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FINAL

PHASE III RI

VOLUME I - NARRATIVE

DRAKE CHEMICAL SITE
LOCK HAVEN, PENNSYLVANIA

AUGUST 1988
W.A. NO. 123-3L31

EBASCO SERVICES INCORPORATED

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EBASCO

August 10, 1988
RMIII/88-424
Response Requested

Mr. Roy Schrock
U.S. Environmental Protection Agency
Region III
841 Chestnut Street
Philadelphia, PA 19017

Subject: REM III PROGRAM - EPA CONTRACT NO. 68-01-7250
WORK ASSIGNMENT NO. 123-3L31
DRAKE CHEMICAL SITE - PHASE III RI/FS
FINAL RI REPORT

Dear Mr. Schrock:

Enclosed, please find four (4) bound and one (1) unbound copies of the Drake Chemical Phase III Final Remedial Investigation Report (RI) which are being provided for your distribution. The RI has been prepared in a fast-track manner, at your direction, following the approach presented by the REM III Team on March 29, 1988 in your offices.

We have incorporated the comments which you supplied during the week of August 1, 1988.

If you have any questions, please contact me or our Site Manager, Dennis Smith at 412/788-1080.

Very truly yours,

John F. Gorgol for

Richard C Evans, PE
Regional Manager

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File: Drake Chemical (620Y/552)
Daily

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NARRATIVE

DRAKE CHEMICAL SITE
LOCK HAVEN, PENNSYLVANIA

EPA WORK ASSIGNMENT NUMBER 123-3L31
UNDER
CONTRACT NUMBER 68-01-7250

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EXECUTIVE SUMMARY

INTRODUCTION

A Remedial Investigation (RI) was performed at the Drake Chemical Site to resolve the data limitations of previous investigations in order to provide a sufficient basis for a focused Feasibility Study (FS). The FS scope is limited to developing remedial alternatives to remediate, if necessary, groundwaters affected by contaminants originating at the site. Consequently, the RI focused only on issues related to contaminated groundwater and the source of groundwater contamination - that is, the soils and sludges at the site.

THE SITE

The Drake Chemical Site

The Drake Chemical Site, located in Lock Haven, Pennsylvania, is now inactive and covers an area of about 12.5 acres.

Present at the site are two synthetic-lined wastewater treatment impoundments, an unlined leachate impoundment, another smaller and presently dry unlined "canal" lagoon, and a synthetic-lined and covered onsite landfill containing materials excavated during the Phase I remediation along the leachate stream. Chemical sludge and contaminated soils cover much of the open area at the site. Miscellaneous debris is also strewn about various areas. Existing site buildings, aboveground tanks, and surface impoundments are reportedly scheduled for demolition and removal.

Facilities of the former American Color and Chemical Company (AC&C) occupy the area immediately adjacent to and west of the Drake Chemical Site. The Hammermill Paper Company operates industrial facilities about one-half mile to be southwest. An apartment complex, shopping center, and the Castanea Township Park are situated within one-fourth mile from the site. Bald Eagle Creek is located less than one-half mile south of the site, and the West Branch Susquehanna River is located approximately three-fourths mile north of the site where it is joined by Bald Eagle Creek.

OBJECTIVES AND APPROACH

The primary objective of the Phase III Drake Chemical Site RI was to resolve data limitations of previous investigations in order to provide a sufficient basis for the Phase III FS determination of appropriate groundwater remedial alternatives.

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Specific objectives of the Phase III RI were:

- Characterize chemical contamination in the overburden groundwater system.

- Investigate the bedrock flow system, to determine its flow characteristics, its' relationship to the overburden system and assess the impact of site waste activities on groundwater quality.

- Verify the existence and location of an erosional channel believed to lie within the groundwater flow system south of the site.

- Characterize the soils and sludges onsite which constitute the source of groundwater contamination at and around the site.

- Develop a groundwater flow and solute transport model for use in the evaluation of remedial alternatives in the FS.

A technical approach relying on traditional, proven methods was developed and implemented. Major scope elements of the approach included:

- Surface water and sediment investigation
- Soils and source material investigation
- Groundwater investigation
- Data quality objectives development, an analytical chemistry program, and data evaluation
- Public and environmental health assessment

All major elements have been successfully completed with only minor modifications from project plans.

RESULTS OF INVESTIGATION

The specific project objectives of the Phase III RI have been achieved and are documented in the body of the report. This report provides adequate basis for the FS to proceed. Significant findings of the RI are presented below.

- Onsite surface waters and sediments in the three impoundments were found to be contaminated with site-related contaminants as expected. The relevance of this observation is minor since the two lined impoundments are slated for remediation during the forthcoming surface remediation project. Detection of site-related contaminants in the leachate impoundment, also expected, implies that this relatively small source of groundwater contamination needs to be factored into the overall site remedy strategy.

- Fenac was the only site-related contaminant detected in offsite surface waters. Other site-related compounds

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detected in offsite surface waters were limited to metals which, by comparison with results from background sampling locations, cannot be linked to waste activities at the site.

- Based on this assessment, it appears that more soils and sludges on the site are affected than was reported previously (NUS, 1987). Contamination with organic compounds constitutes a major concern, but not an unexpected finding. Inorganic contamination appears to be less significant. The assessment indicates that the approximately 12.5 acres (by 12.5 feet deep) covered in the soil/sludge investigation is a homogenous mixture containing organics which cannot be discretized. This volume is approximately 3.6 times the quantity of material projected as candidate for remediation (NUS, 1987).

- Overburden groundwater beneath the site (referred to as Zone 1) is polluted with a variety of organics and several inorganics, some of which exceed water quality standards. The source of this contamination is the soils/sludges in the vadose zone. Depending on the overall source treatment/management of migration, and risk management strategy to be developed in the FS, substantial quantities of Zone 1 groundwater may require remediation. Groundwaters in the bedrock formation beneath site (Zone 1) appear to be only marginally affected by site-related contamination.

- Zone 2 overburden groundwaters are affected by site-related contaminants at varying degrees. The degree of contamination is mainly a function of distance from the source as contaminant concentrations are observed to diminish with increasing distance from the site. Contaminant concentrations exceed water quality standards in some locations, particularly near the site. Consequently, depending on the overall site remedy strategy including the assessment of risk, certain Zone 2 overburden groundwaters may require remediation. Bedrock groundwaters in Zone 2 do not appear to be appreciably affected.

- Groundwaters in the Zone 3 overburden appear to be much less affected than in Zone 2, however, some observed concentrations exceed water quality criteria. The need to remediate overburden groundwaters will have to be assessed along with a review of the attendant risks in the overall site remedy strategy. Bedrock groundwaters in Zone 3 do not appear to be affected by site-related contamination.

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1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

This report presents results of the Phase III Remedial Investigation of the Drake Chemical Site, including field investigation activities, characterization of site contaminants, and risk assessment. This report has been prepared under Task 8 of the Phase III RI for the United States Environmental Protection Agency (USEPA), Region III, under Work Assignment Number 123-3L31, Contract Number 68-01-7250.

1.2 SCOPE AND OBJECTIVES OF INVESTIGATION

The primary objective of the Phase III Drake Chemical Site RI is to resolve data limitations of previous investigations to provide a sufficient basis for the Phase III A Feasibility Study (FS) determination of appropriate soil and sludge, and groundwater remedial alternatives. Specific goals integral to this objective include site characterization with respect to physical/environmental conditions, determination of the nature and extent of contamination, and assessment of risks posed to human health and the environment.

Specific objectives of the Phase III RI were developed to address existing data limitations. These objectives include the following

- Characterize chemical contamination in the overburden groundwater system. Data quality problems, particularly with volatile organic analyses, were encountered in the Phase II study. These limited contaminant characterization and the risk assessment.

- Investigate the bedrock flow system to determine its flow characteristics and its relationship to the overburden system and to assess the impact of site waste activities on groundwater quality. The previous Phase I field activities were directed primarily at characterizing the overburden system.

- Verify the existence and location of an erosional channel believed to lie within the groundwater flow system south of the site. Concerns that such a channel existed were raised in previous reports (NUS; April and August 1985, August 1986).

- Perform a detailed characterization of the soils and sludges on site that constitute the source of groundwater contamination at and around the site.

- Develop a groundwater flow and solute transport model for use in the evaluation of remedial alternatives in the Feasibility Study (FS).

The scope of the Phase III RI includes the following general tasks:

- Surface water and sediment investigation: Sampling, analysis, and elevation measurement of onsite and offsite surface water bodies was performed to better determine the characteristics and degree of contamination and to determine changes that may have occurred since previous investigations.

- Soils and source material investigation: Sampling and analysis were performed to determine physical properties and contamination depth, extent, constituents, and concentrations in onsite soils and source materials. Collection of these data was necessitated by an objective to determine the volume of waste materials that exceed groundwater protection action levels.

- Groundwater investigation: To estimate contaminant transport directions and rates, several new monitoring wells were installed and used along with existing wells to determine flow conditions in overburden and bedrock formations. Groundwater sampling (via monitoring wells) and analysis were also performed to determine contaminants.

- Data quality objectives and data evaluation: Data quality objectives where determined and used to select analytical methods appropriate to the site-specific parameters (i.e., type and concentration of contaminants). Analytical data were reduced and evaluated to support risk assessment and geologic/hydrogeologic, soils/source material, and surface water investigations.

- Risk Assessment: The current and potential impact on human health and the environment of contamination from site soils, source materials, and groundwater were evaluated. The baseline risk assessment was performed based on the present site conditions, assuming no remedial action is taken.

1.3 SITE INFORMATION

1.3.1 History and Description

Information relating the history of the site, the site setting, and relevant background information has been previously presented (NUS; July 1984, April 1985, August 1986). A brief restatement of the pertinent facts, to acquaint persons not familiar with the site follows.

The Drake Chemical Site, located in Lock Haven, Pennsylvania, is now inactive and covers an area of about 12 acres (see Figure A.1-1). Site use before Drake's ownership (1962) is not

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known with certainty; however, but is reports indicate that the site may have been used for chemical production as early as 1951. During operations at this site, the Drake Chemical Company manufactured specialty, intermediate chemicals for the producers of dyes, pharmaceuticals, cosmetics, herbicides, and pesticides.

Two synthetic-lined wastewater treatment lagoons, an unlined leachate lagoon, another smaller and currently dry unlined "canal" lagoon, and a synthetic-lined and covered onsite landfill containing materials excavated during the Phase I remediation along the leachate stream are located on the site. Chemical sludge and contaminated soils cover much of the open area at the site. Miscellaneous debris is also strewn about various areas. Existing site buildings, aboveground tanks, and surface impoundments are reportedly scheduled for demolition and removal.

Facilities of the former American Color and Chemical Company (AC&C) occupy the area immediately adjacent to and west of the Drake Chemical Site. The Hammermill Paper Company operates industrial facilities about one-half mile to the southwest. An apartment complex, shopping center, and the Castanea Township Park are situated within one-fourth mile from the site. Bald Eagle Creek is located less than one-half mile south of the site, and the West Branch Susquehanna River is located approximately three-fourths of a mile north of the site where it is joined by Bald Eagle Creek.

Detailed descriptions of the site geology and stratigraphy, hydrology, and climatology have been previously prepared (NUS; July 1984, April 1985, August 1986, 1987) and will not be restated. Readers seeking additional background information are urged to review these sources.

1.3.2 Previous Investigations

Drake Chemical, Inc., was cited several times between 1973 and 1982 for violations of environmental and health and safety regulations. After Drake Chemical, Inc., failed to respond to a request for voluntary cleanup, the EPA began emergency cleanup activities at the site on February 28, 1982. During the emergency cleanup, surface drums and sludges and liquids from process and storage tanks were removed from the site. A fence was also erected around the site. The cleanup was completed on April 21, 1982. The Environmental Response Team of EPA performed an Extent of Contamination Study in March 1982, which focused on the area around the leachate stream.

In August 1982, the EPA requested remedial action studies of the Drake Chemical Site. These studies included the preparation of a Remedial Action Master Plan by Roy F Weston (NUS; January 1983), a Work Plan for an RI/FS (NUS; May 1983), a Toxicological Impact Assessment by the Region III Field Investigation Team (FIT) of NUS Corporation.

Table 1-1 summarizes the history of remedial investigation activities conducted at the Drake Chemical Site prior to the current study. The table reveals the initial data collection activities performed in 1984 and a supplemental 1985 activity have spawned 5 separate reports. Following is a brief amplification of each report:

- Phase I RI: In response to EPA's concerns for hazards associated with the leachate stream, the fast-track Phase I RI was focused to provide an assessment of the associated impacts. The report indicated that remediation of the leachate stream was appropriate based upon the public and environmental health impacts.

- Phase I FS: Issued shortly after the Phase I RI, this report dealt only with remediation of the leachate stream. A Record of Decision for remediating the leachate stream was signed in September 1984. Design and construction phases ensued and the leachate stream remediation project was completed in early 1987.

- Phase II RI: Following completion of the Leachate Stream (Phase I) reports, and a supplemental field data collection activity a separate RI report dealing with two operable units: the onsite buildings and surface features including the lined lagoons; and the soils/sludges and groundwater was prepared. Conclusions of the report indicated the need to consider remediation for the buildings and surface features. A quantitative risk assessment of the potential impact of contaminated groundwaters on Bald Eagle Creek indicated that no remedial actions were necessary.

- Phase II FS: A feasibility study establishing the basis and specifying actions for remediation of the buildings and surface feature was completed in August, 1985. A Record of Decision was prepared in late 1985. Remediation is scheduled to begin in the second half of 1988.

- Phase III FS. A reevaluation of the effects of site related contamination emphasizing groundwater as a potential drinking water source indicated the need for remedial action. The Phase III FS established a basis and prescribed actions for remediating groundwaters and the soils/sludges (i.e. the source of contamination). A Record of Decision, however, could not be prepared because of data gaps including analytical data of questionable quality, limited characterization of the bedrock flow system, incomplete delineation and assessment of an erosional channel in the groundwater flow system, and limited source characterization information.

TABLE 1-1

SUMMARY OF PREVIOUS INVESTIGATIONS
DRAKE CHEMICAL SITE, PHASE III RI

Initial Activity	Description	Reference
Remedial Investigation Field Data Collection	Phase I RI report indicated remediation was necessary for the leachate stream area.	NUS, July 1984
	Phase I FS report established basis and actions for remediation of the leachate stream.	NUS, August 1984
Supplemental Field Data Collection	Phase II RI Report indicated remediation was necessary for onsite buildings and surface features.	NUS, April 1985
	Risk-based no action was was indicated for soils/sludges and affected groundwaters.	
	Draft Phase II FS Report established the basis and actions for remediation of the on site buildings and surface features, as well as the soils/sludges and affected groundwater.	NUS, August 1985
	Draft Phase III FS report revised the basis and actions for remediation of the soils/sludges and affected groundwaters.	NUS, August 1986

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In April, 1987, the REM III Team received a work assignment to conduct an RI/FS focused at resolving the limitation of the 1986 FS.

1.4 REPORT OVERVIEW

The presentation of investigation methods and findings within this report are pointed and intentionally brief. As stated in Section 1.2, the primary objective of the Phase III RI was to resolve data limitations from the existing body of knowledge. Consequently, findings are presented at a level of detail consistent with their impact of the existing body of knowledge. Major findings which cast light upon current limitations are emphasized, while those which simply underscore the present state of knowledge are given lesser prominence. The vast majority of the data collected is portrayed on figures. All figures are provided in a separate appendix (see Appendix A). This is intended to facilitate access and application of the data.

The organization and content of this report are as follows:

- Section 1.0: INTRODUCTION - Overviews the scope, objectives, and content of the Phase III Remedial Investigation; identifies site characteristics, history, and previous investigations and remediation work done at the site.

- Section 2.0: STUDY AREA INVESTIGATION - Presents a synopsis of the study design and details and significant variations from project planning documents.

- Section 3.0: PHYSICAL CHARACTERISTICS OF STUDY AREA - Develops the existing knowledge to a level commensurate with project objectives; emphasis is placed on the erosional channel investigation and results of the bedrock aquifer study.

- Section 4.0: NATURE AND EXTENT OF CONTAMINATION - Relevant results of the environmental sampling and chemical analysis program are described using contaminant locator maps (i.e., figures) and summary statistics, interpretations are provided for each media (i.e., surface water, groundwater, etc.), major classes of contaminants are identified, and observations particularly relevant to the risk assessment and/or identification of remedial process alternatives are offered.

- Section 5.0: CONTAMINANT FATE AND TRANSPORT - The major elements comprising the contaminant migration processes are described, and factors affecting the transport of contaminants from the site are identified; select contaminant isoconcentration contours are used to illustrate contaminant migration; methods and results of

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the groundwater flow/solute transport, numerical modeling task are presented.

- Section 6.0: RISK ASSESSMENT - An assessment of the public health risks associated with chemical contamination under the current site conditions is provided, chemical specific ARARs are identified and contrasted with actual measured concentrations, carcinogenic and noncarcinogenic risks are characterized for select relevant exposure scenarios, and an assessment of the hazards posed to aquatic receptors is presented.

- Section 7.0: SUMMARY AND CONCLUSIONS - Relevant findings are presented in a format to enhance decision making within the regulatory framework; conclusions are drawn from the summation of all germane work performed at the site.

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2.0 STUDY AREA INVESTIGATION

2.1 OVERVIEW

Results from previous investigations indicated the need for a more detailed evaluation of the elements comprising the groundwater and contamination regime. Specifically; additional information was required to characterize the source of contamination; the groundwater flow and contaminant migration dynamics, particularly the bedrock system; and the interaction between groundwater and surface waters (i.e., Bald Eagle Creek and the West Branch of the Susquehanna).

A study design, employing traditional investigative techniques was developed and implemented. Details of the investigation are described in the following documents:

- Final Work Plan, Phase III RI/FS Drake Chemical Site, Lock Haven, Pennsylvania (Ebasco, July 1987).

- Final Field Operations Plan, Phase III RI/FS, Drake Chemical Site, Lock Haven, Pennsylvania (Ebasco, October 1987).

Both documents were reviewed and approved by EPA. Overall, plans detailed those documents were followed; significant deviations are described in Section 2.1 Table 2-1 summarizes the field investigation study. Additional detail on the field investigation is provided in Section 3.0. As indicated by Table 2-1, the site investigation was successfully completed.

2.2 DEVIATIONS FROM INVESTIGATION PLANS

As previously stated, the study investigation generally proceeded according to the project planning documents. Several necessary deviations occurred. They are described below.

- Preliminary onsite tests of the electromagnetic (EM) technique planned for delineation of the buried erosional channel indicated that a high level of electrical interference existed in the study area. Therefore, the technique could not be expected to provide reliable results. Additional soil borings were added to the work scope to replace EM.

- Test pit excavations in the soil/sludge material indicated the possible presence of a clay strata in the sludge deposition area. Concerns that the clay strata might constitute a barrier to vertical migration, and that further test pitting (using a backhoe) would cause a significant breach of the barrier dictated that a hollow-stem auger technique be substituted for the backhoe at the clay strata. Borings with hollow steam augers were then placed directly adjacent to test pits and samples of the clay material and materials below were obtained.

TABLE 2-1

INVESTIGATION SUMMARY
DRAKE CHEMICAL SITE - PHASE III RI

Component	Purpose	Description	Comment
Geophysics	Delineate erosional channel	Electromagnetics	Additional soil borings were substituted and the erosional channel was delineated after trial efforts.
Test pit excavations and supplemental borings	Source characterization	• 41 test pits/5 borings • Soil/waste sampling	Successfully completed
Monitoring well installations	Groundwater flow and contamination characterization	• 16 overburden wells • 6 bedrock wells	Successfully completed
Aquifer testing	Groundwater flow characterization	• Drawdown/recovery pumping tests; slug tests • Groundwater elevation measurements (3 rounds)	Successfully completed
Surveying	Groundwater flow characterization	Well casings, etc., of new installed monitoring wells surveyed	Successfully completed
Surface water/sediment sampling and chemical analysis	Site characterization	13 surface water/sediment pairs collected from onsite and offsite surface water bodies	Successfully completed
Soil/waste (test pit) sampling, chemical and physical analysis	Site (source) characterization	187 individual samples collected and submitted for chemical and physical analysis • Multiple analyses on individual samples	Successfully completed
Groundwater sampling and chemical analysis	Site characterization	• Existing wells sampled once • New wells sampled twice • 6 select wells sampled for supplemental analysis	Successfully completed
Offsite boring	Delineate erosional channel	2 borings installed in lieu of geophysics	Successfully completed

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Additionally, due to the soft nature of materials encountered at test pit location 15, the hollow steam auger technique was substituted for the backhoe.

- A powered craft was employed for obtaining surface water and sediment samples from Bald Eagle Creek and West Branch Susquehanna River. It was originally, felt that these samples could be obtained from the river banks.

- Original planning called for sampling six of the existing Bar-Cad wells. Attempts of obtaining samples indicated that the wells could not produce water sufficient for sample volume requirements. Consequently, the Bar-Cad sampling effect was truncated.

The deviations identified above are the only major variations from the project planning documents. They enabled a successful field investigation by meeting project data requirements in a cost-efficient manner. Appendix E contains copies of all Field Change Requests (FCRs) that document all deviations, most of which were very minor. All FCRs were handled in accord with REM III Team Program Procedures (Ebasco, November 1987).

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3.0 PHYSICAL CHARACTERISTICS OF STUDY AREA

3.1 FIELD ACTIVITIES

Forty-one test pits were excavated during the field investigation to collect information necessary to characterize the contaminated soils and sludges according to contaminant type and concentration, mass-volume, and physical location. Each test pit was excavated to the water table or a maximum of 15 feet. The pits were located as near to the proposed 100-foot by 100-foot grid spacing as possible, although minor adjustments were made. Figure A.3-1 depicts the 41 test pit locations. Thirty-two of the test pits were located within the fenced area of the Drake Chemical Site and nine test pits were situated on the Gorham Property, immediately northeast of the former Drake facility. In addition, six test borings were drilled adjacent to areas where the excavation of test pits was difficult because of sidewall collapse. Monitoring well MW-M108 was installed in one of the onsite test borings (SB-32), and was the only onsite well installed during the Phase III RI. Two soil borings (SB-100 and SB-101) were drilled offsite to explore for the buried erosional channel which was discovered in Well E-3 during the Phase II RI. Both borings successfully located the channel soil boring and SB-101 was converted to monitoring well MW-M125. An additional 20 soil borings and monitoring wells were installed in 13 locations throughout the study area as shown in Figure A.3-2. A total of 28 borings were drilled and 22 monitoring wells were installed during Phase III. A copy of test pit logs and soil boring logs are included in Appendix B.

Table 3-1 is a summary of pertinent data for each of the 22 monitoring wells installed during the field activities of the Phase III RI.

The locations of monitoring wells were as proposed in the FOP with the exception of the following wells: MW-M101, MW-M102, MW-M103, MW-M104, MW-M109, and MW-M112. Locations of monitoring wells MW-M101, 102, 103, and 104 were reassigned from private property where they had been proposed onto city-owned property for safety and convenience during drilling operations.

The proposed locations for monitoring wells MW-M109 and MW-M112 were moved from Hammermill property onto city-owned property to eliminate potential delays resulting from the time needed to obtain legal clearance for site access. It would have been necessary to remove a portion of the chain link fence recently erected around the Hammermill Property during drilling operations. This would reduce security of the property at a time when site security was a major concern.

These location changes for the 6 monitoring wells mentioned above did not affect the integrity of the targeted data scoped for the Phase III study. The EPA RPM and the project officer from PADER came to the site and inspected and approved each of the 16 original and 6 relocated proposed monitoring well

TABLE 3-1

MONITORING WELL DATA
DRAKE CHEMICAL SITE - PHASE III RI

Monitoring Well	Well Type	Total Depth of Well (feet)	Monitored Interval (feet below ground surface)	Screen Slot Size x Length	Screen and Riser Pipe Inner Diam (feet)	Annulus Diameter (feet)	Lithology of Monitored Interval	Well Construction Type	Ground Elevation (feet msl)	Water Level Measuring Point (feet msl)	Water Level Meas Point Elevation (feet msl)	Depth/ Elevation to Bedrock	Saturated Thickness
MW-M101	Shallow Overburden	25'	15 5 24 5'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	557 25'	Top of Riser Pipe (flush mounted)	557 09'	NA	
MW-M102	Deep Overburden	41'	30 5-39 5	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	557 30'	Top of Riser Pipe (flush mounted)	557 10'	42'/515 30'	
MW-M103	Shallow Overburden	26'	16 5-25 5'	10 Slot x 9'	0 167'	0 833'	Silty Sand and Gravel	Sched 40 PVC	556 28'	Top of Riser Pipe (flush mounted)	556 06'	NA	
MW-M104	Deep Overburden	41'	31 5-40 5'	10 Slot x 9'	0 167'	0 833'	Silty Sand and Gravel	Sched 40 PVC	556 24'	Top of Riser Pipe (flush mounted)	556 01'	41'/515 24'	
MW M105	Deep Bedrock	106 2'	86 5-105 5'	10 Slot x 19'	0 167'	0 323'	Fractured Claystone/Shale	Sched 40 PVC	556 16'	Top of Riser Pipe	558 20	40 5'/515 66'	
MW M106	Shallow Overburden	25 5'	13 22'	10 Slot x 9'	0 167'	0 5'	Sand and Gravel	Sched 40 PVC	554 72'	Top of Riser Pipe	556 57'	NA	
MW M107	Deep Bedrock	108'	86-105'	10 Slot x 19'	0 167'	0 323'	Fractured Claystone/Shale	Sched 40 PVC	556 00'	Top of Riser Pipe	558 11'	41 3 /514 70	
MW M108	Shallow Overburden	23'	10 19'	10 Slot x 9'	0 167'	0 5'	Sand & Sandy Clay	Sched 40 PVC	555 41'	Top of Riser Pipe	557 33'	NA ~ 39/516 41'	
MW-M109	Deep Bedrock	104'	89 3 103 3'	10 Slot x 14'	0 167'	0 323'	Fractured Shaley Limestone	Sched 40 PVC	554 14	Top of Riser Pipe	556 32'	36 5'/517 64	
MW M112	Deep Overburden	35 5'	25 3-34 3'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	552 86'	Top of Riser Pipe	554 80'	35'/517 86	
MW M113	Deep Overburden	46 5'	35 3-44 3'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	551 72'	Top of Riser Pipe	554 02'	46'/505 72'	

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TABLE 3-1
MONITORING WELL DATA
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Monitoring Well	Well Type	Total Depth of Well (feet)	Monitored Interval (feet below ground surface)	Screen Slot Size x Length	Screen and Riser Pipe Inner Diam (feet)	Annulus Diameter (feet)	Lithology of Monitored Interval	Well Construction Type	Ground Elevation (feet msl)	Water Level Measuring Point (feet msl)	Water Level Meas Point Elevation (feet msl)	Depth/ Elevation to Bedrock	Saturated Thickness
MW M114	Deep Bedrock	111'	90 3-109 3'	10 Slot x 19'	0 167'	0 323'	Fractured Shaley Claystone	Sched 40 PVC	552 49'	Top of Riser Pipe	553 92	46/506 49'	
MW-M115	Deep Overburden	37'	25 3-34.3'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	547 48'	Top of Riser Pipe	549 64	37/510 48	
MW M116	Shallow Overburden	25'	14 3 23 3'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	551 57'	Top of Riser Pipe	553 68	NA	
MW M117	Deep Overburden	41'	30 3-39 3'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	551 69'	Top of Riser Pipe	553 82	40 5'/511 19	
MW M118	Shallow Overburden	25'	15 24'	10 Slot x 9'	0 167'	0 5'	Sand and Gravel	Sched 40 PVC	553 25'	Top of Riser Pipe	555 47	NA	
MW-M119	Deep Overburden	50'	40-49'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	553 39'	Top of Riser Pipe	555 45	50'/503 39'	
MW M120	Deep Bedrock	140'	120.3-139.3'	10 Slot x 19'	0 167'	0 323'	Fractured Limestone & Shaley Claystone	Sched 40 PVC	552 29'	Top of Riser Pipe	555 34	50'/502 29'	
MW-M122	Deep Overburden	51'	35 3-44 3'	10 Slot x 9'	0 167'	0 833'	Sand	Sched 40 PVC	556 29'	Top of Riser Pipe	558 53	46'/510 29'	
MW-M123	Shallow Bedrock	80'	59 78'	10 Slot x 19'	0 167'	0 323'	Fractured Shale	Sched 40 PVC	556 13'	Top of Riser Pipe	558 19	46'/510 13'	
MW-M124	Deep Overburden	51'	40 49'	10 Slot x 9'	0 167'	0 833'	Sand and Gravel	Sched 40 PVC	556 61'	Top of Riser Pipe	559 07	51'/505 61	
MW M125	Overburden	99'	61-70'	10 Slot x 9'	0 167'	0 5'	Sand	Sched 40 PVC	553 53'	Top of Riser Pipe	555 34	98'/455 53'	

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locations. Field Change Request No. 6 documents the rationale and approval for the relocation of the 6 monitoring wells (See Appendix E).

Table 3-2 outlines the drilling and test pit excavation program conducted at the Drake Chemical Site during the Phase III RI field investigations.

An electromagnetic geophysical survey was performed in an effort to determine the orientation of the buried bedrock channel identified in the Phase II RI. A grid of data points was established in the vicinity of Well E-3 along three lines spaced approximately 200 feet apart in a northeast direction. Each line was approximately 800 feet long and was marked with a pin flag at 20 foot intervals. A Geonics EM-31 terrain conductivity meter was used to obtain data at grid points. Conductivity readings were recorded along one line and part of a second line. Many of the readings at various grid point stations displayed reversed polarity and needle deflection indicating electrical interference with equipment measurements. The geophysics program was discontinued after a day's worth of data were collected, evaluated, and determined to be erroneous or of poor quality. Possible explanations for poor data are numerous power lines and fences located around the site and the impact of possible buried metallic objects on the sensitivity of the EM-31 (i.e., these features affected the EM data and masked anomalies that may have represented the buried channel).

Rising head slug tests were performed on each of the 22 newly installed wells. Also, short term pumping tests were performed on 4 of the newly installed wells. Results of the details of the aquifer testing and later discussed in the hydrogeology section of this report (Section 3.8).

3.2 SURFACE FEATURES

A minimum of three backfilled sludge lagoons are present at the Drake Chemical Site as shown on Figure A.3-1 and accompanying test pit cross-sections. In addition, sludge was found in Test Pit TP-28 located in the area south of the former office trailer and decontamination pad. The ground surface reflects the extent of each of the three lagoons, whereas the area near the decontamination pad has no surface expression to indicate lateral extent of the sludge material.

