable areal trend.

In the saturated soils of the shallow portion of the sand aquifer, lead is detected in one sample (SB3804) at 215 mg/kg and in five samples at concentrations of up to 24 mg/kg. All of the other saturated soil samples from this zone have reported lead concentrations of less than 10 mg/kg, most of which range from 2 mg/kg to 4 mg/kg. These data do not suggest a clearly definable areal trend.

Mercury. Groundwater analytical data for total dissolved mercury for samples from the water table wells in the shallow portion of the sand aquifer show reported concentrations ranging from not detected (at detection limits of 0.001 µg/L to 0.13 µg/L) to 2.2 µg/L. One sample from each of Wells MW-3S, MW-9S, and MW-10S have reported detections of total dissolved mercury at concentrations of 0.13 µg/L, 2.2 µg/L, and 0.25 µg/L, respectively. Dissolved mercury is not detected in the samples from these wells during the other sampling event and is not detected in any of the samples from the other wells. The dissolved mercury concentration of 2.2 µg/L for the November/ December 1993 sample from Well MW-9S is considered anomalous because it was not consistent with the nondetectable result reported for the September/October 1993 sample from this well and because it is nine times greater than any other detected concentration of mercury from this zone. These data do not suggest a clearly definable areal trend.

In the saturated soils of the shallow portion of the sand aquifer, mercury is detected in five samples in the eastern half of the site at concentrations between 0.3 mg/kg and 1.6 mg/kg. All of these

samples were collected from the depth interval of 4.5 feet to 11.5 feet. All of the other detections of mercury in the saturated soil samples from the shallow portion of the sand aquifer are below 0.14 mg/kg.

Selenium. Groundwater analytical data for total dissolved selenium for samples from the water table wells in the shallow portion of the sand aquifer show reported concentrations ranging from not detected (at a detection limit of approximately 1.5 µg/L) to 10 µg/L. One sample from each of Wells MW-3S, MW-6S, MW-5S, and MW-10S and both samples from Well MW-9S have reported detections of total dissolved selenium at concentrations of 3 µg/L, 3 µg/L, 2 µg/L, 2 µg/L, 3 µg/L, and 10 µg/L, respectively. Selenium is not detected in any of the samples from the other wells. These data do not suggest a clearly definable areal trend.

In the saturated soils of the shallow portion of the sand aquifer, selenium is reported as detected in 10 samples in the northeastern quarter of the site at concentrations between 2 mg/kg and 12 mg/kg. Most of these samples were collected from the depth interval of 4.5 feet to 11.5 feet. All of the other detections of selenium in the saturated soil samples from the shallow portion of the sand aquifer are below 2 mg/kg; most are below 1 mg/kg.

7.7.1.4 General Chemistry Parameters

This section of the report discusses the results for ammonia, as it is the only general chemistry parameter listed in Section 6.0 as a key chemical parameter for the characterization of extent of contamination at the WCP site. Other general chemistry parameters, as they relate to determining whether aquifer conditions are dominantly aerobic or anaerobic, are discussed in Section 7.7.2.4.2.

Groundwater Quality. Total ammonia concentrations in samples from the water table monitoring wells in the shallow portion of the sand aquifer are presented on Figure 7.7-8. The November/December 1993 sampling event is the only sampling event for which samples were collected for analysis of ammonia.

In general, total ammonia concentrations in the shallow portion of the sand aquifer are higher in the central and western portions of the site and decrease to the north, east, and south. The highest total ammonia concentrations are reported for samples from Wells MW-1S and MW-6S. The total ammonia concentrations in the samples from these wells range from 44,000 µg/L to 72,000 µg/L. Significantly lower total ammonia concentrations (400 µg/L to 2,000 µg/L) are reported for the samples

for Wells MW-5S, MW-7S, MW-9S, and MW-11S. Ammonia is not detected (at a detection limit of 200 µg/L) in any of the other wells to the north, east, and south.

Saturated Soil Quality/Groundwater Quality Interactions. Saturated soil samples were not collected for analysis of ammonia.

7.7.1.5 Summary

This subsection summarizes the previous subsections in which the magnitude and extent of key chemical parameters in groundwater and saturated soils in the shallow portion of the sand aquifer at the WCP site were discussed. The key chemical parameters are phenol (representative of phenolic compounds), total and carcinogenic PAHs, benzene (representative of BETX compounds), arsenic, cyanide, lead, mercury, cadmium, selenium, and ammonia. In general, the groundwater data from the shallow portion of the sand aquifer indicate that key parameters are found at the highest concentrations in the western and/or west-central portions of the site and that concentrations diminish to the north, east, and south. Saturated soil concentrations for all compounds except phenol are significantly less than the concentrations of these compounds in vadose zone soils and typically decrease with depth within the shallow portion of the sand aquifer.

The groundwater concentrations and/or distribution patterns of these parameters in the shallow portion of the sand aquifer are consistent with expectations for soil-water interactions given the concentrations and distribution of these parameters in the saturated soils of this zone. As would be expected given that PAHs are nearly insoluble in water, only the most soluble and mobile PAHs are detected in groundwater in the shallow portion of the sand aquifer and then only in the immediate vicinity of soils containing PAHs. Phenolic compounds either are not detected or are detected at low concentrations in the soils of this zone. Accordingly, phenolic compounds either are not detected or are detected at low concentrations in the groundwater of this zone. Benzene concentrations in groundwater of the shallow portion of the sand aquifer are generally in equilibrium with soil concentrations. Dissolved arsenic and cyanide are more widespread than organic compounds in the groundwater of the shallow portion of the sand aquifer, possibly because these inorganic parameters are relatively nonbiodegradable. The highest groundwater concentrations of dissolved arsenic and cyanide in this zone are also generally spatially associated with the highest saturated soil concentrations of those compounds. Concentrations of total dissolved cadmium, lead, mercury, and selenium are low and trends are not evident.

7.7.2 Deep Portion of the Sand Aquifer

This section discusses the magnitude and extent of key chemical parameters in groundwater and saturated soils in the deep portion of the sand aquifer at the WCP site. As discussed in the introduction to Section 7.7, the deep portion of the sand aquifer extends from a depth of approximately 21.5 feet to the top of the till unit (at a depth of approximately 30 feet).

Analytical data for groundwater samples collected from the deep portion of the sand aquifer during the RI are summarized in Tables 4.3-7 through 4.3-17. The monitoring wells in this portion of the sand aquifer are screened immediately above the till in the last 5 feet of the sand aquifer. The temporary well points were also screened within this depth interval.

Two rounds of groundwater data were collected at each well. The first round was for Wells MW-1D through MW-6D on April 7-9, 1992, and for Wells MW-7D through MW-15D on September 30 through October 1, 1993. The second round of sampling was performed on all wells between November 29 and December 2, 1993. The second round data and the temporary well point data, collected on September 16, 1993, are used here for developing concentration isopleths of the groundwater data and interpreting the extent of groundwater contamination.

Analytical data for the key chemical parameters for soil samples collected during the RI are summarized, together with field screening results, in Table 7.1-1. Analytical data for soil samples collected during previous investigations are presented in PSCS Appendices 3-B and 3-D.

The following subsections discuss the extent and magnitude of semivolatile organic compounds, volatile organic compounds, inorganic parameters, and general chemistry parameters in the groundwater and saturated soils in the deep portion of the sand aquifer. In general, the groundwater data from the deep portion of the sand aquifer indicate that all key parameters except cyanide and PAHs are found at the highest concentrations in the central portions of the site and that concentrations diminish to the north and east. Except for PAHs, which do not have a significant presence in groundwater, the presence of these parameters in the deep portion of the sand aquifer is much more extensive and at higher concentrations than in the shallow portion of the sand aquifer. Concentrations are generally orders of magnitude higher in the deep portion of the sand aquifer than in the shallow. Organic compounds are detected in samples from the westernmost, but not the easternmost, points of the monitoring network. Inorganic parameters are detected in samples from the westernmost and easternmost points of the monitoring network. Both organic and inorganic parameters decrease in concentrations to the north and east. The full extent of the presence of most

of these parameters in the deep portion of the sand aquifer is not defined to the south. This matter is addressed in Section 8.4.

The observed distribution of key parameters in the groundwater and saturated soils at the WCP site is inconsistent with what would be observed if the soils in the vadose zone were the current source of these parameters in groundwater of the deep portion of the sand aquifer, namely, soil and groundwater concentrations both decreasing with depth or distance from the source.

7.7.2.1 Semivolatile Organic Compounds

The semivolatile organic compounds presented in the following subsections are phenolic compounds, total PAHs, and carcinogenic PAHs.

7.7.2.1.1 Phenolic Compounds

Groundwater Quality. Only four phenolic compounds are routinely reported as detected in the groundwater samples from the deep portion of the sand aquifer at the site. These compounds are (in order of generally decreasing concentrations and solubility limits) phenol, p-cresol, o-cresol, and 2,4-dimethylphenol. Because phenol is the most soluble of the four parameters and because it is detected most frequently and at the highest concentrations, it is used as an indicator compound for evaluation of the distribution of phenolic compounds in the deep portion of the sand aquifer.

Phenol concentrations in samples from the wells in the deep portion of the sand aquifer are presented on Figure 7.7-9. Phenol concentrations in the samples from these wells are three or more orders of magnitude higher than the concentrations in the samples from the water table wells in the shallow portion of the sand aquifer. In those samples in which phenol is detected, the concentrations range from 3 µg/L (in a sample from Well MW-5D) to 660,000 µg/L (in a sample from Well MW-7D). Generally, higher phenol concentrations are detected in deep groundwater in the following areas of the site: west-central and central (Wells MW-6D and MW-1D), east-central (Wells MW-9D and MW-4D), and northeast (Wells MW-7D and MW-13D). Concentrations decrease rapidly to the northwest, north, northeast, southeast, and southwest, as phenol is not detected (at a detection limit of 1.2 µg/L) in the samples from Wells MW-11D, MW-15D, MW-14D, and MW-12D or in the samples from temporary well points at Soil Borings SB-52 and SB-53. Phenol concentrations do not decline as rapidly directly to the east of the site along a path from Wells MW-7D to MW-13D and Soil Boring SB-51. A phenol concentration of 3,400 µg/L is reported for the groundwater sample from the temporary well point at Soil Boring SB-51. Phenol concentrations decrease by an order of magnitude

from the central portion of the site to the south, but the complete southern extent of the presence of phenol in groundwater of the deep portion of the sand aquifer is not delineated. The predicted extent of the presence of phenol in groundwater south of the site is discussed in Section 8.4.

There is some variability in the phenol concentrations between sampling events. The April 1992 sample from Well MW-4D has a reported phenol concentration of 1,500,000 µg/L. The sample duplicate from this well has a reported phenol concentration of 320,000 µg/L. Since the November/ December 1993 sample from this well has a reported phenol concentration of 200,000 µg/L, the concentration of 1,500,000 µg/L is believed to be erroneous and is not used in the above evaluation. There is also a discrepancy in the samples from Well MW-7D. The September/October 1993 sample has a reported phenol concentration of 73,000 µg/L, while the sample duplicate has a reported concentration of 590,000 µg/L. Since the November/December 1993 sample from this well has a phenol concentration of 660,000 µg/L, the report of 73,000 µg/L is thought to be erroneous. At Monitoring Wells MW-6D and MW-1D, the concentrations of phenol in the samples from the second sampling event are approximately one-third of the concentrations reported in the samples from these wells during the first sampling event. The second round of data from each of these wells is used in the above evaluation.

Saturated Soil Quality/Groundwater Quality Interactions. In order to facilitate the discussion of the relationship between saturated soil quality and groundwater quality in the deep portion of the sand aquifer, phenol is used as an indicator parameter for evaluation of the distribution of phenolic compounds.

Phenol concentrations in saturated soil samples from directly above the till (the approximate screened interval of the deep portion of the sand aquifer) exceed 100 mg/kg over much of the eastern and west-central portions of the site. The maximum reported concentration of phenol is 310 mg/kg. Phenol concentrations in saturated soil samples from this interval range from 10 to 50 mg/kg over much of the remainder of the site. These soil concentrations appear to be in equilibrium with the phenol concentrations in the groundwater. The soil-water partitioning coefficient for phenol is approximately 0.8 to 1.6. Those areas of the site where groundwater in the deep portion of the sand aquifer has phenol concentrations ranging from 100,000 µg/L to over 500,000 µg/L, also have saturated soil concentrations of phenol in the 50 mg/kg to 300 mg/kg range, which is generally consistent with the soil-water partitioning coefficients. Similarly, in those areas of the site where groundwater concentrations range from 1,000 µg/L to 100,000 µg/L, the saturated soil concentrations range up to 50 mg/kg.

Summary. Phenol concentrations in the samples from the wells in the deep portion of the shallow aquifer are three or more orders of magnitude higher than the concentrations in the samples from the water table wells in the shallow portion of the sand aquifer. Generally, higher phenol concentrations are detected in deep groundwater in the west-central and central, east-central, and northeast portions of the site. Concentrations decrease rapidly to the northwest, north, northeast, southeast, and southwest. Phenol concentrations decrease by an order of magnitude from the central portion of the site to the south but the southern extent of the presence of phenol in groundwater of the deep portion of the sand aquifer is not fully defined. Soil and groundwater phenol concentrations measured in samples from this zone are consistent with soil-water partitioning calculations.

7.7.2.1.2 PAHs

As compared to phenolic compounds or volatile organic compounds, PAHs typically have very low solubilities in water and tend to be highly adsorbed onto soil organic carbon (Table 6.1-2). PAHs are generally concentrated in soils and relatively immobile in groundwater.

Groundwater Quality. Two rounds of groundwater samples were collected for analysis of PAHs from each well screened in the deep portion of the sand aquifer. If PAHs were not detected in the sample from a well during the first sampling event, a low level (parts per trillion) PAH analysis was performed on the sample from that well during the second sampling event.

Total PAH concentrations in samples from the wells screened in the deep portion of the sand aquifer are presented on Figure 7.7-10. The highest concentrations of total PAHs for groundwater in the deep portion of the sand aquifer are reported in samples from Monitoring Wells MW-1D, MW-6D in the west-central portion of the site and Monitoring Well MW-7D in the northeast-central portion of the site. In the samples from these wells, naphthalene (the most soluble and mobile of the PAH compounds) is the only PAH compound detected. Its concentrations range from 80 µg/L to 1,400 µg/L. In samples from all of the other wells (or temporary monitoring points) located on the east-central portion of the site (MW-4D and MW-9D) or located north (MW-3D, MW-11D, and MW-15D), east (MW-12D, MW-13D, MW-14D, SB-51, SB-52, and SB-53), and south (MW-5D, MW-8D, and MW-10D) of the central portion of the site, PAH compounds either are not detected or are detected at part-per-trillion concentrations similar to those detected in blanks. At some of the wells, namely MW-3D, MW-4D, MW-7D, MW-8D, MW-9D, and MW-10D, high concentrations of phenol raise the detection limits for the PAH compounds to approximately 680 µg/L. However, if the PAH concentrations in the deep portion of the sand aquifer were the same as those reported in the shallow portion of the sand aquifer, they would be detected even with the higher detection limit.

The total carcinogenic PAH concentrations in samples from these wells are presented on Figure 7.7-11. No carcinogenic PAH compounds are reported above detection limits for groundwater samples from the wells screened in the deep portion of the sand aquifer. As stated above, some of the detection limits for these compounds are raised to approximately 100 µg/L or, in some cases, even 1,000 µg/L because of elevated concentrations of phenol in some of the samples. The detection limit for carcinogenic compounds for the samples from Wells MW-11D, MW-12D, MW-14D, and MW-15D is 6 parts per trillion.

Saturated Soil Quality/Groundwater Quality Interactions. The presence of PAHs in saturated soil samples from directly above the till (the approximate screened interval of the deep portion of the sand aquifer) decreases in magnitude and extent from the presence of PAHs in the shallow portion of the sand aquifer. PAHs are not detected in the vast majority of saturated soil samples from this interval. Limited areas in the northeast central (Soil Borings SB-07, SB-21, SB-60, and SB-24) and east-central (Soil Borings SB-32 and SB-33, Soil Borings SB-41 and SB-45, and Soil Boring SB-39) portions of the site and along the southern edge of Slip No. 4 have reported total PAH concentrations in excess of 1 mg/kg. Only seven samples have reported total PAH concentrations of greater than 10 mg/kg. Only three samples (SB2712, S-61-03, and SB4112) have reported detections of carcinogenic PAHs. The highest total PAH concentrations of 19 mg/kg, 14 mg/kg, 141 mg/kg, and 52 mg/kg were reported for samples from Soil Borings SB-21, SB-28, SB-27, and SB-41 respectively.

The results of the test trenching completed during the first phase of the field investigation indicated areas of vadose zone soils that exhibited visible contamination. As such, the second phase of the field investigation was designed to specifically investigate the potential presence of DNAPL in the sand aquifer. Soil borings were placed at approximate 100-foot centers along transects in and through those areas exhibiting visible contamination in the vadose zone. Each soil boring was advanced to the top of the till and sampled at nearly continuous intervals with a split-spoon sampler. A split-spoon sample from immediately above the till was specifically collected from each boring at the contact between the sand unit and the top of the till. Field screening, which consisted of recording observations of discoloration and odor, testing for the presence of an oil sheen, and measuring headspace organic vapor concentrations, was performed on each sample. An analytical sample was collected from every soil boring from the interval just above the top of the till unit for the specific purpose of assessing the presence of PAHs as DNAPL. Finally, monitoring wells in the deep portion of the sand aquifer were specifically screened in the interval immediately above the till.

For the following reasons, neither the field observations nor the analytical results from the field investigation activities described above indicated the presence of DNAPL deposits at the site that could

account for the observed distribution of key parameters in the groundwater in the deep portion of the sand aquifer:

1. No evidence of the presence of DNAPL was observed during the installation, development, or sampling of the monitoring wells. The analytical results for groundwater samples from the wells screened in the deep portion of the sand aquifer did not indicate the presence of DNAPL at the top of the till.

2. DNAPL, if present at this site, would have accumulated in depressions in the surface of the till and would have been readily apparent in the soil boring samples. Borings placed in till surface depressions (shown on Figure 5.1-5) found no DNAPL. The only instance in which an apparent DNAPL was reported (the presence of a golden-brown oil [coal tar or creosote DNAPL is black and viscous] coating the grains of gravel in the thin [less than 2.5 inches] gravel seam immediately above the till at Soil Boring SB-41) was not accompanied by DNAPL presence in the till depression immediately to the northeast (P-108) or in the draw to the south (SB-45, SB-50, and SB-59).