A slow, but continuous leachate seep was observed at the base of the dike near the southeast corner of the east lagoon (See Figure A.3-1). The leachate infiltrated the ground approximately 10 feet from the seep, leaving surface stains along a linear flow path, up to the point of infiltration.

TABLE 3-2

OUTLINE OF DRILLING AND TEST PIT EXCAVATION PROGRAM
DRAKE CHEMICAL SITE - PHASE III RI

Onsite Activities	Offsite Activities
• 32 test pits	• 9 test pits
• 5 soil borings	• 1 soil boring
• 1 soil boring converted to a monitoring well	• 21 soil borings converted to monitoring wells (6 borings were cored and converted to bedrock wells)

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The canal lagoon, located at the southern tip of the site (See Figure A.3-1), was completely dry throughout the field investigation from October, 1987 to January, 1988. The adjacent leachate lagoon contains water to an approximate depth of 5 feet. Further discussion concerning surface features are contained in the Phase I and Phase II RI Reports (NUS; April 1985, August 1986).

3.3 METEOROLOGY

The Climatology section of the Phase II RI Report (NUS; August 1986) contains a detailed discussion of the meteorology of the Drake Chemical Site.

3.4 SURFACE WATER

Surface water on site was briefly discussed in Section 3.1 of this report. Offsite surface water includes Bald Eagle Creek, south of the site, and the West Branch of the Susquehanna River, north of the site. Three onsite surface water bodies exist and include the east and west lined waste water impoundments, and the leachate impoundment at the southern tip of the site. Additional information is available in the Phase I and Phase II RI Reports (NUS; April 1985, August 1986).

Both Bald Eagle Creek and the West Branch Susquehanna River are clearly wetland areas. Previous reports describe native aquatic species and flora (NUS, 1984). The three onsite surface water bodies were not considered as wetlands in this study though water and sediment quality samples were collected from each. An examination of arial photographs from EPIC reveals that the three onsite surface water bodies were constructed during the late 1950's probably as waste impoundments. The shape of the impoundments has changed as revetments were constructed and fill material added to displace their contents.

There is no knowledge of aquatic species habitating these impoundments. The two lined impoundments clearly do not support any terrestrial flora. Flora surrounding the leachate impoundment is typical of the surrounding area.

The waters and most notably the sediments within these impoundments are highly contaminated by site related organic and inorganic contaminants. The leachate impoundment at the south end of the site is the topographical low and is felt to be the recepient of all precipitation not lost to infiltration or evaporation.

A total of 13 surface water and sediment sample pairs were collected from surface water bodies during the Phase III field investigations. A sample pair was collected from the West Lagoon, East Lagoon, and the Leachate Pond, for a total of 3 onsite surface water/sediment samples. Seven surface water/sediment sample pairs were collected along Bald Eagle Creek and three sample pairs were collected along the West

Branch of the Susquehanna River. Further discussion and a location map are contained in Section 4.0 of this report.

3.5 SOILS AND OVERBURDEN MATERIAL

The additional subsurface data obtained during the Phase III RI field investigation verified the lithology as described during the previous investigations of the Drake Chemical Site (NUS; April 1985, August 1986). Seven cross-sections (Figures A.3-3 through A.3-9) as indicated on Figure A.3-1, are included in Appendix A. These depict the findings of the test pit data and onsite soil boring program. The alluvial deposits, which underlie the site and adjacent areas, consist of clay to sandy clay floodplain deposits. These coarsen in grain size at depth to sand and gravel stream channel deposits, then finally to medium to coarse grained sands mixed with gravel-sized sandstone fragments. The clay and sandy clay layer occurs from ground surface to an average depth of 15 feet, based on both onsite and offsite soil borings throughout the study area. This clay-rich layer varies laterally throughout the study area from brown and gray sandy clay to an almost pure clay lense, colored gray with orange mottling. Two onsite soil borings (SB-15 and SB-25) penetrated this mottled gray, clay lense beneath two of the former sludge lagoons (see Figure A.3-1). The soil boring for monitoring well MW-M124, located near the sewage treatment plant, also penetrated a lense of the mottled gray clay. None of the remaining twenty-five soil borings nor any of the test pits encountered this mottled gray clay. Based on the new and existing data, the general lithology of the upper 15 feet of overburden material interpreted as floodplain deposits, may be thought of as a layer of sandy clay with various lenses of clay dispersed throughout.

Below approximately 15 feet, the alluvial sediments increase in grain size with increasing depth to sand and gravel and then to sand with gravel- and cobble-sized sandstone "fragments." These sandstone "fragments" are subrounded and may have originated from the more resistant sandstone formations that comprise adjacent Bald Eagle Mountain.

3.6 BURIED CHANNEL

During the Phase II RI study (NUS; August 1986) monitoring well boring E-3 encountered what was thought to be a possible stream channel incised into bedrock. The top of bedrock is generally encountered within 40 to 50 feet below ground surface in the adjacent areas, whereas boring E-3 was drilled to a depth of 68 feet without penetrating bedrock.

One of the goals of the Phase III RI field investigation was to confirm the existence of the channel, to determine orientation of the channel, and to monitor water quality within the channel.

Both of the two test borings drilled were successful in locating this erosional channel that bisects the underlying bedrock. The

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first boring (SB-100) was drilled to 60 feet and did not encounter bedrock. This boring was located approximately 170 feet east-northeast of monitoring well E-3. No soil samples were collected from the boring since the purpose of the boring was only to locate the channel. A second boring (SB-101) was drilled approximately 410 feet east-northeast of E-3. Bedrock was encountered at a depth of 98 feet below ground surface in this boring. Split spoon samples were collected at 5-foot intervals from 60 to 98 feet. Figure A.3-10 is a bedrock surface contour map which illustrates the orientation of the buried channel.

The channel is filled with brown, fine-grained, well-sorted sand with some silt and gravel dispersed throughout. The gravel is composed of subrounded feldspar and sandstone fragments. Based on samples collected from soil boring SB-101, there are two zones containing coarse-grained sand and gravel; one encountered at a depth of 60 to 61.5 feet and one at a depth of 81 to 83 feet. The gravel consists of "pea-sized" subrounded grains of quartz and feldspar. During drilling of soil boring SB-101, an odor was noted from the water table surface, located at a depth of about 12 feet, to a depth of approximately 60 feet. Because of rain the HNU was not being used; therefore, no HNU readings were recorded. Monitoring well MW-M125 was installed in soil boring SB-101 within the buried channel. The screen was placed immediately below the observed odor - from 58 to 68 feet. This interval was selected to maintain consistency since the screened interval of the only other well within the channel (E-3) is screened at a similar interval.

Based on new and previously collected data, this buried alluvial channel is oriented in an east-west direction roughly paralleling Bald Eagle Creek (see Figure A.3-10). The sediment within the erosional channel contains quartz and feldspar gravel, which is compositionally unique to the area. Typically, the gravel found in the overburden material consists of sandstone fragments that originated from the adjacent bedrock commonly found in the area. The quartz and feldspar gravel infer an igneous source material that is not common to the area bedrock. This gravel may be glaciofluvial in origin.

3.7 BEDROCK

The study area is situated on the north limb of a northeast trending anticline that is part of the Valley and Ridge Physiographic Province. The West Branch Valley is the result of differential erosion of non-resistant sedimentary rock units (i.e. shale, claystone, limestone). The underlying bedrock throughout the Drake Chemical Site study area has a regional dip of 20° to 50° to the northwest (Vendel Enviro-Industrial Consultants, Inc., 1987).

According to a local study performed by the U.S. Army Corps of Engineers, the Drake Chemical Site is underlain by shales of the Marcellus Formation. Figure A.3-11 illustrates the general

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lithology of the bedrock surface as well as the location of two regional cross sections. Cross section E-E' (see Figure A.3-12) which runs roughly north to south, illustrates the general attitude of the underlying bedrock beneath the study area.

Section F-F' (see Figure A.3-13) is a cross-section in the northeast (strike) direction. These two sections, along with the cross-sections depicted in Figure 3-1 of the Phase II RI (NUS; August 1986) and the test pit cross sections as shown on Figure 3-1 of this study, represent the basic hydrogeologic interpretation of the Drake Chemical Study Area.

Six bedrock wells were drilled and installed during the Phase III RI field investigation to further investigate groundwater conditions within bedrock. Wells MW-M105 and MW-M107, located adjacent to the north end of the site (see Figure A.3-11), penetrated a black shaley claystone unit of the Marcellus Formation. The top of the shaley claystone was found to be very weathered and highly fractured in these two borings, with high angle fracturing for a vertical distance of approximately 20 feet from the top of bedrock. The rock becomes progressively less fractured with lower angle fracturing and more blocky in character beginning at about 20 feet into bedrock and extending downward to the bottom of the borings that penetrated this unit (maximum depth, 108 feet at location MW-M107). Calcite filled fractures became more common with depth, although isolated open fracture zones measuring from 1 to 3 feet thick occur throughout the cored interval between 60 and 105 feet in both borings. These zones are highly fractured with moderate to high angle fractures and are saturated.

The boring at MW-M109 penetrated the contact between the Marcellus Formation and the Keyser/Oldport Limestone at a depth of approximately 78 feet from ground surface. According to the rock sequence as described in the report issued by the U.S. Army Corps of Engineers, a rock unit called the Shriver Chert Ridgely Sandstone separates the Marcellus Formation and the Keyser/Oldport Limestone (see Figure A.3-11). This rock unit was not identified in the core at MW-M109 and, consequently, is not shown on cross-section E-E' (see Appendix A). The Keyser/Oldport Limestone was described as hard, brittle, and highly fractured from 78 to 105 feet in depth and becomes blocky and less fractured between 105 feet and 110 feet, the total depth of boring MW-M109.

Wells MW-M114 and MW-M120 also penetrated the Keyser/Oldport Limestone Formation. Boring MW-M114 penetrated a soft gray shaley claystone unit of this formation. The rock was noted as fractured, with high angle fracturing to about 60 feet below ground surface. Sandstone fragments were noted in some of the fractures, presumably originating from the overburden material that may have migrated downward through fractures or may have resulted from drilling operations. The rock was described as less fractured and blocky in nature from approximately 60 to

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90 feet in depth below ground (20 to 50 feet into bedrock) and containing isolated 1 to 2-foot thick zones of intense fracturing that are open and saturated. The rock is fractured to very fractured from 90 feet to the total depth of the boring at 110 feet.

Because of the soft nature of the rock, the top of bedrock was not identified in boring MW-M120, although the boring did penetrate a substantial thickness of bedrock. The boring was advanced to a depth of 110 feet using hollow stem augers. The bedrock surface was encountered at a depth of 55 feet in adjacent borings MW-M118 and MW-M119. Bedrock at this location consists of alternating layers of gray, lime-rich claystone, black shaley claystone, and gray limestone. No rock core was collected throughout this interval and split spoon recovery was very poor. As a result, limited data regarding bedrock to a depth of 110 feet were collected. Apparently, the bedrock is a soft gray claystone to shaley claystone from 55 to 110 feet. Alternating layers of medium soft claystone and medium hard limestone ranging from less than 1 foot to more than 10 feet in thickness occur from a depth of 110 feet (onset of rock coring operations) to the total depth of the boring at 141 feet below ground surface. This 31-foot, cored interval ranges from very broken to blocky in the alternating sequences of claystone and limestone. Portions of the blocky limestone reveal former highly-fractured zones bound within a secondary, calcite-cement matrix. Based on rock core data, the Keyser/Oldport Limestone Formation contains a variety of lithologies throughout the study area.

3.8 HYDROGEOLOGY

One of the objectives of the Phase III field investigation was to obtain information to enhance the understanding of the hydrogeology in the overburden materials and the underlying fractured bedrock beneath the Drake Chemical Site. In general, no confining layers were identified during the drilling program. Sand and gravel deposits form the principal flow zone beneath the study area. The alluvial deposits comprising the floodplain and erosional stream channel and the fractured bedrock are all hydraulically connected, although the top of the bedrock consists of a 2 to 5 foot-thick layer of weathered material that may act as a poor aquitard, based on visual observations. Groundwater flows north, east, and south from the Drake Chemical Site because of localized mounding, then gradually to the south and southeast toward Bald Eagle Creek. The groundwater regime at the site consists of saturated alluvial deposits overlying fractured shale bedrock. The bedrock and overlying deposits are hydraulically connected, forming the unconfined aquifer in the area.

Hydraulic conductivities within the unconsolidated deposits obtained from field permeability tests of newly installed wells range from 1.94×10^{-4} cm/sec for a fine-grained sand within the erosional channel at about 60 feet (monitoring well MW-M125) to

3.70×10^{-2} cm/sec in a medium-grained sand at about 35 feet (monitoring well MW-M122). Results from Phase II (NUS; August 1986) and Phase III data reveal considerable variation in hydraulic conductivities, both vertically and horizontally, within the unconsolidated deposits. These variations are caused by both formation changes and by gradational changes in the relative percentages of silts, sands, and clays within each lithologic unit.

Slug tests were performed on each of the newly installed monitoring wells to estimate the hydraulic conductivity of the overburden and fractured bedrock. In addition, short-term pumping tests were performed on four selected wells (three bedrock wells and one overburden well) to confirm the slug test data. Table 3-3 summarizes the results of the permeability testing performed during the field activities of the Phase III RI. The hydraulic conductivities mentioned below were calculated from the slug tests.

Fractured shale and claystone units of the Marcellus Formation were screened in three new wells (MW-M105, MW-M107, and MW-M123) and two previously existing wells (E-1 and E-2). The calculated hydraulic conductivity of the fractured shale and claystone ranged from 2.31×10^{-4} cm/sec in well MW-M107 to 1.3×10^{-3} cm/sec in well MW-M123. The average value based on the slug test data collected from each of the five wells screened in the Marcellus Formation is 7.2×10^{-4} cm/sec.

Three wells are screened in the Keyser/Oldport Limestone (MW-M120, MW-M109, and MW-M114). Well MW-M109 is screened in fractured interval consisting of alternating layers of limestone and shaley claystone. This interval of the Keyser/Oldport Limestone has a measured hydraulic conductivity of 3.33×10^{-3} cm/sec. Well MW-120 is screened in a zone of alternating limestone and shaley claystone. This interval has a hydraulic conductivity value of 5.38×10^{-3} cm/sec. Based on data from wells MW-M120 and MW-M109, the limestone and lime-rich portion of the Keyser/Oldport Limestone has an average hydraulic conductivity value of 4.4×10^{-3} cm/sec.

Well MW-M114 is screened in the fractured shaley claystone portion of the Keyser/Oldport Limestone. This interval has hydraulic conductivity of 2.74×10^{-4} cm/sec, which is similar to those values for Marcellus Shale discussed earlier.

TABLE 3-3

FIELD PERMEABILITY TEST RESULTS
DRAKE CHEMICAL SITE - PHASE III RI

Well Number	Screened Interval	Screened Material	Hydraulic Conductivity			Transmissivity			Saturated Thickness (H) ft.	Remarks
			Slug Test Value cm/sec	Pumping Test Value		Slug Test Value gpd/ft	Pumping Test Value			
				Drawdown cm/sec	Recovery cm/sec		Drawdown gpd/ft	Recovery gpd/ft		
MW-M101	15.5 - 24.5'	Sand and Gravel	8.08×10^{-3}			5,217			30.46'	Hydraulic Conductivity and Transmissivity Values Computed by NUS
MW-M102	30.5 - 39.5'	Sand and Gravel	5.49×10^{-3}			3,490			30.02'	
MW-M103	16.5 - 25.5'	Silty Sand and Gravel	6.36×10^{-3}			2,014			29.44'	
MW-M104	31.5 - 40.5'	Silty Sand and Gravel	9.04×10^{-3}			5,655			29.50'	
MW-M105	86.5 - 105.5'	Fractured Claystone/Shale	4.92×10^{-4}	3.06×10^{-4}	3.28×10^{-4}	678	615	658	94.71'	
MW-M106	13 - 22'	Sand and Gravel	2.21×10^{-3}			1,411			30.07'	
MW-M107	86 - 105'	Fractured Claystone/Shale	2.31×10^{-4}	1.20×10^{-4}	1.23×10^{-4}	313	238	244	93.19'	
MW-M108	10 - 19'	Sand and Sandy Clay	4.37×10^{-4}			282			30.47'	
MW-M109	89.3 - 103.3'	Fractured Shaley Limestone	3.33×10^{-3}	1.39×10^{-3}	NA	1,411	2,687	NA	91.63'	
MW-M112	25.3 - 34.3'	Sand and Gravel	1.03×10^{-3}			534			24.43'	

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TABLE 3-3
FIELD PERMEABILITY TEST RESULTS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Well Number	Screened Interval	Screened Material	Hydraulic Conductivity			Transmissivity			Saturated Thickness (H) ft.	Remarks
			Slug Test Value cm/sec	Pumping Test Value		Slug Test Value gpd/ft	Pumping Test Value			
				Drawdown cm/sec	Recovery cm/sec		Drawdown gpd/ft	Recovery gpd/ft		
MW-M113	35.3 - 44.3'	Sand and Gravel	3.23×10^{-2}			23,804			34.69'	Hydraulic Conductivity and Transmissivity Values Computed by NUS
MW-M114	90.3 - 109.3'	Fractured Shaley Claystone	2.74×10^{-4}			366			97.11	
MW-M115	25.3 - 34.3'	Sand and Gravel	1.75×10^{-2}			11,512			30.98'	
MW-M116	14.3 - 23.3'	Sand and Gravel	3.62×10^{-4}			228			29.71'	
MW-M117	30.3 - 39.3'	Sand and Grvel	5.64×10^{-3}			3,533			29.59'	
MW-M118	15' - 24'	Sand and Gravel	2.84×10^{-3}			2,187			36.34'	
MW-M119	40 - 49'	Sand and Gravel	5.38×10^{-3}			4,125			36.16'	
MW-M120	120.3 - 139.3'	Fractured Limestone + Shaley Claystone	5.38×10^{-3}			9,586			126.34'	
MW-M122	35.3 - 44.3'	Sand	3.70×10^{-2}			25,312			32.22'	
MW-M123	59 - 78'	Fractured Shale	1.30×10^{-3}			882			64.31'	
MW-M124	40 - 49'	Sand and Gravel	2.49×10^{-4}			188			35.74'	
MW-M125	61 - 70'	Sand	1.94×10^{-4}	1.54×10^{4}	2.10×10^{-4}	360	286	390	87.41'	

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The higher hydraulic conductivity values for the limestone and shaley limestone bedrock, as compared to the fractured shale and shaley claystone, may be due to the degree of competency of the two rock types (see Table 3-4). Because limestone generally is a more competent rock than shale and claystone, it usually displays a high degree of fracturing, resulting in a more interconnected network of fractures, as compared to the less competent shale and shaley claystone. Also, solution channels may be present throughout the limestone. Based on the existing data from the eight bedrock wells, the limestone has a slightly higher hydraulic conductivity (average value from two wells: 4.4×10^{-3}) than the shale and shaley claystone (average value from six wells: 6.4×10^{-4}).

The site is underlain by shale and shaley claystone of the Marcellus Formation. The Keyser/Oldport limestone is located beneath the shale and shaley claystone in the site vicinity and is in direct contact with the overburden material southeast (downgradient) of the site. The aquifer characteristics of the various screened intervals of the bedrock do not vary enough to create a substantial difference in groundwater migration throughout the different bedrock units. Therefore, the bedrock shall be considered a relatively uniform and homogeneous flow system for purposes of modeling.

Groundwater flows north, east, and south from the Drake Chemical Site, then gradually heads to the south and southeast toward Bald Eagle Creek (see Figure A.3-14), based on the January 1988 water level elevations (see Table 3-5) taken from new and existing monitoring wells screened at or near the water table. Comparing the new and potentiometric map with the potentiometric maps developed for the Phase II RI (NUS; August 1986) reveals a southeastern component of groundwater flow direction previously unidentified, based on the additional Phase III data. A potentiometric map based solely on the eight monitoring wells screened in bedrock shows a less detailed but similar groundwater flow direction, as illustrated on the map constructed from the water table wells (see Figure A.3-15).

Based on existing data, the buried channel apparently does not affect or influence groundwater flow direction or contaminant migration.

There is no indication of a vertical hydraulic gradient, although there are minor differences in water level elevations within well clusters that are screened in various lithologies and at different depths. Regardless, no set pattern is observed.

A comparison of seven sets of water level elevations collected during the Phase II study during autumn of 1983 and the winter of 1984, as well as the three data sets collected during 1988, reveals little change in water levels over time, indicating a relatively constant condition for the groundwater flow pattern throughout the study area.

TABLE 3-4

COMPARISON OF HYDRAULIC CONDUCTIVITY VALUES
CALCULATED FOR BEDROCK WELLS
DRAKE CHEMICAL SITE - PHASE III RI

Monitoring Well	Hydraulic Conductivity Values (cm/sec)	Lithology of Screened Intervals
Marcellus Black Shale		
MW-M105	4.92×10^{-4}	claystone/shale
MW-M107	2.31×10^{-4}	claystone/shale
MW-E-1	8.5×10^{-4}	shale
MW-E-2	7.0×10^{-4}	shale
MW-M123	1.3×10^{-3}	shale
Keyser/Oldport Limestone		
MW-M120	5.38×10^{-3}	limestone & shaley claystone
MW-M109	3.33×10^{-3}	shaley limestone
MW-M114	2.74×10^{-4}	shaley claystone

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TABLE 3-5

GROUNDWATER ELEVATIONS
DRAKE CHEMICAL SITE - PHASE III RI

Well Number	Groundwater Elevation		
	05/12/88	04/24/88	01/25/88
Drake Wells			
MW-M2	544.90	545.08	544.93
MW-M3	544.24	544.52	544.34
MW-M4	542.85	543.15	543.06
MW-M5	546.67	547.50	546.92
MW-M6	546.94	547.34	547.13
MW-M7	551.45	551.81	552.02
MW-M8	544.86	545.14	545.12
MW-M9	551.21	551.69	551.61
MW-M10	545.81	545.13	545.55
MW-M11A	540.83	541.24	541.05
MW-M11B	540.99	541.06	541.23
MW-M12B	543.78	542.67	543.57
MW-M13	542.12	542.52	542.46
MW-M14	544.98	545.19	544.98
MW-M15	541.40	541.69	541.60
MW-M17	542.29	542.75	542.37
MW-M18	543.56	543.99	543.82
MW-M19	543.22	543.45	543.35
MW-M20	539.78	539.71	540.05
MW-M21	542.94	543.08	542.81
MW-M101	545.79	-	545.52
MW-M102	545.47	-	545.29
MW-M103	544.92	545.08	544.65
MW-M104	544.92	545.08	544.68
MW-M105	545.36	545.61	545.53

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TABLE 3-5
GROUNDWATER ELEVATIONS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Well Number	Groundwater Elevations		
	05/12/88	04/24/88	01/25/88
MW-M106	544.92	545.15	544.99
MW-M107	544.23	544.52	544.25
MW-M108	546.33	546.98	546.85
MW-M109	542.23	542.60	542.52
MW-M112	541.88	542.32	542.35
MW-M113	540.12	540.26	540.73
MW-M114	540.37	540.23	540.73
MW-M115	540.04	539.97	540.38
MW-M116	540.88	540.88	541.02
MW-M117	540.82	540.90	541.03
MW-M118	539.64	539.66	539.79
MW-M119	539.69	539.67	539.85
MW-M120	539.51	539.47	539.68
MW-M122	542.73	542.87	542.50
MW-M123	542.46	542.83	542.45
MW-M124	541.49	541.62	541.35
MW-M125	542.94	543.31	543.04
MW-E-1	545.24	545.27	545.19
MW-E-2	543.40	543.75	543.56
MW-E-3	543.84	544.12	543.84
S.G. #1	539.39	539.21	-
S.G. #2	544.29	543.60	-

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TABLE 3-5
GROUNDWATER ELEVATIONS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE THREE

Well Number	Groundwater Elevations		
	05/12/88	04/24/88	01/25/88
AC+C Wells			
MW-1	546.18	546.70	
MW-2A	545.78	545.69	
MW-2B	544.63	545.02	
MW-4	544.76	544.82	
MW-5	549.46	550.88	
MW-6	548.79	549.25	
MW-7	549.03	549.33	
MW-8	555.26	555.48	
MW-9	554.94	555.05	
MW-11	554.64	554.94	
MW-12B	548.97	549.63	
MW-14	546.95	547.38	
MW-15	556.00	555.59	
MW-16	555.18	555.18	
MW-17	544.99	545.10	
MW-18A	544.87	544.89	
MW-18B	544.75	544.96	
MW-19A	554.57	554.74	
MW-19B	549.06	549.41	
MW-20	544.92	-	
MW-21	545.01	545.08	
MW-22	546.82	547.28	
MW-23	555.12	555.05	
MW-23B	556.84	557.07	

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3.9 OBSERVATIONS FROM TEST PIT OPERATIONS

This section is a brief description of various observations made during the test pit operations condensed throughout the study area of Drake Chemical during the Phase III investigation.

- Buried wastes were identified outside the fenced portion of the Drake Property. for example:

  - A 6-inch drain pipe, uncovered in test pit number T-44, was transporting leachates from an unknown source on Drake Chemical Site off site to the Gorham Property (see Photo R9P3).

  - A partially buried bag of a red substance was uncovered near the well cluster near MW-M107.

- A blue plastic liner material was observed at about 11.5 feet in soil boring SB-31. During drilling, the drill water was draining beneath a partially buried piece of blue plastic "liner" at the surface adjacent to the boring (see Photos R3P29, R3P30).

- Three distinct sludge-filled lagoons were located. An area of soil-covered sludge was located just south of the decon pad in test pit TP-28. (This may be part of the Old Pennsylvania Canal.)

- The sludge appeared to be layered as follows:

  - Alternating layers of cream-white and red-stained material that was slightly odorous and ranged from very viscous to a hard crust.

  - Less distinct layering of dark blue to green material that had more distinct odor and was viscous to liquid.

  - Black layer of highly odorous material that ranged from liquid to very liquid.

- The southern end of the site contains buried debris resembling possible flood debris. This may have served as a dump site for the debris cleaned up from the area following the major flood that took place during February, 1984.

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4.0 OCCURRENCE AND DISTRIBUTION

4.1 OVERVIEW

Site associated contaminants were found throughout the study area in soil, surface water, sediment, and groundwater samples. The degree of contamination, however, varies throughout the region. This was expected based on previous investigations (NUS, April 1985). In general, the occurrence and concentration of contaminants within a given media is greatest on site and immediately off site, particularly on the Gorham property, which is in the direction of groundwater flow.

To facilitate the assessment of the extent of groundwater contamination and to provide a basis for identifying the scope of groundwater remediation strategies, the study area has been into three zones which are depicted in Figures A.4-5 through A.4-9. Zone 1 groundwaters appear to be more severely affected than believed at the time of the 1985 report (NUS, April 1985). (This is a qualitative judgment. Significant analytical data quality limitations prevented a complete assessment in 1985.) Contamination was also detected in offsite groundwater samples taken from monitoring wells located between the Pennsylvania Railroad track bed and the northern berm of Route 220 (Zone 2) and monitoring wells between the southern berm of Route 220 and the Bald Eagle Creek (Zone 3). Site-related contaminants showed a general attenuating of concentration in Zone 2, as would be expected with migration in the direction of groundwater flow. Some contamination is present in Zone 3 groundwater but the extent of pollution is less than that found in Zones 1 and 2.

Area surface waters and sediment are also affected by site-related contaminants. These media are most likely to be affected in the future by groundwater recharge to surface waters, based on regional hydrology, not by overland flow of contaminants. However, it is probable that site related contamination measured in river reach sediments below the site is largely the residuals of migration through the former leachate stream. The leachate stream was a direct conveyance to Bald Eagle Creek for site-related contaminants until it was remediated in early 1987. Contaminants occurring upstream, however, may be a result of regional flooding events or from industrial applications of pesticides.

Frequent observations in the various media sampled include compounds from the several general chemical classes. Specific examples of prominent site-related classes and compounds are indicated below:

Media Affected	Class	Example Compounds
Offsite Surface Water	Herbicides	Fenac
	Base/Neutral Acid Extractables	
Sediments	Herbicides	Fenac
	Base/Neutral Acid Extractables	Phenol
		4-Methylphenol
	Volatiles	Chlorobenzene
	Metals	Chromium
Onsite Soils	Herbicides	Fenac
	Base/Neutral Acid Extractables	Benzo(a)anthracene
		Napthalene
		Phenol
		2,4-Dinitrophenol
		1,4-Dichlorobenzene
	Volatiles	Chlorobenzene
		Xylene
		Ethylbenzene
		1,2-Dichloroethane
Groundwater	Herbicides	Fenac
	Base/Neutral Acid Extractables	Phenol
		2,4-Dinitrophenol
		1,4-Dichlorobenzene
	Volatiles	Chlorobenzene
		1,2-Dichloroethane
	Metals	Cadmium
		Chromium

No detections of PCBs were observed. Additionally, only sporadic detections of TCL pesticides such as DDT and DDE were noted in a single onsite soil sample. Such observations in conjunction with no historical evidence to indicate the

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production or use of PCBs or TCL pesticides lead to the conclusion that these classes of compounds are not present at the site as a direct result of site related activities.

All analytical data is subjected to both laboratory and independent chemist validation efforts. The data qualifiers *, E, N are laboratory qualifiers and have no effect on the usability of the analytical data. The qualifiers [ ] and J are independent validation qualifiers which mean that the value should be considered an estimation of actual contaminant concentration.

Table 4-1 lists the abbreviations for HSL pollutants that may have been detected by sampling and analysis tasks at the Drake Site. These abbreviations are used throughout the following sections to present the type and amount of contamination found in a particular media. A statistical evaluation of each map is then provided to summarize the extent of contamination. These evaluations will aid in remediation, feasibility studies, and risk analyses. Pertinent points of assessment are provided, where possible, to enhance the presentation.

It is recognized that the reader will have to spend considerable time with the contaminant maps to gain a full appreciation of the information provided. As an aid, it may be useful to read Section 5.0 which describes the contaminant transport and fate mechanism before embarking on a detailed review of the information presented in Section 4.0.

4.2 SURFACE WATER

Figure A.4-1 presents the results of analyses obtained from a map collected from surface water samples throughout the study area. Tables 4-2A through 4-2C summarize the occurrence and range of observations in data obtained from onsite surface waters, the west branch of the Susquehanna above the confluence, Bald Eagle Creek and the West Branch of the Susquehanna River (below the conthrence). Samples from Locations 4 and 13 are upgradient of the site and should be considered indicative of background conditions. Sample locations 1 and 2 are from the onsite lined lagoons; sample location 3 is from the onsite leachate lagoon. Sample locations 5, 6, 7, 8, 9, 10, 11, and 12 are down the watershed from the site.

Site surface water is contaminated by inorganics, base/neutral acid extractables and fenac. The observed, site-related contamination (i.e., organics, especially fenac) is not unexpected since the two lined lagoons are used for the impoundment of wastewater from the site and wastewater from site remedial activities such as well development. Contamination observed in surface water from the leachate lagoon is also not unexpected. This lagoon is at the topographical low point of the site and is believed to be the recipient of surface runoff. The pesticide aldrin was detected in a single sample and is probably the result of a false positive identification since no

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TABLE 4-1

ABBREVIATIONS FOR HSL PRIORITY POLLUTANTS
AND RELATED ANALYTICAL PARAMETERS
DRAKE CHEMICAL SITE - PHASE III RI

Priority Pollutant Number	CAS Number	Compound Name	Compound Abbreviation
	67-64-1	acetone	ATON
	78-93-3	2-butanone	MEK
	591-78-6	2-hexanone	HXON
	108-10-1	4-methyl-2-pentanone	MIBK
4V	71-43-2	benzene	BZ
86V	108-88-3	toluene	TL
38V	100-41-4	ethylbenzene	EBZ
	95-47-6	total xylenes	XY
	100-42-5	styrene	STYR
7V	108-90-7	chlorobenzene	CLBZ
15V	79-34-5	1,1,2,2-tetrachloroethane	1122TCA
11V	71-55-6	1,1,1-trichloroethane	111TCA
14V	79-00-5	1,1,2-trichloroethane	112TCA
10V	75-34-3	1,1-dichloroethane	11DCA
10V	107-06-2	1,2-dichloroethane	12DCA
16V	75-00-3	chloroethane	CETA
85V	127-18-4	tetrachloroethene	PERCE
87V	79-01-6	trichloroethene	TCE
30V	156-60-5	trans-1,2-dichloroethene	12DCE
29V	75-35-4	1,1-dichloroethene	11DCE
88V	75-01-4	vinyl chloride	VC
6V	56-23-5	carbon tetrachloride	CTET
23V	67-66-3	chloroform	CLFRM
44V	75-09-2	methylene chloride	MECL
45V	74-87-3	chloromethane	CLMA
32V	78-87-5	1,2-dichloropropane	12DCPA

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TABLE 4-1
ABBREVIATIONS FOR HSL PRIORITY POLLUTANTS
AND RELATED ANALYTICAL PARAMETERS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Priority Pollutant Number	CAS Number	Compound Name	Compound Abbreviation
33VT	10061-02-6	trans-1,3-dichloropropene	T13DCPE
33VC	10061-01-5	cis-1,3-dichloropropene	C13DCPE
47V	75-25-2	bromoform	BRFRM
46V	74-83-9	bromomethane	BRMA
48V	75-27-4	bromodichloromethane	BRDCMA
51V	124-48-1	chlorodibromomethane	CDBRMA
	75-15-0	carbon disulfide	CS2
19V	110-75-8	2-chloroethylvinyl ether	CEVE
	108-05-4	vinyl acetate	VACT
65A	108-95-2	phenol	PL
	95-48-7	2-methylphenol	2MPL
	106-44-5	4-methylphenol	4MPL
34A	105-67-9	2,4-dimethylphenol	24MPL
24A	95-57-8	2-chlorophenol	2CPL
31A	120-33-2	2,4-dichlorophenol	24DCPL
	95-95-4	2,4,5-trichlorophenol	245TCPL
21A	88-06-2	2,4,6-trichlorophenol	246TCPL
64A	87-86-5	pentachlorophenol	PCPL
22A	59-50-7	4-chloro-3-methylphenol	463MPL
57A	88-75-5	2-nitrophenol	2NPL
58A	100-02-7	4-nitrophenol	4NPL
59A	51-28-5	2,4-dinitrophenol	24DNPL
60A	534-52-1	4,6-dinitro-2-methylphenol	46DNZMPL
66B	117-81-7	bis(2-ethylhexyl)phthalate	BEHP
69B	117-84-0	di-n-octyl phthalate	DNOP
68B	84-74-2	di-n-butyl phthalate	DNBP

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TABLE 4-1
ABBREVIATIONS FOR HSL PRIORITY POLLUTANTS
AND RELATED ANALYTICAL PARAMETERS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE THREE

Priority Pollutant Number	CAS Number	Compound Name	Compound Abbreviation
70B	84-66-2	diethyl phthalate	DEP
67B	85-68-7	butyl benzyl phthalate	BBP
71B	131-11-3	dimethyl phthalate	DMP
1B	83-32-9	acenaphthene	ACNE
77B	208-96-8	acenaphthylene	ACNYE
78B	120-12-7	anthracene	ANTH
72B	56-55-3	benzo(a)anthracene	B(A)A
74B	205-99-2	benzo(b)fluoranthene	B(A)FL
	207-08-9	benzo(k)fluoranthene	B(K)FL
79B	191-24-2	benzo(g,h,i)perylene	B(GHI)P
73B	50-32-8	benzo(a)pyrene	B(A)P
76B	218-01-9	chrysene	CHR
82B	53-70-3	dibenzo(A,H)anthracene	DB(AH)A
39B	206-44-0	fluoranthene	FLNTH
80B	86-73-7	fluorene	FLE
83B	193-39-5	indeno(1,2,3-cd)pyrene	I(CD)P
55B	91-20-3	naphthalene	NPTH
	91-57-6	2-methylnaphthalene	2MNTH
20B	91-58-7	2-chloronaphthalene	2CNTH
81B	85-01-8	phenanthrene	PHEN
84B	129-00-0	pyrene	PYR
	95-50-1	1,2-dichlorobenzene	12DCBZ
26B	541-73-1	1,3-dichlorobenzene	13DCBZ
27B	106-46-7	1,4-dichlorobenzene	14DCBZ
8B	120-82-1	1,2,4-trichlorobenzene	124TCBZ
56B	98-95-3	nitrobenzene	NBZ

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TABLE 4-1
ABBREVIATIONS FOR HSL PRIORITY POLLUTANTS
AND RELATED ANALYTICAL PARAMETERS
DRAKE CHEMICAL SITE - PHASE III RI
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Priority Pollutant Number	CAS Number	Compound Name	Compound Abbreviation
9B	118-74-1	hexachlorobenzene	HCBZ
36B	606-20-2	2,3-dinitrotoluene	23DNT
35B	121-14-2	2,4-dinitrotoluene	24DNT
61B	62-75-9	n-nitrosodimethylamine	NDMA
63B	621-64-7	n-nitrosodipropylamine	NDPRA
62B	86-30-6	n-nitrosodiphenylamine	NDPHA
	62-53-3	aniline	AH
	88-74-4	2-nitroaniline	2NAN
	99-09-2	3-nitroaniline	3NAN
	100-01-6	4-nitroaniline	4NAN
	106-47-8	4-chloroaniline	4CAN
18B	111-44-4	bis(2-chloroethyl)ether	BCEE
42B	39638-32-9	bis(2-chloroisopropyl)ether	BCIE
41B	101-55-3	4-bromophenyl phenyl ether	BPPE
00B	7005-72-3	4-chlorophenyl phenyl ether	CPPE
52B	87-68-3	hexachlorobutadiene	HCBD
53B	77-47-4	hexachlorocyclopentadiene	HCCP
5B	92-87-5	benzidine	BZD
28B	91-94-1	3,3'-dichlorobenzidine	DCBZD
	66-85-0	benzoic acid	BZA
	100-51-6	benzyl alcohol	BZLAL
43B	111-91-1	bis(2-chloroethoxy)methane	BCEM
	132-64-9	dibenzofuran	DBZFN
12B	67-72-1	hexachloroethane	HHCEA
54B	78-59-1	isophorone	ISOP
	319-84-6	alpha-BHC	ABHC

TABLE 4-1
ABBREVIATIONS FOR HSL PRIORITY POLLUTANTS
AND RELATED ANALYTICAL PARAMETERS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE FIVE

Priority Pollutant Number	CAS Number	Compound Name	Compound Abbreviation
103P	319-85-7	beta-BHC	BBHC
104P	319-86-8	delta-BHC	DBHC
105P	58-89-9	gamma-BHC (lindane)	GBHC
100P	76-44-8	heptachlor	HCLR
101P	1024-57-3	heptachlor epoxide	HCLRE
92P	50-29-3	4,4'-DDT	DDT
	72-54-8	4,4'-DDD	DDD
93P	72-55-9	4,4'-DDE	DDE
98P	72-20-8	endrin	END
	53494-70	endrin ketone	ENDK
99P	7421-93-4	endrin aldehyde	ENDA
95P	959-98-8	endosulfan I	ENDOI
	33213-65	endosulfan II	ENDOII
97P	1031-07-8	endosufan sulfate	ENDOS
	309-00-2	aldrin	ALD
90P	60-57-1	dieldrin	DLD
91P	57-749	chlordane	CLD
	72-43-5	methoxychlor	MXCL
113P	8001-35-2	toxaphene	TOXP
	12674-11	aroclor-1016	PCB1016
108P	11104-28-2	aroclor-1221	PCB1221
109P	11141-16-5	aroclor-1232	PCB1232
106P	53469-21-9	aroclor-1242	PCB1242
	12672-29	aroclor-1248	PCB1248
107P	11097-69-1	aroclor-1254	PCB1254
111P	11096-82-5	aroclor-1260	PCB1260

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TABLE 4-1
ABBREVIATIONS FOR HSL PRIORITY POLLUTANTS
AND RELATED ANALYTICAL PARAMETERS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE SIX

Priority Pollutant Number	CAS Number	Compound Name	Compound Abbreviation
1		aluminum	Al
2		antimony	Sb
3		arsenic	As
4		barium	Ba
5		beryllium	Be
6		cadmium	Cd
7		calcium	Ca
8		chromium	Cr
9		cobalt	Co
10		copper	Cu
11		iron	Fe
12		lead	Pb
13		magnesium	Mg
14		manganese	Mn
15		mercury	Hg
16		nickel	Ni
17		potassium	K
18		selenium	Se
19		silver	Ag
20		sodium	Na
21		thallium	Th
22		tin	Sn
23		vanadium	V
24		zinc	Zn
		ammonia (as N)	NH3
		bicarbonate (as $CaCO_3$)	HC03-

TABLE 4-1
ABBREVIATIONS FOR HSL PRIORITY POLLUTANTS
AND RELATED ANALYTICAL PARAMETERS
DRAKE CHEMICAL SITE - PHASE III RI
PAGE SEVEN

Priority Pollutant Number	CAS Number	Compound Name	Compound Abbreviation
		carbonate (as $CaCO_3$)	CO3=
		chloride	Cl-
		COD	COD
		cyanide	CN
		nitrite/nitrate (as N)	NTI/NTA
		pH	pH
		specific conductance	Cond
		sulfate	SO4=
		TDS	TDS
		temperature	Temp
		TKN (as N)	TKN
		TOC	TOC
		Total Petroleum Hydrocarbons	TPHC
		TOX (as Cl)	TOX
		TSS	TSS
		2,3,7,8, TCDD	2378TCDD
		Particulates	Part
		Fenac	Fenac
		B-napthylamine	Bnapth

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TABLE 4-2A

SUMMARY OF ONSITE* SURFACE WATER ANALYSES
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 3 Events	Minimun Detected Concentration (µg/l)	Maximum Detected Concentration (µg/l)	Average (µg/l)
benzoic acid	1	36.00	36.00	36.00
2,4-dimethylphenol	1	7.00	7.00	7.00
2,4,5-trichlorophenol	1	6.00	6.00	6.00
aluminum	2	97.00	3910.00	2003.50
barium	3	42.00	89.00	73.00
calcium	3	63,400.00	70,000.00	67,733.33
chromium	1	13.00	13.00	13.00
cobalt	1	12.00	12.00	12.00
copper	1	106.00	106.00	106.00
iron	3	603.00	9080.00	3449.67
lead	1	16.00	16.00	16.00
magnesium	3	7300.00	7880.00	7680.00
manganese	3	72.00	644.00	265.33
nickel	1	20.00	20.00	20.00
potassium	3	1220.00	6900.00	4966.67
sodium	3	10,800.00	101,000.00	11,200.00
zinc	3	24.00	247.00	100.67
fenac	3	30.00	4900.00	1690.00
hardness	2	180.00**	200.00**	190.00**

* Sample locations 1, 2, and 3
** mg/l

AR302069

TABLE 4-2B

SUMMARY OF OFFSITE SURFACE WATER ANALYSES
BALD EAGLE CREEK AND WEST BRANCH SUSQUEHANNA RIVER
BELOW THE CONFLUENCE*
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 7 Events	Minimun Detected Concentration (µg/l)	Maximum Detected Concentration (µg/l)	Average (µg/l)
aluminum	7	216.00	609	350.57
barium	7	38.00	73	53.86
calcium	7	27,400.00	41,600.00	35,357.00
cobalt	7	14.00	25.00	17.86
copper	2	16.00	20.00	18.00
iron	7	137.00	175.00	151.71
magnesium	7	12,400.00	14,900.00	140,142.29
manganese	7	800.00	1510.00	1055.57
nickel	7	16.00	31.00	22.29
potassium	7	658.00	1190.00	903.43
silver	2	10.00	17.00	13.50
sodium	7	10,500.00	7510.00	10,974.29
zinc		36.00	61.00	45.57
fenac	4	0.09	0.35	0.18
hardness	3	130.00**	140.00**	136.67**

* Sample locations 4, 5, 6, 7, 8, 11, and 12
** mg/l

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TABLE 4-2C

SUMMARY OF OFFSITE SURFACE WATER ANALYSES
WEST BRANCH SUSQUEHANNA RIVER ABOVE THE CONFLUENCE*
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 3 Events	Minimun Detected Concentration (µg/l)	Maximum Detected Concentration (µg/l)	Average (µg/l)
aluminum	3	633.00	733.00	687.67
barium	3	36.00	38.00	37.00
calcium	3	25,700.00	26,700.00	26,233.33
cobalt	3	22.00	24.00	23.00
iron	3	131.00	154.00	142.67
magnesium	3	12,400.00	12,600.00	12,500.00
manganese	3	1580.00	1620.00	1600.00
nickel	3	34.00	35.00	34.67
potassium	3	904.00	1290.00	1071.33
sodium	3	6170.00	7070.00	6620.00
zinc	3	70.00	71.00	70.33
fenac	2	0.03	0.04	0.03
hardness	1	110.00*	110.00*	110.00*

* mg/l

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other analytical results for aldrin were detected in any sampled media.

Results of surface water sampling and analysis for offsite surface waters in the regional water shed are also presented in Figure A.4-1. Evidence that offsite surface waters are affected by site-related contamination is demonstrated in samples collected downstream of the site. The detection of fenac in samples collected from locations 5, 6, and 7 on Bald Eagle Creek and locations 8, 11, and 12 on the West Branch Susquehanna River support this assessment.

Evidence that site-related contaminants occur in surface waters in the watershed above the site (up gradient) is also indicated on Figure A.4-1. The site-specific contaminant detected in both upstream Susquehanna River and Bald Eagle Creek samples is fenac which, because of area hydrology, is not likely to have occurred from site drainage.

Inorganic compounds including aluminum, barium, calcium, cobalt, chromium, iron, lead, nickel, potassium and sodium are found at varying concentrations in samples taken throughout the area but, because of their random distribution including upgradient samples (locations 4 and 13) and possible natural occurrence, they cannot be attributed specifically to the Drake Chemical Site.

4.3 SEDIMENTS

Onsite sediment samples taken from the holding lagoons are highly contaminated by volatile organics, fenac, and base/neutral acid extractable compounds. As previously stated for the onsite surface waters, this observation is in agreement with expectations.

Figure A.4-2 displays the analytical results of sediment samples taken at various locations on site and throughout the watershed. Tables 4-3A through 4-3C provides a summary of contaminant occurrence and distribution onsite, in the sediments of the West Branch of the Susquehanna River and sediments taken from the Bald Eagle Creek and the downstream confluence of the Susquehanna River. Based on these results, the site-related contaminants chlorobenzene, 4-methylphenol, 1,2-dichlorobenzene, dimethyl-phenol, and fenac have migrated from the site to both the Susquehanna River and downstream Bald Eagle Creek sediments. Previous studies indicated that the waters were affected; this information provides substantiation and more definitive characterization to the extent of creek and river contamination.

TABLE 4-3A

SUMMARY OF SEDIMENT ANALYSIS, ONSITE SAMPLES*
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 3 events	Minimum Detected Conc. (µg/kg)	Maximum Detected Conc. (µg/kg)	Average (µg/kg)
2-butanone	1	150.00	150.00	150.00
2-Hexanone	1	44.00	44.00	44.00
4-methyl-2-pentanone	1	110.00	110.00	110.00
Benzene	1	100.00	100.00	100.00
Toluene	1	710.00	710.00	710.00
Ethylbenzene	1	3,500.00	3,500.00	3,500.00
Total xylenes	1	20,000.00	20,000.00	20,000.00
Chlorobenzene	2	9.00	9,100.00	4,554.50
1,1,1-trichloroethane	1	6.00	6.00	6.00
Tetrachloroethene	1	47.00	47.00	47.00
Trichloroethene	1	7.00	7.00	7.00
Carbon tetrachloride	1	350.00	350.00	350.00
Carbon disulfide	1	57.00	57.00	57.00
Bis(2-ethylhexyl)phthalate	1	310.00	310.00	310.00
Butyl benzyl phthalate	1	120.00	120.00	120.00
Acenaphthene	1	150.00	150.00	150.00
Acenaphthylene	1	200.00	200.00	200.00
Anthracene	1	330.00	330.00	330.00
Benzo(a)anthracene	3	1,400.00	100,000.00	54,133.33
Benzo(b)fluoranthene	1	3,300.00	3,300.00	3,300.00
Benzo(k)fluoranthene	1	3,300.00	3,300.00	3,300.00
Benzo(g,h,i)perylene	1	860.00	860.00	860.00
Benzo(a)pyrene	1	1,100.00	1,100.00	1,100.00
Chrysene	1	1,900.00	1,900.00	1,900.00

TABLE 4-3A
SUMMARY OF SEDIMENT ANALYSIS, ONSITE SAMPLES*
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Compound	No. of Positive Detections in 3 events	Minimum Detected Conc. (µg/kg)	Maximum Detected Conc. (µg/kg)	Average (µg/kg)
Dibenzo(a,h)anthracene	1	1,260.00	1,260.00	1,260.00
Fluoranthene	1	2,900.00	2,900.00	2,900.00
Fluorene	1	290.00	290.00	290.00
Indeno(1,2,3-cd)pyrene	1	740.00	740.00	740.00
Naphthalene	2	370.00	43,000.00	21,685.00
2-methylnaphthalene	1	280.00	280.00	280.00
Phenanthrene	1	1,300.00	1,300.00	1,300.00
Pyrene	1	1,600.00	1,600.00	1,600.00
1,2-dichlorobenzene	2	2,200.00	8,600.00	44,100.00
1,4-dichlorobenzene	3	290.00	140,000.00	49,230.00
1,2,4-trichlorobenzene	3	170.00	140,000.00	72,056.66
Nitrobenzene	1	210.00	210.00	210.00
Benzoic acid	1	450.00	450.00	450.00
Dibenzofuran	1	280.00	280.00	280.00
Aluminum**	3	2,320.00	8,720.00	4,860.00
Arsenic**	1	17.00	17.00	17.00
Barium**	3	66.00	120.00	94.00
Beryllium**	1	0.50	0.50	0.50
Calcium**	3	344.00	109,000.00	52,714.66
Chromium**	3	20.00	69.00	37.66
Cobalt**	1	13.00	13.00	13.00
Copper**	3	54.00	1,420.00	619.66
Iron**	3	5,640.00	24,800.00	13,546.66
Lead**	3	13.00	113.00	46.66
Magnesium**	3	368.00	1,940.00	1,000.66

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TABLE 4-3A
SUMMARY OF SEDIMENT ANALYSIS, ONSITE SAMPLES*
DRAKE CHEMICAL SITE - PHASE III RI
PAGE THREE

Compound	No. of Positive Detections in 3 events	Minimum Detected Conc. (µg/kg)	Maximum Detected Conc. (µg/kg)	Average (µg/kg)
Manganese**	3	33.00	313.00	135.00
Mercury**	3	0.29	0.82	0.55
Nickel**	3	12.00	33.00	21.33
Potassium**	3	618.00	810.00	742.66
Vanadium**	3	5.30	103.00	39.23
Zinc**	3	34.00	343.00	166.00
Cyanide**	2	431.00	766.00	598.50
Fenac	3	740.00	1,500,000.00	790,246.66

* Sample locations 1, 2, and 3
** Results reported in mg/kg

TABLE 4-3B

SUMMARY OF SEDIMENT ANALYSIS, BALD EAGLE CREEK TO THE WEST BRANCH OF THE SUSQUEHANNA RIVER BELOW THE CONFLUENCE*
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 7 events	Minimum Detected Conc. (µg/kg)	Maximum Detected Conc. (µg/kg)	Average (µg/kg)
Chlorobenzene	2	2.00	4.00	3.00
Tetrachloroethene	2	3.00	4.00	3.50
Bis(2-ethylhexyl)phthalate	6	71.00	390.00	203.50
Butyl benzyl phthalate	1	83.00	83.00	83.00
Acenaphthene	1	170.00	170.00	170.00
Anthracene	3	120.00	270.00	180.00
Benzo(a)anthracene	4	130.00	1,200.00	517.50
Benzo(b)fluoranthene	5	230.00	1,600.00	602.00
Benzo(k)fluoranthene	5	230.00	1,600.00	602.00
Benzo(g,h,i)perylene	4	70.00	430.00	178.25
Benzo(a)pyrene	4	130.00	740.00	325.00
Chrysene	5	140.00	980.00	434.00
Dibenzo(a,h)anthracene	1	230.00	230.00	230.00
Fluoranthene	5	180.00	2,300.00	828.00
Fluorene	1	110.00	110.00	110.00
Indeno(1,2,3-cd)pyrene	3	67.00	410.00	199.00
Phenanthrene	4	260.00	1,400.00	630.00
Pyrene	5	200.00	1,500.00	660.00
1,2-dichlorobenzene	2	70.00	190.00	130.00
Benzoic acid	2	920.00	1,800.00	1,360.00
Dibenzofuran	1	72.00	72.00	72.00
Phenol	2	740.00	2,700.00	1,720.00
4-methylphenol	3	680.00	24,000.00	9,693.33

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TABLE 4-3B
SUMMARY OF SEDIMENT ANALYSIS, BALD EAGLE CREEK TO THE WEST BRANCH OF THE SUSQUEHANNA RIVER BELOW THE CONFLUENCE*
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Compound	No. of Positive Detections in 7 events	Minimum Detected Conc. (µg/kg)	Maximum Detected Conc. (µg/kg)	Average (µg/kg)
Pentachlorophenol	3	150.00	1,200.00	580.00
Aluminum**	7	6,690.00	35,500.00	16,445.71
Arsenic**	6	5.50	27.00	13.98
Barium**	7	84.00	257.00	138.57
Beryllium**	7	2.30	12.00	5.04
Calcium**	7	909.00	5,120.00	2,675.57
Chromium**	7	8.60	30.00	19.22
Cobalt**	7	104.00	363.00	185.28
Copper**	7	17.00	85.00	48.42
Iron**	7	12,300.00	34,800.00	22,600.00
Lead**	7	21.00	57.00	39.28
Magnesium**	7	777.00	3,170.00	1,746.71
Manganese**	7	1,250.00	15,200.00	5,877.14
Mercury**	1	0.64	0.64	0.64
Nickel**	7	115.00	372.00	195.00
Potassium**	7	609.00	1,680.00	1,008.14
Vanadium**	7	7.40	20.00	14.34
Zinc**	7	279.00	1,580.00	689.14
Fenac	5	27.00	200.00	137.80

* Sample locations 4, 5, 6, 7, 8, 11, and 12
** Results reported in mg/kg

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TABLE 4-3C

SUMMARY OF SEDIMENT ANALYSIS, WEST BRANCH OF THE SUSQUEHANNA RIVER ABOVE THE BALD EAGLE CONFLUENCE*
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 3 events	Minimum Detected Conc. (µg/kg)	Maximum Detected Conc. (µg/kg)	Average (µg/kg)
Bis(2-ethylhexyl)phthalate	3	110.00	460.00	240.00
Butyl benzyl phthalate	1	320.00	320.00	320.00
Dimethyl phthalate	1	180.00	180.00	180.00
Acenaphthylene	1	150.00	150.00	150.00
Anthracene	2	230.00	430.00	330.00
Benzo(a)anthracene	2	380.00	1,100.00	740.00
Benzo(b)fluoranthene	3	210.00	3,300.00	1,670.00
Benzo(k)fluoranthene	3	210.00	3,300.00	1,670.00
Benzo(g,h,i)perylene	2	460.00	890.00	675.00
Benzo(a)pyrene	3	91.00	1,800.00	883.66
Chrysene	3	280.00	2,300.00	1,193.33
Dibenzo(a,h)anthracene	2	200.00	440.00	320.00
Fluoranthene	3	140.00	3,200.00	1,513.33
Fluorene	1	100.00	100.00	100.00
Indeno(1,2,3-cd)pyrene	2	430.00	860.00	645.00
Phenanthrene	2	660.00	1,400.00	1,030.00
Pyrene	3	150.00	3,400.00	1,683.33
Pentachlorophenol	2	310.00	530.00	420.00
Aluminum**	3	12,100.00	25,000.00	16,733.33
Arsenic**	3	8.50	11.00	9.63
Barium**	3	47.00	94.00	65.00
Beryllium**	3	1.40	3.80	2.43
Calcium**	3	621.00	2,310.00	1,219.00

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TABLE 4-3C
SUMMARY OF SEDIMENT ANALYSIS, WEST BRANCH OF THE SUSQUEHANNA RIVER ABOVE THE BALD EAGLE CONFLUENCE*
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Compound	No. of Positive Detections in 3 events	Minimum Detected Conc. (µg/kg)	Maximum Detected Conc. (µg/kg)	Average (µg/kg)
Chromium**	3	19.00	20.00	19.33
Cobalt**	3	21.00	48.00	33.66
Copper**	3	27.00	51.00	36.00
Iron**	3	36,100.00	54,700.00	42,766.66
Lead**	3	27.00	54.00	36.00
Magnesium**	3	1,140.00	1,970.00	1,490.00
Manganese**	3	172.00	867.00	496.66
Nickel**	3	31.00	56.00	40.66
Potassium**	3	837.00	1,710.00	1,269.00
Vanadium**	3	10.00	18.00	13.66
Zinc**	3	147.00	334.00	219.33
Cyanide**	1	2.40	2.40	2.40
Fenac	1	24.00	24.00	24.00

* Sample locations 9, 10, and 13
** Results reported in mg/kg

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Other notable points gleaned from Figure A.4-2 include:

- Fenac, chlorobenzene, and other site-related compounds were observed in upstream samples on Bald Eagle Creek and the West Branch, Susquehanna River.

- Fenac and chlorobenzene were not observed in the West Branch Susquehanna River north of the site above the confluence.

- All samples contained varying amounts of polynuclear aromatic hydrocarbons and inorganics which may or may not be associated with the Drake Chemical Site.

- The compound pentachlorophenol is found sporadically throughout the area and in three onsite samples. Due to the occurrence of this compound in the upstream Susquehanna River sediment and its apparent absence in downstream Bald Eagle Creek sediments the occurrence of the compound is not believed to be site related.

The most significant site-related contaminants (i.e., fenac, phenol, chlorobenzene, 4-methylphenol) are detected in samples taken from points that are part of the normal downstream hydrologic flow pattern of the watershed as expected. The compound fenac is found in upstream samples as well. Its occurrence in these locations may be a result of deliberate application for plant control purposes and/or distribution during regional flooding events. The occurrence of chlorobenzene in upstream sediment samples supports the assessment that regional flooding events were probably major contributors to the migration of site-related compounds to upstream locations.

4.4 SOILS

4.4.1 Level II Field Screening VOAs and Phenolics

Figure A.4-3 presents the results of field screening data for volatile organic analyses and fixed base phenolic analyses obtained from samples taken during test pitting activities.

Based on this data it becomes apparent that the bulk of the vadose zone on the site is contaminated at varying concentrations by chlorinated solvents, benzene, toluene, xylenes, and ethylbenzenes. Substituted chlorinated phenols and alkyl phenols are also present.

These compounds occur throughout the site regardless of sampling depth; therefore, no one particular area of the site or the adjacent Gorham property can be considered a more likely source of contamination to the surrounding environment. Field investigation observations, particularly the discovery of an active shallow subsurface drain pipe (8 inch diameter) leading

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from the vicinity of the process buildings, to the Gorham property, support this assertion.

Statistical analyses of select prominent site contaminants are detailed in Appendix F. Figure A.3-1 depicts the three sectors established for statistical analyses Sector I covers approximately 179,300 square feet, Sector II approximately 219,688 square feet and Sector III encompasses approximately 148,202 square feet. At each test pit, samples were collected at the different levels or strata. Strata A represents the interval ≈ 0-4 feet, Strata B; ≈ 4-8 feet and Strata C ≈ 8-12.5 feet. An assessment is provided below.

- Chlorobenzene was detected in approximately 75 percent of the samples (102/136) with detected concentrations ranging from 1-20,176 µg/kg and a mean of 362 µg/kg (S=2060). Pooled-variance, two sample t-tests(1) indicate no statistically significant difference in mean concentrations in any of the nine sectors (three strata, three sectors; defined in Appendix F) at alpha=0.05.