3. The visual absence of DNAPL described above is consistent with the reported distribution of PAH concentrations in the samples from the soil borings. Even in areas of visible contamination in vadose zone soils, PAH concentrations declined rapidly with depth beneath the water table. Total PAH concentrations did not increase at the top of the till, nor did they approach saturation concentrations. Thus, even in those areas in which DNAPL would most likely be encountered, no DNAPL was observed.

4. DNAPL at the top of the till cannot account for the observed distribution of organic contaminants in the groundwater of the deep portion of the sand aquifer. If that had been the case, naphthalene (or any other relatively mobile PAH constituent of DNAPL) would have been widespread in groundwater as are benzene and phenol, and visible DNAPL would have been found in extensive areas at the top of the till.

5. Finally, inorganic compounds, such as arsenic, cyanide, ammonia, and thiocyanate, exhibit the same stratification in groundwater (i.e., much higher concentrations at depth) as do the organic compounds, although the inorganic compounds would not have been present in DNAPLs associated with creosoting or coking/manufactured gas processes. Thus, DNAPL is not the source of these compounds in the groundwater.

PAHs do not appear to be readily dissolving and migrating from the soils containing PAH compounds. Detections of total PAHs in groundwater samples are essentially limited to samples from wells within soils exhibiting total PAH concentrations of greater than 1 mg/kg.

Summary. As predicted by the solubilities and organic carbon partition coefficients of PAHs, the data indicate that PAHs are concentrated in soils and are relatively immobile in groundwater. The highest reported concentrations of total PAHs for groundwater in the deep portion of the sand aquifer are observed in samples from Monitoring Wells MW-1D, MW-6D, and MW-7D. Total PAHs are not detected in the samples from any other wells. The detections of total PAHs in groundwater samples are limited to detections of naphthalene, the most mobile PAH compound, in samples from wells associated with soils having total PAH concentrations of greater than 1 mg/kg. Carcinogenic PAHs are not detected in any wells. No DNAPL presence is evident at the site that could account for the observed distribution of key parameters in the groundwater of the deep portion of the sand aquifer.

7.7.2.2 Volatile Organic Compounds

The volatile organic compounds to be discussed in the following subsections are BETX compounds and other volatile organic compounds.

7.7.2.2.1 BETX Compounds

Because benzene is the most soluble of the BETX compounds and because it constitutes 66 to 100 percent of the total BETX compound concentrations in the samples from the wells screened in the deep portion of the sand aquifer, it is used as an indicator compound for evaluation of the distribution of BETX compounds in the deep portion of the sand aquifer. Observations about ethyl benzene, toluene, and xylenes will be made as necessary.

Groundwater Quality. Benzene concentrations in samples from the wells in the deep portion of the sand aquifer are presented on Figure 7.7-12. Benzene concentrations in the samples from these wells are typically two or three orders of magnitude higher than the concentrations in the samples from the water table wells in the shallow portion of the sand aquifer. In those samples in which benzene is detected, the concentrations range from 45 µg/L (in a sample from the temporary well point at Soil Boring SB-51) to 4,400 µg/L (in a sample from Well MW-10D). Generally, higher benzene concentrations (greater than approximately 1,000 µg/L) are detected in deep groundwater in the following areas of the site: southern (MW-8D and MW-10D), west-central and central (Wells MW-6D and MW-1D), east-central (Wells MW-9D and MW-4D), northern (MW-3D), and northeast (Wells

MW-7D and MW-13D). Concentrations decrease rapidly to the northwest, north, and southeast, as benzene is not detected (at a detection limit of 10 µg/L) in the samples from Wells MW-11D, MW-15D, and MW-12D or in the samples from temporary well points at Soil Borings SB-52 and SB-53. Benzene concentrations do not decline as rapidly directly to the northeast (Well MW-14D and SB-51) and southwest (MW-5D). Maximum benzene concentrations of 67 µg/L, 49 µg/L, and 560 µg/L are reported in the groundwater samples from Well MW-14D, the temporary well point at Soil Boring SB-51, and Well MW-5D, respectively. The complete southern extent of the presence of benzene in groundwater of the deep portion of the sand aquifer is not defined by the groundwater monitoring data. Contaminant fate and transport analyses that predict the extent of the presence of benzene in groundwater south of the site are discussed in Section 8.4.

Detections of toluene, xylenes, and ethyl benzene are limited to those samples with benzene concentrations of greater than 700 µg/L. Their concentrations range from 32 µg/L to 470 µg/L, with toluene being detected most frequently and at the highest concentrations. All three compounds are detected in the samples from wells in the east-central and west-central (MW-1D, MW-6D, and MW-9D) and southern (MW-10D) portions of the site. Toluene, xylenes, or both are detected in the samples from wells (MW-3D and MW-7D) in the northeastern portion of the site. Toluene, but not xylenes or ethyl benzene, is detected in the samples from Well MW-13D located east of the site and in the samples from Well MW-8D located on the southeast portion of the site. Generally, the concentrations of these compounds decrease to the north, east, and south from the east-central and west-central portions of the site.

With one exception, there is little variability in the benzene concentrations between sampling events. The September/October 1993 sample from Well MW-8D has a reported benzene concentration of 920 µg/L, but the November/December 1993 sample has a reported benzene concentration of 7,800 µg/L. The second round sample (November/December 1993) is used in the data evaluation.

Saturated Soil Quality/Groundwater Quality Interactions. In order to facilitate the discussion of the relationship between saturated soil quality and groundwater quality in the deep portion of the sand aquifer, benzene is used as an indicator parameter for evaluation of the distribution of BETX compounds.

The benzene concentrations in saturated soil samples from directly above the till (the approximate screened interval of the deep portion of the sand aquifer) range from not detected (at a detection limit of 0.0012 mg/kg) to 0.8 mg/kg; most (approximately 85 percent) are below 0.05 mg/kg. These soil concentrations were 5 to 10 times higher than those observed in the shallow portion of the

sand aquifer, while associated groundwater concentrations are 100 to 1,000 times higher. The observation that benzene concentrations in saturated soil samples from the deep portion of the sand aquifer are similar to or slightly higher than those in the shallow portion, while groundwater concentrations are orders of magnitude higher, is inconsistent with what would be observed if the soils in the vadose zone were the current source of benzene in groundwater of the deep portion of the sand aquifer (namely, soil and groundwater concentrations both decreasing with depth from the source).

Summary. Benzene concentrations and BETX concentrations in the samples from the wells in the deep portion of the shallow aquifer are one or two orders of magnitude higher than the concentrations in the samples from the water table wells in the shallow portion of the sand aquifer. Generally, higher benzene concentrations are detected in deep groundwater in the southern, west-central and central, east-central, and northeast portions of the site. Concentrations decrease rapidly to the northwest, north, and southeast, and somewhat less rapidly to the northeast and southwest. The southern extent of the presence of benzene in groundwater of the deep portion of the sand aquifer is discussed in Section 8.4. The distribution of benzene in the groundwater and saturated soils of the shallow and deep portions of the sand aquifer indicates that shallow soils are not the current source of benzene in the groundwater of the deep portion of the sand aquifer.

7.7.2.2.2 Other Volatile Organic Compounds

As discussed in Section 6.0, volatile organic compounds other than BETX compounds were not identified as key chemical parameters for the characterization of contamination at the WCP site based on the results of the Phase I RI activities. However, several new monitoring wells were installed during the second phase of the RI and were sampled for analysis of the full scan parameter list of volatile organic compounds. For this reason, volatile organic compound data obtained from the wells screened in the deep portion of the sand aquifer for volatile organic compounds other than BETX compounds are discussed here.

Acetone, methylene chloride, carbon disulfide, and styrene are detected in the samples from one or more wells located on-site or downgradient of the site (Wells MW-1D, MW-3D, MW-4D, MW-6D, MW-7D, MW-8D, MW-9D, MW-10D, and MW-13D). Styrene was detected in the samples from three wells (MW-1D, MW-7D, and MW-9D) at concentrations ranging from 8 µg/L to 31 µg/L. Carbon disulfide was detected in the samples from two wells (MW-1D and MW-4D) at concentrations of 6 µg/L to 7 µg/L. Acetone and methyl ethyl ketone are detected in the samples from all of these wells: acetone concentrations range from 100 µg/L to of 1,300 µg/L and methyl ethyl ketone concentrations range from 21 µg/L to 180 µg/L. These detections of acetone and methyl ethyl ketone are generally

associated with high concentrations of BETX and phenolic compounds. Acetone and methyl ethyl ketone are common laboratory contaminants (U.S. EPA, 1988) and may, therefore, not be associated with site operations. However, the reported concentrations for these compounds do not meet specific criteria for identifying false positive results.

Chlorinated volatile organic compounds are detected in the sample from Monitoring Well MW-10D along the southern perimeter of the site, in the samples from Wells MW-11D, MW-14D, and MW-15D located along the upgradient side of the site, and in the sample from temporary well point SB-51. Methylene chloride is detected in samples from all of these wells at concentrations of 2 µg/L to 14 µg/L. However, methylene chloride is detected in only one of the two rounds of samples at these locations. 1,2-Dichloroethylene is detected at concentrations of 2 µg/L to 50 µg/L in all of the samples from Wells MW-11D and MW-14D and temporary well point SB-51. 1,1-Dichloroethane and vinyl chloride are detected in both samples from Well MW-14D at maximum concentrations of 6 µg/L and 160 µg/L, respectively. Trichloroethylene is detected in one of two samples from the temporary well point at Soil Boring SB-51 at a concentration of 2 µg/L.

The chlorinated volatile organic compounds detected in the samples from Monitoring Wells MW-10D, MW-11D, MW-14D, and MW-15D and in the samples from the temporary well point at SB-51 are likely related to off-site activities or are a result of laboratory or sampling bias. These compounds are not detected in on-site soils and groundwater and are not associated with site operations. The wells in which these chlorinated compounds were detected are located: upgradient of the site (MW-11D and MW-15D); in the vicinity of OMC Plant No. 2, the reported location of 27 underground storage tanks used for storage of petroleum products, naphthalene, and trichloroethylene (MW-14D, MW-15D, and SB-5D); or in the vicinity of the OMC petroleum product storage tanks and/or solvent storage cabinet in the southwestern corner of the site (MW-10D).

7.7.2.3 Inorganic Parameters

The inorganic parameters to be discussed in the following subsections are total dissolved arsenic, cyanide, cadmium, lead, mercury, and selenium. The distribution of total dissolved arsenic, cadmium, and selenium in groundwater of the deep portion of the sand aquifer are similar, with higher concentrations located in the east-central, west-central, and north-central portions of the site and decreasing concentrations to the north, east, and south. Dissolved cyanide concentrations are highest in the southern portion of the site and decrease gradually to the north. Concentrations of total dissolved lead and mercury are low and no clearly definable trends are evident. Total dissolved arsenic and cyanide are present in the groundwater of the deep portion of the sand aquifer at the

boundaries to both the harbor and lake. The complete southern extent of the presence of total dissolved arsenic and cyanide is not delineated.

The groundwater samples collected from the temporary well points for analysis of inorganic parameters were inadvertently not filtered prior to analysis. The sediment in the samples may have interfered with the analyses and biased the results high. The results are used in a general way to identify presence of parameters in the groundwater at these locations, but they are not directly comparable to the filtered results at the other wells and are not used to contour concentrations.

7.7.2.3.1 Arsenic

Groundwater Quality. Total dissolved arsenic concentrations in samples from the wells in the deep portion of the sand aquifer are presented on Figure 7.7-13.

In general, total dissolved arsenic concentrations in the deep portion of the sand aquifer are higher in the east-central, west-central, and north-central portions of the site and decrease to the north, east, and south. Dissolve arsenic concentrations in the deep portion of the sand aquifer are generally two orders of magnitude higher than the concentrations of dissolved arsenic reported in the samples from the wells in the shallow portion of the sand aquifer. The highest total dissolved arsenic concentrations for this zone are detected in samples from Wells MW-3D, MW-4D, MW-5D, MW-6D, MW-7D, MW-9D, and MW-13D. The total dissolved arsenic concentrations in the samples from these wells range from 11,000 µg/L to 70,000 µg/L. Significantly lower total arsenic concentrations are reported for areas north of the site (4 µg/L to 61 µg/L in filtered samples from Wells MW-11D and MW-15D), areas east of the site (150 µg/L to 2,620 µg/L in filtered samples from Wells MW-12D and MW-14D and unfiltered samples from temporary well points at Soil Borings SB-51 through SB-53), and the southeastern and eastern portion of the site (3,100 µg/L to 3,700 µg/L in filtered samples from Wells MW-8D and MW-10D). Dissolved arsenic is present in the groundwater of the deep portion of the sand aquifer at the westernmost and easternmost extent of the monitoring network, even though the concentrations of arsenic detected in the samples from the temporary well points on the beach may be overestimated due to the presence of sediment in the samples. The likely southern extent of the presence of arsenic in groundwater of the deep portion of the sand aquifer is presented in Section 8.4.

There is some variability in the total dissolved arsenic concentrations between sampling events. The December 1993 data were generally consistent with data from the first sampling event at each well, with the exception of data for Well MW-4D (22,400 to 27,100 µg/L for April 1992 compared to 70,000 µg/L for November/December 1993), Well MW-8D (600 µg/L for September/October 1993

compared to 3,700 µg/L for November/December 1993), and Well MW-3D (7,110 µg/L for April 1992 compared to 18,000 µg/L for November/December 1993). At Well MW-13D, the total dissolved arsenic concentrations for the September/October 1993 and November/December 1993 samples are similar (27,200 µg/L and 28,000 µg/L, respectively), while the November/December 1993 duplicate sample has a reported total dissolved arsenic concentration of only 13,000 µg/L. The variability in total dissolved arsenic concentrations does not alter the overall characterization of the extent and magnitude of dissolved arsenic in the groundwater of the deep portion of the sand aquifer.

Arsenic speciation analyses were performed on groundwater samples collected in November/ December 1993. The data indicate that both dissolved Arsenic III and dissolved Arsenic V were typically present in the samples from the wells in the deep portion of the sand aquifer. In general, dissolved Arsenic III concentrations are one to two orders of magnitude greater than dissolved Arsenic V concentrations for those groundwater samples that have relatively high concentrations of total dissolved arsenic.

Saturated Soil Quality/Groundwater Quality Interactions. Except for 10 samples, the arsenic concentrations in saturated soil samples from directly above the till (the approximate screened interval of the deep portion of the sand aquifer) range from 1.8 mg/kg to 39 mg/kg. Most of the saturated soil samples from this interval have reported arsenic concentrations of greater than 10 mg/kg. The 10 samples with higher arsenic concentrations are Samples SB0912 (59 mg/kg), SB1011 (134 mg/kg), SB1713 (91 mg/kg), SB3613 (70 mg/kg), SB3913 (49 mg/kg), SB4112 (66 mg/kg), SB4412 (57 mg/kg), SB4613 (42 mg/kg), SB5612 (56 mg/kg), and PW0112 (250 mg/kg).

The area of the deep portion of the sand aquifer in which total dissolved arsenic concentrations in groundwater exceed 10,000 µg/L corresponds to the area in which arsenic concentrations in saturated soil exceed 10 mg/kg. In the same area of the shallow portion of the sand aquifer, the same soil concentrations are areally associated with groundwater concentrations that are two orders of magnitude smaller. The observation that arsenic concentrations in saturated soil samples from the deep portion of the sand aquifer are similar to or slightly higher than those in the shallow portion, while groundwater concentrations are orders of magnitude higher, is inconsistent with what would be observed if the soils in the vadose zone were the current source of arsenic in groundwater of the deep portion of the sand aquifer (namely, soil and groundwater concentrations both decreasing with depth or distance from the source).

Summary. In general, total dissolved arsenic concentrations in the deep portion of the sand aquifer are generally two orders of magnitude higher than the concentrations of total dissolved arsenic

reported in the samples from the wells in the shallow portion of the sand aquifer. Total dissolved arsenic concentrations in the deep portion of the sand aquifer are higher in the east-central, west-central, and north-central portions of the site and decrease to the north, east, and south. Arsenic is present in the groundwater of the deep portion of the sand aquifer at the westernmost and easternmost extent of the monitoring network. Most saturated soil samples from the deep portion of the sand aquifer have reported arsenic concentrations of greater than 10 mg/kg, but below 40 mg/kg. The distribution of arsenic in the groundwater and saturated soils of the shallow and deep portions of the sand aquifer indicates that shallow soils are not the current source of arsenic in the groundwater of the deep portion of the sand aquifer.

7.7.2.3.2 Cyanide

Groundwater Quality. Total dissolved cyanide concentrations in samples from the wells in the deep portion of the sand aquifer are presented on Figure 7.7-14.

Total dissolved cyanide concentrations in samples from wells in the deep portion of the sand aquifer range from 3 µg/L to 710 µg/L. These concentrations are approximately one order of magnitude higher than those in the samples from the shallow portion of the sand aquifer. The data show higher total dissolved cyanide concentrations for the southern edge of the site (130 µg/L to 610 µg/L for samples from Monitoring Wells MW-5D, MW-8D, and MW-10D) and declining concentrations of total dissolved cyanide to the northeast of the site (3 µg/L to 83 µg/L for samples from Monitoring Wells MW-14D and MW-15D). Cyanide is present in the groundwater of the deep portion of the sand aquifer at the westernmost and easternmost extent of the monitoring network, although the concentrations of total cyanide detected in the samples from the temporary well points on the beach may be overestimated due to sediment in the samples. The likely southern extent of the presence of cyanide in groundwater of the deep portion of the sand aquifer is presented in Section 8.4.

There is considerable variability in the total dissolved cyanide concentrations between sampling events. In the samples from all but a few wells, total dissolved cyanide concentrations decrease or increase by a factor of two to three times between sampling events. The variability does not affect the general pattern of distribution of cyanide in the deep portion of the sand aquifer.

Analysis of weak acid dissociable cyanide was performed on groundwater samples collected from all but one well (MW-14D) in November/December 1993. Weak acid dissociable cyanide is the analytical method used in the Illinois surface water standard for cyanide. Weak acid dissociable

cyanide is detected in the samples from all but two wells (MW-9D and MW-10D at a detection limit of 25 µg/L) at concentrations ranging from 25 µg/L to 255 µg/L. Most detections are 40 µg/L or less.

Saturated Soil Quality/Groundwater Quality Interactions. The cyanide concentrations in saturated soil samples from directly above the till (the approximate screened interval of the deep portion of the sand aquifer) are below 10 mg/kg. Most of the saturated soil samples from this interval that were collected from the southern and northeastern portions of the site have reported cyanide concentrations of greater than 1 mg/kg. Cyanide is generally not detected or detected at concentrations of less than 1 mg/kg outside of these areas.