- 1,2-Dichloroethane was detected in 90 percent (124/138) of the samples with detected concentrations ranging from 2.3-248 µg/kg and a mean of 26.4 µg/kg (s=40.5). Pooled-variance, two sample t-tests(1) indicate a statistically significant difference in mean concentrations between Strata A (i.e., the top 1/3 of the waste material) and Strata B (P=0.0009, the middle 1/3) and between Strata A and Strata C, (the lower 1/3) (P=0.0058). No difference is indicated between Strata B and C (P=0.39) or between any of the sectors. The difference between the upper strata and the middle (B) and lower (C) is notable and possibly a result of volatilization of 1,2-dichloroethane from the upper (A) Strata. Chlorobenzene is less volatile than 1,2-dichloroethane, hence not as likely to have volatilized from the upper soil column to the atmosphere. Another factor is the differential in leaching potentials. 1,2-Dichloroethane has the higher water solubility of the two; therefore, it would tend to

(1) A review of the histograms for both data sets indicates a right skewed data set. This implies a log normal data distribution and undermines, somewhat the use of normal distribution based hypothesis tests without transforming the data. A lognormal distribution is a common observation with environmental sampling and analytical results. One factor contributing to this occurrence is the artificial left tail limit imposed by a minimum analytical detection limit. Notwithstanding this technical point, and considering the data set overall, impressions from field investigations and previous studies, the results are considered valid and suitable for application to the selection of remediation alternatives, source loading computations, and other applications not requiring high precision.

migrate to the lower strata more readily by leaching than the less soluble chlorobenzene. Either of the two migration mechanisms could account for the observed differences. This analysis does not eliminate the possibility that the observed difference is a function of waste practices at the sites.

The statistically based 100-foot x 100-foot x 12.5-foot grid (Ebasco, October 1987) is amendable to assessment using a technique for locating hot spots (Gilbert, 1987). Table 4-4 presents an assessment summary. According to Table 4-4 we can be confident at a 90-percent level (i.e., 9 times out of 10) that sampling on the grid would detect a 67,860 ft^3 (cylinder radius of 60 feet and a depth of 6 feet) or larger, cylindrical hot spot. This volume represents approximately 1.0 percent of the vadose zone volume. It must be noted that 11 grid points are located beneath the process buildings and could not be sampled. However, considering the dilapidated condition of structures, the numerous sewers and sumps within and beneath the structures, the handling of pure product at the site, and the apparent sloppy practices during operations it is reasonable to assume that contamination beneath the buildings is similar to, if not more extensive, than that observed in the soils and sludges of the vadose zone.

From the forgoing and a review of the statistical summaries in Appendix F the following key points can be advanced.

- Although pockets of heterogeneity may exist in the soil/sludge matrix, there is clear evidence of overall homogeneity with respect to the occurrence and distribution of the volatile organic and phenolic compounds used in this assessment. The data do not support a conclusion that "hot spots" of certain types of wastes exist in the matrix. This is a significant result from a soil treatment perspective, particularly if these results can be extended to other classes of contaminants.

- An assessment of the three-dimensional grid supports the conclusion advanced above. It appears that these conclusions can be applied to quantities as low as 67,860 cubic feet of waste (1.0 percent of the total vadose zone waste) with approximately 90 percent confidence.

4.4.2 Level IV Fixed Base Analyses

Site soil is contaminated by volatile organic compounds inorganics, base/neutral acid extractables, fenac, and β-naphthylamine (Tables 4-5 and 4-6). Some very high and consistent concentrations of organics (i.e., fenac) are observed.

Figure A.4-4 displays the analytical results attained from soil samples acquired during test pitting operations. Site-specific

AR302082

TABLE 4-4

STATISTICALLY-BASED ASSESSMENT OF DETECTION VOLUME FROM THE 100-FOOT BY 100-FOOT BY 6-FOOT GRID DRAKE CHEMICAL SITE - PHASE III RI

Chance of Detection(1)	Cylindrical Volume	Percent of Vadose Zone Waste Volume(2)
90%	67,860 ft^3	~1.0
86%	51,000 ft^3	~0.8
76%	47,124 ft^3	~0.7

(1) Assumes 95 percent detection confidence in the vertical
(2) Volume including Gorham Property down to the water table at 12.5 feet; volume = 6,802,388 cubic feet.
See Appendix F for computations.

AR302083

TABLE 4-5

TEST PIT ANALYSES (FIXED BASE LEVEL IV) FOR ORGANIC COMPOUNDS
DRAKE CHEMICAL SITE - PHASE III RI
(All results in µg/kg)

Compound	No. of Positive Detections in 42 events	Minimum Detected Concentration*	Maximum Detected Concentration*	Average*
Acetone	20	4.00	1,400.00	190.60
2-Butanone	2	29.00	44.00	36.50
2-Hexanone	1	4.00	4.00	4.00
2-Methyl-2-pentanone	2	1.00	270.00	135.50
Benzene	1	3.00	3.00	3.00
Toluene	9	1.00	79.00	15.56
Ethylbenzene	11	1.00	27,000.00	2,479.09
Total Xylenes	15	3.00	220,000.00	15,019.73
Chlorobenzene	24	2.00	14,000.00	868.38
1,1,1-Trichloroethane	1	43.00	43.00	43.00
1,2-Dichloroethane	6	13.00	74.00	29.50
Tetrachloroethene	5	2.00	38.00	23.80
Trichloroethene	1	2.00	2.00	2.00
Chloroform	2	4.00	79.00	41.50
Methylene chloride	5	2.00	170.00	49.40
Carbon disulfide	8	1.00	91.00	26.38
Di-n-butyl phthalate	3	130.00	9,200.00	3,170.00
Butyl benzyl phthalate	1	32,000.00	32,000.00	32,000.00

AR302084

TABLE 4-5
TEST PIT ANALYSES (FIXED BASE LEVEL IV) FOR ORGANIC COMPOUNDS
DRAKE CHEMICAL SITE - PHASE III RI
(All results in µg/kg)
PAGE TWO

Compound	No. of Positive Detections in 42 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Acenaphthylene	2	4,200.00	5,800.00	5,000.00
Anthracene	3	150.00	8,200.00	2,950.00
Benzo(a)anthracene	15	100.00	42,000.00	6,993.33
Benzo(b)fluoranthene	4	570.00	41,000.00	14,140.00
Benzo(k)fluoranthene	4	560.00	29,000.00	11,565.00
Benzo(g,h,i)perylene	2	710.00	24,000.00	12,355.00
Benzo(a)pyrene	4	430.00	34,000.00	13,605.00
Chrysene	4	870.00	52,000.00	19,292.50
Dibenzo(a,h)anthracene	1	11,000.00	11,000.00	11,000.00
Fluoranthene	4	1,200.00	110,000.00	41,150.00
Fluorene	1	7,200.00	7,200.00	7,200.00
Indeno(1,2,3-cd)pyrene	3	610.00	22,000.00	10,870.00
Naphthalene	8	74.00	7,000.00	1,295.50
2-Methylnaphthalene	1	390.00	390.00	390.00
Phenanthrene	6	120.00	140,000.00	32,680.00
Pyrene	4	870.00	100,000.00	37,742.50
1,2-Dichlorobenzene	10	200.00	100,000.00	17,801.00

AR302085

TABLE 4-5
TEST PIT ANALYSES (FIXED BASE LEVEL IV) FOR ORGANIC COMPOUNDS
DRAKE CHEMICAL SITE - PHASE III RI
(All results in µg/kg)
PAGE THREE

Compound	No. of Positive Detections in 42 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
1,3-Dichlorobenzene	2	210.00	310.00	260.00
1,4-Dichlorobenzene	12	190.00	12,000.00	3,250.83
1,2,4-Trichlorobenzene	8	98.00	21,000.00	4,268.50
Nitrobenzene	2	220.00	9,900.00	5,060.00
4-Nitroaniline	1	48,000.00	48,000.00	48,000.00
4-Chloroaniline	3	600.00	680.00	650.00
3,3'-Dichlorobenzidine	6	910.00	29,000.00	7,001.67
Benzoic acid	2	240.00	2,500.00	1,370.00
Dibenzofuran	1	7,500.00	7,500.00	7,500.000
Phenol	4	160.00	1,800.00	662.50
2,4-Dichlorophenol	2	1,400.00	1,800.00	1,600.00
2,4,6-Trichlorophenol	1	13,000.00	13,000.00	13,000.00
Pentachlorophenol	3	1,200.00	130,000.00	44,166.67
2,4-Dinitrophenol	2	3,000.00	36,000.00	19,500.00

AR302086

TABLE 4-5
TEST PIT ANALYSES (FIXED BASE LEVEL IV) FOR ORGANIC COMPOUNDS
DRAKE CHEMICAL SITE - PHASE III RI
(All results in µg/kg)
PAGE FOUR

Compound	No. of Positive Detections in 42 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
4,4'-DDT	1	110,000.00	110,000.00	110,000.00
4,4'-DDD	1	11,000.00	11,000.00	11,000.00
Fenac	32	3.80	8200.00	1363.81
β-naphthylamine	18	470.00	1,500,000.00	88,624.44

AR302087

TABLE 4-6

TEST PIT ANALYSES (FIXED BASE) FOR INORGANIC ANALYTES*
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 42 events	Minimum Detected Concentration**	Maximum Detected Concentration**	Average**
Aluminum	41	271.00	19,500.00	8,093.83
Arsenic (total)	29	2.00	21.00	7.34
Barium	38	7.70	382.00	111.65
Beryllium	24	0.20	2.30	1.10
Cadmium	9	1.10	283.00	33.94
Calcium	42	15.00	221,000.00	28,895.50
Chromium	40	6.80	269.00	49.54
Cobalt	27	2.10	104.00	14.98
Copper	39	4.20	17,200.00	489.85
Iron	42	12.00	55,700.00	18,905.90
Lead	31	3.30	1,170.00	63.12
Magnesium	42	34.00	46,200.00	5,161.64
Manganese	41	3.00	3,760.00	421.22
Mercury	8	0.20	18.00	2.54
Nickel	37	3.00	41.00	17.48
Potassium	36	107.00	3,040.00	1,121.03
Selenium	1	1.60	1.60	1.60
Silver	1	3.80	3.80	3.80
Sodium	24	62.00	4,100.00	511.67
Vanadium	39	2.40	36.00	17.30
Zinc	42	7.00	1,530.00	126.33
Cyanide	3	1.30	189.00	92.43

* Incomplete data set; results of eight analyses not received as of yet.
** All results in mg/kg.

AR302088

contaminants including chlorobenzene, dichlorobenzenes, phenol, chlorinated phenolics, and nitrophenols were detected in varying amounts throughout the site, regardless of sampling depth.

The organic compound chlorobenzene occurs with the greatest frequency; ethylbenzene and total xylenes occur in the highest concentrations. The compounds pentachlorophenol and 4-nitroaniline were detected in significant amounts but their frequency of occurrence was limited. Polynuclear aromatic hydrocarbons including fluoranthene, pyrene, phenanthrene, and benzo(a)pyrene constitute a significant amount of contamination.

A prominent and frequently-detected soil contaminant was fenac. Its occurrence and distribution was subjected to statistical assessment applying the techniques used for 1,2-dichloroethane and chlorobenzene in the previous section. A full statistical summary is provided in Appendix F. Pertinent points include

- Fenac was observed in 71 percent (34/48) of the soils analyzed.
- Concentrations ranged from 4 µg/kg to 8,200 µg/kg with a mean of 1,416 µg/kg (s = 2,200).
- Seventy-five percent of the observations were between 54 and 1,600 µg/kg.
- Tests of significant statistical difference of means between strata and sectors indicate that fenacs' occurrence is essentially homogeneous within the soils(2)(3).

Based on this assessment, it appears that the observation of overall contaminant homogeneity can be extended to other site-related species found within the vadose zone soil/sludge matrix. Caution should be taken and further assessment of the data base conducted if the data are to be employed for applications requiring high precision.

The significance of this finding has major implications for soil (source) remediation strategies. Previous estimates for source remediation considered a total quantity of approximately 84,000 cubic yards (NUS; December 1986). If a risk-based cleanup level were to be established for a contaminant that is determined to be homogeneously distributed throughout the soils and sludges in the vadose zone, the total quantity of material requiring treatment would be approximately 252,000 cubic yards, which is roughly 3.6 times the quantity estimated in 1986. This would undoubtedly have a significant impact on previously estimated site remediation costs.

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(2) The previously stated qualifier on log normal distribution applies.

(3) The power to detect a difference in this data set is less than those presented previously, due to a much smaller sample size (n = 48).

AR302089

Inorganics, including cyanide, mercury, nickel, lead, chromium, and cadmium, were also detected and may or may not occur as a result of site contamination. The compounds lead, nickel, chromium, barium, aluminum, iron, manganese, and magnesium occur with greatest frequency and in large concentrations. Heavy metals including mercury and selenium were present but did not occur in great concentrations or frequency. Table 4-7 presents the metals detected in soils and sludges which exceed the commonly expected range for soils. This table was developed by contrasting the results presented in Table 4-6 with Table 1.1 from Lindsay (1979).

An assessment of Table 4-7 indicates that cadmium clearly exceeds expected ranges and is probably site related. The contrast is less dramatic for cobalt, copper, lead, and silver; however, it cannot be concluded that they are not residual contaminants from past waste practices at the site. The remainder of the metals found in samples from the soils and sludges as presented in Table 4-6 are considered to be indicative of the native mineral content and probably not site related.

4.5 GROUNDWATER

4.5.1 VOAs

As previously mentioned, to facilitate assessment of the extent of groundwater contamination and to provide a basis for identifying the scope of groundwater treatment remedial technologies, the study area has been divided into three logical zones. Zones are identified on relevant occurrence and distribution figures. This was done in previous studies to augment the groundwater pumping strategy based on the intensity of observed contamination (NUS, April 1985). These distinctions are thus, maintained. These are

- Zone 1 groundwaters north of the access road that circles the south and east edges of the site. By excluding upgradient wells (MW-M9, MW-M103, M104), Zone 1 represents essentially groundwaters beneath the site and the Gorham Property. Based on previous studies (NUS, July 1984, August 1986), groundwaters in Zone 1 have been the most severely impacted.

- Zone 2 groundwaters include those underlying the area between Zone 1 (i.e., the site) and State Route 220. This area south of the site has historically been less severely impacted by site-related contamination than Zone 1.

- Zone 3 groundwaters are those south of State Route 220 to Bald Eagle Creek.

AR302090

TABLE 4-7

METALS IN SOILS/SLUDGES EXCEEDING
COMMON RANGES FOR SOILS
DRAKE CHEMICAL SITE - PHASE III RI
(All units in mg/kg)

Metal	Observed Range	Common Range for Soils(1)
Cadmium	1.1 - 283	0.01 - 0.07
Cobalt	2.1 - 104	1 - 40
Copper	4.2 - 17,200	2 - 100
Lead	3.3 - 1,170	2 - 200
Silver	3.8	0.01 - 5(2)

(1) Lindsay, 1979.
(2) Single observation is probably a spurious detection.

AR302091

Figure A.4-5 presents the results of volatile organic compound analysis obtained from both rounds of groundwater sampling activities.

In general, samples taken from monitoring wells in all three zones are affected by site-related contaminants. Groundwater in the Zone 1 area is characterized by contamination with compounds including benzene, trichloroethene, chlorobenzene, ethylbenzene, 1,2-dichloroethane, 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene in varying amounts (Tables 4-8 and 4-9). These compounds are detected in the first comprehensive (new and most existing wells) and the second more selective (new and select existing wells) sampling rounds. In both cases chlorobenzene was detected at the highest concentration while 1,2-dichloroethane was detected with the greatest frequency. Solvents including benzene, toluene, and ethylbenzene were also detected.

Offsite groundwater taken from Zone 2 monitoring wells displays the same characteristic organic contamination (Tables 4-10 and 4-11). Compounds, including benzene, chlorobenzene, 1,2-dichloroethane, tetrachloroethene, and trichloroethene are present in varying amounts. Chlorobenzene was detected at the highest concentrations in both rounds downgradient of Zone 2 samples but at a lower level than samples taken from Zone 1. The dichlorobenzenes detected in Zone 1 sample analyses are present but, as with chlorobenzene, at somewhat lower levels.

Samples taken from further downgradient Zone 3 monitoring wells show that site-related organic contamination is extending toward the Bald Eagle Creek. Consistently, chlorobenzene was detected in both rounds but at lower levels of contamination than 1,2-dichloroethane (Tables 4-12 and 4-13). This observation is consistent with the expected contaminant migration pathway in the direction of groundwater flow and the increased mobility in soils of 1,2-dichloroethane (lower K_{oc} and K_{ow}) over chlorobenzene.

4.5.2 BNAs, Pesticides/PCBs

Figure A.4-6 presents the results of base/neutral-acid extractables, pesticides, and PCB analyses obtained from the first and second rounds of groundwater sampling. Tables 4-14 and 4-15, summarize Zone 1 results; Zone 2 results are summarized in Tables 4-16 and 4-17 and Zone 3 results in Tables 4-17 and 4-18. Samples taken from monitoring wells in all three zones are affected by site-related contaminants. No TCL pesticides or PCBs were detected in any groundwater samples collected throughout the study area. This observation is consistent with results obtained for the soil/sludges (i.e., source materials). Groundwater in the Zone 1 area is contaminated with compounds including 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, nitrobenzene, 1,2,4-trichlorobenzene, phenol, and alkyl and chlorinated phenolics (Table 4-13 and 4-14). The compound phenol is

AR302092

TABLE 4-8

ZONE 1
GROUNDWATER - FIRST ROUND ANALYSES FOR VOAs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	# of Positive Detections in 15 events	Minimum Detected Conc.*	Maximum Detected Conc.*	Average*
Benzene	6	3.30	110.00	38.75
Toluene	10	1.30	8100.00	853.16
Ethylbenzene	5	3.40	900.00	195.18
Chlorobenzene	12	72.00	18000.00	3108.50
1,1,2,2-Tetrachloroethane	1	0.09	0.09	0.09
1,1,1-Trichloroethane	1	1.00	1.00	1.00
1,1,2-Trichloroethane	7	0.19	12.00	4.03
1,1-Dichloroethane	2	0.18	1.10	0.64
1,2-Dichloroethane	14	0.08	5100.00	931.01
Tetrachloroethene	10	0.33	8.90	2.97
Trichloroethene	11	1.40	500.00	76.85
Trans-1,2-Dichloroethene	1	0.11	0.11	0.11
1,1-Dichloroethene	2	0.16	1.40	0.78
Vinyl Chloride	4	1.40	64.00	19.95
Chloroform	10	1.30	840.00	205.94
Methylene Chloride	6	4.20	210.00	65.43

AR302093

TABLE 4-8
ZONE 1
GROUNDWATER - FIRST ROUND ANALYSES FOR VOAs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)
PAGE TWO

Compound	# of Positive Detections in 16 events	Minimum Detected Conc.	Maximum Detected Conc.	Average
1,2-Dichlorobenzene	8	4.70	440.00	105.00
1,3-Dichlorobenzene	4	4.50	78.00	31.90
1,4-Dichlorobenzene	9	3.40	110.00	25.22

AR302094

TABLE 4-9

ZONE 2
GROUNDWATER - SECOND ROUND ANALYSES FOR VOA
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	# of Positive Detections in 4 events	Minimum Detected Conc.*	Maximum Detected Conc.*	Average*
Benzene	1	5.30	5.30	5.30
Ethylbenzene	1	1600.00	1600.00	1600.00
Chlorobenzene	2	670.00	12000.00	6335.00
1,2-Dichloroethane	3	0.06	56.00	27.35
Tetrachloroethene	1	12.00	12.00	12.00
Trichloroethene	1	1.10	1.10	1.10
Chloroform	1	120.00	120.00	120.00
1,2-Dichlorobenzene	1	9.90	9.90	9.90
1,3-Dichlorobenzene	1	100.00	100.00	100.00
1,4-Dichlorobenzene	1	60.00	60.00	60.00

AR302095

TABLE 4-10

ZONE 2
GROUNDWATER - FIRST ROUND ANALYSES FOR VOAs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	# of Positive Detections in 13 events	Minimum Detected Conc.*	Maximum Detected Conc.*	Average*
Benzene	3	1.90	76.00	27.34
Toluene	2	0.68	32.00	16.34
Chlorobenzene	6	2.40	11000.00	3002.07
1,1,1-Trichloroethane	3	0.09	35.00	20.36
1,1,2-Trichloroethane	3	0.43	6.30	2.52
1,1-Dichloroethane	6	0.10	0.88	0.39
1,2-Dichloroethane	6	6.70	680.00	269.28
Tetrachloroethene	6	0.38	3.30	1.81
Trichloroethene	3	23.00	130.00	66.33
Trans-1,2-Dichloroethene	1	1.00	1.00	1.00
1,1-Dichloroethene	2	0.14	0.97	0.55
Vinyl Chloride	1	0.56	0.56	0.56
Chloroform	5	2.30	620.00	133.04
Methylene Chloride	1	2.70	2.70	2.70
Cis-1,2-Dichloroethene	6	0.13	2.20	1.15
1,2-Dichlorobenzene	4	2.40	35.00	12.50
1,4-Dichlorobenzene	1	4.40	4.40	4.40

AR302096

TABLE 4-11

ZONE 2
GROUNDWATER - SECOND ROUND ANALYSES FOR VOAs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	# of Positive Detections in 6 events	Minimum Detected Conc.*	Maximum Detected Conc.*	Average*
Benzene	1	4.40	4.40	4.40
Chlorobenzene	2	2.40	580.00	291.20
1,1,1-Trichloroethane	1	14.00	14.00	14.00
1,1,2-Trichloroethane	1	0.61	0.61	0.61
1,1-Dichloroethane	2	0.21	0.27	0.24
1,2-Dichloroethane	2	6.70	170.00	88.35
Tetrachloroethene	2	0.38	0.93	0.66
Trichloroethene	1	20.00	20.00	20.00
Trans-1,2-Dichloroethene	1	1.00	1.00	1.00
1,1-Dichloroethene	1	0.97	0.97	0.97
Vinyl Chloride	2	0.50	2.50	1.50
Cis-1,2-Dichloroethene	2	0.97	1.50	1.23
1,2-Dichlorobenzene	1	8.20	8.20	8.20

AR302097

TABLE 4-12

ZONE 3
GROUNDWATER - FIRST ROUND ANALYSES FOR VOAs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	# of Positive Detections in 13 events	Minimum Detected Conc.	Maximum Detected Conc.	Average
Benzene	3	0.20	1.70	0.74
Chlorobenzene	1	40.00	40.00	40.00
1,1,1-Trichloroethane	3	0.07	1.80	0.65
1,1,2-Trichloroethane	1	0.47	0.47	0.47
1,1-Dichloroethane	3	0.09	1.90	0.71
1,2-Dichloroethane	8	0.12	210.00	43.94
Chloroethane	1	0.66	0.66	0.66
Tetrachloroethene	1	0.07	0.07	0.07
Trichloroethene	3	0.22	40.00	13.74
Trans-1,2-Dichloroethene	1	0.11	0.11	0.11
1,1-Dichloroethene	1	0.18	0.18	0.18
Vinyl Chloride	2	0.46	1.20	1.83
Chloroform	6	0.05	57.00	9.81
Methylene Chloride	3	0.37	6.80	2.71
Bromodichloromethane	1	0.13	0.13	0.13
Cis-1,2-Dichloroethene	4	0.10	1.20	1.41

AR302098

TABLE 4-13

ZONE 3
GROUNDWATER - SECOND ROUND ANALYSES FOR VOAs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	# of Positive Detections in 7 events	Minimum Detected Conc.*	Maximum Detected Conc.*	Average*
Benzene	1	7.40	7.40	7.40
Chlorobenzene	1	52.00	52.00	52.00
1,1,1-Trichloroethane	1	1.40	1.40	1.40
1,1,2-Trichloroethane	1	1.10	1.10	1.10
1,1-Dichloroethane	2	0.07	0.07	0.07
1,2-Dichloroethane	5	0.83	950.00	193.49
Trichloroethene	1	54.00	54.00	54.00
Vinyl Chloride	1	4.80	4.80	4.80
Cis-1,2-Dichloroethene	1	2.30	2.30	2.30

AR302099

1,1-Dichloroethene

TABLE 4-14

ZONE 1
GROUNDWATER - FIRST ROUND ANALYSES FOR BNAs, PESTICIDES/PCBs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 15 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Bis(2-Ethylhexyl)Phthalate	2	1.00	2.00	1.50
Naphthalene	2	8.00	29.00	18.50
1,2-Dichlorobenzene	1	530.00	530.00	530.00
1,3-Dichlorobenzene	1	30.00	30.00	30.00
1,4-Dichlorobenzene	2	8.00	140.00	74.00
1,2,4-Trichlorobenzene	2	13.00	130.00	71.50
Nitrobenzene	1	20.00	20.00	20.00
4-Chloroaniline	2	25.00	620.00	322.50
Phenol	1	2,500.00	2,500.00	25,000.00
2-Methylphenol	1	71.00	71.00	71.00
4-Methylphenol	1	200.00	200.00	200.00
2,4-Dimethylphenol	1	220.00	220.00	220.00
2-Chlorophenol	2	7.00	47.00	27.00
2,4-Dichlorophenol	2	150.00	210.00	180.00

AR302100

TABLE 4-15

ZONE 1
GROUNDWATER - SECOND ROUND ANALYSES FOR BNAs, PESTICIDES, AND PCBs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 15 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Bis(2-Ethylhexyl)Phthalate	1	8.00	8.00	8.00
Di-N-Octyl Phthalate	1	66.00	66.00	66.00
Naphthalene	2	13.00	16.00	14.50
2-Methylnaphthalene	1	2.00	2.00	2.00
1,3-Dichlorobenzene	2	34.00	51.00	42.50
1,4-Dichlorobenzene	2	6.00	22.00	14.00
1,2,4-Trichlorobenzene	2	12.00	52.00	32.00
4-Chloroaniline	2	5.00	450.00	227.50
Phenol	1	42.00	42.00	42.00
2,4-Dimethylphenol	1	16.00	16.00	16.00
2-Chlorophenol	1	3.00	3.00	3.00
2,4-Dichlorophenol	2	66.00	110.00	88.00
2,4,5-Trichlorophenol	1	5.00	5.00	5.00

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TABLE 4-16

ZONE 2
GROUNDWATER - FIRST ROUND ANALYSES FOR BNAs, PESTICIDES/PCBs
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 13 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Bis(2-Ethylhexyl)Phthalate	1	2.00	2.00	2.00
Naphthalene	2	1.00	440.00	220.50
1,2-Dichlorobenzene	3	12.00	56.00	28.33
1,4-Dichlorobenzene	3	4.00	27.00	12.00
1,2,4-Trichlorobenzene	1	120.00	120.00	120.00
4-Chloroaniline	1	430.00	430.00	430.00
Benzoic Acid	1	680.00	680.00	680.00
Phenol	1	360.00	360.00	360.00
2-Methylphenol	1	16.00	16.00	16.00
2,4-Dimethylphenol	3	3.00	41.00	19.00
2-Chlorophenol	2	4.00	24.00	14.00
2,4-Dichlorophenol	2	18.00	31.00	24.50
Pentachlorophenol	1	14.00	14.00	14.00

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TABLE 4-17

DRAKE CHEMICAL SITE - PHASE III RI
GROUNDWATER - ZONE 3 - FIRST ROUND ANALYSES FOR BNAs, PESTICIDES/PCBs
(All values in µg/l)

Compound	No. of Positive Detections in 13 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Bis(2-Ethylhexyl)Phthalate	4	1.00	27.00	7.75

TABLE 4-18

DRAKE CHEMICAL SITE - PHASE III RI
GROUNDWATER - ZONE 3 - SECOND ROUND ANALYSES FOR BNAs, PESTICIDES/PCBs
(All values in µg/l)

Compound	No. of Positive Detections in 13 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
3,3'-Dichlorobenzidine	1	9.00	9.00	9.00

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detected at the highest level of contamination; however, the concentration is lower than that found in Zone 1 samples. 2,4-Dimethylphenol, 1,2-dichlorobenzene, and 1,4-dichlorobenzene occur with greatest frequency in the first round of samples. No positive results are reported in Zone 2 second round samples.

Only two extractable compounds were detected in Zone 3 monitoring well samples. Bis(2-ethylhexyl)phthalate was detected in four samples at low concentrations and may have occurred as a result of laboratory contamination. The compound 3,3'-dichlorobenzidine was detected in only one sample and, since it is an organic dye precursor, may be present as a result of activities at the Drake Chemical Site (see Tables 4-17 and 4-18).

The compounds phenol and 4-chloroaniline were compounds with the highest concentrations in the first and second rounds, respectively; however, the frequency of occurrence for any one compound is somewhat inconclusive since all compounds were detected in either one or two samples.

Samples taken from Zone 2 monitoring wells contain many of the same contaminants found in Zone 1 (see Table 4-16).

4.5.3 Fenac, β-naphthylamine, Cyanide

Figure A.4-7 displays the results of analyses for fenac β-naphthylamine and cyanide obtained from both the first and second rounds of groundwater sampling activities. Statistical summarizes by zones and sampling rounds are detailed in Tables 4-19 to 4-24.

Samples taken from monitoring wells in all three zones are contaminated by one or more site-related contaminants. Both rounds of sampling indicate that Zone 1 groundwater is contaminated by both fenac and β-naphthylamine. Cyanide is detected in the first, more comprehensive sampling round but not in the second round samples (see Tables 4-19 and 4-20). Fenac was detected at the highest level of contamination and with the greatest frequency. β-naphthylamine was also detected in significant amounts.

Fenac and β-naphthylamine were also detected in offsite, Zone 2, monitoring well samples. Fenac was again found at the highest levels and with greatest frequency. Analytical values for both β-naphthylamine and fenac were lower in downgradient Zone 2 samples than those reported in Zone 1 (see Tables 4-21 and 4-22). This attenuating effect is consistent with the expected contaminant migration pathway and corresponding diluting effects of uncontaminated groundwater. The compound cyanide was not detected in either round of Zone 2 samples.

Samples taken from downgradient Zone 3 monitoring wells display further dilution in the concentration of fenac, while β-naphthylamine was not detected in any Zone 3 sample. The

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TABLE 4-19

ZONE 1
FIRST ROUND ANALYSES FOR GROUNDWATER -
FENAC, β-NAPHTHYLAMINE, CYANIDE
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 15 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Cyanide	4	10.00	6,780.00	1,711.00
Fenac	12	20.00	20,000.00	3,617.00
β-Naphthylamine	8	1.00	2,300.00	311.25

TABLE 4-20

ZONE 1
SECOND ROUND ANALYSES FOR GROUNDWATER -
FENAC, β-NAPHTHYLAMINE, CYANIDE
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 15 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Fenac	4	0.16	8,600.00	2,372.58
β-Naphthylamine	1	3,000.00	3,000.00	3,000.00

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TABLE 4-21

ZONE 2
FIRST ROUND ANALYSES FOR GROUNDWATER -
FENAC, β-NAPHTHYLAMINE, CYANIDE
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 13 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Fenac	5	7.60	9,200.00	2,020.00
β-Naphthylamine	1	12.00	12.00	12.00

TABLE 4-22

ZONE 2
SECOND ROUND ANALYSES FOR GROUNDWATER -
FENAC, β-NAPHTHYLAMINE, CYANIDE
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 6 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Fenac	6	0.03	270.00	49.27

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TABLE 4-23

ZONE 3
FIRST ROUND ANALYSES FOR GROUNDWATER -
FENAC, β-NAPHTHYLAMINE, CYANIDE
DRAKE CHEMICAL - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 6 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Cyanide	1	16.00	16.00	16.00
Fenac	2	5.90	18.00	11.95

TABLE 4-24

ZONE 3
SECOND ROUND ANALYSES FOR GROUNDWATER -
FENAC, B-NAPHTHYLAMINE, CYANIDE
DRAKE CHEMICAL SITE - PHASE III RI
(All values in µg/l)

Compound	No. of Positive Detections in 6 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Fenac	7	0.06	700.00	104.60

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compound cyanide was detected in a single sample; however, no case can be made for its occurrence as a result of site contamination (see Tables 4-23 and 4-24).

4.6 GROUNDWATER

4.6.1 Total Metals

All groundwater samples were analyzed for total inorganics and dissolved metals. Table 4-25 summarizes the known background concentrations of total and dissolved metals within the study area and surrounding region. These data are based on observed values and reported the literature values.

Pertinent points observed from review of Table 4-25 include:

- Moderate to high concentrations of alkali metals are observed. Notable are potassium, sodium, and calcium.
- The transition metals, iron and manganese, are evident at relatively high background concentrations.
- Barium, cadmium, chromium, and lead concentrations in unfiltered (total) metal values.
- Samples from upgradient wells exceed their respective Maximum Concentration Limits. This may be the result of sampling monitoring wells that have not settled in. Consequently, the observed total metal concentration reflects a high suspended-particular fraction that is a residual from well development.
- Iron and manganese concentrations in filtered (dissolved) samples from upgradient wells exceed secondary water quality MCLs.

The occurrence of iron and manganese at the observed concentrations is probably related to earth workings such as mining in the area or the presence of fine, suspended particulate matter in unfiltered sample media from well drilling activities. This assessment is based on the history of the study area and the abundance of these metals in local strata. Table 4-26 contrasts analytical results total iron and manganese measurements with typical groundwater. The relationship that iron concentrations always exceeds manganese is evident. The iron to manganese ratio ranges from 1.2 to 16.7. Regressing iron on manganese provides a correlation coefficient of 0.77. This patterned relationship, in conjunction with the conclusions drawn from Table 4-26 and the lack of documented evidence to indicate that iron or manganese were used in the manufacture of color dyes at the site, supports the conclusion that the observed concentrations of iron and manganese in groundwaters are background levels in the area.

TABLE 4-25

SUMMARY OF BACKGROUND CONCENTRATIONS
OF METALS IN GROUNDWATER
DRAKE CHEMICAL SITE - PHASE III RI

Compound	Dissolved Concentration (µg/l)	Total Concentration (µg/l)
Aluminum	78.0(1)	8,220.0(1)
Antimony	---	---
Arsenic (Total)	---	46.1(1)
Barium	64.0(1)	1,540.0(1)*
Beryllium	---	7.2(1)
Cadmium	---	11.3(1)*
Calcium	68,400.0(1)	76,400.0(1)*
Chromium	---	153.0(1)*
Cobalt	---	111.0(1)*
Copper	---	161.0(1)*
Iron	721.0(1)**	224,000.0**
Lead	6.5(1)	87.0(3)*
Magnesium	13,100.0(1)	29,500.0(1)
Manganese	1,440.0(1)**	35,300.0(3)*
Mercury	---	0.4(1)
Nickel	19.1(1)	222.0(1)
Potassium	8,330.0(1)	15,400.0(1)
Selenium	---	---
Silver	---	---
Sodium	42,200.0(3)	40,400.0(3)
Thallium	---	---
Vanadium	---	124.0(1)
Zinc	49.1(1)	564.0(1)

(1) From monitoring well M101
(2) From monitoring well M9
(3) From monitoring well M102
* Exceeds DWS - Primary MCLs. See text for discussion.
** Exceeds DWS - Secondary MCL

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TABLE 4-26

RELATIONSHIP BETWEEN TOTAL (UNFILTERED) IRON AND MANGANESE CONCENTRATIONS, TYPICAL OBSERVATIONS DRAKE CHEMICAL SITE - PHASE III RI

Sample Number	Iron (mg/l)	Manganese (mg/l)
DC-M102-202	303.0	35.3
MC-M18-145	319.0	180.0
DC-114-114	168 (µg/l)	13.9 (µg/l)
DC-107-107	159 (µg/l)	129 (µg/l)
DC-M9-136	15.0	4.9
DC-M-122	102.0	6.1
DC-M-125	94.8	17

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Metals concentrations portrayed in Table 4-25 will be used as benchmarks from which site-associated contamination will be assessed. Measured concentrations equal to or below those presented in Table 4-25 will not be considered as related to site activities. Additionally, all measured iron and manganese concentrations in groundwater will be considered indicative of background conditions.

Figure A.4-8 displays the results of analyses for total metals obtained from both rounds of groundwater sampling.

In general, samples acquired from monitoring wells in all three zones demonstrate the presence of metals as would be expected in a geochemical setting. Groundwater in Zone 1 is contaminated with aluminum, arsenic, beryllium, cadmium, chromium, nickel, iron, and vanadium (Table 4-27). These compounds are detected in the first sampling round but not in the more selective second round samples.

The metals aluminum, iron, magnesium, manganese, potassium, and sodium occur at the highest concentrations and with the greatest frequency but do not appear to be site related. Heavy metals, including mercury, lead, barium, cadmium, chromium, and cyanide, are also detected at varying levels.

Offsite groundwater samples taken from Zone 2 monitoring wells display the same type of contamination present in Zone 1 samples (Tables 4-28 and 4-29). Again, aluminum, iron, magnesium, manganese, potassium, and sodium occur at the highest concentrations and with greatest frequency but their relationship to site activities is not readily discernable. The heavy metals, however, occur in somewhat lower contamination levels and cyanide is not detected. This observation is consistent with the expected contaminant migration pathway and the corresponding dilution effect from previously uncontaminated groundwater aquifers.

Zone 3 samples show that aluminum, iron, magnesium, potassium, and sodium occur at the greatest concentrations and frequency but the heavy metals seem to increase in concentration with distance from the site, hence, they are probably not site related, as opposed to Zone 2 (see Tables 4-30 and 4-31). These trace amounts of metals occur in samples upgradient of the site and may be indigenous to the area and may occur as natural constituents of groundwater.

Antimony, and arsenic are also detected in low concentrations in Zone 3 samples but occur with limited frequency. Due to their erratic occurrence and distribution these elements may or may not occur as a result of activities at the site.

TABLE 4-27

ZONE 1
FIRST ROUND ANALYSES FOR GROUNDWATER - TOTAL INORGANICS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	First Round No. of positive detections in 15 events	Minimum Detected Concentration*	Maximum Detected Concentration*	Average*
Aluminum	14	36.40	354,000.00	39,096.07
Arsenic (Total)	6	5.50	400.00	101.25
Barium	10	28.00	14,800.00	2,526.30
Beryllium	5	5.00	13.00	9.02
Cadmium	11	5.90	202.00	55.90
Calcium	15	52,600.00	842,000.00	299,066.67
Chromium	10	10.30	448.00	141.65
Cobalt	11	10.70	270.00	99.43
Copper	4	206.00	299.00	257.25
Iron	15	159.00	1,080,000.00	227,821.93
Lead	4	15,000.00	237,000.00	95,500.00
Magnesium	15	7,820.00	861,000.00	157,992.00
Manganese	15	14.40	129,000.00	23,996.23
Mercury	4	0.22	1.00	0.43
Nickel	6	31.50	424.00	182.42
Potassium	15	936.00	208,000.00	57,417.73
Silver	1	19.00	19.00	19.00
Sodium	15	9,170.00	1,400,000.00	415,231.33
Thallium	1	25.00	25.00	25.00
Vanadium	13	3.40	177.00	84.22
Zinc	6	165.00	4,150.00	1,711.00
Cyanide	4	10.00	6,780.00	1,711.00

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TABLE 4-28

ZONE 2
FIRST ROUND ANALYSES FOR GROUNDWATER - TOTAL INORGANICS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 13 Events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Aluminum	12	149.00	44,000.00	10,712.58
Arsenic (Total)	6	3.90	35.40	14.07
Barium	9	42.40	512.00	252.54
Beryllium	3	3.30	100.00	32.75
Cadmium	4	4.30	100.00	32.75
Chromium	9	5.00	125.00	35.10
Cobalt	11	12.20	264.00	78.40
Copper	6	9.10	122.00	52.97
Iron	12	471.00	664,000.00	153,027.58
Magnesium	13	5,720.00	650,000.00	98,970.77
Manganese	13	37.10	176,000.00	35,620.70
Mercury	2	0.30	0.50	0.40
Nickel	11	17.00	260.00	92.67
Potassium	13	1,300.00	158,000.00	25,298.46
Sodium	13	7,200.00	1,660,000.00	295,638.46
Vanadium	9	8.70	137.00	44.39
Zinc	7	29.00	2,000.00	468.36

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TABLE 4-29

ZONE 2
SECOND ROUND ANALYSES FOR GROUNDWATER - TOTAL INORGANICS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 13 Events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Aluminum	6	190.00	8,120.00	4,611.50
Arsenic (Total)	3	3.10	4.30	3.77
Barium	4	136.00	805.00	394.00
Cadmium	2	6.00	10.00	8.00
Calcium	6	55,700.00	234,000.00	146,833.33
Chromium	5	11.00	33.00	21.20
Cobalt	4	28.00	55.00	44.25
Copper	5	24.00	83.00	47.80
Iron	6	1,300.00	89,000.00	22,783.33
Lead	4	49.00	139.00	90.00
Magnesium	6	9,630.00	90,800.00	36,238.33
Manganese	6	81.00	13,800.00	7,473.50
Mercury	2	0.40	0.82	0.61
Nickel	5	17.00	167.00	70.60
Potassium	6	1,020.00	19,500.00	7,803.33
Silver	1	21.00	21.00	21.00
Sodium	6	8,080.00	338,000.00	105,113.33
Vanadium	5	12.00	43.00	27.60
Zinc	5	29.00	136.00	80.60

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TABLE 4-30

ZONE 3
FIRST ROUND ANALYSES FOR GROUNDWATER - TOTAL INORGANICS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 13 Events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Aluminum	13	103.00	313,000.00	82,687.77
Antimony	1	188.00	188.00	188.00
Arsenic (Total)	6	19.30	128.00	59.50
Barium	12	35.00	5,390.00	1,536.82
Beryllium	6	2.80	31.80	14.85
Cadmium	7	5.00	34.00	16.46
Calcium	13	19,400.00	1,240,000.00	213,469.23
Chromium	6	9.50	468.00	262.63
Cobalt	9	10.00	679.00	240.48
Copper	7	70.90	725.00	383.12
Iron	13	188.00	1,320,000.00	313,933.54
Lead	4	1.40	372.00	164.95
Magnesium	13	6,610.00	634,000.00	100,030.00
Manganese	13	13.90	76,800.00	18,422.56
Mercury	6	0.20	1.70	0.93
Nickel	8	17.60	1,400.00	485.96
Potassium	10	1,580.00	34,600.00	12,091.00
Sodium	13	5,000.00	617,000.00	96,427.69
Vanadium	9	22.00	552.00	227.68
Zinc	6	150.00	2,570.00	1,274.00
Cyanide	1	16.00	16.00	16.00

AR302115

TABLE 4-31

ZONE 3
SECOND ROUND ANALYSES FOR GROUNDWATER - TOTAL INORGANICS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 7 Events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Aluminum	5	3.69	14,900.00	4,995.34
Arsenic (Total)	1	9.00	9.00	9.00
Barium	6	67.00	643.00	280.83
Beryllium	2	6.00	8.00	7.00
Cadmium	1	6.00	6.00	6.00
Calcium	7	81,100.00	495,000.00	179,271.43
Chromium	3	15.00	36.00	25.00
Cobalt	3	73.00	157.00	117.33
Copper	5	13.00	127.00	61.20
Iron	7	153.00	9,950.00	3,381.43
Lead	6	4.00	535.00	120.83
Magnesium	7	24,200.00	152,000.00	49,871.43
Manganese	7	11.00	31,800.00	11,520.86
Mercury	4	0.20	1.70	0.98
Nickel	5	8.00	249.00	142.40
Potassium	7	834.00	10,800.00	4,826.29
Sodium	6	11.00	63.00	26.50
Vanadium	6	11.00	63.00	26.50
Zinc	4	60.00	225.00	151.50

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4.6.2 Dissolved Metals

Figure A.4-9 displays the results of dissolved metals analyses obtained from both the first and second round of groundwater sampling.

Samples acquired from monitoring wells in all three zones appear to be polluted by site-associated contaminants. Groundwater in Zone 1 is contaminated with dissolved metals including barium, beryllium, cadmium, cobalt, nickel, vanadium, and zinc at higher levels than these considered to be background levels (Table 4-32).

Groundwater samples taken from downgradient monitoring wells in Zone 2 display the same constituents of contamination found in Zone 1.

The extent of contamination, however, is somewhat attenuated by the diluting effects of uncontaminated groundwater contribution during migration away from the site. This effect is seen in both rounds of Zone 2 samples (Tables 4-33 and 4-34). Heavy metal contaminant values may be within the range of normal background concentrations for regional groundwaters.

Zone 3 groundwater samples (taken during both sampling rounds) downgradient of the site and of Zone 2 contain iron, magnesium, sodium, and potassium and contain similar concentrations of heavy metals and aluminum characteristic in Zone 2 sample analyses (Tables 4-35 and 4-36).

These amounts are probably within the range of normal background values for uncontaminated regional groundwaters and cannot be easily attributed to activities that occurred at the site.

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TABLE 4-32

ZONE 1
SECOND ROUND ANALYSES FOR GROUNDWATER - DISSOLVED METALS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 7 Events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Aluminum	2	13,100.00	102,000.00	57,550.00
Arsenic	2	26.00	53.00	39.50
Barium	7	29.00	14,600.00	3,469.73
Beryllium	2	6.90	14.00	10.45
Cadmium	6	17.00	213.00	77.67
Calcium	13	30,100.00	850,000.00	269,869.23
Chromium	8	5.10	458.00	111.59
Cobalt	8	11.00	286.00	98.75
Copper	2	17.60	18.20	17.90
Iron	10	16,300.00	1,240,000.00	300,520.00
Magnesium	13	7,680.00	400,000.00	115,096.15
Manganese	13	12.70	61,800.00	16,995.52
Nickel	3	7.00	436.00	229.00
Potassium	13	963.00	239,000.00	47,851.77
Sodium	13	9,210.00	1,540,000.00	484,246.92
Vanadium	9	9.30	174.00	56.48
Zinc	4	24.70	4,270.00	1,348.80

AR302118

TABLE 4-33

ZONE 2
FIRST ROUND ANALYSES FOR GROUNDWATER - DISSOLVED METALS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 7 Events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Aluminum	2	91.10	5,940.00	3,015.55
Antimony	1	66.50	66.50	66.50
Arsenic	2	3.20	27.30	15.25
Barium	7	15.80	429.00	107.07
Beryllium	1	6.10	6.10	6.10
Cadmium	2	13.00	123.00	68.00
Calcium	11	24,200.00	325,000.00	132,309.09
Chromium	2	7.10	165.00	86.05
Cobalt	6	15.00	238.00	90.28
Copper	1	20.00	20.00	20.00
Iron	8	130.00	666,000.00	187,249.00
Magnesium	11	3,380.00	670,000.00	101,343.64
Manganese	10	5.90	474,000.00	69,310.99
Mercury	1	0.20	0.20	0.20
Nickel	8	8.00	204.00	78.01
Potassium	9	1,050.00	161,000.00	32,982.22
Sodium	11	8,960.00	880,000.00	234,605.45
Vanadium	4	12.00	120.00	54.50
Zinc	7	34.00	1,960.00	323.49

AR302119

TABLE 4-34

ZONE 2
SECOND ROUND ANALYSES FOR GROUNDWATER - DISSOLVED METALS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 7 Events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Arsenic	1	3.20	3.20	3.20
Barium	3	49.00	338.00	153.00
Cadmium	2	8.00	10.00	9.00
Calcium	6	35,300.00	227,000.00	107,566.67
Chromium	1	10.00	10.00	10.00
Cobalt	3	10.00	24.00	14.67
Copper	2	20.00	29.00	24.50
Iron	4	156.00	83,700.00	22,609.50
Lead	3	3.00	6.10	4.30
Magnesium	6	8,780.00	46,600.00	23,463.33
Manganese	5	1,440.00	10,800.00	5,518.00
Mercury	1	0.20	0.20	0.20
Nickel	5	8.00	50.00	29.00
Potassium	6	798.00	18,800.00	6,763.00
Sodium 4	6	8,320.00	329,000.00	101,820.00
Vanadium	3	10.00	70.00	37.67
Zinc	4	34.00	179.00	80.25

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TABLE 4-35

ZONE 3
FIRST ROUND ANALYSES FOR GROUNDWATER - DISSOLVED METALS
DRAKE CHEMICAL SITE - PHASE III RI
(All values are in µg/l)

Compound	No. of Positive Detections in 13 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Aluminum	1	21.90	21.90	21.90
Barium	9	25.20	230.00	76.09
Calcium	10	17,500.00	155,000.00	69,890.00
Chromium	1	5.40	5.40	5.40
Cobalt	2	10.00	23.00	16.50
Copper	3	14.80	16.20	15.40
Iron	4	47.90	238,000.00	59,538.70
Magnesium	10	4,430.00	35,500.00	19,410.00
Manganese	7	20.40	8,550.00	1,873.94
Nickel	2	17.60	54.90	36.25
Potassium	6	569.00	4,900.00	2,154.83
Sodium	8	5,270.00	98,400.00	43,833.75
Zinc	3	19.10	148.00	70.60

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TABLE 4-36

ZONE 3
SECOND ROUND ANALYSES FOR GROUNDWATER - DISSOLVED METALS
DRAKE CHEMICAL SITE - PHASE III RI

Compound	No. of Positive Detections in 7 events	Minimum Detected Concentration	Maximum Detected Concentration	Average
Antimony	3	37.00	191.00	91.33
Barium	3	54.00	129.00	91.33
Calcium	7	67,400.00	392,000.00	142,885.71
Chromium	2	10.00	16.000	13.00
Cobalt	3	10.00	53.00	28.33
Copper	1	13.00	13.00	13.00
Iron	2	127.90	273.00	200.00
Lead	5	3.60	44.00	19.66
Magnesium	7	22,500.00	94,600.00	37,000.00
Manganese	6	26.00	26,500.00	7,747.50
Mercury	1	0.62	0.62	0.62
Nickel	3	53.00	164.00	97.33
Potassium	7	989.00	10,700.00	3,862.71
Sodium	7	6,551.00	588,000.000	132,372.86
Vanadium	5	12.00	49.00	20.60
Zinc	5	28.00	158.00	81.40

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5.0 CONTAMINANT FATE AND TRANSPORT

5.1 CONTAMINANT MIGRATION PATHWAY

This Phase III RI considers only the migration of contaminants from the source on the site to pertinent offsite receptors via the groundwater pathway. Other migration pathways such as air and surface water, have been considered in previous reports (NUS; July 1984, August 1986)

Figure A.5-1 is a conceptual cross section of the study area that details the central components of the groundwater contaminant migration system. The groundwater flow regime is an unconfined, two-segment, flow system comprised of a shallow water table aquifer underlain by a bedrock unit. The two segments are contiguous, with no detectable, appreciable, vertical-flow component. Seepage velocities in the upper segment tend be about an order of magnitude greater than in the lower. The general flow pattern is from upgradient of the site to Bald Eagle Creek (i.e., northeast to southwest). It is believed that groundwater, and therefore any solutes, discharge into the creek. Two physical features of the system depicted on Figure A.5-1 support this assertion.

- Bald Eagle Creek is a gaining stream and constitutes a natural groundwater flow intercept.
- A very significant, natural water elevation head differential exists between the water table adjacent to the site (north) side of the Creek, and the opposing elevation head on the Bald Eagle Mountain (south) side of the Creek.

As indicated on the figure, the average grade in the region between the site and Bald Eagle Creek is small (0.35 percent) and hence, average groundwater velocities are not great (approximately 6-60 feet/year).

Residual chemical contaminants in the vadose zone sludges and soils are the main source of contamination in the flow system. Evidence that the entire site is an essentially homogeneous source was presented in Section 4.0. With two exceptions, there appears to be no significant(1) difference in the occurrence and distribution of contamination across the site.

Contaminant loading to the groundwater occurs as natural precipitation percolates through contaminated soils and sludges in the vadose zone and solubilizes or "leaches" chemicals from the solid matrix. It is estimated that approximately 16 inches of the annual 42.5 inches of precipitation actually infiltrates

(1) Summary statistics, and test of significant variation are provided in Appendix F.

to the water table[2]. The estimated mass of contaminant presently available for leaching varies with the occurrence and concentration of the chemical within the vadose zone as indicated for three prominent site-associated contaminants in Table 5-1.

Chemical-specific leaching behavior presented in the table demonstrates the variability between the various types of contaminants that are characteristic of the Drake Chemical Site. Leach fractions (rates) were estimated based on contaminant retardation factors (Rd) and site specific data (Beas, et al., 1983). The variable controlling the rate differential is the partition coefficient, Kd. Partition coefficients and retardation factors employed for these and several other site-related compounds are presented in Table 5-2.

In addition to use in the leaching fraction estimate, chemical specific Rds were employed to estimate average contaminant velocities in the groundwater system where:

Vcontaminant = Vseepage/Rd (Freeze, et al., 1979)

Using this relationship and applying a typical groundwater velocity (60 feet/yr) for the overburden system yields the expected average contaminant velocities and travel times from the Site to Bald Eagle Creek displayed in Table 5-3.

The average contaminant velocity and average expected travel times present a basis for comparing the relative mobility of the general range of site-associated contaminants. The expected average travel time is figured for the center of the contaminant plume. As indicated by contaminant maps presented in Section 4.0, the leading portion of the contaminant plume has already traversed the typical 2,000-foot travel distance (see MW-M115, M117, A.4-5). Contaminant measurements taken from Bald Eagle Creek sediments indicate that contaminants have been transported by the groundwater pathway and discharged into the surface water.

Figure A.5-1 identifies several processes that are possibly active in the groundwater flow system. All the processes will tend to reduce contaminant concentrations. Advection is simply physical transport in a fluid system. It is the main means of contaminant migration in groundwater. Dispersion is undoubtedly active as evidenced by the spreading plume pattern (See Figures A.5-1, A.5-2, A.5-3, A.5-4, and A.5-5). Diffusion is usually only appreciable at low groundwater velocities (Mills, et al., 1985) and could be an active process in the bedrock system. Retardation is probably a significant process; adsorptive processes are typical for organic compounds while metals retardation is likely to be the result of cation exchange processes. McCarty (et al., 1981) reports that transformations

(2) Using Thornwaite and Mather Water Balance method, (Thornwaite, et al., 1957 See Appendix F).

TABLE 5-1

SELECT CONTAMINANTS LEACHING CHARACTERISTICS
DRAKE CHEMICAL SITE - PHASE III RI

Compound	Estimated (1) Mass Presently Available for Leaching	Percent of Currently Available Mass Potentially Leached to Groundwater (2)			
		Year 1	Year 10	Year 30	Year 100
1,2-dichloroethane	8.28 kg	29.7	97.1	99.9	~100
chlorobenzene	113.6 kg	9.7	64.3	95.4	99.9
fenac	327.2 kg	4.4	40	74	98.8

(1) Based on summary statistics, Appendix F.
(2) Assumes 95% of mass leaches in the theoretical chemical specific leach period. Computations provided in Appendix F.

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TABLE 5-2

TYPICAL RETARDATION (Rd) FACTORS
DRAKE CHEMICAL SITE - PHASE III RI

Compound	Kd(1)	Rd
1,2-dichloroethane	0.3	2.7
chlorobenzene	1.6	9.1
fenac	4.0	22.7
cadmium	6.3(2)	36
chromium	37(2)	211

(1) Assumes 1% organic carbon content.
(2) For the more mobile species Cr VI, (Baes et al., 1983 and Looney et al., 1987) Cr III is the predominantly expected species.

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TABLE 5-3

CONTAMINANT VELOCITIES AND TRAVEL TIMES
DRAKE CHEMICAL SITE - PHASE III RI

Compound	Average Vcontaminant	Expected Average Travel Time
1,2-dichloroethene	22 feet/year	91 years
chlorobenzene	6.6 feet/year	303 years
fenac	2.6 feet/year	770 years
chromium	0.3 feet/year	7,033 years

Velocities and travel times are for the center of a plume. Lead and trail (first view, last view) travel times will be earlier and later, respectively.

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of organic compounds in groundwater systems can occur through the action of microorganisms attached to particles or contained within the void spaces.

5.2 SITE SPECIFIC CONTAMINANT MIGRATION

Contaminants have obviously migrated offsite via the pathway described above. This is evidenced by the information presented in Section 4.0 (See Figures A.4-5, A.4-6, A.4-7, A.4-8, and A.4-9). Data presented on figures in this section blends the information presented in Section 4.0 with the pathway description provided in Section 5.1 using site indicator parameters. The figures for reference in the forthcoming discussion are:

- Figure A.5-1 Isoconcentration Map for 1,2-Dichloroethane
- Figure A.5-2 Isoconcentration Map for Chlorobenzene
- Figure A.5-3 Isoconcentration Map for Fenac
- Figure A.5-4 Isoconcentration Map for Cadmium
- Figure A.5-5 Isoconcentration Map for Chromium

Inspection of Figure A.5-2 reveals that the 1,2-dichloroethane plume follows the general groundwater flow directions. 1,2-Dichloroethane is regarded as highly mobile in groundwater (Rd=2.7). The strongest component of flow and, hence contaminant migration, is southeasterly with an elliptical spreading due to hydrodynamic dispersion which causes radiation of contaminants, to either side of the plume centerline. This is particularly evident for the water table (shallow overburden) data as indicated by the heavier line. The deep overburden data exhibits a similar pattern that appears offset slightly to the north and east of the water table well plume. The deep overburden contours also extend somewhat further along the main southeasterly flow path than do the water table contours. Hence, two plumes are actually depicted.

Viewing the 1,000 µg/l isopleth for the deep overburden plume (the thin line) reveals that there probably exists an area of high 1,2-dichloroethane concentration on the northeast edge of the site which is not observed in the water table well strata. A 1,000 µg/l isopleth for the water table plume is not identified. This higher-concentration region could account for the northerly expanse of the deep overburden plume. The observed easterly flow component is also a probable contributing factor to the observed easterly migration in the deep overburden groundwater.

The concentration gradient for both plumes diminishes elliptically out from the source along the groundwater flow lines. This observation is consistent with expectations and the migration pathway developed in Section 5.1.

Review of the data table found on Figure A.5-2 reveals that no real pattern of contamination in the bedrock formation is discernable. Sampling results from offsite bedrock wells

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MW-M107 and MW-M109 reveal 1,2-dichloroethane concentrations of 0.1 µg/l and 6.0 µg/l, respectively.

Chlorobenzene is a site-related contaminant whose occurrence is consistently observed in the source and groundwater investigations. With a site specific Rd of 9.1, chlorobenzene is expected to be mobile in the groundwater, though not as mobile as 1,2-dichloroethane. Figure A.5-3 is an isoconcentration map based on observed monitoring well chlorobenzene concentrations. The chlorobenzene plume follows the general groundwater flow pattern, featuring a strong south easterly trend with appreciable easterly and southerly components radiating laterally from the centerline. This is the expected effect of hydrodynamic dispersion. The deep overburden and water table data show similar patterns of dispersion. Relevant features gleaned from this figure include:

- The deep overburden portion of the contamination generally extends considerably further along the central axis of the plume than does the water table portion.

- Deep overburden groundwaters east of the site are affected where the water table portion, of the system is not. This pattern is similar to that observed for 1,2-dichloroethane.

- There appear to be two areas of high concentration in the water table portion as indicated by the 1,000 µg/l contours. One is located on the northeast border and the other along the southeast side which is actually beyond the site boundary.

- One area of high concentration in the deep overburden system is evident in the northeast portion of the site.

- Deep overburden groundwaters are impacted in Zones 1, 2, and 3 while only Zones 1 and 2 appear to be affected in the water table portion.

- Contamination in the bedrock system displays no obvious pattern. The data table shows that onsite Well MW-E1 is contaminated (220 µg/l) as is offsite well MW-M109 (3 µg/l).

Fenac is a prominent site-associated contaminant whose mobility in groundwater would be expected to be considerably less that of 1,2-dichloroethane (Rd 2.7) or even chlorobenzene (Rd 9.1). The Rd for fenac is 22.7. Figure A.5-4 displays the field-data-based isoconcentration map for fenac. Inspection of the figure indicates that the occurrence of fenac in both the deep overburden and water table groundwaters is widespread. Pertinent points that can be extracted from this figure include:

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- The overall migration pattern is similar to those observed for 1,2-dichloroethane and chlorobenzene.

- The extent of fenac contamination in the water table portion extends farther to the northeast and most notably--further to the south, than for 1,2-dichloroethane or chlorobenzene. Note that the 1 µg/l water table contour extends to the southerly most well clusters (i.e., MW-M11, 12, 13, 14).

- Areas where fenac concentrations exceed 1,000 µg/l are evident at and around the vicinity of the site.

- A large 1,000 µg/l contour in the water table portion is seen to roughly underlie the southern two-thirds of the site, as well as offsite areas to the southeast.

- A 1,000 µg/l contour in the deep overburden portion is indicated for the north and northeast portion of the site. This contour extends offsite to areas east and southeast.

- Within the 1000 µg/l deep overburden contour is the 10,000 µg/l contour which underlies the offsite area just east of the fenceline.

- A pattern of fenac contamination in the bedrock unit is not apparent. Review of the data table on Figure A.5-3 indicates that fenac was detected in two onsite wells (MW-E2, E3: 44 µg/l, 8 µg/l, respectively) and at 3 µg/l in the MW-M109, an offsite well immediately downgrade of the site.