In the area of the deep portion of the sand aquifer in which total dissolved cyanide concentrations in groundwater range from 100 to 500 µg/L, cyanide concentrations in saturated soil are 3.4 mg/kg or less. In the same area of the shallow portion of the sand aquifer, similar soil concentrations are associated with groundwater concentrations that were 10 to 50 times smaller. The observation that cyanide concentrations in saturated soil samples from the deep portion of the sand aquifer are similar to or slightly higher than those in the shallow portion, while groundwater concentrations are orders of magnitude higher, is inconsistent with what would be observed if the soils in the vadose zone were the source of cyanide in groundwater of the deep portion of the sand aquifer (namely, soil and groundwater concentrations both decreasing with depth or distance from the source).

Summary. In general, total dissolved cyanide concentrations are approximately one order of magnitude higher than those in the samples from the shallow portion of the sand aquifer. The data show higher dissolved cyanide concentrations for the southern half of the site with declining concentrations for areas northeast of the site. Cyanide is present in the groundwater of the deep portion of the sand aquifer at the westernmost and easternmost extent of the monitoring network. Weak acid dissociable cyanide was detected in the samples from all but two wells. The cyanide concentrations in saturated soil samples from directly above the till are below 10 mg/kg. The distribution of cyanide in the groundwater and saturated soils of the deep and shallow portions of the sand aquifer indicates that shallow soils are not the current source of cyanide in the groundwater of the deep portion of the sand aquifer.

7.7.2.3.3 Other Inorganic Parameters

Total dissolved cadmium, lead, mercury, and selenium concentrations in samples from the wells screened above the till in the deep portion of the sand aquifer are presented on Figure 7.7-15.

Cadmium. Groundwater analytical data for total dissolved cadmium for samples from the wells in the deep portion of the sand aquifer show reported concentrations ranging from not detected (at a detection limit of approximately 3 µg/L) to 51 µg/L. Most concentrations are higher than those detected in the samples from the wells screened in the shallow portion of sand aquifer. The highest concentrations are detected in samples from wells located in the north-central, east-central, and west-central portions of the site (Wells MW-1D, MW-3D, MW-4D, MW-5D, MW-6D, MW-7D, MW-9D, and MW-13D). Dissolved cadmium either is not detected or is detected at low concentrations (less than 5 µg/L) in wells located north (MW-11D and MW-15D), northeast (MW-14D), southeast (MW-12D and MW-8D), and south (MW-10D) of the site. Low total cadmium concentrations (5 µg/L to 8 µg/L) are also reported for the unfiltered samples from the temporary well points at Soil Borings SB-51 through SB-53, although these concentrations may be overestimated due to the presence of sediment in these samples.

In the saturated soils of the deep portion of the sand aquifer, cadmium is detected in only 10 samples at concentrations of up to 1.5 mg/kg. Only four of those samples have reported cadmium concentrations greater than 1 mg/kg. Cadmium is not detected (at detection limits of approximately 0.7 mg/kg) in any of the other soil samples from this zone. These data do not suggest a clearly definable areal trend.

Lead. Groundwater analytical data for total dissolved lead for samples from the wells in the deep portion of the sand aquifer show reported concentrations ranging from not detected (at a detection limit of 1.6 µg/L) to 16 µg/L. These concentrations are generally somewhat higher than those detected in samples from the shallow portion of the sand aquifer, but are not indicative of any clearly definable trend. There is considerable variability in the dissolved lead data, as dissolved lead is not detected (at a detection limit of 1.6 µg/L) in at least one round of sampling for each well.

Total lead is reported at concentrations of 58 µg/L to 120 µg/L in the unfiltered samples from the temporary well points at Soil Borings SB-51 through SB-53. These concentrations are likely overestimated due to the presence of sediment in the samples and are not considered to be representative of groundwater quality in this vicinity.

In the saturated soils of the deep portion of the sand aquifer, lead is detected in nine samples at concentrations of 5 mg/kg to 10 mg/kg. All of the other saturated soil samples from this zone have reported lead concentrations of less than 5 mg/kg, most of which range from 2 mg/kg to 4 mg/kg. These data do not suggest a clearly definable areal trend.

Mercury. Groundwater analytical data for total dissolved mercury for samples from the wells in the deep portion of the sand aquifer show reported concentrations ranging from not detected (at detection limits of 0.001 µg/L to 0.16 µg/L) to 0.44 µg/L. In one sample from each of Wells MW-6D, MW-7D, MW-10D, and MW-13D, total dissolved mercury is reported at concentrations of 0.14 µg/L to 0.44 µg/L. Dissolved mercury is not detected in the samples from these wells during the other sampling event and is not detected in any of the samples from the other wells. Total mercury is detected in two of the samples from the temporary well points at concentrations of up to 0.26 µg/L, however, these concentrations may be overestimated due to the presence of sediment in the samples. The mercury data do not suggest a clearly definable areal trend.

The concentrations of mercury in the saturated soil samples from the deep portion of the sand aquifer range from not detected (at a detection limit of 0.02 mg/kg) to 0.14 mg/kg. The data do not suggest a clearly definable areal trend.

Selenium. Groundwater analytical data for total dissolved selenium for samples from the wells in the deep portion of the sand aquifer show reported concentrations ranging from not detected (at a detection limit of approximately 1.5 µg/L) to 97 µg/L. These concentrations are higher than those detected in the samples from the shallow portion of the sand aquifer. In general, the highest reported total dissolved selenium concentrations are reported for samples from wells located in the east-central and west-central portions of the site (Wells MW-1D, MW-4D, MW-6D, and MW-9D) and from an area east of the site (MW-13D).

In the saturated soils of the deep portion of the sand aquifer, selenium is detected at 2 mg/kg in Sample PW0112 and at 3 mg/kg in Sample SB2612. All of the other detections of selenium in the saturated soil samples from the deep portion of the sand aquifer are below 2 mg/kg; most are below 1 mg/kg. The data do not suggest a clearly definable areal trend.

7.7.2.4 General Chemistry Parameters

This section of the report discusses the results for ammonia in the deep portion of the sand aquifer as it is the only general chemistry parameter listed in Section 6.0 as a key chemical parameter for the characterization of extent of contamination at the WCP site. This section also discusses the results for dissolved oxygen, redox potential, ammonia, nitrate, sulfide, and sulfate as they relate to determining whether aquifer conditions in both the shallow and deep portions of the aquifer are dominantly aerobic or anaerobic.

7.7.2.4.1 Ammonia

Groundwater Quality. Total ammonia concentrations in samples from the wells in the deep portion of the sand aquifer are presented on Figure 7.7-16. The November/December 1993 sampling event is the only sampling event for which samples were collected for analysis of ammonia.

In general, total ammonia concentrations in the deep portion of the sand aquifer are two to three orders of magnitude higher than those in the shallow portion of the sand aquifer. Ammonia concentrations in samples from wells in the deep portion of the sand aquifer range from 12,300 µg/L (in a sample from Well MW-4D) to 1,500,000 µg/L (in a sample from Well MW-8D). Generally, higher concentrations of ammonia are detected in samples from wells in the deep portion of the sand aquifer from the following areas of the site: west-central and central (Wells MW-1D and MW-6D); east-central and eastern (MW-4D, MW-7D, MW-9D, and MW-13D); southeastern (MW-8D); and north-central (MW-3D). Ammonia concentrations decrease to the north, east, and southwest.

Saturated Soil Quality/Groundwater Quality Interactions. Saturated soil samples were not collected for analysis of ammonia.

7.7.2.4.2 Other General Chemistry Parameters

The following section discusses the results for dissolved oxygen concentrations, redox potential, ammonia/nitrate concentrations, and sulfide/sulfate concentrations as they relate to determining whether aquifer conditions are dominantly aerobic or anaerobic in both the shallow and deep portions of the sand aquifer. A more thorough consideration of all general chemistry parameters will be addressed during the evaluation of potential remedial actions. Dissolved oxygen and redox potential results for samples from the shallow and deep portion of the sand aquifer are presented in Tables 4.3-1

and 4.3-2, respectively. The results for other general chemistry parameters are presented in Tables 4.3-11 and 4.3-12.

In general, dissolved oxygen is measured to determine whether aquifer conditions are aerobic or anaerobic. Several other general chemistry parameters such as redox potential, ammonia/nitrate concentrations, and sulfide/sulfate concentrations assist in the determination of aquifer conditions.

In general, when dissolved oxygen concentrations are above 2 mg/L, microorganisms utilize oxygen as an electron acceptor to oxidize organic chemical compounds to carbon dioxide, water, and biomass (McAllister and Chiang, 1994). At low dissolved oxygen concentrations (approximately ranging from 0.1 to 2 mg/L), secondary electron acceptors, such as nitrate, sulfate, and carbon dioxide, are used to oxidize organic chemical compounds. When anaerobic conditions prevail, the environment is in a reducing condition, as opposed to an oxidizing condition.

The dissolved oxygen measurements for samples from the wells screened in the shallow portion of the sand aquifer were compared statistically to those in the samples from the deep portion of the aquifer. There was no statistically significant difference between the measured dissolved oxygen concentrations in samples from the two aquifer zones based on an unpaired t-test analysis. Tables 4.3-1 and 4.3-2 show that the dissolved oxygen concentrations in the samples from shallow wells are generally higher than those in samples from the corresponding wells in the deep portion of the sand aquifer. These results imply that aerobic biodegradation (oxidation) likely has a greater effect in the shallow portion of the sand aquifer than in the deep portion.

Measurement of redox potential provides a good qualitative indicator of the overall oxidation/reduction status of the aquifer. For aquifer areas in which the redox potential is positive, the groundwater is oxidizing. When the redox potential is negative, conditions are reducing. In general, it is difficult to determine whether conditions at the WCP site are clearly oxidizing or reducing in either aquifer zone based on the measured redox potentials of samples from the wells. However, the measured redox potentials in the samples from shallow wells generally appear to be more positive than those in samples from the corresponding wells in the deep portion of the sand aquifer.

When ammonia is present under aerobic conditions, aerobic microorganisms may nitrify the ammonia to nitrite and then nitrate. When the oxygen supply is depleted and nitrate is present, some microorganisms will use nitrate as an electron acceptor instead of oxygen. With few exceptions, nitrate was not detected in the samples from the monitoring wells, implying either that the nitrate

in the system has been consumed by organisms or that nitrification under aerobic conditions probably is not occurring.

When the oxygen and nitrate supply is depleted, some microorganisms may use sulfate as an electron acceptor, although it is not as preferred as other acceptors because microorganisms gain less energy from it (Borden, 1994). If used as an electron acceptor, sulfate will be reduced to sulfide. The reported sulfide concentrations in the samples from the wells in both the shallow and deep portions of the aquifer are too low to conclude that such conditions exist.

In summary, dissolved oxygen and redox potential results indicate that conditions are likely more aerobic and oxidizing in the shallow portion of the sand aquifer than in the deep portion. This indication is reasonable considering the likely influx of dissolved oxygen to the shallow portion of the aquifer from infiltrating precipitation. The evaluation of ammonia/nitrate and sulfate/sulfide concentrations is inconclusive with regard to determining whether conditions in either portion of the aquifer are dominantly aerobic or anaerobic.

7.7.2.5 Summary

This subsection summarizes the previous subsections in which the magnitude and extent of key chemical parameters in groundwater and saturated soils in the deep portion of the sand aquifer at the WCP site were discussed. The key chemical parameters are phenol (representative of phenolic compounds), total and carcinogenic PAHs, benzene (representative of BETX compounds), ammonia, and total dissolved arsenic, cyanide, lead, mercury, cadmium, and selenium. In general, the groundwater data from the deep portion of the sand aquifer indicate that most key parameters are found at the highest concentrations in the central portions of the site and that concentrations diminish to the north and east. Except for PAHs, the presence of these parameters in the deep portion of the sand aquifer is much more extensive and at higher concentrations than in the shallow portion of the sand aquifer. Concentrations are generally orders of magnitude higher in the deep portion of the sand aquifer than in the shallow.

Groundwater data from the deep portion of the sand aquifer indicate that organic compounds reach the westernmost points of the monitoring network, but show rapid declines in concentrations to the east. Inorganic parameters reach the westernmost and easternmost points of the monitoring network. The full extent of the presence of most of these parameters is not defined to the south. This matter is addressed in Section 8.4.

Saturated soil concentrations for all compounds except phenol are significantly less than the concentrations of these compounds in vadose zone soils. The concentrations of benzene, cyanide, and arsenic remain the same or increase slightly in saturated soils from the shallow to the deep portion of the sand aquifer. Phenol concentrations increase significantly as a result of adsorption from groundwater.

For PAHs and phenol, the groundwater concentrations and/or distribution patterns of these parameters in the deep portion of the sand aquifer are consistent with expectations for soil-water interactions given the concentrations and distribution of these parameters in the saturated soils of this zone. As would be expected given that PAHs are highly insoluble in water, only the most mobile PAH compound, naphthalene, is detected in groundwater in the deep portion of the sand aquifer and then only in the immediate vicinity of soils containing PAHs. High concentrations of phenolic compounds are detected in the soils of this zone and the concentrations of phenol in the soils are generally in equilibrium with the concentrations of phenol in the groundwater.

For benzene, arsenic, and cyanide, soil concentrations in the deep portion of the sand aquifer are similar to or slightly higher than those in the shallow portion of the sand aquifer, while groundwater concentrations increase by orders of magnitude. This observation is inconsistent with what would be observed if the soils in the vadose zone were the current source of these parameters in groundwater of the deep portion of the sand aquifer, namely, soil and groundwater concentrations both decreasing with depth or distance from the source.

While dissolved concentrations of cadmium and selenium are generally higher in samples from wells located in the central portion of the site, no other clearly definable trends are evident. The dissolved concentrations of lead and mercury are low and clearly definable trends could not be established. Ammonia has a distribution similar to that of phenol, benzene, arsenic, and cyanide.

Field observations and analytical data indicate that no DNAPL presence is evidence at the site that could account for the observed distribution of key parameters in the groundwater in the deep portion of the sand aquifer.

Finally, dissolved oxygen and redox potential results indicate that conditions are likely more aerobic and oxidizing in the shallow portion of the sand aquifer than in the deep portion. This indication is reasonable considering the likely influx of dissolved oxygen to the shallow portion of the aquifer from infiltrating precipitation.

7.7.3 Summary and Conclusions

The observed distribution of key chemical parameters in the groundwater and saturated soils at the WCP site indicate the following:

- PAH concentrations in saturated soil decrease significantly with depth and detections of PAHs above parts per trillion concentrations in groundwater at the site are limited to detections of the most mobile PAH compounds in samples from upgradient wells or wells within or immediately adjacent to soils containing PAHs.

- Both inorganic (arsenic and cyanide) and organic parameters (phenol and benzene) are present over a greater extent and at higher concentrations in the groundwater of the deep portion of the sand aquifer than in the shallow portion.

- Groundwater data from the deep portion of the sand aquifer indicate that inorganic parameters reach the westernmost and easternmost points of the monitoring network. The concentrations of these inorganic parameters decrease significantly or are not detected north of the site. The southern extent of these compounds is not fully defined by the monitoring data to the south (see Section 8.4 for a discussion of this matter).

- Groundwater data from the deep portion of the sand aquifer indicate that organic compounds reach the westernmost points of the monitoring network, but show rapid declines in concentrations to the east. The concentrations of organic compounds decrease significantly or are not detected north of the site. The southern extent of these compounds is not fully defined by the monitoring data to the south (see Section 8.4 for a discussion of this matter).

- While phenol is generally not detected in the soils and groundwater of the shallow portion of the sand aquifer, it is present in high concentrations in both the groundwater and the saturated soils of the deep portion of the sand aquifer. The soil and groundwater concentrations are in equilibrium with each other, indicating that soil concentrations in the deep portion of the sand aquifer are the result of adsorption of phenol from groundwater.

- For benzene, arsenic, and cyanide, the groundwater concentrations and/or distribution patterns in the shallow portion of the sand aquifer are consistent with expectations for

soil-water interactions given the concentrations and distributions of these parameters in the saturated soils of this zone. Benzene concentrations are generally in equilibrium with soil concentrations. The highest dissolved groundwater concentrations of arsenic and cyanide are spatially associated with the highest saturated soil concentrations of those compounds.

- For benzene, arsenic, and cyanide, saturated soil concentrations in the deep portion of the sand aquifer are similar to or slightly higher than those in the shallow portion of the sand aquifer, while groundwater concentrations are orders of magnitude higher. This observation is inconsistent with what would be observed if the soils in the vadose zone were the current source of these parameters in groundwater of the deep portion of the sand aquifer, namely, soil and groundwater concentrations both decreasing with depth or distance from the source.

- DNAPL is not the source of key site parameters in the groundwater of the deep portion of the sand aquifer. The results of the test trenching completed during the first phase of the field investigation indicated areas of vadose zone soils that exhibited visible contamination. As such, the second phase of the field investigation was designed to specifically investigate the potential presence of DNAPL in the sand aquifer. Soil borings were placed at approximate 100-foot centers along transects in and through those areas exhibiting visible contamination in the vadose zone. Each soil boring was advanced to the top of the till and sampled at nearly continuous intervals with a split-spoon sampler. A split-spoon sample from immediately above the till was specifically collected from each boring at the contact between the sand unit and the top of the till. Field screening, which consisted of recording observations of discoloration and odor, testing for the presence of an oil sheen, and measuring headspace organic vapor concentrations, was performed on each sample. An analytical sample was collected from every soil boring from the interval just above the top of the till unit for the specific purpose of assessing the presence of PAHs as DNAPL. Finally, monitoring wells in the deep portion of the sand aquifer were specifically screened in the interval immediately above the till.

For the following reasons, neither the field observations nor the analytical results from the field investigation activities described above indicated the presence of DNAPL deposits at the site that could account for the observed distribution of key parameters in the groundwater in the deep portion of the sand aquifer:

1. No evidence of the presence of DNAPL was observed during the installation, development, or sampling of the monitoring wells. The analytical results for groundwater samples from the wells screened in the deep portion of the sand aquifer did not indicate the presence of DNAPL at the top of the till.

2. DNAPL, if present at this site, would have accumulated in depressions in the surface of the till and would have been readily apparent in the soil boring samples. Borings placed in till surface depressions (shown on Figure 5.1-5) found no DNAPL. The only instance in which an apparent DNAPL was reported (the presence of a golden-brown oil [coal tar or creosote DNAPL is black and viscous] coating the grains of gravel in the thin [less than 2.5 inches] gravel seam immediately above the till at Soil Boring SB-41) was not accompanied by DNAPL presence in the till depression immediately to the northeast (P-108) or in the draw to the south (SB-45, SB-50, and SB-59).

3. The visual absence of DNAPL described above is consistent with the reported distribution of PAH concentrations in the samples from the soil borings. Even in areas of visible contamination in vadose zone soils, PAH concentrations declined rapidly with depth beneath the water table. Total PAH concentrations did not increase at the top of the till, nor did they approach saturation concentrations. Thus, even in those areas in which DNAPL would most likely be encountered, no DNAPL was observed.

4. DNAPL at the top of the till cannot account for the observed distribution of organic contaminants in the groundwater of the deep portion of the sand aquifer. If that had been the case, naphthalene (or any other relatively mobile PAH constituent of DNAPL) would have been widespread in groundwater as are benzene and phenol, and visible DNAPL would have been found in extensive areas at the top of the till.

5. Finally, inorganic compounds, such as arsenic, cyanide, ammonia, and thiocyanate, exhibit the same stratification in groundwater (i.e., much higher concentrations at depth) as do the organic compounds, although the inorganic compounds would not have been present in DNAPLs associated with creosoting or coking/manufactured gas processes. Thus, DNAPL is not the source of these compounds in the groundwater.

- Finally, dissolved oxygen and redox potential results indicate that conditions are likely more aerobic and oxidizing in the shallow portion of the sand aquifer than in the deep portion. This indication is reasonable considering the likely influx of dissolved oxygen to the shallow portion of the aquifer from infiltrating precipitation.

7.8 SURFACE WATER AND SEDIMENT CONTAMINATION DISTRIBUTION

Surface water data from the RI are reviewed and compared to water quality standards in this section. Past surface water data are summarized and possible trends in water quality in Waukegan Harbor are noted.

The rationale for not collecting sediment samples during the RI is also presented.

7.8.1 Surface Water Quality

The water quality of Lake Michigan and Waukegan Harbor was monitored to evaluate potential impacts on surface water associated with chemical migration from the WCP site. Because other sources, including nonpoint sources, are contributing contaminants to the harbor and the lake, the chemicals detected in the surface water samples collected during this investigation or previous studies are thought to be from numerous sources along the lake and harbor. The WCP site is located immediately south of a series of industries on Lake Michigan, including Johns-Manville, Commonwealth Edison, the NSSD, former industrial plants and disposal areas, and OMC to the north. Facilities adjacent to the WCP site include National Gypsum, Polyfoam Packers, LaFarge, and Larsen Marine. South of the WCP site are OMC, Dexter Corporation, Diamond Scrap Yard, and other active or abandoned facilities. It is beyond the scope of this review to assess the contribution of each contaminant source to the degradation of water quality in the lake or harbor.

Water samples were collected from five locations within the harbor and seven locations in the near-shore waters of Lake Michigan near the WCP site (see Figure 4.4-1. The water quality data from this investigation were supplemented with data from previous studies discussed in Section 3.6. The following sections summarize the surface water quality data for Lake Michigan and Waukegan Harbor, provide comparisons to potentially applicable water quality standards and potentially relevant criteria, and provide comparisons with other Lake Michigan and Waukegan Harbor water quality studies.

7.8.1.1 Lake Michigan

Lake Michigan is located east of the site across Sea Horse Drive and Waukegan Beach. The water samples from Lake Michigan were collected from approximately 300 to 1,700 feet from the shoreline of the lake east and southeast of the WCP site. The depth of sampling ranged from 2 to 22 feet below the surface. The sampling activities and analyses are presented in Section 4.4, Tables 4.4-1 through 4.4-6, and Figure 4.4-1.

7.8.1.1.1 Summary of Lake Michigan Water Quality Results

A summary of the analytical results of the surface water samples collected from Lake Michigan is provided in Tables 4.4-1 through 4.4-6. In general, the volatile and semivolatile organic compounds were either not detected or detected at low concentrations. Figures 7.8-1, 7.8-2, and 7.8-3 present the analytical results for total PAH concentrations in the 1993 RI surface water samples, BETX concentrations in the 1993 RI surface water samples, and BETX concentrations in the 1988 surface water samples, respectively.

The BETX concentrations reported for the lake samples collected on August 30-31, 1993, are shown on Figure 7.8-2. The only lake sample with a reported concentration was SW-04D, for which an estimated concentration of 1 µg/L was reported for toluene. That concentration is one-tenth of the CRDL of 10 µg/L.

Surface water BETX results for samples collected in 1988 are shown on Figure 7.8-3. A sample collected 200 feet east of North Ditch (Sample 6) was reported to have 11 µg/L benzene, 5 µg/L toluene, and 60 µg/L xylenes. The other lake sample (Sample 4) from the city water intake had no detected BETX compounds.

Two volatile organic compounds in addition to toluene were reported in the 1993 surface water samples. Trichloroethylene was reported at an estimated concentration of 5 µg/L, one-half the CRDL of 10 µg/L, in Sample SW-01D, which was collected opposite OMC Plant No. 2, north of the WCP site. Acetone was reported, generally at a concentration below the CRDL (10 µg/L), in lake surface water samples. Based on the laboratory blanks, acetone is a suspected laboratory contaminant.

The 1988 sampling reported no detections of volatile organic compounds (except a suspected laboratory contaminant, acetone) at the city water intake (Sample 4). The sample collected 200 feet east of North Ditch (Sample 6) reported an estimated 3 µg/L trichloroethylene, an estimated 4 µg/L

1,1,1-trichloroethane, 140 µg/L 1,2-dichloroethylenes, 8 µg/L 1,1-dichloroethane, and 65 µg/L vinyl chloride. The laboratory reports for the 1988 sampling are in Appendix 3-E of the PSCS.

The semivolatile organic compounds that were detected were at low levels (i.e., 0.00304 µg/L to 0.00964 µg/L) in the lake samples. The following PAH compounds were detected: -fluoranthene; fluorene; phenanthrene; and pyrene. Total PAH concentrations are shown on Figure 7.8-1. The highest concentrations of these PAH compounds were primarily reported for samples collected near the entrance channel to Waukegan Harbor.

Inorganic parameters detected in the lake samples consist of total arsenic, cadmium, lead, and mercury. The inorganic parameters detected in the samples were primarily at concentrations less than the CRDL, but greater than or equal to the IDL.

Ammonia, total cyanide, weak acid dissociable cyanide, amenable cyanide, and thiocyanate were not detected in any of the samples from Lake Michigan. The detection limit for total cyanide ranged from 0.96 µg/L to 4.8 µg/L. The detection limits for ammonia, weak acid dissociable cyanide, amenable cyanide, and thiocyanate were 200 µg/L, 5.0 µg/L, 5.0 µg/L, and 100 µg/L, respectively.

7.8.1.1.2 Water Quality Standards and Criteria

The water quality data from Lake Michigan were compared to the potentially applicable water quality standards and potentially relevant criteria shown in Table 7.8-1. These standards and criteria include the following:

- Illinois Water Quality Standards (IWQS);
- Federal Ambient Water Quality Criteria (FAWQC); and
- Great Lakes Water Quality Initiative Criteria (GLWQIC).

The IWQS are potentially applicable standards for Lake Michigan water quality. The FAWQC and GLWQIC were reviewed because they represent water quality information that may be useful in evaluating potential impacts to aquatic organisms.

The IWQS were exceeded only for total cadmium. The chronic general use standard was exceeded in Samples SW-01D, SW-03D, SW-05D, and SW-06S. All these exceedences were based on reported sample values less than the CRDL. The acute general use standard was exceeded in Sample SW-03D. Ammonia was not detected in any of the lake samples at a detection limit of

200 µg/L. This detection limit is below the general use and public water and food supply IWQS, but above the Lake Michigan IWQS of 20 µg/L. All other detection limits were less than the standards.

The water quality criteria (FAWQC and GLWQIC) for three metals were exceeded in several surface water samples collected from Lake Michigan. Samples SW-01D, SW-03D, SW-05D, and SW-06S exceeded the acute and chronic FAWQC, and the acute and chronic GLWQIC for total cadmium. The chronic FAWQC for total lead was exceeded in Samples SW-01D, SW-04D, SW-07S, SW-07D. No samples exceeded the acute criteria for total lead. The GLWQIC wildlife criteria for total mercury was exceeded in Lake Michigan Samples SW-01D and SW-04S.

7.8.1.1.3 Other Lake Michigan Water Quality Studies

The analytical results of the lake samples collected for the remedial investigation were compared to the results of other water quality studies in Lake Michigan near Waukegan Harbor. The mean and range of parameters that were more frequently detected in the investigations are provided in Table 7.8-2. Based on these limited comparisons, it appears that the surface water samples collected and analyzed for the RI show that mean concentrations of parameters in the near-shore area are within the typical concentration range in previous sampling of Lake Michigan.

7.8.1.2 Waukegan Harbor

The Waukegan Harbor is located along the western edge, and south of, the WCP site. The harbor is considered to include the main inner harbor, the entrance channel, and two boat slips (Slips No. 1 and No. 4). Slip No. 4 was constructed in the northwest corner of the WCP site in 1991. Surface water sampling locations in the harbor for the RI consisted of a station in Slip No. 4, a station in the entrance channel, and three stations within the inner harbor. Samples were collected at depths ranging from 2 to 22 feet below the surface. The sampling activities and analyses are presented in Section 4.4, Tables 4.4-1 through 4.4-6, and Figure 4.4-1.

7.8.1.2.1 Summary of Waukegan Harbor Water Quality Results

A summary of the analytical results of the surface water samples collected from Waukegan Harbor is provided in Tables 4.4-1 through 4.4-6. Volatile organic compounds, semivolatile organic compounds, and total metals were detected in all samples collected from the harbor. In general, the concentrations of these chemicals were highest at Station SW-10 in the inner harbor south of the WCP site. Concentrations decreased both north and south of this station.

The volatile organic compounds most frequently detected in the harbor samples were BETX compounds. The concentrations of these four compounds (BETX) at each 1993 sampling station in the harbor are shown on Figure 7.8-2. The highest concentrations of BETX compounds were detected at Station SW-10, and the lowest concentrations in the harbor were detected at Station SW-12 in Slip No. 4. These volatile organic compounds were not, however, detected in the samples collected from the outer harbor area in Lake Michigan (Station SW-07).

Surface water samples collected from the harbor in 1988 were analyzed for volatile organic compounds. BETX compounds were the predominant volatile organic compounds detected in the harbor water samples. Acetone and methylene chloride, likely laboratory contaminants, were reported in some samples. Figure 7.8-3 shows the reported BETX concentrations for the 1988 sampling. The highest concentration was reported for the sampling location adjacent to the OMC motor testing area (Sample 7 reported a BETX sum of about 1,600 µg/L). BETX concentrations decreased with distance from the OMC motor testing area to a sum of about 17 µg/L at the harbor entrance (Sample 2). These volatile organic compounds were not detected in the city's water sample from the water intake located in Lake Michigan a mile and a quarter from shore (Sample 4). The laboratory reports for the 1988 surface water sampling are in Appendix 3-E of the PSCS.

The semivolatile organic compounds most frequently detected in the harbor samples were the following PAH compounds: benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, indeno(1,2,3-cd)pyrene, benzo(g,h,i)perylene, fluoranthene, fluorene, and pyrene. Fluoranthene and pyrene were typically detected at the highest concentrations in the harbor samples. The sums of the carcinogenic PAH compounds ranged from not detected in Samples SW-09D, SW-10D, SW-10S, and SW-12D to 0.0450 µg/L in Sample SW-11D. The sums of total PAH compounds (Figure 7.8-1) ranged from not detected in Samples SW-10D and SW-10S to 0.0998 µg/L at Station SW-11D. Matrix interferences during the analysis of samples collected from Station SW-10 resulted in higher detection limits for PAH compounds than at the other sampling stations.

The inorganic parameters detected most frequently in the harbor samples were total arsenic and lead. Total arsenic was detected at concentrations up to 3.0 µg/L. Total lead was detected at concentrations up to 3.7 µg/L. These parameters were primarily detected at concentrations between the CRDL and the IDL.

Ammonia, total cyanide, weak acid dissociable cyanide, amenable cyanide, and thiocyanate were not detected in any of the samples from Waukegan Harbor. The detection limit for total cyanide ranged from 0.96 µg/L to 13.3 µg/L. The detection limits for weak acid dissociable and amenable

cyanide were 5.0 µg/L for all but three samples and 25 µg/L for those three samples. The detection limits for ammonia and thiocyanate were 200 µg/L and 100 µg/L, respectively.

Total mercury and cadmium were detected in some lake samples, but in no harbor samples. The concentrations of total arsenic and lead in the harbor samples were slightly higher than concentrations in the lake samples.

7.8.1.2.2 Water Quality Standards and Criteria

The water quality data from Waukegan Harbor were compared to the potentially applicable water quality standards and potentially relevant criteria shown in Table 7.8-1. No samples exceeded the water quality standards. Ammonia was not detected in any of the harbor samples at a detection limit of 200 µg/L. This detection limit is below the general use and public water and food supply IWQS, but above the Lake Michigan IWQS of 20 µg/L. Weak acid dissociable cyanide was not detected in any harbor samples. However, the detection limit for three samples was above the acute and chronic general use IWQS for weak acid dissociable cyanide. The detection limits were otherwise less than the standards.

The water quality criteria (chronic FAWQC) for total lead was exceeded in samples collected from all surface water stations in the harbor except Station SW-12 in Slip No. 4. No samples exceeded the acute criteria for total lead.

7.8.1.2.3 Other Waukegan Harbor Water Quality Studies

The analytical results of the harbor samples collected for the remedial investigation were compared to the results of other water quality studies in Waukegan Harbor. The mean and range of parameters that are more frequently detected in the investigations are provided in Table 7.8-3. Based on the comparisons of these data, and based on the BETX data on Figures 7.8-2 and 7.8-3, the concentrations of total cyanide and the BETX compounds have decreased in the harbor waters during the last three to five years. The 1991 dredging of the northern portion of the harbor may have favorably affected harbor water quality.

7.8.2 Sediment Quality

As discussed in Section 3.5, several sediment investigations have been conducted in and/or near the Waukegan Harbor since 1977. Based on the results of these investigations, it is apparent that the sediment in the harbor became contaminated with several chemicals, including PCBs and metals. The PCB contamination in the sediments was addressed as part of the remedy for the Waukegan Harbor Superfund Site. The remedy for the harbor consisted of dredging the sediments in the central portion of the northern half of the harbor to a depth of approximately 25 feet and disposing of the dredged material in the Slip No. 3 containment facility. The dredging of the contaminated sediments was completed in 1991.

Sediment samples were not collected and analyzed during this RI. Existing data on sediment quality in Waukegan Harbor and Lake Michigan was not further evaluated in the RI for the following reasons:

- Numerous sediment investigations have previously been conducted in the harbor and the lake.
- The potential sources of contaminants in the sediment are numerous, so sediment quality data would not be representative of WCP site impacts.
- Limited sediment criteria are available to assess the significance of any contaminants detected.
- Lake-going ship traffic and other activities such as intense marine engine testing disrupt the harbor aquatic environment in the harbor entrance channel up to Slip No. 1.
- The sediments in the north half of the harbor were disrupted by the 1991 dredging activities, with consequent disruptions to the aquatic environment.
- Plans to dredge most of the remainder of the harbor are being developed by the U.S. Army Corps of Engineers. Users of Slip No. 1 have indicated interest in dredging the slip and its entrance once the U.S. Army Corps of Engineers obtains a dredge spoils disposal site (Walker, 1994).

- The sediments in the near-shore area of the lake are constantly accreting and, thus, are not expected to be representative of steady-state conditions.

- The entrance to the harbor east of the piers, referred to as the outer harbor, is dredged on a nearly annual basis (see Section 2.2.4) due to the sediment accretion in the near-shore area.

7.8.3 Summary

This review of the surface water quality samples found the only exceedences of IWQS in Lake Michigan samples to be for total cadmium.

There were no exceedences of IWQS in the samples collected from Waukegan Harbor during the RI.

The water quality in Waukegan Harbor appears to have improved as compared to water quality reported from 1988 through 1991.

Dredging of the harbor sediments, which is repeated periodically, alters the sediment quality and ecological conditions in the harbor; therefore, no sediment sampling was performed in the RI investigation.

7.9 EXTENT OF CONTAMINATION SUMMARY

This section of the RI report restates the main conclusions that can be drawn from the extent of contamination data discussed in Section 7.0. Section 7.0 discusses the distribution of PCBs, as well as the distribution of key chemical parameters in background soils, ground surface soils, soil stockpile soils, vadose zone soils, groundwater and saturated soils, and surface water and sediments at or in the vicinity of the WCP site.

7.9.1 Distribution of PCBs

It is reasonable to conclude from the soil and groundwater sampling that PCBs are not widespread at the WCP site. Those areas where PCBs are found appear to be associated with storage by OMC of oils containing PCBs.

7.9.2 Background Soil Chemical Concentrations

The background soil samples (Samples BS-01 through BS-08, GS-01, GS-02, and GS-04) provide information on the character of off-site soils in the general vicinity of the WCP site. The data indicate that, with the exception of phenolic compounds, all key chemical parameters were detected in background soils. Arsenic is detected at concentrations ranging from 2 to 235 mg/kg. It is routinely detected at concentrations of 10 mg/kg or less. Cyanide is generally reported as not detected. All detections of cyanide were at concentrations less than 1.4 mg/kg. Cadmium is reported in several samples at concentrations ranging from about 1 mg/kg to 7 mg/kg. Lead is detected in all the background samples at concentrations generally in the range of 3 mg/kg to 10 mg/kg, but ranging as high as 430 mg/kg. Mercury is reported in background samples at concentrations of 0.1 to 1.7 mg/kg. Selenium is reported at concentrations of 0.55 to 0.93 mg/kg. Sums of BETX compounds are reported in most of the background samples at concentrations up to 9 µg/kg. Total PAHs and carcinogenic PAHs are reported in most background soil samples at concentrations ranging from 0.1 to 19 mg/kg and 0.04 to 10 mg/kg, respectively. PCBs are also reported in background samples at concentrations up to 23 mg/kg.

7.9.3 Ground Surface Soil Contamination Distribution

The ground surface soil data indicate that those samples containing visible or solid residues (i.e., blue or black staining, clinkers, slag) are also likely to display concentrations of total PAHs greater than 100 mg/kg. The only ground surface sample with a cyanide concentration above 5 mg/kg exhibited a blue tint. The ground surface soil samples with the highest concentrations of total PAHs also have the highest concentrations of inorganic parameters. Arsenic is detected at a maximum concentration of 164 mg/kg, but is detected above 40 mg/kg in only three ground surface soil samples. Cadmium is not detected above a concentration of 3.5 mg/kg. Lead is detected at a concentration of 128 mg/kg in one ground surface soil sample and is otherwise detected at concentrations of less than 100 mg/kg. Mercury is detected at a maximum concentration of 38 mg/kg, but is detected above a concentration of 1 mg/kg in only three samples. Selenium is detected at a maximum concentration of 4.9 mg/kg, but is detected at concentrations of less than 1.3 mg/kg in all but two ground surface soil samples. Phenolic and BETX compounds are not detected above total concentrations of 0.6 mg/kg and 7 µg/kg, respectively.