Fenacs' mobility and observed widespread occurrence relative to 1,2-dichloroethane and chlorobenzene cannot be explained in terms of it mobility predictor, Rd. However, a review of Table 5-1 reveals that the estimated mass of fenac resident in source material is substantial (327.2 kg). It is reasonable to assume that the mass of fenac disposed during the operations at the site was very high and over a long duration. The quantity was obviously sufficient to affect the contamination pattern observed.

Figure A.5-5 presents an isoconcentration mapping of the occurrence of cadmium in the groundwater. Cadmium is a site-associated heavy metal with an Rd of 36; it would be expected to be moderately mobile in a groundwater flow system. Factors such as low pH or facilitated transport which might result from the formation of ligands (aka complexation) with organic or carbonate materials could enhance cadmium's mobility.

As indicated on Figure A.5-5, cadmium appears to have migrated from the site in the water table and deep overburden groundwaters as marked by the 100 µg/l isopleth.

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- In the water table portion of the overburden system, an area of higher concentration (marked by 100 µg/l isopleth) is observed south of deep overburden high concentration region. This area is actually off the site proper and is, therefore, within Zone 2.

- Cadmiums' occurrence and distribution in groundwater is considerably less frequent than 1,2-dichloroethene, chlorobenzene, and fenac. Consequently, there are fewer data points on which to base isoconcentration contours.

- The water table, high-concentration area is encircled by a 100 µg/l isopleth that does not track the groundwater flow pattern. This observation could be due to the absence of water table well immediately downgrade of the high concentration area.

- As evidenced by the data table, cadmium was detected only once in the bedrock system, 17 µg/l in MW-E3, an onsite (Zone 1) monitoring well.

- A 1,000 µg/l cadmium isopleth is not identified for either segment; hence, overburden system concentrations are not as high, overall, as those observed for 1,2-dichloroethane, chlorobenzene, and fenac.

- A high concentration area in the deep overburden segment is observed in the northeast portion of the site; it extends to offsite environs north and east.

- The deep, overburden isopleth generally responds to the more southerly groundwater-flow component rather than the southeasterly as observed for other compounds.

- The deep overburden isopleth does not extend beyond Zone 2.

Isoconcentration contours for chromium are presented on Figure A.5-6. Chromium is a site-associated heavy metal contaminant which, based upon its Rd (211), would not be expected to migrate from the site as readily as other contaminants discussed in this section. Inspection of Figure A.5-6 reveals that chromium has migrated substantially from the site, particularly in the deep overburden portion of the overburden segment. Features evident from this figure include:

- Similar to cadmium, a 1,000 µg/l chromium isopleth is not evident for either the deep overburden or water table segments of the overburden system.

- A high-concentration region in the deep overburden segment is evident just off the site proper, to the northeast.

- The 10 µg/l isopleth in the deep overburden segment extends through Zone 2 and well into Zone 3. This migration pattern appears to be in response to the southerly flow component in the system. This is similar to, and more extensive than, the migration pattern observed with cadmium in the deep overburden groundwater.

- Within the water table segment, a 100 µg/l crescent-shaped isopleth is observed in the southwestern portion of the site. A portion of the crescent extends to groundwater in Zone 2 that is offsite. (This crescent shape could be an anomaly associated with well placement.)

- There are fewer data points on which to base contours than in the case of 1,2-dichloroethane, chlorobenzene, and fenac.

- Surrounding the 100 µg/l water table segment crescent is a 10 µg/l isopleth which covers the bulk of the site and extends well into Zone 2. It appears that chromium migration has advanced from the site, in accordance with the general groundwater flow regime.

- A review of the data table reveals that chromium occurs in many wells, including those upgradient (see MW-M103, 104). As reported in Section 4.0, these observations are probably indicative of native conditions. On this basis, it does not appear that the bedrock system is affected by chromium, hence no isopleth is provided.

Table 5-4 provides an overall summary of the distribution of the five contaminants for which isoconcentration maps were prepared. Based on the data provided, it appears that the deep overburden segment of the overburden system is more highly contaminated than the water table portion in all three zones. Additionally, it is also apparent that Zone 1 is the most highly contaminated. Finally, the data presented indicate that groundwater in the bedrock system is not as appreciably affected by these site-related contaminants.

5.3 CONTAMINANT MIGRATION SIMULATION

The previous discussion of groundwater contaminant retardation factors and resultant travel times in the affected groundwaters indicates that contaminant migration to potential receptors distant from the site will be a long and ongoing process. Table 5-3 indicates that typical average travel times from the site to Bald Eagle Creek could range into the hundreds of years. With this realization, a requirement to simulate and evaluate contaminant behavior in the future is clearly indicated. This requirement was met through use of conceptual groundwater flow and solute transport model.

TABLE 5-4

HIGHEST ISOPLETH CONCENTRATIONS WITHIN AQUIFER SEGMENTS
IN THE THREE ZONES
CONCENTRATIONS IN µg/l
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	Water Table Zones			Deep Overburden Zones			Bedrock* Zones		
	1	2	3	1	2	3	1	2	3
1,2-dichloroethane	100	100	10	1,000	1,000	100	*	--	--
chlorobenzene	1,000	1,000	--	1,000	1,000	10	*	--	--
fenac	1,000	1,000	1	10,000	1,000	100	*	--	--
cadmium	100	100	--	100	10	--	*	--	--
chromium	100	100	--	100	100	10	*	--	--

* No patterns were observed in the bedrock segment, however, contaminants were detected in several onsite and Zone 1 offsite wells.

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Specific objectives of the model to be selected were:

- Provide a means for evaluating long term contaminant migration patterns, particularly as they might impact Bald Eagle Creek and to a lesser extent areas where groundwater measurements were not taken (i.e., no wells).

- Provide a means of assessing the effects of groundwater treatment strategies which would develop in the feasibility study.

The long-term, steady-state, groundwater flow and time-dependent contaminant transport in the flow system were simulated using the Sandia Waste-Isolation Flow and Transport Model (aka SWIFT-III) (Reeves, et al, 1986).

Swift III is a numerical model which has been extensively employed, tested, and is considered a state-of-the-art simulation technique, applicable to hazardous waste investigation (see Ward et. al,. 1984 and Ward, 1985). The model is a transient/steady-state, three-dimensional, groundwater and solute transport code used to solve the coupled equations governing the head and contaminant distributions for the conceptual model of the site. SWIFT III uses the finite-difference approximation method to solve the governing equations.

A finite-difference solution grid was developed to represent the spatial structure of the conceptual model (see Figure A.5-7). The X coordinates (block columns) are numbered left to right from 1 to 15; Y coordinates (block rows) are numbered on the top to bottom, 1 to 17. The top left block corresponds to block coordinates 1,1 and is referred to a block 1,1. Block 8,10 containing MW-15 is located near the center of the figure. Block widths in either direction (X or Y) are also provided adjacent to the X or Y coordinates. Block 1,1 is 300 feet long in the X and Y directions, Block 8,10 is 200 feet by 200 feet. The three-dimensional model grid was established based on the amount of data available horizontally and the size of the area of interest for the modeling analysis. Since this modeling analysis was required to simulate a steady-state local groundwater flow, a model grid size that greatly exceeds the area in which measured data are available is necessary. The orientation of the grid was determined based on the local general groundwater flow direction as well as the direction of existing natural boundaries such as the no-flow or constant head boundary. Smaller grid block sizes were selected for the on-site area, where ground water flow gradient is higher, because more data are available on-site and because the groundwater flow gradient needs to be simulated without being artificially smoothed by the use of broader grid sizes.

The groundwater model was constructed by including three vertical zones. Two of them are located within the overburden porous media. The bedrock was considered as a single conceptual

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zone. The depth of the bedrock zone was determined by the deepest well where groundwater contamination was detected.

The boundary of the model was treated as an interface between the local aquifer and the regional aquifer. Groundwater flow between the local and regional aquifers was assumed to be at steady-state as well as the local groundwater flow at the site.

Input data for the model used to represent the site-related contaminants and local aquifers included:

- Water elevation at the selected reference point
- Pressure of the constant pressure source such as river
- Hydraulic conductivities of the porous media
- Porosity and bulk density of the porous media
- Geometry and location of the aquifers
- The groundwater recharge rate from the vadose zone
- Disperstivities of contaminant in the aquifers
- Mass loading of contaminants from the vadose zone
- Distribution coefficient
- Initial concentration of the contaminants of concern

Since the model simulates a steady-state groundwater flow, the parameter of storage capacity for the aquifer materials was not needed. Molecular diffusion coefficient was considered negligible compared with hydrodynamic dispersion coefficient because of the significant flow velocity in the porous media. The process of adsorption - desorption of contaminant on the aquifer materials are considered in the model as linear for the partitioning of contaminants between water and aquifer material. Processes of biodegradation were not considered because the kinetics and reaction rate for each contaminant were unknown. Effective porosities of 0.35 and 0.4 were used, respectively, for the overburden and bedrock materials based on the properties of the aquifer materials determined from the well logs.

Uniform disperstivities were, individually, applied to the overburden and bedrock materials. The calibrated longitudinal disperstivities for the overburden and bedrock were 170 feet and 480 feet respectively. The associated transverse disperstivities for these aquifer materials are, respectively, 15 feet and 30 feet. They are within the normal range for the aquifer materials of concern (Freeze, et al., 1979).

Major assumptions for the groundwater and contaminant transport model include:

- Regional and local groundwater flows are under steady-state conditions.

- The steady-state local groundwater flow pattern does not change within the simulated time period.

- Vertical hydraulic conductivities in the overburden and bedrock are 1/100 of the related horizontal hydraulic conductivities.

- Groundwater density is constant in the aquifers.

- Contaminated groundwater in the aquifers is considered as a single-phase fluid which is governed by Darcy's Law.

- Contaminants recharged from vadose zone are completely miscible with the groundwater.

- Horizontal hydraulic conductivity is isotropic.

- Longitudinal and transverse disperstivities of contaminants are homogeneous in both the bedrock and the overburden.

- Adsorption-desorption reaction in the groundwater is instantaneous in the aquifer.

- The equilibrium isotherm is linear.

- Contaminants recharged from the aquifer are completely mixed with the river water.

Conceptually, the groundwater and contaminant transport model developed in this study will provide an approximation to the current groundwater system. Based on the assumptions listed above, all the major processes and general characteristics of the aquifers are included in the model. The major processes are mathematically described by the governing equations contained in the computer code, which includes the following relatively sensitive model parameters; hydraulic conductivity, hydrodynamic disperstivity, and partition coefficients. Although no detailed sensitivity analysis has been conducted for this modeling, the level of sensitivity for the model parameters was identified in the documentations related to this computer code.

The extent of agreement between the measured and simulated data during model calibration is dependent upon the complexity of the real system and the type of the simplification imposed on the model. From a practical standpoint, exact agreement between the field measured data and the computer simulated data is not possible or a requirement for the stated objectives. Typically, less agreement between the measured and simulated data is frequently encountered for contaminant simulation relative to the flow simulation. Furthermore, the extent of agreement depends on the type of model variables and the unit of the variables used in the model. Since the flow component of the model was employed under steady-state condition, the numerical errors induced by the flow equation of the computer code are comparatively less than those caused by the contaminant transport equations of the model. Verification of the model algorithms was performed by comparing the simulated results with

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field measured data under various well pumping conditions in the leaky aquifer. The maximum numerical errors in the calculation of drawdown at different times were found to be less than 1 meter. (Ward and Duda, 1984). This constitutes a very good correlation with field data for the flow component.

The flow system in the present aquifer was accurately calibrated before the calibration for contaminant transport was initiated. Exact agreement for the contaminant concentrations at every sampled well location was not reached because of the use of uniform disperstivities and other simplifying assumptions. Review of Figure A.5-8 indicates that there appears to be good agreement for most simulated results along the main groundwater flow pattern at and near the site. This is an important point because it is in these areas that groundwater remediation is most likely. Calibration accuracy along this core portion of the study area flow field is therefore a desirable feature of the model. Further review of Figure A.5-8 reveals that simulation results on the edges of the contaminant plume do not, in some cases, correlate well with measured values. This observation is an artifact of the two following interrelated elements:

- A uniform dispersivity is applied across each aquifer medium within the study area. This assumption is a requirement of the computer code and, therefore, poses a limitation on modeling a large and complex aquifer, even though it is known that dispersivity varies through the study flow area.

- The study area flow field is quite large. A large study area flow field is required because the information necessary from the model will have to be for times (temporal) very far in the future and contaminants may migrate considerable distances over long periods.

Joining the two above requirements is difficult because they can induce uncertainties in the simulation results which are undesirable. Consequently, a tradeoff between modeling contaminant concentrations accurately at specific locations, and application of the model to large space and long time requirements must be made. The judgement was made to enhance accuracy in the more contaminated areas at the expense of the periphal, less impacted areas. This was because the more contaminated areas will likely require more intense groundwater remediation and greater accuracy will be useful to guide decisions regarding remedial alternate selection in these areas.

From the practical viewpoint, the flow and contaminant model calibration this study is considered to be valid because the model will provide information to meet the above stated objectives which are: supporting the evaluation of long term migration, patterns and assessing groundwater remediation alternatives. Due to certain simplifying assumptions such as the use of uniform disperstivity for the entire aquifer, exact

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agreement between the measured and simulated results for every sampled locations is not possible.

Results of the model application are presented for six key locations (blocks) in the study area using two mobile, prominent, site-related contaminants (chlorobenzene, 1,2-dichloroethane). These locations, which are all in the shallow overburden layer except the creek, include:

Block: 4,6, Zone 1 - Central (center of the site)
Block: 8,10, Zone 2 - Southwest
Block: 11,4, Zone 2 - Northeast
Block: 8,15, Zone 3 - Southeast
Block: 14,12, Zone 3 - Northeast
Bald Eagle Creek: Center of Creek at the Castanea Bridge

Simulations were provided for six different years over the period from the present 1988 to 2288, 300 years in the future.

Results of the simulations are depicted on Figure A.5-9. Additionally, time trends of the contaminant concentration in the shallow overburden are also presented graphically on Figures A.5-10 through A.5-15. To facilitate the review of results, each block will be described separately.

- <u>Block: 4,6-Zone 1 Central (Figures A.5-9 and A.5-10)</u>

  The trend of contaminant concentrations over time is clearly decreasing. This is consistent with the exponential decay function employed for estimating leaching (i.e., loading) from the vadose zone which contains sludges and soils to groundwater. As indicated in Section 5.1, (see Table 5-1), chlorobenzene constitutes a much stronger source of contamination than 1,2-dichloroethane. (Source loading computations are included in Appendix F.) Additionally, chlorobenzenes' Rd, being greater than 1,2-dichloroethanes, (9.1 vs 2.7) would indicate that leaching to the groundwater of chlorobenzene would be slower than 1,2-dichloroethane (See Table 5-2). Referring again to the mass leaching estimates displayed in Table 5-1, source loading computation assumes that the contaminant in the vadose zone will be largely leached out over the first 30 years and that nearly 100% of the source mass will be leached to the groundwater within 100 years. This effect is demonstrated by the steeper portions of the curve in Figure A.5-10 over the years 1-30 followed by years 31-100. If more time periods were plotted, the curve would be smoother and the exponential decay would be more clearly defined.

- <u>Block: 8,10-Zone 2 Southwest (Figures A.5-9 and A.5-11)</u>

  These figures clearly indicate that the maximum, anticipated, groundwater contaminant concentrations for

the simulated compounds in this portion of Zone 2 are expected to occur between year 10 and 50 for 1,2-dichloroethane and between year 50 and 200 for chlorobenzene. The simulated years in which peak concentrations appear (i.e., year 30 for 1,2-dichloroethane and year 100 for chlorobenzene) are probably reasonable considering the source leaching and retardation aspects of the model. Likewise, concentrations simulated for those years provide good estimations of the maximum anticipated concentrations.

- Block: 11,4-Zone 2 Northeast (Figures A.5-9 and A.5-12)

  Simulated results for this location indicate that peak concentration arrival times are between years 35 and 200 for 1,2-dichloroethane and years 100 and 300 for chlorobenzene. Compared to the Southwest portion of Zone 2 (Block: 8,10) arrival times in the Northeast portion of Zone 2 tend to be later and the concentrations are lower. This trend is consistent with observed data presented on isoconcentration maps for these compounds (Figures A.5-2 and A.5-3). This observation is probably an artifact of the blocks selected for observation as well as a weaker flow component in the groundwater flow. Block-11,4 (Zone 2 northeast) is about twice as far from the source as Block-8,10 (Zone 2 southwest).

- Block: 8,15-Zone 3 Southwest (Figures A.5-9 and A.5-13)

  Simulation results for this location indicate that peak concentration arrival times are anticipated between years 30 and 200 for 1,2-dichloroethane and years 100 and 300 for chlorobenzene. The peak years indicated year 100 for 1,2-dichloroethane and year 200 for chlorobenzene are probably reasonable approximations of high concentration arrival times.

- Block: 14,12-Zone 3, Southeast (Figures A.5-9 and A.5-14)

  Simulation results presented on these two figures reveal that the peak concentration arrival time for 1,2-dichloroethane is between years 100 and 300. The peak concentration arrival time and concentration for chlorobenzene, however, cannot be determined within 300 years from the present. Considering the trend observed in the 4 previous locations, the peak concentration arrival time for chlorobenzene is probably greater than 300 years. 200 years is probably a good estimate of the peak arrival time for 1,2-dichloroethane.

- Bald Eagle Creek (Figure A.5-15)

  Simulation results provided for Bald Eagle Creek were obtained by taking the load contributed to the river through each block contiguous to the river and assuming

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the loads over the accumulated flow as indicated by the following:

$$C_{a,creek,j} = \frac{C_{a,creek,j-1} \cdot Q_{(7-10)} + C_{aj} \cdot d_j}{Q_{(7-10)} + Q_j}$$

Where:

$C_{a,creek,j}$	=	Concentration of 'a' in the Creek block j
$C_{a,creek,j-1}$	=	Concentration of 'a' in block j-1
Q_j	=	Groundwater discharge from a groundwater block adjacent to creek block j
C_{aj}	=	Concentration of 'a' in the groundwater block adjacent to creek block j
$Q_{(7-10)}$	=	7 day, 10 year low flow in Bald Eagle Creek

*As mentioned above, assumes no contaminant 'a' load upstream and rapid complete mixing in every creek block.

This equation routes the concentration 'a' sequentially along the river together with the inflow from the adjacent groundwater blocks in the downstream direction. The river flow (i.e., $Q_{(7-10)}$) was assumed to be steady. Additionally, the groundwater discharge into the river was assumed to be negligible compared with the river flow.

Figure A.5-9 indicates that the point of assessment is the center of Bald Eagle Creek at the Castanea Bridge, estimated concentrations are provided. Inspection of Figure A.15 reveals that peak concentrations of 1,2-dichloroethane will occur between years 50 to 200. Using the 100-year simulation as a reasonable predictor indicates that a maximum 1,2-dichloroethane concentration in the range of 0.2 µg/l (≈20 parts per trillion, ppb) can be expected.

Peak chlorobenzene concentrations in Bald Eagle Creek of around 0.06 µg/l (≈60 ppt) are expected to occur around year 200 and remain constant until around year 300. Considering the source loading characteristics employed in the model, the peak concentrations will eventually decay, similar to the pattern observed for 1,2-dichloroethane.

Table 5-5 illustrates the estimated trend of contaminant migration from the site through the overburden flow system to Bald Eagle Creek. It is apparent peak contaminant concentrations are currently being experienced in Zone 1. In Zone 2, peak contaminant concentrations are estimated to occur in the time period of 30-200 years henceforth. Zone 3 peak concentrations should occur in the 100-300 year range. It is estimated that Bald Eagle Creek will see peak contaminant concentrations in the time period of approximately 100 to possibly 300 years in the future. Notwithstanding the limitations detailed in Table 5-5 notes, it is apparent that

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contaminant migration occurs rather slowly and the bulk of the contaminant plume has not yet been transported from the site.

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TABLE 5-5

TREND OF ESTIMATED PEAK CONCENTRATIONS AND ESTIMATED YEARS TO OCCURRENCE*
DRAKE CHEMICAL SITE - PHASE III RI
All Units in µg/l and Years from Present (1988)

Compound	Zone 1 Central	Zone 2 Southwest	Zone 2 Northeast	Zone 3 Southeast	Zone 3 Northeast	Bald Eagle Creek and Castanea Bridge
chlorobenzene	2464 / 5	378 / 100	300 / 200	173 / 200	127 / >300**	0.06 / 200-300**
1,2-dichloroethane	156 / 5	109 / 30	28 / 100	48 / 100	32 / 200	0.02 / 100

* All concentrations and arrival times are estimates because only select time periods (5, 10, 30, 100, 200, and 300 years) were evaluated. It is possible that if all years were evaluated, both estimates could change. Hence, the data presented in this table should be used only to obtain a general tend analysis of contaminant migration dynamics. If a more precise assessment is necessary, additional simulations should be performed.

** At or after year 300.

*** At years 200, 300, the concentration has plateaued; it will diminish with time.

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6.0 PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT

6.1 INTRODUCTION

This section presents the public health risk and the environmental assessment for the Drake Chemical Site. The objective of this assessment is twofold. First, the actual risks to human health and the environment from the occurrence of site-related contaminants in groundwater and surface water will be defined. Then, the assessment will provide the basis for risk-substantiated cleanup criteria necessary for a comprehensive feasibility study as outlined in the technical approach in Appendix G.

Risk is a function of both contaminant toxicity and exposure. Without one of these parameters no risk will exist. Therefore, to assess risks, three aspects of chemical contamination and environmental fate and transport must be considered: (1) contaminants of some defined toxicity must be detected in environmental media, released by some natural or manmade processes; (2) pathways by which actual or potential exposure occur must be present and; (3) human or environmental receptors must be present to complete the exposure route.

The risk assessment estimates the potential for human health and environmental risks at the site by combining information on the toxicity of the compounds detected and site specific exposure scenarios. Because risks associated with inhalation and direct contact exposures are addressed in previous investigations, this assessment focuses on the ingestion of contaminated groundwater and reasonable accidental or recreational exposures to groundwater recharged surface waters. The assessment also emphasizes a comparison of environment concentrations with Applicable or Relevant and Appropriate Requirements (ARARs). The assessment is present in the following subsequent sections; (1) Hazard Assessment; (2) Dose-Response Evaluation; (3) Exposure Assessment; and (4) Risk Assessment, as defined by the most current EPA guidance (USEPA; September 1986).

The Hazard Assessment is made up of two parts--the hazard identification and the toxicological evaluation. The hazard identification is primarily concerned with the selection of chemical contaminants that are associated with wastes at the site. Chemicals not originating from the site or those within concentration ranges indigenous to the regional geosphere will not be considered. The toxicological evaluation of the chemicals present qualitative discussions of acute, chronic, or carcinogenic effects in humans and/or animals.

The Dose-Response evaluation presents available human health and environmental impact information for site-associated contaminants. For noncarcinogens, quantitative toxicity indices are presented, including regulatory standards or criteria which define "acceptable" levels of exposure. Legally enforceable standards such as Maximum Contaminant Levels (MCLs), and

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regulatory guidelines such as Ambient Water Quality Criteria (AWQC), Reference Doses (RfDs) or Human Health Advisories are used to define the toxic effects associated with the contaminants detected at the site. Carcinogenic Potency Factors (CPFs) or AWQC (if applicable) are used to estimate the risks associated with exposure to carcinogenic substances present in site media.

The Exposure Assessment is based on source contaminant concentrations, contaminant release mechanisms based on relevant hydrologic and hydrogeologic information, and other pertinent information such as land and water use or demographic information. Potential human and environmental exposures to contaminants at the source or offsite are identified in this section.

Exposure Assessment, within the context of this report, includes only receptor exposure mechanisms including the ingestion of groundwater, ingestion of surface water during recreational activities such as swimming or fishing, dermal contact during these activities, and the ingestion of fish. Inhalation and dermal contact exposures considered previous investigations. The analytical results presented in Section 4.0 and Appendix H will be used to make quantitative, semiquantitative, or qualitative estimates of exposure duration and concentrations.

The Risk Characterization contrasts the predicted exposure concentrations to ARARs including MCLs, AWQC, or other relevant regulatory standards or guidelines define the risks associated with threshold (noncarcinogenic) effects of contaminants identified in various site media. Carcinogenic risks associated with individual chemicals are also presented in this section.

6.2 HAZARD ASSESSMENT

6.2.1 Hazard Identification

Tables 4-2 through 4-36 summarize the occurrence of organic compounds, fenac, β-naphthylamine, and, inorganic compounds detected in environmental samples (soil, sediment, surface water, and groundwater) taken from the Drake Chemical Site and the surrounding study area.

Numerous TAL compounds were detected both on and offsite. All chemicals for which a CPF, RfD, or ARAR exist will be included in the risk assessment.

6.2.1.1 Volatile Organic Compounds

Volatile organic chemicals representing several classes including aromatics (benzene, toluene, ethylbenzene); chlorinated aromatics (chlorobenzenes, chlorotoluenes); halogenated alkanes (1,2-dichloroethane, 1,1,2-trichloroethane); halogenated alkenes (trichloroethene, vinyl chloride, cis- and trans-1,2-dichloroethene); and halomethanes (chloroform,

methylene chloride) were detected in samples collected on and about the site. All of the volatiles chemicals detected at the site not qualified as "R" (rejected) or as "B" (blank contamination) during data validation, are retained as site-related contaminants.

6.2.1.2 Base/Neutral-Acid Extractables

Selection of base/neutral-acid extractable compounds is based on the availability of toxicity data and the occurrence and distribution in environmental media. Base/neutral-acid extractables detected in site soils include various Polynuclear Aromatic Hydrocarbons (PAHs): benzo(a)pyrene, naphthalene, nitrobenzene, dichlorophenols, chlorobenzenes, trichlorophenols, 3,3'-dichlorobenzidine, pentachlorophenol, and phthalate esters. Only a limited number of these compounds were detected in groundwater samples because of the extremely low solubility of the base/neutral extractable compounds in water. Acid extractables, however, including 2,4-dichlorophenol, 2,4-dimethylphenol, nitrobenzene, 1,2,4-trichlorobenzene, and Bis(2-ethylhexyl)phthalate were detected in groundwater and are retained for the risk assessment.

6.2.1.3 Pesticides/PCBs

No pesticides or PCBs were detected in groundwater or surface water samples at or around the Drake Chemical Site. These compounds will not be addressed in risk assessment.

6.2.1.4 Fenac and β-Naphthylamine

Fenac and β-naphthylamine were detected in both site soil and groundwater samples at various levels. Both are retained for the risk assessment.

No ARAR, CPF, or RfD exists for the compound fenac. Since the compound is a major contaminant both on and offsite in various media, a water quality value and a reference dose must be calculated from published toxicological data (see Appendix G).

6.2.1.5 Inorganic Analyses and Cyanide

Soil, groundwater, and surface water samples contained various levels of inorganics and cyanide. Some of these metals exceed background soil and dissolved, groundwater, background values and exhibit toxic or carcinogenic human health effects as well as environmental toxicity. These elements include: arsenic, cadmium, lead, antimony, and silver. Analytical results obtained from background wells (DC-MW101, DC-MW-102, DC-MW-103, and DC-MW-104) and documented groundwater equilibria data will be compared to site impacted samples. Values which do not exceed background sample levels or equilibria values for the region will not be included in the final assessment of risks.

6.2.2 Toxicological Evaluation

The purpose of this section is to identify both health and environmental hazards associated with the site-related contaminants identified in Section 6.2.1. These compounds represent the greatest public health and environmental concerns associated with the Drake Chemical Site.

A toxicological evaluation characterizes the inherent toxicity of a compound. It consists of the review of current and relevant scientific data to determine the nature and extent of the human health and environmental hazards associated with exposure to the various chemicals. The end product is a toxicity profile for each chemical. These toxicity profiles provide the weight of evidence that site contaminants pose hazards to human health and/or the environment.

Toxic effects considered in these profiles include:

- Noncarcinogenic Health Effects - Noncarcinogenic health effects may occur upon exposure to a certain dose of a chemical. Toxicological endpoints, routes of exposure, and doses in humans and/or animal studies are discussed as appropriate.

- Carcinogenic Health Effects - Any exposure to a carcinogen could potentially be associated with adverse implications (cancer). Routes of exposure and doses in humans and/or results of animal studies are provided. Also considered is the EPA's weight-of-evidence for a compound's carcinogenicity (i.e., Group A, human carcinogens; Group B, probable human carcinogens; Group C, possible human carcinogens; Group D, not classifiable as to its carcinogenicity (USEPA; October 1986).

- Environmental Effects - Acute and chronic toxic effects observed in aquatic biota and terrestrial wildlife.

The available toxicological information indicates that many of the indicator chemicals are have both noncarcinogenic and carcinogenic health effects in humans and/or in experimental animals. Although the indicator chemical may have adverse health and environmental effects, dose-response relationships and the potential for exposure must be evaluated before the risks to receptors can be determined. Dose-response relationships correlate the magnitude of the dose with the probability of toxic effects, as discussed in the following section.

6.3 DOSE-RESPONSE EVALUATION

6.3.1 Health Effects

An important component of the risk assessment is the relationship between the dose of a compound (amount to which an individual or population is exposed) and the potential for adverse health effects resulting from exposure to that dose. Dose-response relationships provide a means by which potential public health impacts may be evaluated.

Table 6-1 presents available regulatory standards or guidelines (ARARs) for the chemicals detected in both ground and surface water samples from the Drake Chemical Site.

Table 6-2 presents reference doses (RfDs) and Carcinogenic Potency Factors (CPFs) that are used to quantitatively estimate the potential for human health effects. Currently, the only enforceable regulatory standards are the Maximum Concentration Levels (MCLs). However, MCLs have not been specified for all of the contaminants. Therefore, regulatory guidelines may be used for comparative purposes to suggest health risks and environmental impacts. Relevant regulatory guidelines include the Ambient Water Quality Criteria, Maximum Contaminant Level Goals, and Health Advisories, and Carcinogenic Potency Indices.

The methodology used to establish these dose-response parameters are summarized briefly below. A discussion of the implications and limitations of the dose-response relationships, and the derived regulatory criteria is also included.

Maximum Contaminant Levels (MCLs/MCLGs) - are enforceable standards promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day, but also reflect the technical feasibility of removing the contaminant. These enforceable standards also reflect the fraction of the toxicant expected to be adsorbed by the gastrointestinal tract.

Maximum Contaminant Level Goals (MCLGs) are specified as zero for carcinogenic substances, based on the assumption of nonthreshold toxicity and do not consider the technical or economic feasibility of achieving these goals. MCLGs are nonenforceable guidelines based entirely on health effects. The MCLs have been set as close to the MCLG as is considered technically and economically feasible.

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TABLE 6-1

COMPARISON OF EXISTING DATA AND HEALTH BASED ARARs
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	NPDWR (ug/l)		Longer Term Health Advisories (ug/l)		AWQC			
					Aquatic Life (ug/l)		Human Health (ug/l)	
	MCL/PMCL	MCLG/PMCLG	Child	Adult	Acute	Chronic	Ingestion of Drinking Water and Aquatic Life	Ingestion of Drinking Water Only
Benzene	5.0/NKC	0.0/NKC	NA	NA	5,300	NKC	0(0.66)*	0(0.67)*
Toluene	NKC/NKC	NKC/2000.0	NKC	NKC	17,500	NKC	14,300	15,000
Ethylbenzene	NKC/NKC	NKC/680.0	NKC	NKC	32,000	NKC	NKC	NKC
Chlorobenzene	NKC/NKC	NKC/60.0	9,000	30,000	250	NKC	NKC	NKC
1,1,2,2-Tetrachloroethane	NKC/NKC	NKC/NKC	NKC	NKC	9,320.0	2,400.0	0(0.17)*	0(0.17)*
1,1,1-Trichloroethane	200.0/NKC	200.0/NKC	35,000	125,000	18,000.0	9,400.0	18,400	19,000
1,1,2-Trichloroethane	NKC/NKC	NKC/NKC	NKC	NKC	18,000.0	9,400.0	0(0.60)*	0(0.60)*
1,1-Dichloroethane	NKC/NKC	NKC/NKC	NKC	NKC	NKC	NKC	ID	ID
1,2-Dichloroethane	5.0/NKC	0.0/NKC	740	2,600	NKC	NKC	0(0.94)*	0(0.94)*
Tetrachloroethene	NKC/NKC	NKC/NKC	1,940	6,800	5280.0	840.0	0(0.80)*	0(0.88)*
Trichloroethene	5.0/NKC	0.0/NKC	NKC	NKC	45,000.0	21,900.0	0(2.7)*	0(2.7)*
Trans-1,2-Dichloroethene	NKC/NKC	NKC/70.0	1,000	3,500	11,600.0	NKC	ID	ID
1,1-Dichlroethene	7.0/NKC	7.0/NKC	1,000	3,500	11,600.0	NKC	0(0.0033)*	0(0.0033)*

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TABLE 6-1
COMPARISON OF EXISTING DATA AND HEALTH BASED ARARs
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Contaminant	NPDWR (ug/l)		Longer Term Health Advisories (ug/l)		AWQC			
					Aquatic Life (ug/l)		Human Health (ug/l)	
	MCL/PMCL	MCLG/PMCLG	Child	Adult	Acute	Chronic	Ingestion of Drinking Water and Aquatic Life	Ingestion of Drinking Water Only
Vinyl Chloride	2.0/NKC	0.0/NKC	13	46	NKC	NKC	0(2.0)*	0(2.0)*
Chloroform	100/NKC	NKC/NKC	NKC	NKC	28,900	1,240	0(0.19)*	0(0.19)*
Methylene Chloride	NKC/NKC	NKC/NKC	NKC	NKC	NKC	NKC	0(0.19)*	0(0.19)*
Cis-1,2-Dichloroethene	NKC/NKC	NKC/70.0	1,000	3,500	11,600.0	NKC	ID	ID
1,2-Dichlorobenzene	NKC/NKC	NKC/620.0	8,930	31,250	1,120	763	400	470
1,3-Dichlorobenzene	NKC/NKC	NKC/NKC	8,930	31,250	1,120	763	400	470
1,4-Dichlorobenzene	75.0/NKC	75.0/NKC	10,700	37,500	1,120.0	763.0	400	470
Bis(2-ethylhexyl) phthalate	NKC/NKC	NKC/NKC	NKC	NKC	940.0	3.0	NKC	NKC
Naphthalene	NKC/NKC	NKC/NKC	NKC	NKC	2,300.0	620.0	NKC	NKC
1,2,4-Trichlorobenzene	NKC/NKC	NKC/NKC	NKC	NKC	NKC	NKC	NKC	NKC
Nitrobenzene	NKC/NKC	NKC/NKC	NKC	NKC	27,000.0	NKC	19,800.0	19,800.0
2,4-Dimethylphenol	NKC/NKC	NKC/NKC	NKC	NKC	2,120.0	NKC	400 (organoleptic)	400 (organoleptic)
2-Chlorophenol	NKC/NKC	NKC/NKC	NKC	NKC	4,380.0	2,000.0	NKC	NKC

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TABLE 6-1
COMPARISON OF EXISTING DATA AND HEALTH BASED ARARs
DRAKE CHEMICAL SITE - PHASE III RI
PAGE THREE

Contaminant	NPDWR (ug/l)		Longer Term Health Advisories (ug/l)		AWQC			
					Aquatic Life (ug/l)		Human Health (ug/l)	
	MCL/PMCL	MCLG/PMCLG	Child	Adult	Acute	Chronic	Ingestion of Drinking Water and Aquatic Life	Ingestion of Drinking Water Only
2,4-Dichlorophenol	NKC/NKC	NKC/NKC	NKC	NKC	2,020.0	365.0	0.3 (organoleptic)	0.3 (organoleptic)
Fenac	NKC/NKC	NKC/NKC	NKC	NKC	NKC	NKC	NKC	NKC
Pentachlorophenol	NKC/NKC	NKC/220.0	300.0	1,050.0	***	***	1,010.0	1,010.0
B-naphthylamine	NKC/NKC	NKC/NKC	NKC	NKC	NKC	NKC	NKC	NKC
Phenol	NKC/NKC	NKC/NKC	NKC	NKC	10,200.0	2,560.0	3,500.0	3,500.0
Arsenic	50.0/NKC	NKC/50.0	50.0	50.0	360.0	190.0	0(0.0022)*	0(0.025)*
Cadmium	10.0/NKC	NKC/5.0	5.0	180	**	**	10.0	10.0
Chromium	50.0/NKC	NKC/120.0	240.0	840	**	**	50.0	50.0
Copper	NKC/NKC	NKC/1,300.0	NKC	NKC	**	**	NKC	NKC
Lead	50.0/NKC	NKC/20.0	20.0/ day	20.0/ day	**	**	50.0	50.0
Manganese	NKC/NKC	NKC/NKC	NKC	NKC	NKC	NKC	NKC	NKC
Mercury	2.0/NKC	NKC/3.0	NKC	NKC	1.1	0.2	0.144	10.0
Nickel	NKC/NKC	NKC/NKC	NKC	NKC	**	**	13.4	15.4

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TABLE 6-1
COMPARISON OF EXISTING DATA AND HEALTH BASED ARARs
DRAKE CHEMICAL SITE - PHASE III RI
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Contaminant	NPDWR (ug/l)		Longer Term Health Advisories (ug/l)		AWQC			
					Aquatic Life (ug/l)		Human Health (ug/l)	
	MCL/PMCL	MCLG/PMCLG	Child	Adult	Acute	Chronic	Ingestion of Drinking Water and Aquatic Life	Ingestion of Drinking Water Only
Silver	NKC/NKC	NKC/NKC	NKC	NKC	**	**	50.0	50.0
Thallium	NKC/NKC	NKC/NKC	NKC	NKC	1,400.0	40.0	13.0	17.8
Vanadium	NKC/NKC	NKC/NKC	NKC	NKC	NKC	NKC	NKC	NKC
Zinc	5000.0[a]/NKC	NKC/NKC	NKC	NKC	**	**	5,000 (Organoleptic)	5,000.0 (Organoleptic)
Cyanide	NKC/NKC	NKC/NKC	220.0	750.0	22.0	5.2	NKC	NKC
Iron	300.0[a]/NKC	NKC/NKC	NKC	NKC	**	**	NKC	NKC
Beryllium	NKC/NKC	NKC/NKC	NKC	NKC	130.0	5.3	0(0.0037)*	0(0.0039)*
Antimony	NKC/NKC	NKC/NKC	NKC	NKC	9,000.0	1,600.0	146	146
Barium	1000.0/NKC	NKC/1,500	NKC	NKC	NKC	NKC	NKC	NKC

(a) Secondary Water criteria
* AWQC is zero. The value in parentheses corresponds to a 1 x 10-6 lifetime cancer risk.
** Criterion dependent on water hardness.
*** Criterion dependent on water pH.
ID Insufficient data
NA Not analyzed
NKC No known criterion for this category
NPDWR National Primary Drinking Water Regulations
AWQC Ambient Water Quality Criteria (µg/l)

MCLs Maximum Contaminant Levels (µg/l)
PMCL Proposed MCL
MCLG Maximum Contaminant Level Goal (µg/l)
PMCLG Proposed MCLG

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TABLE 6-2

CARCINOGENIC POTENCY FACTORS (CPFs)
AND REFERENCE DOSES (RfDs)
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	CPF	Chronic RfD
	Ingestion	Ingestion
benzene	5.20×10^{-2}	-
toluene	-	3.00×10^{-1}
ethylbenzene	-	1.00×10^{-1}
chlorobenzene	-	2.70×10^{-2}
1,1,2,2-tetrachloroethane	2.00×10^{-1}	-
1,1,1-trichloroethane	-	8.6×10^{-2}
1,1,2-trichloroethane	5.73×10^{-2}	-
1,1-dichloroethane	9.1×10^{-2}	1.20×10^{-1}
1,2-dichloroethane	9.10×10^{-2}	-
tetrachloroethene	5.10×10^{-2}	-
trichloroethene	1.10×10^{-2}	-
trans-1,2-dichloroethene	-	-
1,1-dichloroethene	5.80×10^{-1}	9.00×10^{-3}
vinyl chloride	2.30	-
chloroform	8.10×10^{-2}	1.00×10^{-2}
methylene chloride	7.50×10^{-3}	6.00×10^{-2}
cis-1,2-dichloroethene	-	-
1,2-dichlorobenzene	-	-
1,3-dichlorobenzene	-	-
1,4-dichlorobenzene	-	-
bis(2-ethylhexyl)phthalate	6.84×10^{-4}	2.00×10^{-2}
naphthalene	-	4.1×10^{-1}
1,2,4-trichlorobenzene	-	2.00×10^{-2}
nitrobenzene	-	5.00×10^{-4}
2,4-dimethylphenol	-	-
2-chlorophenol	-	5.7×10^{-3}

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TABLE 6-2
CARCINOGENIC POTENCY FACTORS (CPFs)
AND REFERENCE DOSES (RfDs)
DRAKE CHEMICAL SITE - PHASE III RI
PAGE TWO

Contaminant	CPF *	Chronic RfD
	Ingestion	Ingestion
2,4-dichlorophenol	-	3.00×10^{-3}
fenac	-	7.00×10^{-2}
pentachlorophenol	-	3.00×10^{-2}
B-naphthylamine	-	-
phenol	-	4.00×10^{-2}
arsenic	1.50	-
cadmium	-	2.90×10^{-4}
chromium	-	5.00×10^{-3}
copper	-	3.70×10^{-2}
lead	-	1.40×10^{-3}
manganese	-	2.20×10^{-1}
mercury	-	1.40×10^{-3}
nickel	-	1.00×10^{-2}
silver	-	3.00×10^{-3}
thallium	-	4.00×10^{-4}
vanadium	-	2.00×10^{-2}
zinc	-	2.10×10^{-1}
cyanide	-	2.90×10^{-2}
iron	-	-
beryllium	-	5.00×10^{-3}
antimony	-	4.00×10^{-4}
barium	-	5.70×10^{-2}

Source: EPA Toxics Integration Branch, November 16, 1987. Updated Reference Dose and Cancer Potency Numbers for Use in Risk Assessments.

* Derived by NUS Corporation

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An RfD was developed for the herbicide Fenac using the following equation (Hallenbeck and Cunningham, 1987)

$$RfD = LD_{50} / \prod_{i=1}^{n} F_i$$

where: n = number of sources of uncertainty
Fi = one of n safety factors. It is common practice to set the upper limit of the value of an uncertainty factor at 10.

$$\prod_{i=1}^{n} F_i = F_1 \bullet F_2 \bullet F_3 \cdots F_n$$

The following is a list of recommended safety factors:

F_1 = 1 to 10 to adjust for potential intraspecies variation in sensitivity.

F_2 = 1 to 10 to adjust for potential synergism.

F_3 = 1 to 10 when using an NOEL, NOAEL, or LOAEL based on a less appropriate route (inhalation or oral).

F_4 = 1 to 10 F_4=1 in risk analysis. F5=10 when using an LOAEL or some other toxicity value (LD_{50}) instead of a NOEL or NOAEL in the safety factor method for calculating acceptable concentration.

F_5 = 1 to 10 to adjust for potential interspecies variation in sensitivity. F_5=1 for human data. F_5=10 for animal data.

An LD_{50} value for rats (via ingestion) was modified by the inclusion of several safety factors which compensate for intraspecies variation in sensitivity (F_1=10), interspecies variation in sensitivity (F_5=10), potential synergism (F_2=10) and the use of an LD_{50} instead of an NOEL, NOAEL or LOAEL (F_4=10).

The resultant RfD of 7.0×10^{-2} mg/kg-day seemed appropriate when compared to other published herbicide RfD values (See Appendix G).

<u>Ambient Water Quality Criteria (AWQC)</u> - are not enforceable regulatory guidelines, that may be used for identifying human health risks. AWQCs consider adverse carcinogenic and non-carcinogenic health effects in humans from ingestion of water (2 liters/day) and aquatic organisms. The AWQCs for protection of human health for carcinogenic substances are based on the EPA's specified incremental cancer risk range of one

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additional case of cancer in an exposed population of 10,000,000 to 100,000 persons (i.e., the 10^{-7} to 10^{-5} range).

Health Advisories - are guidelines developed by the EPA Office of Drinking Water for non-regulated contaminants in drinking water. These guidelines are designed to consider both acute and chronic toxic effects in children (assumed body weight of 10 kg) who consume 1 liter of water per day or for adults (assumed body weight of 70 kg) who consume 2 liters of water per day. Health Advisories are generally available for acute (1 day), subchronic (10 days), and chronic (longer-term) exposure scenarios. These guidelines are designed to consider only threshold effects and, as such, do not consider carcinogenicity.

Reference Dose (RfD) - applies to prolonged human exposure to hazardous chemicals (i.e., chronic exposure) and is based solely on the non-carcinogenic effects of chemical substances. The RfD is usually expressed as an acceptable dose (mg) per unit body weight (kg) per unit time (day). It is generally derived by dividing a no-observed-adverse-effect-level (NOAEL or NOEL) or a lowest-observed-adverse-effect-level (LOAEL) by an appropriate "uncertainty factor." NOAELs are determined from laboratory or epidemiological toxicity studies. The uncertainty factor (10,000, or 1,000) is based on the availability of toxicity data; 10 is used if appropriate chronic human data are available 100 is used if sufficient chronic animal data are available and 1,000 is used if only sub-chronic animal data can be obtained. Thus the RfD incorporates the surety of the evidence for chronic human health effects. Even if applicable human data exist, the RfD (as diminished by the uncertainty factor) still maintains a margin of safety such that chronic human health effects are not underestimated. Thus, the RfD is an acceptable guideline for evaluation of noncarcinogenic risk, although the associated uncertainties preclude its use for precise risk quantitation.

Carcinogenic Potency Factor (CPF) - is applicable for estimating the lifetime probability (assumed 70-year lifespan) of human receptors contracting cancer as a result of exposure to known or suspected carcinogens. This index is derived through an assumed low-dosage linear relationship and an extrapolation from high to low dose-responses determined from animal studies. The value used in reporting the slope factor is the upper 95 percent confidence limit.

6.3.2 ARAR Comparison

Inorganic contaminants like manganese and other heavy metals occur naturally in subsurface strata. If fine particulates from well drilling and development activities are present in groundwater (i.e., total inorganics) detected sample results for these analytes may exceed ARARs. The following section discusses only those inorganic results not attributed to

TABLE 6-3

ZONE 1 - CONTAMINANTS EXCEEDING ARARs
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	NPDWR				Health Advisories		AWQC
	MCL	PMCL	MCLG	PMCLG	Long Term Child	Long Term Adult	Human Health Ingestion of Drinking Water
Benzene	A,B		A,B				
Toluene				A,B			
Ethylbenzene				A			
Chlorobenzene				A,B	A		
1,1,2-Trichloroethane							A,B
1,2-Dichloroethane	A,B		A,B,C	A,B	A,B		A,B
Tetrachloroethene							A,B
Trichloroethene	A,B		A,B				A,B
1,1-Dichloroethene							A
Vinyl Chloride	A		A	A	A		A
Chloroform	A,B						A,B
Methylene Chloride							A,B
1,2-Dichlorobenzene							A,B
1,4-Dichlorobenzene	A,B		A,B				
2,4-Dichlorophenol							A,B

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TABLE 6-3
ZONE 1 - CONTAMINANTS EXCEEDING ARARs
DRAKE CHEMICAL SITE - PHASE III RI
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Contaminant	NPDWR				Health Advisories		AWQC
	MCL	PMCL	MCLG	PMCLG	Long Term Child	Long Term Adult	Human Health Ingestion of Drinking Water
Arsenic	A			A	A	A	A
Cadmium	A,B			A,B	A	A	A,B
Chromium	A,B			A	A		A,B
Nickel							A
Thallium							A
Cyanide					A	A	

A - Maximum Observable Worst Case Scenario
B - Concentration in Typical Overburden Well
C - Concentration in Bedrock Well
(a) Secondary Water criteria
* AWQC is zero. The value in parentheses corresponds to a 1×10^{-6} lifetime cancer risk.
** Criterion dependent on water hardness.
*** Criterion dependent on water pH.
ID Insufficient data
NA Not analyzed
NKC No known criterion for this category
NPDWR National Primary Drinking Water Regulations
AWQC Ambient Water Quality Criteria (µg/l)

MCLs Maximum Contaminant Levels (µg/l)
PMCL Proposed MCL
MCLG Maximum Contaminant Level Goal (µg/l)
PMCLG Proposed MCLG

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background or natural levels of contamination. Table 6-3 presents the constituents detected in Zone 1 that exceed Available Relevant and Applicable Requirements (ARARs). The contaminant concentrations were compared to ARARs in the following groundwater contamination scenarios:

(a) Maximum contaminant concentration detected in the zone groundwater samples.

(b) Concentration in typical case overburden well.

(c) Concentration in typical case bedrock well.

Pertinent findings presented by examination of Table 6-3 are as follows:

- The maximum concentrations observed for (9) nine contaminants detected in Zone 1 (Case A) and the representative concentration of seven contaminants detected in the typical case overburden wells (Case B) exceed current Maximum Contaminant Levels (MCLs):

6.3.3 Environmental Effects

Dose response relationships for environmental effects are limited to AWQC for the protection of aquatic life. These criteria are derived from both plant and animal data and were developed to protect the types of organisms necessary to support a healthy aquatic community. AWQC specify the concentration of a compound in surface water, which, if not exceeded, should protect most, but not necessarily all aquatic life and its uses. For example, brook trout and brown trout are not protected by the hard water function AWQC for cadmium because of the inherent susceptibility of these species.

Case A	Case B
benzene	benzene
1,2 dichloroethane	1,2 dichloroethane
trichloroethene	trichloroethene
vinyl chloride	chloroform
chloroform	1,4 dichlorobenzene
1,4 dichlorobenzene	cadmium, chromium
arsenic, cadmium, chromium	

Concentrations detected in the typical case bedrock well (Case C) DO NOT exceed the MCLs.

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- The maximum/representative concentrations observed for eleven (11) contaminants in Case A, seven (7) in Case B and one (1) in Case C exceed proposed or final Federal SDWA maximum contaminant level goals (MCLGs) .

- The maximum/representative concentrations observed for seven (7) contaminants in Case A and one (1) in Case B exceed long-term EPA Drinking Water Health Advisories. The advisories are typically developed from data describing non-carcinogenic endpoints of toxicity.

- The maximum/representative concentration observed for fifteen (15) contaminants in Case A and ten (10) contaminants in Case B exceed Federal Ambient Water Quality Criteria (AWQC) these non-enforceable health based criteria are based on estimate of contaminant concentrations (typically in surface water) that will not result in adverse health effects in humans.

Table 6-4 presents the compounds detected in Zone 2 groundwater samples that exceed ARARs and cannot be attributed to background levels of contamination. The contaminant concentrations were compared to ARARs in the following groundwater contamination scenarios:

(a) Maximum contaminant concentration detected in the zone groundwater sample.

(b) Concentration in typical case overburden well.

(c) Concentration in typical case bedrock well.

Pertinent findings presented by an examination of Table 6-4 are as follows:

- The maximum concentrations of 7 contaminants in Case A, 3 contaminant concentrations in Case B, and 2 contaminant concentrations detected in Case C exceed the MCL. The contaminants that exceed in some or all cases are: benzene, 1,2-dichloroethane, trichloroethane, vinyl chloride, chloroform, cadmium, and lead.

- The MCLG or the PMCLG is exceeded for 7 maximum contaminant concentrations in Case A, 5 representative contaminants in Case B, and 2 representative contaminants in Case C.

- Health advisories for a child or an adult are exceeded by 4 maximum contaminant concentrations reported in Case A, and 1 concentration in both Case B and Case C.

- Ambient Water Quality Criteria are exceeded by 14 maximum concentrations in Case A, 6 representative concentrations for Case B, and 3 representative concentrations for Case C.

TABLE 6-4

ZONE 2 - CONTAMINANTS EXCEEDING ARARs
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	NPDWR				Health Advisories		AWQC
	MCL	* PMCL	MCLG	PMCLG	Long Term Child	Long Term Adult	Human Health Ingestion of Drinking Water
Benzene	A		A,B				A,B
Chlorobenzene				A,B	A		
1,1,2-Trichloroethane							A
1,2-Dichloroethane	A,B,C		A,B,C				A,B,C
Tetrachloroethene							A
Trichloroethene	A,B		A,B				A,B
1,1-Dichloroethene							A
Vinyl Chloride	A		A				A
Chloroform	A						A,B,C
Methylene Chloride							A
2,4-Dichlorophenol							A
Arsenic							A
Cadmium	A,B			A,B	A,B		A,B
Nickel							A,B
Lead	A,C			A,C	A,C	A,C	A,C
Mercury						A	

A - Maximum Observable Worst Case Scenario
B - Concentrationin Typical Overburden Well
C - Concentrationin Bedrock Well

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Table 6-5 presents the constituents detected in Zone 3 which exceed ARARs and cannot be attributed to background levels of contamination. The contaminant concentrations were compared to ARARs in the following groundwater contamination scenarios:

(a) Maximum contaminant concentration detected in the zone groundwater samples.

(b) Concentrations in a typical case overburden well.

(c) Concentrations in a typical case bedrock well.

Pertinent findings presented by an examination of Table 6-5 are as follows:

- The maximum concentrations (Case A) of 6 contaminants, and 1 representative concentration (Case B) exceed the MCL. The compounds exceeding MCLs are 1,2-dichloroethane, trichloroethylene, arsenic, cadmium, iron, and lead.

- The MCLG or the PMCLG is exceeded by 9 maximum contaminant concentrations (Case A) and 1 concentration (Case B).

- Health Advisories for both children and adults are exceeded by 4 maximum observable contaminant concentrations.

- The AWQC is exceeded by 13 maximum contaminants in Case A and 1 contaminant concentration for Case B.

6.4 EXPOSURE ASSESSMENT

6.4.1 Introduction

The purpose of this section is to evaluate the potential for human exposure to the hazardous constituents associated with the Drake Chemical Site. This section will not duplicate assessments from previous reports (NUS; July 1984 - RI, August 1986 - FS) and will consider only the actual or potential routes of exposure to contaminated ground and/or surface waters. Furthermore, a detailed characterization of the exposed population will not be attempted. Only the degree or magnitude of the exposure will be considered.

To determine if an exposure might occur currently or some time in the future, the human and environmental situation near the site must be considered. A complete exposure pathway has four components: (1) a source of chemicals released to the environment; (2) a route of contaminant transport through an environment media; (3) an exposure or contact point; and (4) the presence of a human or environmental receptor at the exposure point. These components are addressed in the following subsections.

TABLE 6-5

ZONE 3 - CONTAMINANTS EXCEEDING ARARs
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	NPDWR				Health Advisories		AWQC
	MCL	PMCL	MCLG	PMCLG	Long Term Child	Long Term Adult	Human Health Ingestion of Drinking Water
Benzene			A				A
1,2-Dichloroethane	A		A,B				A
Trichloroethene	A		A				A
1,1-Dichloroethene							A
Vinyl Chloride			A				
Chloroform							A
Methylene Chloride							A
Arsenic	A			A	A	A	A
Cadmium	A			A	A	A	A
Chromium	A			A	A	A	A
Copper				A			
Lead	A			A	A	A	A
Nickel					A		A,B
Beryllium							A
Antimony							A

A - Maximum Observable Worst Case Scenario
B - Concentration in Typical Overburden Well
C - Concentration in Bedrock Well
* Secondary SDWA Standard

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6.4.2 Sources of Contamination and Routes of Transport

6.4.2.1 Existing Source of Contamination

Sampling and analysis of environmental media during the Phase III-RI indicated the presence of both organic and inorganic contaminants throughout the site. The occurrence and distribution of these pollutants were discussed in Section 4.0. A review of these sections shows that site-related chemicals were found in highest concentrations in surface and subsurface soil, sludge, surface water, and groundwater samples taken both onsite and on the adjacent Gorham property. Therefore the site and the Gorham property must be considered a uniform source of contaminant loading to nearby environmental media.

6.4.2.2 Routes of Contaminant Transport

The distribution of site contamination demonstrated by the analytical results of the sampling effort indicate that some migration through environmental media is occurring. Barring any further human influence (i.e., excavation of contaminated soils or large-scale geologic or meteorologic events), the migration of the site contaminants will be controlled by the physical and chemical site conditions and by the inherent physical and chemical properties of the contaminants themselves.

The majority of site contaminants are organic compounds; however, some inorganic contamination is also apparent.

In general, volatile compounds and acid extractables, including phenol, have higher water solubilities and vapor pressures than contaminants like Polynuclear Aromatic Hydrocarbons (PAHs) or phthalate esters. Their high solubilities make them prone to leaching by precipitation and more subject to groundwater advection. Compounds in these classes can also volatilize readily from surface soils and waters making them more susceptible to atmospheric transport as well.

Base/neutral extractables including PAHs are relatively insoluble water and have low vapor pressures. These compounds are not as susceptible to volatilization or solubilization and groundwater transport. Instead, these compounds tend to absorb to carbonaceous material in soil or sediment materials. Their primary mechanism of mobility is by the convection of particulates in surface water runoff.

Inorganic compound solubility (hence, mobility) is directly proportional to the oxidation state of the analyte. Qualitative estimations of valence state can be made knowing the eh and pH of the particular media and cation exchange capacity of the surrounding soil . Nevertheless, the transport of these contaminants by volatilization or groundwater advection under most circumstances is relatively small. Their primary mechanism

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of mobility is by the convection of particulates in surface water runoff.

The presence of TCL compounds in groundwater indicates that some mechanism may be or may have been present to transport contaminants from surface or subsurface deposits to the groundwater. Direct percolation of liquid wastes or solubilization of solid or semi-solid wastes could account for the existing high levels of groundwater contamination. The large amounts of sludge and contaminated soil left on the site and Gorham property indicate that groundwater quality and the extent of contamination may change as these compounds are released. Based on existing hydrogeologic and chemical analytical data it is likely that contaminated groundwater could continue to move in a north eastward direction and downward through nonperfect confining layers to further contaminate bedrock water tables. Bald Eagle Creek may also be affected by groundwater recharge of this surface water body.

Inorganic constituents that may or may not be site related were detected in surface water samples taken from the Bald Eagle Creek and the Susquehanna River. No organic contamination other than fenac was detected in any surface water sample off site.

6.4.3 Receptor Identification and Exposure Routes

Human and environmental receptors that may potentially be exposed to hazardous site associated contaminants are as follows:

- People who may, at some time in the future, reside on or near the site and use site-contaminated groundwater as a source drinking water or those who currently reside off site and consume clean groundwater that who may be affected by site associated contamination at some future time.

- Those involved in recreational water activities such as swimming, boating, or fishing at the Bald Eagle Creek and downstream Susquehanna River (below the Bald Eagle Confluence).

- Those who consume fish taken from both Bald Eagle Creek and below the creek confluence with the Susquehanna River.

- Children playing in the Bald Eagle Creek and the Susquehanna River.

- Aquatic flora and fauna in Bald Eagle Creek and Susquehanna River (including domestic and game animals) that traverse the site.

Generally, there are five environmental media through which receptors may come into contact with site contaminants:

groundwater, surface soil, surface water, sediments, and air. This section considers only the receptors most likely to be at risk through the groundwater and surface-water exposure pathways.

Use of contaminated groundwater by local residents or future residents is a potential route of exposure to site-associated contaminants. Analytical data collected during the most recent RI indicates that site-related contaminants are present in groundwater below the site (Zone 1) and the downgradient properties adjacent to the site fence line (Zones 2 and 3).

Receptors could be exposed to contaminants through normal domestic uses. Ingestion of groundwater is considered the major future potential route. This scenario characterizes the risks associated with the future use of groundwater. Receptors may also be potentially exposed to contaminants in surface waters via dermal contact, accidental ingestion while swimming, or ingestion of aquatic biota. Exposure scenarios for surface waters in Section 6.4.4.2. Exposure scenarios for the future use of groundwater are presented in Section 6.4.4.

6.4.4 Exposure Estimates

The final step in an exposure assessment is a quantitative estimate of the dose of a contaminant incurred by a receptor. This section provides route-specific estimates of the amount of a contaminant to which a receptor may be exposed. Estimated doses of site contaminants are presented in Appendix B.