7.9.4 Soil Stockpiles Contamination Distribution

Except one sample, total PAHs are not detected at concentrations of greater than 6 mg/kg in the samples from the dredge spoils soil stockpile. Cyanide, cadmium, mercury, selenium, phenolic compounds, and BETX compounds are not reported as present in these samples. Except for the reported lead concentration in one sample, arsenic and lead are not reported at concentrations greater than 10 mg/kg. PCBs were detected in three samples at concentrations of less than 2 mg/kg.

The soil samples from the designated soil stockpile exhibit concentrations of total PAHs that range from 194 to 221 mg/kg. Phenolic compounds, BETX compounds, and mercury are not detected. Detected concentrations of arsenic and lead are 14.1 mg/kg or less. Cyanide and selenium are detected in only one sample at concentrations below the CRDL. Cadmium is detected in only one sample. PCBs were detected in one sample at a concentration of 3 mg/kg.

7.9.5 Vadose Zone Soil Contamination Distribution

The field screening and analytical data for samples collected from vadose zone soils indicate the following:

- Total PAH concentrations of up to 76,000 mg/kg are present in vadose zone soils in the eastern and west-central areas of the site within the area delineated by the 100 mg/kg total PAH concentration contour shown on Figure 7.6-1.

- Benzene concentrations above 1 mg/kg are associated with total PAH concentrations of greater than 100 mg/kg.

- Arsenic, cyanide, and selenium are at concentrations above 10 mg/kg, 1 mg/kg, and 1.7 mg/kg, respectively, in samples from the eastern portion of the site. Mercury is detected at concentrations of greater than 1 mg/kg in the east-central portion of the site and a limited area in the northeastern corner of the site. The highest concentrations of these compounds are not directly associated with the highest concentrations of PAHs and benzene.

- Lead and cadmium are generally not present at concentrations above 80 mg/kg and 3 mg/kg, respectively, in vadose zone soils.

7.9.6 Groundwater and Saturated Soil Contamination Distribution

The observed vertical distribution of key chemical parameters in the vadose zone soils and in the groundwater and saturated soils at the WCP site are summarized in Table 7.9-1. The observed vertical distribution of these parameters indicate that: (1) vadose zone soils act as a contributory source to observed concentrations of some key site chemicals in the groundwater of the shallow and deep portions of the sand aquifer; (2) vadose zone soils are not the current source of high concentrations of key chemicals in the groundwater of the deep portion of the sand aquifer; and (3) no DNAPL presence is evident at the site that could account for the observed distribution of key parameters in the groundwater in the deep portion of the sand aquifer.

The highest groundwater concentrations of inorganic parameters (total dissolved arsenic and cyanide) in the shallow portion of the sand aquifer are spatially associated with the highest concentrations of these parameters in vadose zone soils. Detections of PAHs in groundwater samples from the shallow portion of the sand aquifer are limited to detections of the most mobile PAH compounds in samples from wells within or immediately adjacent to soil containing PAHs.

Vadose zone soils are not the current source of concentrations of phenol, benzene, arsenic, and cyanide in the groundwater of the deep portion of the sand aquifer. The following considerations support this conclusion:

- Both inorganic (total dissolved arsenic and cyanide) and organic parameters (phenol and benzene) are present over a greater extent and at higher concentrations in the groundwater in the deep portion of the sand aquifer than in the shallow portion (Table 7.9-1).

- While phenol is generally not detected in vadose zone soils or in the groundwater and soils of the shallow portion of the sand aquifer, it is present at concentrations in the part-per-million range in both the groundwater and saturated soils of the deep portion of the sand aquifer (Table 7.9-1).

- While benzene, arsenic, and cyanide concentrations decrease significantly between the vadose zone and saturated soils of the shallow portion of the sand aquifer and remain constant or increase slightly between the saturated soils of the shallow and deep portions of the sand aquifer, their groundwater concentrations increase by orders of magnitude with depth (Table 7.9-1). This observation is inconsistent with what would be observed

if the soils in the vadose zone were the current source of these parameters in groundwater of the deep portion of the sand aquifer, namely, soil and groundwater concentrations both decreasing continuously with depth or distance from the source.

No DNAPL presence is evident at the site that could account for the observed distribution of key parameters in groundwater of the deep portion of the sand aquifer. The results of the test trenching completed during the first phase of the field investigation indicated areas of vadose zone soils that exhibited visible contamination. As such, the second phase of the field investigation was designed to specifically investigate the potential presence of DNAPL in the sand aquifer. Soil borings were placed at approximate 100-foot centers along transects in and through those areas exhibiting visible contamination in the vadose zone. Each soil boring was advanced to the top of the till and sampled at nearly continuous intervals with a split-spoon sampler. A split-spoon sample from immediately above the till was specifically collected from each boring at the contact between the sand unit and the top of the till. Field screening, which consisted of recording observations of discoloration and odor, testing for the presence of an oil sheen, and measuring headspace organic vapor concentrations, was performed on each sample. An analytical sample was collected from every soil boring from the interval just above the top of the till unit for the specific purpose of assessing the presence of PAHs as DNAPL. Finally, monitoring wells in the deep portion of the sand aquifer were specifically screened in the interval immediately above the till.

For the following reasons, neither the field observations nor the analytical results from the field investigation activities described above indicated the presence of DNAPL deposits at the site that could account for the observed distribution of key parameters in the groundwater in the deep portion of the sand aquifer:

1. No evidence of the presence of DNAPL was observed during the installation, development, or sampling of the monitoring wells. The analytical results for groundwater samples from the wells screened in the deep portion of the sand aquifer did not indicate the presence of DNAPL at the top of the till.

2. DNAPL, if present at this site, would have accumulated in depressions in the surface of the till and would have been readily apparent in the soil boring samples. Borings placed in till surface depressions (shown on Figure 5.1-5) found no DNAPL. The only instance in which an apparent DNAPL was reported (the presence of a golden-brown oil [coal tar or creosote DNAPL is black and viscous] coating the grains of gravel in the thin [less than 2.5 inches] gravel seam immediately above the till at Soil Boring SB-41) was not

accompanied by DNAPL presence in the till depression immediately to the northeast (P-108) or in the draw to the south (SB-45, SB-50, and SB-59).

3. The visual absence of DNAPL described above is consistent with the reported distribution of PAH concentrations in the samples from the soil borings. Even in areas of visible contamination in vadose zone soils, PAH concentrations declined rapidly with depth beneath the water table. Total PAH concentrations did not increase at the top of the till, nor did they approach saturation concentrations. Thus, even in those areas in which DNAPL would most likely be encountered, no DNAPL was observed.

4. DNAPL at the top of the till cannot account for the observed distribution of organic contaminants in the groundwater of the deep portion of the sand aquifer. If that had been the case, naphthalene (or any other relatively mobile PAH constituent of DNAPL) would have been widespread in groundwater as are benzene and phenol, and visible DNAPL would have been found in extensive areas at the top of the till.

5. Finally, inorganic compounds, such as arsenic, cyanide, ammonia, and thiocyanate, exhibit the same stratification in groundwater (i.e., much higher concentrations at depth) as do the organic compounds, although the inorganic compounds would not have been present in DNAPLs associated with creosoting or coking/manufactured gas processes. Thus, DNAPL is not the source of these compounds in groundwater.

The observed vertical distribution of key parameters in the vadose zone soils and groundwater and saturated soils at the site indicates that no current source, such as vadose zone soils or DNAPL at the top of the till, explains the presence of significantly higher concentrations of key parameters in the deep portion of the sand aquifer as compared to the concentrations present in the shallow portion. The presence of significantly higher concentrations of key parameters in the deep portion of the sand aquifer is most likely related to historic site operations, including discharges from the wood-treating plant, the manufactured gas plant, and the coke plant, as well as activities associated with demolition of these facilities by OMC. Given those potential former sources, the chemical constituents now found in the deep portion of the sand aquifer must have passed through the shallow portion of the sand aquifer. Natural processes such as greater biodegradation in the shallow portion of the aquifer may have contributed to the currently observed stratification of key parameters in soil and groundwater.

7.9.7 Surface Water and Sediment Contamination

The review of surface water quality samples indicate that the only exceedences of IWQS in Lake Michigan samples are for total cadmium, a compound that is either not detected or is reported at only low parts-per-billion concentrations in groundwater samples from the groundwater monitoring network points closest to Lake Michigan.

The water quality in Waukegan Harbor appears to have improved as compared to the water quality reported from 1988 through 1991. There are no exceedences of IWQS in the samples collected from Waukegan Harbor during the RI.

Dredging of the harbor sediments, which is repeated periodically, alters the sediment quality and ecological conditions in the harbor.

SECTION 8.0
CONTAMINANT FATE AND TRANSPORT

This section presents an evaluation of the environmental fate and transport of key chemical parameters identified at the WCP site. The evaluation is based on: chemical parameter characteristics; the identified distribution of chemicals in soil, groundwater, and surface water; and data from the site and published sources that describe transport processes affecting chemical parameter migration.

Chemical parameter characteristics are used to assess volatilization, attenuation, and degradation as fate and transport processes affecting chemical constituents identified at the WCP site. Based on this assessment, chemical migration pathways in air, soil, groundwater, and surface water are examined using the data base assembled during the RI.

In order to provide a framework for the following detailed discussions of chemical migration pathways, the main points and conclusions of the section are summarized here:

- Based on a preliminary review, the RI data indicate that the air migration pathway may not be significant at the WCP site.

- Current contaminated concentrations in the vadose zone and upper portion of the sand aquifer do not explain the elevated concentrations of key parameters (benzene, phenol, arsenic, cyanide, and ammonia) in the groundwater of the deep portion of the sand aquifer. The presence of significantly higher concentrations in the deep portion of the sand aquifer is most likely related to historic site operations including discharges from the wood-treating plant, the manufactured gas plant, and the coke plant, as well as activities associated with the demolition of these facilities by OMC.

- The conceptual characterization of groundwater transport pathways involves migration of dissolved constituents present in the deep portion of the sand aquifer from areas near the groundwater divide; representative computed groundwater migration rates for the key parameters range from approximately 3 to 80 feet/year.

- Mass loading estimates for groundwater transport from the WCP site indicate that, in general, the majority of the computed loadings of benzene, phenol, and cyanide to surface

waters is discharged to Waukegan Harbor. The computed loadings of arsenic and ammonia are approximately the same to both Waukegan Harbor and Lake Michigan.

- Surface water data collected during the RI show no exceedences of surface water standards for the key chemical constituents evaluated in this section.

- Dilution and other fate and transport processes attenuate the chemical loading from groundwater, reducing the groundwater impacts on surface water significantly from what might be assumed on review of groundwater sample data alone.

8.1 CHEMICAL PARAMETER CHARACTERISTICS

8.1.1 Volatilization

Chemical constituents may be transported from near-surface soils and/or surface waters by volatilization. This process involves the transfer of organic chemicals from the soil or water surface to the atmosphere. As a result, volatilization can result in reduced concentrations of organic chemicals in near-surface soils or surface water as chemicals are transported to the atmosphere. Parameters that quantitatively describe an organic compound's tendency to volatilize are vapor pressure and Henry's Law constant (Table 6.2-1).

A chemical's vapor pressure describes its propensity to exist in the atmosphere as opposed to existing as a pure chemical in liquid or solid form (Dragun, 1988). Chemicals with vapor pressures of less than 10^{-7} millimeter mercury will volatilize to a negligible degree, while chemicals with vapor pressures greater than 10^{-2} millimeter mercury will volatilize and be present primarily in the atmosphere or in soil air (Dragun, 1988). On this basis, vapor pressure values for the key organic chemicals listed in Table 6.2-1 indicate that BETX and phenolic compounds would be the most likely to volatilize from near-surface soils.

The Henry's Law constant describes a chemical's propensity to volatilize from water to the atmosphere. Chemicals with Henry's Law constant values of less than 5×10^{-6} atm.cm^3/gm will volatilize to a negligible degree from moist near-surface soils or surface waters, while chemicals with Henry's Law values greater than 5×10^{-3} atm.cm^3/gm will volatilize and be present primarily in the atmosphere or soil air (Dragun, 1988). On this basis, Henry's Law constant values for the organic chemicals of concern listed in Table 6.2-1 indicate that BETX compounds would be the most susceptible to volatilization.

8.1.2 Attenuation

Attenuation describes a chemical constituent's tendency to be adsorbed onto solid particles of the aquifer during transport in groundwater. The property is commonly quantified by a retardation factor (R_d) that reflects the relative velocity of the groundwater compared to the effective transport velocity of the adsorbed constituent (Freeze and Cherry, 1979).

For organic compounds, R_d values are computed based on: aquifer bulk density (ρ_b), porosity (n), and organic carbon content (f_{oc}); and on compound-specific values for organic carbon partition coefficient (K_{oc}). Retardation factors are computed using the following equation (Dragun, 1988):

$$R_d = 1 + \frac{\rho_b}{n} \times K_d$$

where: K_d is the distribution coefficient ($K_{oc} \times f_{oc}$).

For the WCP site, the average laboratory porosity for sand unit samples is 0.38, the average bulk density of the aquifer materials is 1.7 g/cm^3, and laboratory TOC data show organic carbon contents of 2.0 to 5.8 percent (Tables 4.6-2 and 4.6-3). Organic carbon partition coefficients for the chemicals of concern are listed in Table 6.2-1. For an organic carbon content of 2 percent, these data indicate that benzene, naphthalene, cresols, and phenol would be the most mobile of the identified organic chemicals of concern (i.e., R_d less than 6). The data also indicate that carcinogenic PAHs can be expected to be essentially immobile in groundwater (i.e., R_d greater than 20,000) and that PAHs in general are relatively immobile (i.e., R_d greater than 50).

For inorganic parameters, retardation factors can also be computed using the equation presented above (Dragun, 1988). However, distribution coefficient values for inorganic parameters are less likely to be dependent on organic carbon content and more likely to be influenced by the molecular or ionic form(s) of the constituent, the acidity/alkalinity of the groundwater, and the presence of other solutes (EPRI, 1984). These variabilities are reflected in the wide range of K_d values presented in Table 6.2-2 for inorganic parameters of concern. In general, available data suggest that cyanide is likely to be a relatively mobile constituent (ATSDR, 1988), while the metals of concern are likely to be somewhat less mobile.

8.1.3 Degradation

Biodegradation refers to a biologically induced structural change in an organic chemical that results in removal of the initial chemical over time (Dragun, 1988). Organic chemicals are susceptible to biodegradation to varying degrees, expressed quantitatively by biodegradation rate constants and half-life values (i.e., the time needed for half of an initial concentration to be degraded). Values for these parameters listed in Table 6.2-1 indicate that BETX and phenolic compounds can be considered to be readily biodegradable in the environment. Other degradation processes that can result in reduced concentrations of organic constituents include hydrolysis and photolysis.

8.2 MIGRATION PATHWAYS IN AIR

Based on analyses of soil samples collected from the upper 6 inches of soils present at the WCP site, the chemical parameters identified in Section 8.1.1 as being susceptible to volatilization are not typically encountered in near-surface soils. The analytical data (Tables 4.1-12 and 4.1-13) typically show no detection of BETX compounds, with no reported individual concentrations exceeding 1 µg/kg. Results for phenolic compounds also show no detections for 15 out of 17 samples. Two samples show occurrences of low concentrations (less than 1 mg/kg) of one or more phenolic compounds.

Organic vapor monitoring data recorded during the RI typically show no detectable concentrations of organic compounds in air, even during intrusive investigative activities in areas of contaminated soil (Barr, 1993a). Thus, the soil quality and air quality data collected during the RI do not indicate that the air migration pathway is significant at the WCP site.

8.3 MIGRATION PATHWAYS IN SOIL

Chemicals present in soils above the water table may be transported: (1) to the atmosphere, by volatilization (addressed above in Section 8.2); or (2) to the groundwater, by downward vertical migration in infiltrating precipitation or as a separate phase.

Section 7.6 identifies specific areas of the site where elevated PAH concentrations are present in soils above the water table. While infiltration through these soil areas may transport PAHs to groundwater, this is a relatively minor transport pathway for the following reasons:

- Most PAH compounds, particularly carcinogenic PAHs, have relatively low solubilities (Table 6.2-1) that limit potential concentrations that may result from dissolution into infiltration;

- As discussed in Section 8.1.2, PAHs are relatively immobile in soil and groundwater environments; and

- PAHs are less significant than other groundwater chemicals of concern due to their comparatively limited frequency of detection and extent of occurrence (Section 7.7.2).

Other organic constituents of concern (i.e., benzene and phenol) and inorganic constituents of concern (i.e., arsenic and cyanide) are present in soils above the water table at specific site locations (Section 7.6). However, as described in Section 7.9.6, vadose zone soils are not the current source of concentrations of phenol, benzene, arsenic, and cyanide in the groundwater of the deep portion of the sand aquifer since: (1) these parameters are present over a greater extent and at higher concentrations in the groundwater in the deep portion of the sand aquifer than in the shallow portion; (2) phenol is generally not detected in vadose zone soils or in the groundwater and soils of the shallow portion of the sand aquifer, but is detected at relatively high concentrations (parts per million) in both the groundwater and saturated soils of the deep portion of the sand aquifer; and (3) vertical trends in observed benzene, arsenic, and cyanide concentrations in soils and groundwater are inconsistent with what would be observed if the soils in the vadose zone were the current source of the reported concentrations of these parameters in groundwater of the deep portion of the sand aquifer.

The evaluations presented above indicate that migration pathways from soils above the water table do not explain the observed chemical distribution in groundwater in the deep portion of the sand aquifer. Migration pathways for the groundwater chemicals of concern (primarily in the deep portion of the sand aquifer) are addressed in the following section.

8.4 MIGRATION PATHWAYS IN GROUNDWATER

8.4.1 Groundwater Transport Pathways

As described below, groundwater transport pathways are identified at the WCP site to assess receptors for, and potential impacts of, groundwater chemicals of concern. The conceptual characterization of groundwater transport pathways for the WCP site is shown on Figure 8.4-1. This characterization involves relatively slow migration of dissolved constituents from groundwater present

in the deeper portions of the aquifer in areas near the groundwater divide. Dissolved constituents present in this deep groundwater would be relatively persistent because there is zero horizontal hydraulic gradient at the divide, and minor seasonal shifts in the location of the divide would create a zone where little net horizontal migration occurs.

Groundwater flow directions at the site are observed to be consistent over time (Section 5.2.1.1), resulting in detected transport of chemical constituents: to the west (and southwest) toward Slip No. 4 and Waukegan Harbor; and to the east (and southeast) toward Lake Michigan. Groundwater flow and groundwater quality data indicate that chemical migration to the north is limited. Groundwater flow to the south occurs at a relatively slow rate (Section 5.2.1.3). This slower flow would result in relatively slower flushing, consistent with the comparatively high parameter concentrations reported for samples from Wells MW-8D and MW-10D.

Chemical migration rates, mass loadings estimates, and simulations of southward contaminant transport are discussed in the following sections.

8.4.2 Chemical Parameter Migration Rates

Chemical parameter migration rates have been estimated to provide a trending analysis to be used in assessing site groundwater quality data for key parameters. As described below, the estimated migration rates indicate that benzene, cresol, phenol, and cyanide may be more mobile than other groundwater chemicals of concern.

Dissolved chemical constituents transported by groundwater flow will move along the corresponding groundwater flow path. The rate of transport for conservative parameters (i.e., parameters that are not adsorbed on aquifer solids) will be equal to the corresponding groundwater pore velocity. For areas not in the immediate vicinity of the groundwater divide, average groundwater pore velocities are computed to be on the order of 60 feet per year west toward Waukegan Harbor, 80 feet per year east toward Lake Michigan, and 20 feet per year toward the south (Section 5.2). Distances from the groundwater divide to potential discharge points range from approximately 400 feet (west toward Slip No. 4) to 2,000 feet (south toward the harbor entrance channel).

Evaluations of potential attenuation during groundwater transport (Section 8.1.2) indicate that many organic compounds of interest at the WCP site will move at rates significantly slower than the groundwater pore velocity. Table 8.4-1 summarizes computed chemical parameter migration rates for organic compounds.

Migration rates summarized in Table 8.4-1 were computed using retardation factors (Section 8.1.2) developed for a minimum value of 0.2 percent TOC (Shimp et al, 1971), a maximum value of 6 percent TOC (maximum reported TOC for samples from sand unit, and a value of 2 percent TOC, assumed as representative of on-site soils (Table 4.6-2). The representative value is in the lower range of reported values for samples from the sand unit (2 to 6 percent), and is consistent with prior data from site investigations that showed 1.4 to 2.0 percent TOC (OMC, 1990c).

As shown in Table 8.4-1, the carcinogenic PAH compounds show representative computed transport velocities of 0.4 to 10^{-5} feet per year, indicating that these compounds are expected to show little, if any, migration in groundwater.

Organic compounds of concern that are significantly less attenuated are benzene, cresols, and phenol. Representative computed transport velocities for the most mobile of these compounds suggest travel times on the order of 40 to 80 years for transport from areas near the groundwater divide to Waukegan Harbor. This time frame compares to the period of 86 years since operations began at the CT&T wood-treating plant and the period of 22 years since the coking plant facilities were dismantled.

As discussed in Section 8.1.2, attenuation of inorganic parameters is variable and depends on numerous interrelated geochemical factors. Available published data for inorganic parameters is not sufficient to accurately predict relevant migration rates in the complex geochemistry of WCP site groundwater. However, ranges of distribution coefficient values presented in Table 6.2-2 suggest that arsenic, cadmium, lead, mercury, and selenium are all likely to be attenuated to a significant degree during groundwater transport (i.e., K_d values that correlate with R_d values on the order of 10 or greater). Available information for cyanide (ATSDR, 1988) indicates that this parameter is likely to be relatively mobile in the groundwater environment (i.e., R_d values of less than 10).

8.4.3 Mass Loading Calculations

Mass loading calculations have been performed to provide a basis for assessing relative discharges of groundwater constituents to Waukegan Harbor and Lake Michigan. As described below, the calculations indicate that most of the groundwater constituents transported from the WCP site discharge to the harbor.

Potential impacts on surface water quality are evaluated in Section 8.5, primarily on the basis of water quality data for surface water samples (Section 7.8). However, mass loading rates of chemicals to Waukegan Harbor and Lake Michigan have been estimated to: (1) provide a basis for

comparing site groundwater quality data to surface water quality data; and (2) indicate relative potential site-related impacts on the harbor and the lake. The calculations were based on groundwater flow patterns and rates, and on the observed distribution of groundwater parameters of concern.

In order to provide information for comparison to observed surface water quality and to evaluate relative potential impacts on the harbor and the lake, mass loading rates were computed for the following key chemical parameters: benzene, phenol, arsenic, cyanide, and ammonia.

Because benzene and phenol are susceptible to biodegradation (Section 8.1.3), degradation rates based on site groundwater quality data were incorporated in the mass loading calculations to estimate groundwater concentrations for these parameters at relevant points of potential discharge (i.e., the harbor wall and the lake shoreline). The mass loading calculations are described in Appendix 8-A.

As described in Appendix 8-A, the degradation rates were derived using a method that relies on the validity of soil-water partitioning theory (using the distribution coefficient approach) to site conditions. While the theory is likely not valid for benzene in those portions of the aquifer where benzene concentrations are 100 to 500 times less than those of phenol (because of competitive adsorption processes [Luft, 1984]), it is thought to be valid in those areas of the aquifer where benzene and phenol concentrations are similar (namely, downgradient of the site and in the shallow portion of the sand aquifer). Soil-water partitioning theory for benzene and the mass loading estimates derived from it were only applied in those areas of the aquifer.

The results of the mass loading calculations are summarized in Table 8.4-2. The estimated mass loading rates show that the majority of the benzene, phenol, and cyanide transported by groundwater from the WCP site is discharged to Waukegan Harbor. The estimated arsenic and ammonia mass loading rates calculated for the harbor and Lake Michigan are similar in value. Discharges from the deep portion of the sand aquifer account for the vast majority of the computed mass loadings.

Environmental fate and transport of chemicals of concern in Waukegan Harbor and in Lake Michigan are evaluated in Section 8.5.

8.4.4 Contaminant Transport Simulations

As a result of the WCP site's position on the peninsula between Waukegan Harbor and Lake Michigan, the areal extent of existing and potential contaminant transport in groundwater is limited. The downgradient extent of contaminant transport to the west is defined by groundwater quality data from monitoring well nests placed in the immediate vicinity of the harbor wall. Contaminant transport to the east is defined by groundwater quality data from monitoring well nests placed on the beach east of the site and by data for in-situ groundwater samples collected from borings placed further to the east. Contaminant transport to the north is limited, as defined by groundwater quality data from monitoring wells placed near the northern boundary of the site and by groundwater flow patterns that show little potential for transport to the north. Accordingly, the available groundwater quality data describe contaminant transport to the west, east, and north of the site.

Groundwater flow patterns and groundwater quality data from monitoring wells screened in the deep portion of the sand aquifer at the southern boundary of the site indicate the potential for off-site transport to the south. The potential areal extent of contaminant transport to the south is necessarily limited by the limited areal extent of the peninsula. Contaminant transport simulations have been performed to provide supplemental information about potential contaminant distributions in groundwater within this area south of the WCP site. The results of the simulations will be relevant to: (1) future evaluations of potential groundwater remedies (i.e., assessments of groundwater extraction and/or containment systems); and (2) associated predesign studies (i.e., groundwater quality investigations to refine final design parameters for extraction and/or containment systems).

As described in the 1993 Revised Technical Memorandum describing proposed modeling for the WCP RI/FS (Barr, 1993c), the MYGRT Version 2.0 computer code (EPRI, 1989) was used for the contaminant transport simulations. The MYGRT code was used to develop two-dimensional simulations of horizontal contaminant transport along selected flow paths originating at the southern boundary of the WCP site. Because groundwater quality data indicate that higher concentrations of relatively mobile constituents (e.g., BETX and phenolic compounds, arsenic, and cyanide) occur essentially in the deep portion of the sand aquifer, simulations were performed to assess contaminant transport in this zone. The simulation approach, input parameters, parameter values, and the rationale for parameter value selection are discussed in detail in Appendix 8-B.

Figures 8.4-2 and 8.4-3 illustrate results for contaminant transport simulations of key organic and inorganic chemicals, respectively, for a flow path originating at the southern site boundary and discharging at the harbor entrance channel directly south of the site. The figures show computed

relative concentrations (as percentages of the concentration at the southern site boundary) at various distances with transport to the south along the flow path (i.e., the plume center line). Analyses of transport along additional flow paths, discussion of uncertainties, and sensitivity analyses are presented in Appendix 8-B. The contaminant transport simulations indicate that for areas of the deep portion of the sand aquifer located south of the WCP site:

- Inorganic constituents that show little or no retardation/degradation are likely to be present in groundwater south of the site at concentrations similar to historical concentrations at the southern site boundary (Figure 8.4-3). Concentrations in more distant areas directly south of the site are likely to show reductions from historical source concentrations due to dispersion.

- Organic constituents susceptible to attenuation and degradation processes are likely to show significant decreases from concentrations that have historically been present at the southern site boundary (Figure 8.4-2). Along shorter flow paths toward Waukegan Harbor (i.e., to the southwest) and Lake Michigan (i.e., to the southeast), the simulation results suggest that concentrations of such constituents may reach the ends of the flow paths, but at significantly reduced concentrations. Along longer flow paths toward the harbor entrance channel (i.e., to the south), the simulation results suggest that such constituents may not have reached the ends of the flow paths for the examined travel times.

The contaminant transport simulation results indicate that: (1) evaluation of groundwater remedies will likely need to address areas south of the WCP site; and (2) limited predesign groundwater quality investigations could be implemented to provide information for final remedy design.

8.5 MIGRATION PATHWAYS IN SURFACE WATER

8.5.1 Surface Water Transport

Waukegan Harbor and Lake Michigan are the receiving waters for groundwater discharging from the WCP site. The transport process for chemicals in surface water appears quite different than that for groundwater because of the different nature of flow in surface water.

Groundwater flow is generally laminar and involves relatively little mixing. In contrast, surface water, such as Lake Michigan, is turbulent and is constantly mixing (Wetzel, 1975). Currents, winds, and motions of the lake such as seiches move and mix the water. Stratification occurs in the lake creating, in effect, two mixing zones: one above the thermocline (stratification interface) and one below. However, in the near-shore environment of the lake, storms and large waves tend to break up the stratification and produce full-depth mixing of the water column. In the harbor, the stratification is also broken up by the frequent passage of ships and by intensive energy inputs to the water, such as OMC's marine engine testing operations. Evidence of this sort of mixing can be observed in the temperature profiles shown in Table 4.4-1 for the surface water sampling on August 31, 1993. The measurements were collected on a windy, wavy day. The uniformity of the temperature profile at the station near the OMC marine engine testing operation (SW-10) is probably the result of energy inputs from the testing. None of the temperature profiles in Table 4.4-1 would be considered to show a stratified condition.

8.5.2 Chemical Parameter Fate

The same processes affecting chemical parameter fate in groundwater apply in surface water. In addition to the volatilization, attenuation, and biodegradation processes described earlier in Section 8.0, sedimentation, chemical environment changes, and complex interactions at the sediment-water interface affect chemical parameter fate and transport in surface waters.

The attenuation and biodegradation processes described in Sections 8.1.2 and 8.1.3 affect the rate of transport and the concentration of chemical parameters as they migrate through sediments.

At the sediment-water interface, a number of processes can significantly affect chemical parameter fate. The dissolved oxygen content, pH, alkalinity, and other water chemistry parameters typically change as groundwater enters surface water. These changes can have significant effects on the solubility of inorganic chemicals, their stable chemical forms, and their affinity for sediments. The presence of plant life, organic detritus, and benthic organisms at the sediment-water interface can also influence chemical parameter fate.

A significant fate mechanism for many chemical constituents in surface water is sedimentation. Whether through adsorption to particles which settle, through change in chemical form to insoluble precipitates, or through other mechanisms, many chemical constituents removed from the water column accumulate in the bottom sediments.

Biodegradation processes are described in Section 8.1.3. Biodegradation in surface water is likely aerobic, because of the high dissolved oxygen content of surface water. Aerobic biodegradation is a more significant and effective natural process in surface water than in groundwater and aerobic biodegradation half-lives for parameters such as phenol and benzene would be shorter than anaerobic half-lives. Similarly, volatilization is much greater from surface water than from groundwater because of the unimpeded air-water interface and the well-mixed nature of surface water.

8.5.3 Surface Water Evaluation

There are many sources of chemical constituents to surface water in the Waukegan Harbor area. Activities that contribute to the chemical constituent loading affecting water quality in the Waukegan Harbor area include atmospheric deposition, storm sewer discharge, industrial discharges, runoff from stockpiles of raw materials, runoff from industrial and commercial facilities, commercial and recreational boat activities, transfer from sediments, leachate from former and current land disposal areas, groundwater flow at leaking underground storage tanks, sanitary sewer-storm sewer cross connections, and leaks or spills of chemicals during boat servicing or during other industrial and commercial activities (Hey and Associates, undated). No study has been performed which would estimate the relative magnitude of the various contributing sources of chemical constituents to the harbor or lake.

Estimates of potential mass loading from the WCP site groundwater are shown in Table 8.4-2. These loadings may overestimate the amounts reaching the waters of the harbor and lake because of the fate mechanisms at the sediment-water interface and other fate processes described above.

Runoff from the vacant portion of the WCP site is not a likely transport mechanism to the harbor or lake. The site is very flat, promoting infiltration of precipitation, and, as described in Section 5.2.1.4, the absence of developed surface water drainage features at the site suggests that runoff infiltrates before reaching a discharge point. Surface drainage to the west is also blocked by soil stockpiles along much of the west side of the site. Runoff from the Larsen Marine facility, and from the OMC facilities on the southeast and south portions of the site, discharges to the harbor. Water quality impacts associated with this runoff would be a result of the operations at those facilities and are outside the scope of this RI.

A review of the groundwater concentrations, mass loading, and surface water concentrations for Waukegan Harbor and Lake Michigan illustrates the impact of the surface water fate processes. Two organic parameters and two inorganic parameters were selected for review. Phenol and benzene,

which are also representative of the phenolic compounds and BETX, are presented. PAHs are also evaluated, but are discussed much more briefly because of their relatively limited extent in the groundwater, strong tendency to adsorb onto aquifer solids, and few extremely low reported concentrations in surface water. These factors suggest the WCP site groundwater is a relatively insignificant contributor of PAHs to the surface water.

The inorganic parameters selected for review are total arsenic and cyanide. Ammonia was not selected because it was not reported as present in the surface water samples. The other inorganic parameters -- cadmium, lead, mercury, and selenium -- are of relatively limited extent in the groundwater and are not present at concentrations in the groundwater that could explain the reported surface water concentrations of these parameters. Figures 8.5-1 through 8.5-4 illustrate the groundwater and surface water concentrations of phenol, benzene, and total arsenic and cyanide. The August 31, 1993 surface water sampling results and November/December 1993 deep portion of the sand aquifer groundwater sampling results are shown on the figures. Although the sampling dates for surface water and groundwater differ, the groundwater concentrations are not expected to change significantly over relatively short time periods, such as a year.

8.5.3.1 Waukegan Harbor

On the west side of the WCP site, sheet pile walls separate the surface water from the groundwater. The Slip No. 4 sheet pile extends into the till unit. The harbor wall may or may not extend all the way to the till unit. A buttress of soil was left against the harbor wall during the 1991 PCB removal work in the harbor. The buttress is generally 30 to 45 feet wide (Canonie, 1989). Groundwater passes through the sheet pile harbor and slip walls to the harbor and to Slip No. 4. Groundwater in the deep portion of the sand aquifer also encounters the buttress of sediment before entering the harbor. Slip No. 4 was built only 10 feet deep, so groundwater from the deep portion of the sand aquifer either discharges up through the sand bottom of the slip or flows through the sand to discharge within the harbor.

The harbor waters discharge to Lake Michigan. The concentration of constituents in the groundwater are significantly attenuated as they pass through the harbor to discharge to Lake Michigan. Based on an evaluation of the hydrodynamics of the harbor, a dilution factor of approximately 2,000 is likely representative of the reduction in concentration for site groundwater discharging via the harbor to Lake Michigan. Using a range of assumptions about the nature of exchange of water between the harbor and Lake Michigan, the dilution factor for groundwater reaching Lake Michigan (at the east edge of the harbor entrance piers) ranges from about 1,000 to over

8,000. The dilution factor does not include the biodegradation, volatilization, or other fate mechanisms described above. The basis for the dilution factor is the surface water model presented in Appendix 8-C. A description of how the results of the ANL study were incorporated into the model and a summary of the limitations of the surface water model are in Appendix 8-C.

The loading of contaminants from the WCP site to the harbor is predominantly (more than 95 percent) from the deep portion of the sand aquifer. The calculated loadings for phenol, benzene, arsenic, and cyanide, based on groundwater quality data, are in Table 8.4-2. A brief summary of the surface water pathway for groundwater discharge to the harbor is presented below for these four parameters. Observations regarding PAHs detected in the harbor are also noted, as the PAH situation does not parallel the phenol situation. The benzene summary includes information on toluene concentrations, as both benzene and toluene are relevant to the pathway.

Phenol. The groundwater and surface water concentrations of phenol are shown on Figure 8.5-1. No phenol was reported to be present in any of the harbor surface water samples. Biological activity and organic matter content at the sediment-water interface may significantly affect the mass loading to surface water by degrading/attenuating phenol in groundwater before it discharges to the surface water. Biodegradation, mixing with lake water, and volatilization are three potentially significant fate mechanisms once phenol enters the harbor water.

The 1990 IEPA harbor sampling data (PSCS Appendix 3-E) reported phenolic compounds in the surface water, with concentrations declining from 43 µg/L in the upper harbor to not detected (less than 5 µg/L) at the harbor entrance channel. These data illustrate the effect of the fate processes on phenol concentrations in the harbor surface water before it discharges to Lake Michigan.

Benzene and Toluene. The groundwater and surface water concentrations of benzene are shown on Figure 8.5-2. Surface water concentrations of BETX for the 1993 and 1988 sampling events are shown on Figures 7.8-2 and 7.8-3, respectively. Discharges of site groundwater to the harbor do not appear to explain the benzene concentrations shown in the surface water data. This conclusion can be drawn from considering the relative concentrations of benzene and toluene in the surface water and groundwater, the pattern of surface water benzene concentrations, and the uses of the harbor. As can be ascertained from Figure 7.8-2, the toluene concentrations in the harbor surface water samples in 1993 were higher than the benzene concentrations, generally about 3 times higher. A similar pattern can be seen for 1988 harbor water samples 1, 3, and 7, although the factor appeared to be approximately 2 in the 1988 data. This ratio is the opposite of what is observed for the site groundwater. For instance, the benzene concentration is more than 10 times the toluene concentration

in the groundwater samples from Well MW-10D (from the deep portion of the sand aquifer). Toluene was not detected in the groundwater samples from Well MW-5D, but benzene was reported at concentrations of 200 to 500 µg/L. For Monitoring Wells MW-6D and MW-1D, the ratio is close to 3 benzene:1 toluene. The aerobic degradation half-lives are similar for benzene and toluene, so differential degradation is not likely to produce such a dramatic switch in relative proportions of benzene and toluene between groundwater and surface water. This strongly suggests that site groundwater is not the only source of benzene and toluene to the harbor waters.

The pattern of surface water benzene concentrations on Figures 8.5-2 and 7.8-2 is one of increasing concentrations from north (Surface Water Sample SW-12) to south (Surface Water Sample SW-10), then decreasing concentrations toward the harbor mouth. A more dramatic pattern of decrease toward the harbor mouth is apparent in the 1988 data on Figure 7.8-3. This pattern is opposite to the pattern of groundwater benzene concentrations, which are higher in samples from Wells MW-1D, MW-3D, and MW-6D near Slip No. 4, and lower in samples from Well MW-5D near the south end of the site and near the location of Surface Water Sample SW-10. This difference in patterns of benzene concentrations between surface water and groundwater also implies that the groundwater is not the explanation for the pattern of benzene concentrations in the surface water.

OMC Plant No. 1 is located adjacent to surface water sampling station SW-10. OMC was testing marine engines during the day of the sampling at SW-10, both before and after the sampling. The U.S. EPA has performed a study of nonroad engine emissions, including outboard motors, and has found them to be significant contributors of hydrocarbons to the environment. The engines emit unburned gasoline, which contains benzene and toluene, and other products of combustion including PAHs (Hilchey, 1994). The engine testing activity by OMC may be a reasonable explanation for both the general pattern of benzene concentrations and the toluene:benzene ratios in the surface water. The toluene:benzene ratio of unleaded gasoline is commonly in the range of 4:3 to 4:1. The higher toluene concentration than benzene concentration in gasoline is consistent with all of the BETX data for surface water samples.

Arsenic. The arsenic concentrations in surface water and groundwater are shown on Figure 8.5-3. Little total arsenic was reported in the harbor samples (concentrations range from not detected to 3.0 µg/L). None of the reported surface water total arsenic concentrations exceed the applicable Illinois water quality standards. The fate mechanisms controlling arsenic concentrations are adsorption to particles, with subsequent sedimentation, and mixing with lake water.

Cyanide. The cyanide concentrations in surface water and groundwater are shown on Figure 8.5-4. Total cyanide was not reported to be present in any of the harbor water samples. However, elevated detection limits for samples from the north end of the harbor and Slip No. 4 suggest that total cyanide may be present in the surface water. The Illinois surface water standard is not for total cyanide, but for weak acid dissociable (or weak and dissociable) cyanide. Weak acid dissociable cyanide was not reported to be present in any of the harbor surface water samples.

The primary fate mechanisms for reduction of cyanide concentrations once cyanide enters the surface water are likely to be adsorption to particles and subsequent sedimentation, and mixing with lake water. Cyanide can also undergo aerobic biodegradation.

The 1990 IEPA harbor sampling data (PSCS Appendix 3-E) reported total cyanide in the surface water, with concentrations declining from 50 µg/L in the upper harbor to 10 µg/L at the harbor entrance channel.

PAHs. The total PAH concentrations detected in the harbor water samples are shown on Figure 7.8-1. None of the reported concentrations exceeded 0.1 µg/L. The PAH compounds that were detected most frequently and at the highest concentrations in the harbor water were fluoranthene and pyrene. These compounds were not detected in the groundwater samples from the monitoring wells near the harbor. Naphthalene, the dominant PAH in monitoring well samples in which PAHs were detected (MW-1S, MW-1D, MW-6S, and MW-6D), does not appear in the surface water samples. Similarly, the carcinogenic PAH detected in these monitoring well samples, carbazole, did not appear in the surface water samples. Thus, the site groundwater may not be the source of PAHs in the surface water.

As noted above, outboard motors emit PAHs. The detection limits of the samples at SW-10 were 0.08 µg/L and above, which is higher than the total PAH concentration reported at most surface water stations and higher than any individual PAH concentration in the surface water samples. Thus, the absence of reported PAHs at SW-10 does not exclude the possibility that engine testing contributed to the reported surface water PAH concentrations. Other potential sources of PAHs include stormwater runoff, boat traffic, and atmospheric deposition. The ubiquity of PAHs in the environment makes it difficult to identify a particular source as a most likely source.

8.5.3.2 Lake Michigan

Groundwater flowing east from the WCP site discharges to Lake Michigan. Unlike the harbor, which is bounded by a wall, Lake Michigan is bordered by a beach. The slope of the beach east of the

site is flatter than 100 feet horizontal to 1 foot vertical. It is more than half a mile from the lake shore to a lake depth of 21 feet. The discharge of groundwater through the lake-bottom sediments would be distributed across this zone, with the proportion of flow discharge typically decreasing with distance from the lake shore (McBride and Pfannkuch, 1975). The discharge of groundwater from the deep portion of the sand aquifer may, therefore, be spread over a large area as it enters the lake.

When the groundwater enters the surface water, the turbulent nature of surface water will mix the groundwater into the water column. Allowing for only the currents in Lake Michigan, the groundwater concentrations would be reduced by a factor conservatively estimated to be 10,000 due to entrainment with the surface water (see Appendix 8-C). The actual dilution factor would be much larger because typical currents are 10 or more times faster than modeled (see Appendix 8-C), and because other motions of the water, such as waves, seiches, and other water level changes, as well as the other fate mechanisms described earlier, would reduce the concentration in the lake.

The near-shore area of the lake where site groundwater would discharge is a sand deposition area. The breakwater east of OMC Plant No. 1 causes sand carried by the littoral drift to deposit, building the beach and adding to the sand bed in the littoral zone. This ongoing accretion of sand limits the nature of any benthic community in the affected area.

The City of Waukegan draws its water supply from Lake Michigan about 6,000 feet southeast of the peninsula. The intake water is routinely tested for inorganic parameters. Copies of the intake water laboratory reports are in Appendix 3-E of the PSCS. A review of the water testing records from 1976 through the present shows that cyanide has not been detected (5 to 10 µg/L detection limit) and arsenic has not exceeded 2 µg/L (the Illinois Lake Michigan and drinking water standards are both 50 µg/L) in the intake water samples. This long-term record of water quality leads to the conclusion that, even including discharge of water from Waukegan Harbor, the water quality of the open waters of Lake Michigan has not been impaired by WCP site groundwater.

A public beach is located southeast of the WCP site. No benzene, phenol, arsenic, or cyanide were reported to be present in the surface water samples from the beach area. The absence of these, the key parameters with the highest groundwater concentrations at the site, in the surface water samples from the public beach area, strongly suggests that constituents in the site groundwater at lesser concentrations would also not be compromising the beach area lake water quality.

The surface water pathway for groundwater discharge directly to the lake is presented below for phenol, benzene, arsenic, and cyanide. A brief review of the surface water PAH data is also provided.

Phenol. The groundwater and surface water concentrations of phenol are shown on Figure 8.5-1. Phenol was not reported to be present in the Lake Michigan surface water samples. The comparatively small mass loading rates shown in Table 8.4-2 for phenol discharging to Lake Michigan are due to: (1) the relatively smaller area of the WCP site that provides groundwater flow toward Lake Michigan; and (2) attenuation and biodegradation in the groundwater prior to reaching the lake shore. The groundwater phenol concentrations of interest are at the base of the sand unit. The computed loading in Table 8.4-2 does not account for the distance groundwater must travel from the base of the sand unit at the lake shore, upward through the sediments, to reach the interface with surface water. Attenuation and biodegradation during this transport would further reduce the mass loading of phenol. This additional mass loading reduction, the likelihood that the groundwater from the deep portion of the sand aquifer discharges over a very large area, the significant mixing effect of surface water, as well as the other fate mechanisms described earlier, significantly reduce the potential impact of the phenol in the groundwater on Lake Michigan.

Benzene. The groundwater and surface water concentrations of benzene are shown on Figure 8.5-2. Benzene was not reported to be present in the 1993 Lake Michigan water samples. Benzene concentrations in surface water samples are also shown on Figure 7.8-2 for the 1993 sampling and Figure 7.8-3 for the 1988 sampling. The 1988 concentration of benzene reported in Sample 6 from Lake Michigan appears to be associated with the North Ditch. The mass loading of benzene to Lake Michigan is estimated to be very small, as shown in Table 8.4-2. The same considerations as described for phenol reduce the mass loading of benzene to the lake and attenuate any groundwater-borne benzene concentrations that may reach the lake.

Arsenic. The arsenic concentrations reported in the groundwater and the surface water are shown on Figure 8.5-3. Virtually no total arsenic was reported to be present in the Lake Michigan samples, with only 1 sample out of 11 reported to contain arsenic: Sample SW-4D, 1.6 µg/L.

Cyanide. The groundwater and surface water concentrations of cyanide are shown on Figure 8.5-4. No total cyanide and no weak acid dissociable cyanide were reported for the Lake Michigan samples.

PAHs. The concentration of total PAHs in surface water samples from Lake Michigan are shown on Figure 7.8-1. The PAH concentrations in the surface water samples are approximately an order of magnitude lower than those reported for the nearest monitoring wells, Wells MW-12, MW-13, and MW-14. The low mobility of PAHs in groundwater, the similarity between groundwater and surface water total PAH concentrations, and the enormous dilution of site groundwater discharging to Lake Michigan lead to the conclusion that site groundwater may not be the source of the PAHs detected in the surface water samples. The presence of the Commonwealth Edison coal-fired power plant a mile north of the WCP site, outboard motor use on the lake, ship traffic, and other such potential sources may contribute to the trace PAH concentrations reported in the Lake Michigan samples.

8.5.3.3 Summary and Conclusions

This review of the mass loading from the site to the surface water of four of the significant site chemical parameters finds their effects on surface water quality to be negligible or very limited. Phenol was not detected in the surface water samples, indicating the groundwater impacts on surface water are much smaller than might be assumed from review of groundwater sample data alone, without accounting for dilution and other transport and fate processes. Benzene was not found in the 1993 Lake Michigan surface water samples. The benzene detected in the Waukegan Harbor samples is not likely explained by the WCP site groundwater. Reported total arsenic and cyanide concentrations do not exceed potentially applicable surface water quality standards. Ammonia was not detected in the surface water samples. The accumulated evidence leads to the conclusion that the WCP site groundwater does not impair the water quality of the open waters of Lake Michigan.

8.6 SUMMARY

Chemical parameter characteristics have been used to assess volatilization, attenuation, and degradation as fate and transport processes affecting chemical constituents identified at the WCP site. Based on this assessment, chemical migration pathways in air, soil, groundwater, and surface water were examined using the data base assembled during the RI. The conclusions of the contaminant fate and transport evaluations are summarized below:

- Based on a preliminary review, the RI data indicate that the air migration pathway may not be significant at the WCP site.

- Current contaminant concentrations in the vadose zone and upper portion of the sand aquifer do not explain the elevated concentrations of key parameters (benzene, phenol, arsenic, cyanide, and ammonia) in the groundwater of the deep portion of the sand aquifer. The presence of significantly higher concentrations in the deep portion of the sand aquifer is most likely related to historic site operations including discharges from the wood-treating plant, the manufactured gas plant, and the coke plant, as well as activities associated with the demolition of these facilities by OMC.

- The conceptual characterization of groundwater transport pathways involves migration of dissolved constituents present in the deep portion of the sand aquifer from areas near the groundwater divide; representative computed groundwater migration rates for the key parameters range from approximately 3 to 80 feet/year.

- Mass loading estimates for groundwater transport from the WCP site indicate that the majority of the computed loadings of benzene, phenol, and cyanide to surface waters is discharged to Waukegan Harbor. The estimated arsenic and ammonia mass loading rates calculated for Waukegan Harbor and Lake Michigan are similar in value.

- Dilution and other fate and transport processes attenuate the chemical loading from groundwater, reducing the groundwater impacts on surface water significantly from what might be assumed on review of groundwater sample data alone.

- Surface water data collected during the RI show no exceedences of surface water standards for the key chemical constituents evaluated in this section.

SECTION 9.0
SUMMARY AND CONCLUSIONS

This section of the report summarizes and presents the conclusions of the RI Report, stating the limitations of the data as appropriate.

9.1.1 Summary and Conclusions

The main points of each of the major sections of the RI Report are summarized in the following subsections. Each of the subsections corresponds to a major section of the RI Report.

9.1.1.1 Site Setting

Background information for the WCP site as well as regional information for the area surrounding the WCP site may be summarized as follows:

- The following site operations may have contributed to the release of PAHs, phenolic compounds, volatile aromatic compounds, inorganic parameters, and/or PCBs to the soil and groundwater at the site: creosote wood-treating plant which was located on the western portion of the site and was operated for several years beginning in 1908; manufactured gas and coke plant which was located on the eastern portion of the site and was operated from approximately 1928 until 1947 as a gas production and purification plant and from 1947 until 1971 as a coke plant; demolition of the coke plant by OMC in 1972; storage of dredge spoils containing PCBs on the western portion of the site from 1974 until the present; storage of waste oil containing PCBs and gasoline in aboveground storage tanks in the south central portion of the site from 1977 through 1981; storage of waste oil containing PCBs in enclosed trailers in the north-central portion of the site during the summer of 1979; current storage of petroleum products in aboveground storage tanks and solvents in a storage cabinet adjacent to the tanks on the southwestern corner of the site; and storage of petroleum products in underground storage tanks, some of which were reportedly leaking, in the northwestern portion of the site.

- As part of the Record of Decision for the adjacent and overlapping Waukegan Harbor Superfund site, sediments containing PCB/oil mixtures were dredged from Waukegan

Harbor and disposed of in the former Slip No. 3. This PCB containment cell is located across the harbor immediately west of the site.

- Current land use in the vicinity of the WCP site is commercial, industrial, and recreational. OMC Plant No. 2 is located immediately north of the site. North of OMC Plant No. 2, hazardous waste containment cells have been constructed for soils and sediments containing PCB/oil mixtures. The NSSD's Waukegan Sewage Treatment Plant is located north of OMC Plant No. 2 property. Waukegan Harbor, an industrial and commercial harbor for lake-going freighters through which recreational boats and fishing boats also access Lake Michigan, is located west of the site. South of the site is OMC Plant No. 1, where operations include the manufacturing of marine motors and the long-term running and testing of dock-mounted outboard motors in the harbor. South of OMC Plant No. 1 are the City of Waukegan Water Plant, the Waukegan Harbor inlet, a rock breakwater which extends into Lake Michigan and is used by individuals for recreational shore fishing, and a 1,000-boat marina. East of the site is Sea Horse Drive. Asphalt parking lots and Waukegan Public Beach, which includes a public swimming area, are located east of Sea Horse Drive.

- Currently, the northwestern part of the site surrounding Slip No. 4 is utilized by Larsen Marine, a commercial business engaged in boat sales, servicing, repair, refueling, storing, and launching. The western portion of the site is used for stockpiling dredged material from the lake or harbor and soil from the excavation of Slip No. 4. Based on carcinogenic PAH content and appearance, a portion of the soil from the excavation of Slip No. 4 was contained in a membrane-lined cell within a fenced area immediately south of Slip No. 4. The southeast portion of the site is currently occupied by OMC's data building, administration building, parking lots, and lawn space. The rest of the site is vacant.

- Surface water bodies in the vicinity of the site include: Lake Michigan, which is located approximately 600 to 800 feet east of the eastern boundary of the site; Waukegan Harbor, which is adjacent to the western boundary of the site; the Waukegan River, which discharges to Lake Michigan approximately 3,000 feet southwest of the site; and the North Ditch, a constructed drainage channel which discharges to Lake Michigan approximately 1,500 feet north of the site.

- Waukegan Harbor, located west of the site, is an industrial and commercial harbor used by lake-going freighters. It is also used by private boats to reach the repair, supply, and

docking facilities at Slip No. 4. Historically, the harbor was dredged every year or two to maintain its navigability. Dredging of the outer harbor continued after discovery of PCB contamination in the harbor sediments. In 1991, the harbor was dredged to remove sediments containing PCBs as part of the Waukegan Harbor Superfund site remedy. The dredging process was designed to leave in place any sediment with PCB concentrations less than 50 parts per million. No dredging standards were set for other constituents of the PCB/oil mixtures. Former Slip No. 3 has been filled with the sediments containing oils and PCBs. The harbor is also used for long-term running and testing of outboard motors by OMC.

- Lake Michigan impacts Waukegan Harbor by: (1) currents in and out of the harbor that cause an exchange of water that prevents stagnation of the harbor; and (2) waves directly entering the harbor and changes in lake level that also cause mixing.

- Lake Michigan is the source of drinking water in the Waukegan area. The City of Waukegan water supply intake is in Lake Michigan approximately 6,400 feet southeast of the site. A backup intake is in Lake Michigan approximately 3,100 feet southeast of the site. A third intake, which would draw water from Waukegan Harbor, would not be used except in extreme emergency, such as failure of the other two intakes. Water well survey data from 1992 indicate that no active private drinking water wells are located within 1 mile of the site.

- The most significant remaining ecological features in the vicinity of the site include Lake Michigan, Waukegan Beach, and the Illinois Beach State Park. Each of these features is described below.

  - Lake Michigan provides a diversity of aquatic habitat and supports an important commercial and sport fishery. The IDOC stocks salmon and trout into Lake Michigan near Waukegan Harbor. Two state threatened fish species have been reported in Lake Michigan between Zion and Waukegan.

  - Waukegan Beach is a sand and dune area east of the site that is used primarily for recreational purposes. The beach extends north along the shoreline of Lake Michigan to Illinois Beach State Park. Periodic grading of the beach by the City of Waukegan has been discontinued, allowing for the partial development of dune communities. Several endangered, threatened, or rare bird species have nested or

attempted to nest at Waukegan Beach, but none are known to nest adjacent to the site. Three threatened or endangered plant species have also been found at the Waukegan Beach. Wetland vegetation communities are scattered throughout the Waukegan Beach area along Lake Michigan.

- Illinois Beach State Park is a 4,160-acre natural area that is situated along the shore of Lake Michigan. The park contains a diversity of wildlife habitat, including cattail marshes, sand prairies, and savannas. Several state-listed threatened and/or endangered plant and bird species inhabit the park.

- Fish are present in Waukegan Harbor, but the harbor was constructed for industrial purposes, and its value as a fish and wildlife habitat is limited. Factors that limit its value as a habitat for fish include: regular industrial boat traffic that stirs up and muddies the harbor waters; dredging operations that disturb harbor sediments and affect surface water quality; and the lack of cover provided by the deep, vertical harbor walls.

9.1.1.2 Previous Investigations

Several studies have been completed in the area of the WCP site that provide relevant information for the Waukegan Harbor area. These studies consist of: Waukegan Harbor Superfund site PCB investigations which describe the extent of PCB contamination and geologic/hydrogeologic conditions primarily for the area north of OMC Plant No. 2; investigations related to the Waukegan Harbor Superfund site PCB remedy, which describe geotechnical information relevant to the planned excavation of sands north of OMC Plant No. 2, hydraulic conductivity information for the sand and till north of OMC Plant No. 2, and geotechnical, groundwater quality, and soil quality (PCBs and semivolatiles) information for the construction of Slip No. 4; IEPA investigation of shallow soil quality (phenols, PAHs, volatile organic compounds, pesticides, and metals) at the site; Waukegan Harbor area sediment investigations which primarily provide information relating to PCBs; and Waukegan Harbor area surface water investigations.

9.1.1.3 Remedial Investigation Activities

The WCP site RI consisted of a soils investigation, a hydrogeologic investigation, a groundwater quality investigation, a surface water quality investigation, an environmental features survey, remedial technology evaluation sampling, and a quality assurance/quality control review of analytical data. The objectives of these activities were to characterize the lateral and vertical extent of soil contamination, to characterize the soil quality and lithology of the soil stockpiles, to characterize the site geology and stratigraphy, to evaluate the hydraulic characteristics of the sand unit, to assess groundwater quality downgradient of identified source areas, to characterize the site's groundwater flow regime, to characterize surface water quality in the vicinity of the site, to characterize the geotechnical properties of the till and sand units for use in the development of remedial alternatives, and to provide site-specific data needed to evaluate potential treatment technologies for remedial alternatives. RI activities included test trench excavation; background soil sample collection; ground surface and shallow soil sample collection; soil boring, monitoring well, and piezometer placement; permeability testing; continuous and discrete water level measurements; soil, groundwater, and surface water sampling for chemical analysis of metals, cyanide, phenolic compounds, PAHs, volatile organic compounds, PCBs, and pesticides; soil sampling for geotechnical analysis; and evaluation of on-site and off-site ecological features.

9.1.1.4 Physical Characteristics of the Site

Physical characteristics of the WCP site, namely site geology and hydrogeology, may be summarized as follows:

- Geologic conditions at the WCP site consist of a near-surface unit of approximately 30 feet of fill materials and natural sand deposits overlying a lean clay till that is approximately 80 feet thick. No areal zones of distinctly different lithologies are identified in the sand unit.

- Groundwater at the site occurs in the sand unit within 2.5 to 5 feet of the ground surface. Groundwater elevation measurements indicate a consistent flow pattern within the sand unit aquifer, showing a groundwater divide near the eastern site boundary with flow to the east (toward Lake Michigan) and to the south and west (toward Waukegan Harbor). The consistency shown by the flow patterns indicates that transient effects of infiltration or lake level variations do not alter long-term groundwater flow patterns at the WCP site.

- The downward vertical hydraulic gradients within the sand aquifer are the result of infiltration. Groundwater flow is mostly downward near the groundwater divide and predominantly horizontal in other areas.

- Hydraulic conductivity estimates from site specific tests indicate that groundwater flow rates (average linear velocities) are on the order of 60 to 80 feet per year to the east and west and 20 feet per year to the south.

- For the WCP site, annual infiltration rates to the sand unit aquifer are expected to be in the range of 11 to 15 inches per year for average precipitation conditions. This range was determined as the difference between precipitation and evapotranspiration for watersheds in the Waukegan area.

- Resistance to vertical flow through the till, expressed as flow distance divided by hydraulic conductivity, is computed to be 40,000 times the resistance to horizontal flow within the sand unit. Thus, vertical flow through the till would be negligible compared to horizontal flow within the sand unit aquifer.

- A groundwater flow model was developed to integrate the hydrogeologic parameter estimates and to provide a representative simulation of on-site and off-site groundwater flow patterns.

9.1.1.5 Nature of Contamination

Based on sample analytical data, frequency of detection, and constituent toxicity and mobility, chemical parameters were selected from the following parameter groups for characterizing the extent of contamination: PAHs, BETX compounds, phenolic compounds, and inorganic parameters. The nature of these contaminants may be summarized as follows:

- The compiled literature information indicates that PAHs are likely to be relatively immobile in the environment. Potential PAH migration is limited by the compounds' low solubilities and tendency to be adsorbed onto aquifer solids.

- The literature data indicate that benzene is likely to be the most soluble and mobile of the BETX compounds and that phenol is likely to be the most soluble and mobile of the selected phenolic compounds. Benzene and phenol are typically susceptible to

degradation in soil/water environments, potentially resulting in concentration reductions during contaminant migration.

- The inorganic chemicals of interest at the WCP site are arsenic and cyanide. The mobility of these chemicals is variable and is strongly dependent on factors such as constituent speciation, acidity/alkalinity, and soil/groundwater geochemistry. However, sample analytical data indicate that these constituents are the most significant of the selected inorganic chemicals relative to extent of contamination characterizations.

9.1.1.6 Extent of Contamination

This section summarizes the principal findings for the distribution of key chemical parameters (PAHs, phenolic compounds, BETX compounds, arsenic, cyanide, cadmium, lead, mercury, selenium, and PCBs) in background soils, ground surface soils, soil stockpile soils, vadose zone soils, groundwater and saturated soils, and surface water and sediments at or in the vicinity of the WCP site.

9.1.1.6.1 Distribution of PCBs

It is reasonable to conclude from the soil and groundwater sampling that PCBs are not widespread at the WCP site. Those areas where PCBs are found are associated with storage by OMC of oils containing PCBs and are related to the Waukegan Harbor Superfund site, for which a remedy has been approved and is being implemented. None of the WCP site soil samples contains PCB concentrations in excess of 50 mg/kg.

9.1.1.6.2 Background Soil Chemical Concentrations

The background soil samples (Samples BS-01 through BS-08, GS-01, GS-02, and GS-04) provide information on the character of off-site soils in the general vicinity of the WCP site. The data indicate that, with the exception of phenolic compounds, all key chemical parameters are detected in background soils. Arsenic is detected at concentrations ranging from 2 to 235 mg/kg. It is routinely detected at concentrations of 10 mg/kg or less. Cyanide is generally reported as not detected. All detections of cyanide were at concentrations less than 1.4 mg/kg. Cadmium is reported in several samples at concentrations ranging from about 1 mg/kg to 7 mg/kg. Lead is detected in all the background samples at concentrations generally in the range of 3 mg/kg to 10 mg/kg, but ranging as high as 430 mg/kg. Mercury is reported in background samples at concentrations of 0.1 to 1.7 mg/kg. Selenium is reported at concentrations of 0.55 to 0.93 mg/kg. Sums of BETX compounds are reported

in most of the background samples at concentrations up to 9 µg/kg. Total PAHs and carcinogenic PAHs are reported in most background soil samples at concentrations ranging from 0.1 to 19 mg/kg and 0.04 to 10 mg/kg, respectively. PCBs are also reported in background samples at concentrations up to 23 mg/kg.

9.1.1.6.3 Ground Surface Soil Contamination Distribution

Ground surface soil samples were collected for use in direct contact/ingestion scenarios in baseline risk assessment evaluations. The ground surface soil data indicate that those samples containing visible or solid residues (i.e., blue or black staining, clinkers, slag) are also likely to display concentrations of PAHs greater than 100 mg/kg. The only ground surface sample with a cyanide concentration above 5 mg/kg exhibited a blue tint. The ground surface soil samples with the highest concentrations of total PAHs also have the highest concentrations of inorganic parameters. Arsenic is detected at a maximum concentration of 164 mg/kg, but is detected above 40 mg/kg in only three ground surface soil samples. Cadmium is not detected above a concentration of 3.5 mg/kg. Lead is detected at a concentration of 128 mg/kg in one ground surface soil sample and is otherwise detected at concentrations of less than 100 mg/kg. Mercury is detected at a maximum concentration of 38 mg/kg, but is detected above a concentration of 1 mg/kg in only three samples. Selenium is detected at a maximum concentration of 4.9 mg/kg, but is detected at concentrations of less than 1.3 mg/kg in all but two ground surface soil samples. Phenolic and BETX compounds are not detected above total concentrations of 0.6 mg/kg and 7 µg/kg, respectively.

9.1.1.6.4 Soil Stockpiles Contamination Distribution

The investigation of dredge spoils soil stockpile and designated soil stockpile soils may be summarized as follows:

- Except for one sample, total PAHs are not present at concentrations of greater than 6 mg/kg in the samples from the dredge spoils soil stockpile. Cyanide, cadmium, mercury, selenium, phenolic compounds, and BETX compounds are not reported as present in the samples from the dredge spoils soil stockpile. Except for the reported lead concentration in one sample, arsenic and lead are not reported at concentrations greater than 10 mg/kg in these samples. PCBs were detected in three samples at concentrations of less than 2 mg/kg.

- The soil samples from the designated soil stockpile exhibit concentrations of total PAHs that range from 194 to 221 mg/kg. Phenolic compounds, BETX compounds, and mercury are not detected in samples from the designated soil stockpile. Detected concentrations of arsenic and lead are all 14.1 mg/kg or less. Cyanide and selenium are detected in only one sample at a concentration below the CRDL. Cadmium is detected in only one sample. PCBs were detected in one sample at a concentration of 3 mg/kg.

9.1.1.6.5 Vadose Zone Soil Contamination Distribution

The distribution of key chemical parameters in vadose zone soils may be summarized as follows:

- Concentrations of total PAHs of up to 76,000 mg/kg are present in vadose zone soils in the eastern and west-central areas of the site within the area delineated by the 100 mg/kg total PAH concentration contour shown on Figure 7.6-1.

- Benzene concentrations above 1 mg/kg are associated with total PAH concentrations of greater than 100 mg/kg.

- Arsenic, cyanide, and selenium are at concentrations above 10 mg/kg, 1 mg/kg, and 1.7 mg/kg, respectively, in samples from the eastern portion of the site. Mercury is detected at concentrations of greater than 1 mg/kg in the east-central portion of the site and a limited area in the northeastern corner of the site. The highest concentrations of these compounds are not directly associated with the highest concentrations of PAHs and benzene.

- Lead and cadmium are generally not present at concentrations above 80 mg/kg and 3 mg/kg, respectively, in vadose zone soils.

9.1.1.6.6 Groundwater and Saturated Soil Contamination Distribution

The observed vertical distribution of key chemical parameters in the vadose zone soils and in the groundwater and saturated soils at the WCP site indicate that:

- The highest groundwater concentrations of inorganic parameters (total dissolved arsenic and cyanide) in the shallow portion of the sand aquifer are spatially associated with the highest concentrations of these parameters in vadose zone soils. Detections of PAHs in

groundwater samples from the shallow portion of the sand aquifer are limited to detections of the most mobile PAH compounds in samples from wells within or immediately adjacent to soil containing PAHs.

- Vadose zone soils are not the current source of high concentrations of phenol, benzene, arsenic, and cyanide in the groundwater of the deep portion of the sand aquifer. The following considerations support this conclusion:

  - Both inorganic (total dissolved arsenic and cyanide) and organic parameters (phenol and benzene) are present in the groundwater over a greater extent and at higher concentrations in the deep portion of the sand aquifer than in the shallow portion.

  - While phenol generally is not detected in vadose zone soils or in the groundwater and soils of the shallow portion of the sand aquifer, it is present at concentrations in the parts-per-million range in both the groundwater and saturated soils of the deep portion of the sand aquifer.

  - While benzene, arsenic, and cyanide concentrations decrease significantly between the vadose zone soils and saturated soils of the shallow portion of the sand aquifer and remain constant or increase slightly between the saturated soils of the shallow and deep portions of the sand aquifer, their groundwater concentrations increase by orders of magnitude with depth. This observation is inconsistent with what would be observed if the soils in the vadose zone were the current source of these parameters in groundwater of the deep portion of the sand aquifer, namely, soil and groundwater concentrations both decreasing continuously with depth or distance from the source.

- DNAPL is not the source of key site parameters in the groundwater of the deep portion of the sand aquifer. The results of the test trenching completed during the first phase of the field investigation indicated areas of vadose zone soils that exhibited visible contamination. As such, the second phase of the field investigation was designed to specifically investigate the potential presence of DNAPL in the sand aquifer. Soil borings were placed at approximate 100-foot centers along transects in and through those areas exhibiting visible contamination in the vadose zone. Each soil boring was advanced to the top of the till and sampled at nearly continuous intervals with a split-spoon sampler.

A split-spoon sample from immediately above the till was specifically collected from each boring at the contact between the sand unit and the top of the till. Field screening, which consisted of recording observations of discoloration and odor, testing for the presence of an oil sheen, and measuring headspace organic vapor concentrations, was performed on each sample. An analytical sample was collected from every soil boring from the interval just above the top of the till unit for the specific purpose of assessing the presence of PAHs as DNAPL. Finally, monitoring wells in the deep portion of the sand aquifer were specifically screened in the interval immediately above the till.

For the following reasons, neither the field observations nor the analytical results from the field investigation activities described above indicated the presence of DNAPL deposits at the site that could account for the observed distribution of key parameters in the groundwater in the deep portion of the sand aquifer:

1. No evidence of the presence of DNAPL was observed during the installation, development, or sampling of the monitoring wells. The analytical results for groundwater samples from the wells screened in the deep portion of the sand aquifer did not indicate the presence of DNAPL at the top of the till.

2. DNAPL, if present at this site, would have accumulated in depressions in the surface of the till and would have been readily apparent in the soil boring samples. Borings placed in till surface depressions (shown on Figure 5.1-5) found no DNAPL. The only instance in which an apparent DNAPL was reported (the presence of a golden-brown oil [coal tar or creosote DNAPL is black and viscous] coating the grains of gravel in the thin [less than 2.5 inches] gravel seam immediately above the till at Soil Boring SB-41) was not accompanied by DNAPL presence in the till depression immediately to the northeast (P-108) or in the draw to the south (SB-45, SB-50, and SB-59).

3. The visual absence of DNAPL described above is consistent with the reported distribution of PAH concentrations in the samples from the soil borings. Even in areas of visible contamination in vadose zone soils, PAH concentrations declined rapidly with depth beneath the water table. Total PAH concentrations did not increase at the top of the till, nor did they approach saturation concentrations. Thus, even in those areas in which DNAPL would most likely be encountered, no DNAPL was observed.

4. DNAPL at the top of the till cannot account for the observed distribution of organic contaminants in the groundwater of the deep portion of the sand aquifer. If that had been the case, naphthalene (or any other relatively mobile PAH constituent of DNAPL) would have been widespread in groundwater as are benzene and phenol, and visible DNAPL would have been found in extensive areas at the top of the till.

5. Finally, inorganic compounds, such as arsenic, cyanide, ammonia, and thiocyanate, exhibit the same stratification in groundwater (i.e., much higher concentrations at depth) as do the organic compounds, although the inorganic compounds would not have been present in DNAPLs associated with creosoting or coking/manufactured gas processes. Thus, DNAPL is not the source of these compounds in groundwater.

9.1.1.6.7 Surface Water and Sediment Contamination

Surface water quality data for Lake Michigan and Waukegan Harbor and sediment quality data for Waukegan Harbor may be summarized as follows:

- Surface water quality samples indicate that the only exceedences of IWQS in Lake Michigan samples are for total cadmium, a compound that either is not detected or is reported at only low parts-per-billion concentrations in groundwater samples from the monitoring wells and temporary well points closest to Lake Michigan.

- The water quality in Waukegan Harbor appears to have improved as compared to the water quality reported from 1988 through 1991. There are no exceedences of IWQS in the samples collected from Waukegan Harbor during the RI.

- Dredging of the harbor sediments, which is repeated periodically, alters the sediment quality and ecological conditions in the harbor.

9.1.1.7 Contaminant Fate and Transport

The analysis of contaminant fate and migration pathways at the WCP site may be summarized as follows:

- A preliminary review of soil quality and air quality data collected during the RI indicate that the air migration pathway may not be significant at the WCP site.

- RI data indicate that neither DNAPL at the top of the till nor current contaminant concentrations in the vadose zone and upper portion of the sand aquifer explains the observed distribution of key chemical parameters (phenol, benzene, and total dissolved arsenic and cyanide) in the groundwater of the deep portion of the sand aquifer. The presence of significantly higher concentrations in the deep portion of the sand aquifer is most likely related to historic site operations including discharges from the wood-treating plant, the manufactured gas plant, and the coke plant, as well as activities associated with the demolition of these facilities by OMC.

- Estimated mass loading rates show that the majority of the computed loadings of benzene, phenol, and cyanide transported to surface waters by groundwater from the WCP site is discharged to Waukegan Harbor. The estimated arsenic and ammonia mass loading rates calculated for Waukegan Harbor and Lake Michigan are similar in value.

- The surface water data collected during the RI show no exceedences of surface water standards for the primary chemical constituents of interest at the site, namely, phenol, benzene, and total arsenic and cyanide.

- Dilution and other fate and transport processes attenuate the chemical loading from groundwater, reducing the groundwater impacts on surface water significantly from what might be assumed based on review of groundwater sample data alone. A dilution factor of 3,000 is likely representative of the reduction in concentration for site groundwater discharging via the harbor to Lake Michigan. This dilution factor was developed using the surface water model presented in Appendix 8-C. The limitations of the model are stated in Appendix 8-C.

9.1.2 Data Limitations

This section of the report states the data limitations identified during evaluation of the RI data.

- The extent of key chemical parameters in groundwater of the deep portion of the sand aquifer is defined to the east, north, and west of the site, but not to the south. Contaminant transport simulations were performed to provide supplemental information

about potential distributions of key chemicals in the groundwater of the deep portion of the sand aquifer south of the WCP site. The contaminant transport simulation results indicate that: (1) evaluation of groundwater remedies will probably need to address areas south of the WCP site; and (2) limited predesign groundwater quality investigations could be implemented to provide information for final remedy design.

- One round of surface water quality data was collected from Lake Michigan and Waukegan Harbor during the RI. Additional sampling at selected locations could enhance the utility and representativeness of the water quality data set.

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