A dose is defined as the amount of a compound (in mg) absorbed daily by a receptor per kg of body weight. Doses can be calculated for a lifetime (for carcinogens) or for single exposure (for noncarcinogens). A dose is estimated as follows:

Dose = (Contaminant Concentration) x (Contact Rate) x (Absorbed Fraction)/(Body Weight)

6.4.4.1 Exposure to Groundwater

Sampling and analysis of groundwater indicates that both on and offsite aquifers are contaminated at the Drake Chemical Site. The monitoring wells were found to contain a variety of organic and inorganic compounds; however, no residents are known to be currently exposed to site contaminants via groundwater use and none are expected to be exposed in the future. The potential, however, does exist that under a no-action scenario, site-related contaminants may migrate away from the site and impact distant groundwater supplies that are used as potable water sources.

Worst-case and typical (or reasonable) estimates for both adults and children are generated for each groundwater zone to support future clean-up alternatives and the feasibility studies. These

values were obtained using existing groundwater contaminant concentrations from both the first and second sampling rounds.

Both worst-case and reasonable analytical values will be used to quantitate the doses used in the estimation of risks associated with exposure to contaminants originating at the Drake Site.

Worst-case scenarios will use maximum contaminant concentrations from groundwater sampling and analysis activities. The reasonable scenario uses typical wells chosen by locating areas downgradient of the Site which seem amenable to future development (housing, industry) and are most representative of site associated contamination.

For adults, potential doses from the ingestion of carcinogenic and noncarcinogenic contaminants in groundwater can be estimated using the following assumptions:

- A 70-kg adult ingests 2 liters of water per day over a 70 year lifetime.
- 100 percent of an ingested dose is absorbed by the gastrointestinal tract.

$$\text{Dose} = \frac{\left(\text{Concentration } \frac{\text{mg}}{\ell}\right)\left(2\ \ell/\text{day}\right)\left(1\right)}{70\ \text{kg}}$$

$$\text{Dose} = 0.0286\ (\text{Concentration})(\text{mg/kg} - \text{day})$$

The following assumptions were used to estimate potential doses from ingestion of groundwater for children.

- A 10-Kg child ingests 1 liter of water per day.
- 100 percent of the ingested dose is absorbed in the gastrointestinal tract.

$$Dose = \frac{(Concentration\ mg/l)\,(1\,l/day)\,(1)}{10\,Kg}$$

Appendix G presents the detailed calculations for each chemical dose estimation for groundwater ingestion.

6.4.4.2 Exposure to Surface Water

Sampling and analysis of downstream Bald Eagle Creek and Susquehanna River water samples indicates that inorganic contamination is present. No organic compounds were detected other than the herbicide fenac.

In assessing the potential risks due to site-related surface water contamination, three scenarios and their corresponding dose assumptions are considered. These cases are as follows.

Case A - Ingestion of Fish

Potential doses from the ingestion of carcinogenic and noncarcinogenic contaminants bioaccumulated in fish can be estimated using the following assumptions and Biological Concentration Factors (BCFs). Biological Concentration Factors were obtained from EPA document-600/3-78-103, December (1978). All non-listed, inorganic contaminant BCFs were assumed to be 1.0.

- A 70-kg adult ingests 6.5 grams of fish per day over a 70-year lifetime.
- 100 percent of the ingested dose is absorbed by the gastrointestinal tract.

$$\text{Dose (mg/kg-day)} = \left(\text{mg}/\ell\right)\left(\text{BCF}\right)\left(\frac{6.5\,\text{grams}}{\text{day}}\right)\left(\frac{1\,\ell}{10^3\,\text{grams}}\right)\left(\frac{1}{70\,\text{kg}}\right)$$

Case B - Dermal Contact While Swimming

Potential doses from the absorption of both carcinogenic and noncarcinogenic contaminants through the skin during swimming can be estimated using the following assumptions.

- A 45-kg child swims for 2 hours per day, 10 times per year for a period of 10 years.
- The surface area of this child's skin in contact with surface water is approximately 12,000 cm^2 (Superfund Exposure Assessment Manual, 1987 [Final]).
- The water flux through the skin is 0.5 $mg/cm^2/hour$ (Superfund Exposure Assessment Manual, 1987 [Final]).

Carcinogenic Effects:

$$\text{Dose (mg/kg-day)} = \left(\text{mg/l}\right)\left(\frac{0.5\,\text{mg}}{\text{cm}^2\,\text{hr.}}\right)\left(\frac{2\,\text{hrs.}}{\text{day}}\right)\left(\frac{12\,\text{days}}{\text{year}}\right)\left(10\,\text{years}\right)\left(\frac{1\,\ell}{10^3\,\text{cm}^3}\right)\left(\frac{\text{cm}^3}{\text{g}}\right)$$

$$\left(\frac{1\,g}{10^6\,ug}\right)\left(12{,}000\,cm^2\right)\left(0.2^*\right)\left(45\,kg\right)\left(70\,years\right)\left(\frac{365\,days}{year}\right)$$

Noncarcinogenic Effects:

$$\text{Dose (mg/kg-day)} = \left(\text{mg}/\ell\right)\left(\frac{0.5\,\text{mg}}{\text{cm}^2\,\text{hour}}\right)\left(\frac{2\,\text{hrs.}}{\text{day}}\right)\left(\frac{1\,\ell}{10^3\,\text{cm}^3}\right)\left(\frac{\text{cm}^3}{\text{g}}\right)\left(\frac{1\,\text{g}}{10^6\,\mu\text{g}}\right)\left(12{,}000\,\text{cm}^2\right)\left(0.2^*\right)\left(\frac{12\,days}{1\,year}\right)\left(\frac{1\,year}{365\,days}\right)$$

Case C - Accidental Ingestion During Swimming

Potential doses from the accidental ingestion of surface water contaminated by both carcinogenic and noncarcinogenic contaminants during swimming can be estimated using the following assumptions:

- A 45-kg child ingests 0.24 liters of contaminated water each day, 12 days per year during swimming activities over a 10-year period.
- 100 percent of the ingested contamination is absorbed in the gastrointestinal tract.

Carcinogenic Effects:

$$\text{Dose (mg/kg-day)} = \left(\text{mg}/\ell\right)\left(\frac{0.24\,\ell}{\text{day}}\right)\left(\frac{12\text{ days}}{\text{year}}\right)\left(\frac{10\text{ years}}{1}\right)\left(\frac{1\text{ year}}{365\text{ days}}\right)\left(\frac{1}{45\text{ kg}}\right)\left(\frac{1}{70\text{ years}}\right)$$

Noncarcinogenic Effects:

$$\text{Dose (mg/kg-day)} = \left(\text{mg}/\ell\right)\left(\frac{0.24\,\ell}{\text{day}}\right)\left(\frac{1}{45\text{ kg}}\right)\left(\frac{12\,days}{1\,year}\right)\left(\frac{1\,year}{365\,days}\right)$$

Appendix G presents the detailed calculations for each chemical dose estimation for these scenarios.

6.5 RISK CHARACTERIZATION

The objective of this section is to estimate the increase of adverse health or environmental effects under the exposure scenarios presented in Section 6.4. EPA guidelines for the use of dose additive equations are used to combine the risks for individual chemicals to estimate the risks for a mixture of chemicals. A characterization of carcinogenic, noncarcinogenic and environmental risks at the Drake Chemical Site is presented.

6.5.1 Carcinogenic and Noncarcinogenic Risks

Carcinogenic risks can be estimated by combining information in the dose-response assessment (carcinogenic potency factors) with an estimate of the individual intakes (doses) of a contaminant by a receptor.

At low doses, risk can be estimated as follows:

Risk = (q*)(dose)

Where: q* = Carcinogenic potency factor (slope of the dose-response curve).

dose = Amount of a contaminant absorbed by a receptor in mg/kg-day.

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At high doses where linearity of the dose response relationship may be lost risk is calculated using the following equation:

$$Risk = 1 - e^{-(q^*)(dose)}$$

Where: q* = Carcinogenic potency factor (slope of the dose-response curve).

dose = Amount of a contaminant absorbed by a receptor in mg/Kg-day.

The resulting number (risk) is a unitless expression of an individual's likelihood of developing cancer as a result of exposure to the carcinogenic indicator chemicals. The risk (e.g., 1×10^{-6} or a 1 in 1,000,000 chance) can also be applied to a given population to determine the number of excess cases of cancer that could be expected to result from exposure (e.g, 1×10^{-6} is one additional case of cancer in 1,000,000 exposed persons).

Total risks for multiple compounds are presented as the summation of the risk for individual contaminants. Calculating risks in this manner assumes that individual intakes are small, that there are no antagonistic/synergistic effects between chemicals, and that all chemicals produce the same result (cancer). Cancer risks from various exposure routes are also additive, if the exposed populations are the same.

Carcinogenic risks are calculated using a number of assumptions; therefore, many uncertainties are introduced into the values. Factors limiting the extent to which the human and environmental health risks can be characterized are primarily associated with the estimation of toxicity and include various uncertainties in the toxicologic data base. Extrapolation of non-threshold (carcinogenic) effects from high to low doses, variance in endpoints used for determination of potential health effects, extrapolation of the results of animal studies to human receptors, varying sensitivity between individuals are sources of uncertainty.

In addition to these sources of uncertainty, exposure scenarios are based on several assumptions regarding contaminant transport mechanisms and receptor age, body weight, and exposure duration. Additivity of the toxicants and of doses of the same toxicant from different exposure routes also introduces uncertainty. The sources of uncertainty are compensated for by using "uncertainty factors," which are incorporated into the dose-response relationships. These factors will assure that while risks may be overestimated, they are not underestimated.

Risks from exposure to noncarcinogenic compounds can be characterized by comparing the expected exposure levels (doses) to acceptable levels such as the Reference Dose. If the ratio, known as the Hazard Index, exceeds unity, there is a potential health risk associated with exposure to that particular chemical

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(USEPA, September 24, 1986b). The Hazard Index is not a mathematical prediction of the severity of toxic effects; it is simply a numerical indicator of the transition from acceptable to unacceptable levels.

The following sections summarize the potential adverse carcinogenic and noncarcinogenic human health effects posed by exposure to groundwater and surface water contaminated by activities at the Drake Chemical Site.

6.5.1.1 Groundwater

From a risk analysis perspective, groundwater directly beneath the site is contaminated with site-related pollutants. Nearby downgradient, offsite groundwater is also contaminated with site-associated contaminants, although it appears to be less severely impacted than the waters beneath the site. There is also indication that groundwaters distant from the site have also been affected. To optimize the feasibility study and remediation technologies, the site and surrounding area has been divided into 3 zones of contamination (see Figure A.4-5).

Zone 1 is defined as the area on site and off site bordered by the Penn Central Railroad track bed. The data from samples taken from monitoring wells in this area will be used to attain a fenceline value of risk from site-related contaminants. Zone 2 is defined as the area southeast of the site bordered by the Penn Central Railroad track bed and Route 220 North. Zone 3 is the offsite area bordered by Route 220 North and Bald Eagle Creek. Risks associated with each zone will be discussed in ascending order.

Zone 1

Tables 6-6 through 6-9 display the major contaminant contributors to both carcinogenic and noncarcinogenic risks associated with the ingestion of site-contaminated groundwater in Zone 1. Both worst-case (maximum observations) and typical contaminant (individual bedrock and overburden wells) risk are presented. The total contaminant risk calculations for all scenarios are contained in Appendix G.

A total carcinogenic risk of 5.69×10^{-1} is calculated as a worst-case scenario. Table 6-6 presents the major contaminants associated with this risk. The site specific organic contaminants β-naphthylamine and 1,2-dichloroethane are responsible for approximately 94 percent of the total risk. The inorganic contaminant arsenic is also a major contributor. Its individual risk, however, is a more conservative number because analytical results for total inorganics were used in quantitating dose. Samples analyzed for total inorganics usually contain fine particulate matter from the well drilling and development process. Therefore, the values may be biased high because of the presence of fine particles that may contain arsenic suspended in the aqueous matrix.

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TABLE 6-6

ZONE 1: MAJOR CONTAMINANT CONTRIBUTORS
WORST-CASE, MAXIMUM OBSERVATIONS - CARCINOGENIC RISK
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Risk	Percent Total
β-naphthylamine	5.34×10^{-1}*	93.9
arsenic (total)	1.71×10^{-2}	3.0
1,2-dichloroethane	1.33×10^{-2}	2.3
vinyl chloride	4.21×10^{-3}	0.7
TOTAL CARCINOGENIC RISK	5.69×10^{-1}	

* Calculated using an exponential equation for risk.

TABLE 6-7

ZONE 1: MAJOR CONTAMINANT CONTRIBUTORS
WORST-CASE, MAXIMUM OBSERVATIONS - HAZARD INDEX
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Hazard Indices	Percent Total
Cadmium	19.9	30.0
Chlorobenzene	19.1	28.7
Fenac	8.2	12.3
Cyanide	6.7	10.1
TOTAL HEALTH INDEX	66.3	

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TABLE 6-8

ZONE 1: MAJOR CONTAMINANT CONTRIBUTORS
TYPICAL OVERBURDEN WELL - CARCINOGENIC RISK
DRAKE CHEMICAL SITE - PHASE III RI/FS

Contaminant Name	Individual Risk	Percent Total
β-naphthylamine	7.65×10^{-1}	98.2
1,2-DCA	1.33×10^{-2}	1.7
TOTAL CARCINOGENIC RISK	7.78×10^{-1}	

TABLE 6-9

ZONE 1: MAJOR CONTAMINANT CONTRIBUTORS
TYPICAL OVERBURDEN WELL - HAZARD INDEX
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Hazard Indices	Percent Total
Cadmium	4.5	33.3
Chlorobenzene	3.1	22.5
2,4-Dichlorophenol	2.0	14.7
Phenol	1.8	13.1
Nitrobenzene	1.1	8.4
Fenac	0.0086	0.06
TOTAL HEALTH INDEX	13.6	

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A total hazard index of 66.3 is calculated for the same scenario. Table 6-7 shows that chlorobenzene and fenac have individual health indices in excess of 1.0 indicating that, under the assumptions of this assessment, adverse noncarcinogenic health effects are expected. The inorganic compounds cadmium and cyanide contribute roughly 40 percent of the noncarcinogenic health risks. These values are conservative since dose calculations are based on data obtained from total inorganic sample analyses.

An individual Zone 1 overburden well (DC-M18-145) was chosen to present a typical risk for the ingestion of site-contaminated groundwater. Table 6-8 displays the contaminant contributors for carcinogenic risks associated with the groundwater ingestion scenario. A total carcinogenic risk of 7.78×10^{-1} is calculated (Appendix G) for the overburden well. The contaminants β-naphthylamine and 1,2-dichloroethane account for over 99 percent of this risk. Inorganic contaminants were minor contributors to the overall risk and are not mentioned in this table.

A total adverse hazard index of 13.6 is derived from analytical data obtained by sampling and analysis events for well DC-M18-145. The contaminants cadmium, chlorobenzene, 2,4-dichlorophenol, and nitrobenzene have individual hazard indices in excess of 1.0, suggesting the potential for adverse noncarcinogenic human health effects if exposed by the ingestion route (Table 6-9).

The Zone 1 bedrock well DC-M107-107 is also assessed for the potential risk associated with the ingestion of groundwater. The detected contamination and corresponding doses do not suggest any increased likelihood of adverse carcinogenic health effects or noncarcinogenic health effects.

Carcinogenic and noncarcinogenic effects for children are approximately 3.5 times greater than those for adults since a smaller body weight assumption of 10 Kg is made for the child scenario. The determination of risk for a child examines a limited time period and is not applicable throughout the same 70 year lifespan used in the adult assessment.

Due to the significant risks encountered from the ingestion of contaminated groundwater originating from the Drake Site, no numerical estimation of risks to children will be calculated.

Zone 2

Tables 6-10 through 6-15 display the carcinogenic and noncarcinogenic health risk associated with the ingestion of site contaminant concentrations detected in the Zone 2 groundwater samples.

TABLE 6-10

ZONE 2: MAJOR CONTAMINANT CONTRIBUTORS
WORST-CASE, MAXIMUM OBSERVATIONS - HAZARD INDEX
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Hazard Indices	Percent Total
Toluene	11.6	39.2
Cadmium	9.9	33.4
Fenac	3.8	12.8
Lead	2.8	9.5
TOTAL HEALTH INDEX	29.6	

TABLE 6-11

ZONE 2: MAJOR CONTAMINANT CONTRIBUTORS
WORST-CASE, MAXIMUM OBSERVATIONS - CARCINOGENIC RISK
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Risk	Percent Total
1,2-DCA	1.77×10^{-3}	26.0
β-naphthylamine	1.73×10^{-3}	25.5
Arsenic (total)	1.52×10^{-3}	22.4
Chloroform	1.43×10^{-3}	22.1
TOTAL CARCINOGENIC RISK	6.79×10^{-3}	

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TABLE 6-12

ZONE 2: MAJOR CONTAMINANT CONTRIBUTORS
TYPICAL BEDROCK WELL - HAZARD INDEX
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Hazard Indices	Percent Total
Lead	4.3	99.9
Chlorobenzene	0.0035	0.1
TOTAL HEALTH INDEX	4.4	

TABLE 6-13

ZONE 2: MAJOR CONTAMINANT CONTRIBUTORS
TYPICAL BEDROCK WELL - CARCINOGENIC RISK
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Risk	Percent Total
β-naphthylamine	3.61×10^{-4}	95.5
1,2-DCA	1.59×10^{-5}	4.2
TOTAL CARCINOGENIC RISK	3.77×10^{-4}	

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TABLE 6-14

ZONE 2: MAJOR CONTAMINANT CONTRIBUTORS
TYPICAL OVERBURDEN WELL - HAZARD INDEX
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Hazard Indices	Percent Total
Cadmium	2.2	94.3
Chlorobenzene	0.1	5.7
TOTAL HEALTH INDEX	2.3	

TABLE 6-15

ZONE 2: MAJOR CONTAMINANT CONTRIBUTORS
TYPICAL OVERBURDEN WELL - CARCINOGENIC RISK
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Risk	Percent Total
β-naphthylamine	1.02×10^{-1}*	99.6
1,2-DCA	3.38×10^{-4}	0.3
TOTAL CARCINOGENIC RISK	1.03×10^{-1}	

* Calculated using an exponential equation for risk.

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The calculated combined hazard index (HI) for the Zone 2 worst-case, maximum observation presented on Table 6-10 is 30.4. The HI is well above unity indicating that noncarcinogenic adverse health effects are anticipated if exposure conditions presented in this risk assessment are met. Toluene (HI = 11.6) and fenac (HI = 3.8) are the principal organics contributing to the observed noncarcinogenic risk. Cadmium (HI = 9.9), and lead (HI = 2.8) are the major inorganic species contributing to the risk. As discussed previously, the elevated levels of inorganics detected in the Zone 2 groundwater samples may be due, in part, to the fact that total metals, not dissolved metals results, were utilized to calculate the hazard index. Thus, a more conservative estimate of risk is derived.

Table 6-11 depicts the excess lifetime carcinogenic risk associated with the contaminant concentrations under the drinking water supply exposure scenario. Three organics (1,2-dichloroethane, β-naphthylamine, and chloroform) and one inorganic (arsenic) contribute to the total calculated risk of 6.97×10^{-3}.

The calculated combined HI for the Zone 2, representative, typical-bedrock well DC-M15-142, contaminant concentrations is displayed in Table 6-12. The HI of 4.4 is well above unity; however, lead is the predominant contaminant and the only contaminant with a individual hazard index exceeding one. The individual HI for lead is 99.9 percent of the total HI calculated for the Case B contaminant concentrations.

Table 6-13 depicts the excess lifetime carcinogenic risk associated with the typical, bedrock well, contaminant concentrations under the drinking-water-supply exposure scenario. Two organics (β-naphthylamine, 1,2-dichloroethane) are the major contributors to the calculated risk of 3.77×10^{-4}.

The calculated combined hazard index for the Zone 2 representative, overburden well DC-M107-107, contaminant concentrations is presented on Table 6-14. One organic (chlorobenzene) and one inorganic (cadmium) is the major contributor to the combined HI of 2.3. Cadmium (again, results are obtained from total inorganic analyses) is the predominant contaminant (HI = 2.2) and the only contaminant with an individual hazard index exceeding unity. The individual HI for cadmium is 94.3 percent of the calculated combined HI for the overburden well, contaminant concentrations.

Table 6-15 depicts the excess, lifetime, carcinogenic risk associated with well (DC-M107-107) contaminant concentrations under the drinking-water-supply exposure scenario. β-naphthylamine and 1,2-dichloroethane are the major contributors to the calculated risk of 1.09×10^{-1}. β-naphthylamine is the predominant contaminant with a calculated, excess, lifetime, cancer risk of 1.03×10^{-1}.

Carcinogenic and noncarcinogenic effects for children are approximately 3.5 times greater than those for adults.

Zone 3

Tables 6-16 and 6-17 display the hazard indices and the carcinogenic risks associated with site-related contaminants detected in Zone 3 groundwater samples. Again, a worst-case, (maximum observation), typical overburden well and typical bedrock well assessment is made for an ingestion exposure scenario. The total Zone 3 contaminant risk calculations are contained in Appendix G and should be referred to by the reader to fully understand the extent of site-related contamination in each zone.

The worst-case exposure scenario for Zone 3 is presented in Table 6-16. A total carcinogenic risk of 6.04×10^{-3} results from a detection of total arsenic. This contaminant is responsible for roughly 91 percent of the risk. Since the analytical results for this contaminant was obtained from total inorganic analyses (i.e., unfiltered groundwater samples) the level of contamination may be biased high due to the presence of fine particulate matter suspended in the groundwater matrix as a result of drilling and well development. The organic contaminant 1,2-dichloroethane is also present but at concentrations which represent only 4 percent of the total carcinogenic risk.

Table 6-17 presents the total hazard index for the Zone 3 worst-case scenario. Again, inorganics (antimony, lead, cadmium) are responsible for the majority of adverse health risks. The results for these inorganic analytes are obtained from total (i.e., unfiltered sample) inorganic analyses. The site related compound fenac is also a minor contributor to the overall risk.

The carcinogenic and noncarcinogenic risks associated with Zone 3 are primarily due to the presence of inorganic contaminants and cyanide. These values are somewhat conservative since analytical results for these compounds are also obtained from total (nonfiltered) inorganic analyses. Risk from organic constituents (fenac and 1,2-dichloroethane) are relatively low for this zone.

6.5.1.2 Surface Water

Table 6-18 depicts calculated hazard indices and excess, lifetime, carcinogenic risks associated with worst-case contaminant concentrations in the surface waters of Bald Eagle Creek at the confluence of the Susquehanna River. The following three exposure scenarios were considered:

- Ingestion of contaminated fish
- Accidental ingestion during recreation (swimming)
- Dermal absorption during recreation (swimming)

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TABLE 6-16

ZONE 3: MAJOR CONTAMINANT CONTRIBUTORS
WORST-CASE, MAXIMUM OBSERVATIONS - CARCINOGENIC RISK
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Risk	Percent Total
Arsenic (total)	5.49×10^{-3}	91.0
1,2-DCA	5.46×10^{-4}	9.0
TOTAL CARCINOGENIC RISK	6.04×10^{-3}	

TABLE 6-17

ZONE 3: MAJOR CONTAMINANT CONTRIBUTORS
WORST-CASE, MAXIMUM OBSERVATIONS - HAZARD INDEX
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant Name	Individual Hazard Indices	Percent Total
Antimony	13.4	38.6
Lead	7.6	21.8
Cadmium	3.3	9.6
Fenac	0.3	0.8
TOTAL HEALTH INDEX	30.8	

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TABLE 6-18

HEALTH INDICES AND CARCINOGENIC RISKS ASSOCIATED
WITH VARIOUS EXPOSURE SCENARIOS TO SURFACE WATER
(BALD EAGLE CREEK AND THE SUSQUEHANNA RIVER CONFLUENCE)
WORST-CASE, MAXIMUM OBSERVATIONS
DRAKE CHEMICAL SITE - PHASE III RI

Summary Table	Carcinogenic Risk	Non-carcinogenic Risk (Hazard Index)	Percent of Total Carcinogenic Risk	Percent of Total Non-carcinogenic Risk
Fish Ingestion	0.00	1.621	0.00	97.9
Swimming Ingestion	0.00	0.032	0.00	1.9
Dermal Contact	0.00	0.003	0.00	0.2
Total Carcinogenic Risk	0.00			
Total Non-carcinogenic Risk		1.656		

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The HI calculated for the fish ingestion (HI=1.7) scenario exceeds unity, indicating that noncarcinogenic adverse health effects are anticipated. The HI calculated for the dermal absorption and accidental ingestion scenario are well below unity, indicating that noncarcinogenic, health effects would not be anticipated.

Table 6-19 depicts calculated hazard indices and excess, lifetime, carcinogenic risks associated with typical case contaminant concentrations in the surface waters of Bald Eagle Creek at the confluence of the Susquehanna River. The exposure scenarios presented in the preceding section were considered. The HI calculated for the fish ingestion (HI=1.4) is less than the HIs observed under the worst-case contaminant concentrations; but, still exceeds unity, indicating that noncarcinogenic adverse health effects are anticipated under the conditions of the exposure scenario. As noted for the worst-case contaminant concentrations, the HI calculated for the dermal absorption and accidental ingestion during swimming scenarios are well below unity suggesting the potential for adverse health effects is minimal.

6.5.2 Environmental Effects

The environmental effects resulting from the presence of site-related contaminants in Bald Eagle Creek and downstream locations of the Susquehanna River cannot be specifically attributed to the Drake Chemical Site since upgradient sampling locations (DC-SW4-104, DC-SW9-109, and DC-SW10-110) contained similar levels and types of inorganics including barium, nickel, and cobalt. Metal concentrations at these levels and hardness measurements are indigenous to area surface waters. Trace amounts of the site-specific contaminant fenac were also detected throughout the watershed in levels well below established PADER stream goals criteria (NUS-Phase III FS, August 1986). Tables 6-20 and 6-21 display the detected concentrations of fenac and inorganic contaminants compared to pertinent water quality criteria in downgradient Bald Eagle Creek and Susquehanna River surface water samples. Complete contaminant tables are contained in Appendix H. The inorganic constituents copper and zinc are detected in area surface waters in concentrations which exceed AWQC chronic toxicity values for aquatic biota calculated from water hardness measurements (Table 6-22). These contaminants are detected in both upstream and downstream samples in random array. Because of their separate occurrence and the probability of natural occurrence in local surface waters, their presence cannot be attributed solely to the Drake Chemical Site.

TABLE 6-19

HEALTH INDICES AND CARCINOGENIC RISKS FROM
EXPOSURE SCENARIOS OF SURFACE WATER
(BALD EAGLE CREEK AND THE SUSQUEHANNA RIVER CONFLUENCE)
TYPICAL CASE
DRAKE CHEMICAL SITE - PHASE III RI

Summary Table	Carcinogenic Risk	Non-carcinogenic Risk (Hazard Index)	Percent of Total Carcinogenic Risk	Percent of Total Non-carcinogenic Risk
Fish Ingestion	0.00	1.287	0.00	94.5
Swimming Ingestion	0.00	0.025	0.00	1.8
Dermal Contact	0.00	0.050	0.00	3.7
Total Carcinogenic Risk	0.00			
Total Non-carcinogenic Risk		1.362		

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TABLE 6-20

SITE RELATED CONTAMINATION IN BALD EAGLE CREEK
AND DOWNSTREAM SUSQUEHANNA RIVER WATER SAMPLES
DRAKE CHEMICAL SITE - PHASE III

Compound	Surface Water Concentration (µg/l)	PADER Stream Goals Criteria (µg/l)
Fenac	0.052 - 0.35	95.0

TABLE 6-21

INORGANIC CONTAMINANTS IN BALD EAGLE CREEK
AND THE DOWNSTREAM CONFLUENCE OF THE SUSQUEHANNA RIVER
COMPARED TO AWQC VALUES FOR AQUATIC LIFE
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	Maximum Conc. (µg/l)	AWQC (µg/l)	
		Acute	Chronic
Aluminum	609	--	--
Barium	73.0	--	--
Cobalt	25.0	--	--
Copper	20.0	24.3	5.6
Silver	17.0	--	--
Nickel	31.0	1,983.0	103
Zinc	61	348.0	47.0

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TABLE 6-22

AWQC - AQUATIC LIFE VALUES (Hardness=110 mg/l)
DRAKE CHEMICAL SITE - PHASE III RI

Contaminant	Acute (µg/l)	Chronic (µg/l)
Chromium	5,200.0	44.0
Copper	24.3	5.6
Lead	193.0	4.8
Nickel	1,983.0	103.0
Zinc	348.0	47.0

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6.5.3 Uncertainties

The results of the risk assessment must not be considered a characterization of all potential risk. Numerical values have been generated to highlight potential as well as existing sources of risk at the site so that they may be dealt with effectively in the remediation process. These calculations do not consider the exposure of sensitive populations (i.e., atopic, elderly, or immuno-deficient individuals, the extremely young, etc.). They do not consider chemical synergism or antagonism, only simple additivity. This concept of additivity is itself uncertain in that it does not consider chemical affinity or toxic specificity to target organs.

The major uncertainty in the quantitation of risk from the Drake Site is the inability to identify and measure unknown contaminant compounds which may (or may not) have adverse public health and/or environmental impacts upon exposure. For example, a strictly qualitative comparison of TOC (Total Organic Carbon) in soil values to a summation of positive laboratory values for organic target compounds reveal that roughly 90 percent of the organic carbon is unaccounted for by the latest analytical scheme. The associated risk from exposure to these chemicals can, in no way, be calculated or estimated.

6.6 SUMMARY

Contaminated sludges, soils, and groundwater remain on the Drake Site and adjacent Gorham property. These form a single source that continues to release contaminants to the environment, presenting a potential risk to human health.

The groundwater beneath the site contains relatively high levels of volatile organics, phenolics, β-naphthylamine, inorganics, and fenac that exceed relevant regulatory standards and/or guidelines established specifically for these compounds. Their presence (especially in Zones 1 and 2) presents significant public health risks to potential groundwater users under several exposure scenarios.

The bulk of the risk (Zones 1 and 2) is a result of the presence of organic contaminants, β-naphthylamine, and fenac. As these contaminants migrate away from the site (Zone 3) via groundwater advection, an alternating of the associated risk is observed consistent with dispersive and adsorptive effects of transport.

Inorganic contaminants including chromium, cadmium, cyanide, and total arsenic are found throughout the study area (Zones 1, 2, and 3) and account for a sizeable portion of risk in Zone 3. Analytical values for these compounds are, however, from total inorganic analyses (i.e., unfiltered sample media). The presence of contaminants such as antimony, lead, cadmium, and nickel are most likely a result of suspended particulate material in the aqueous samples from drilling and well development operations. A clear pattern of inorganic

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contamination is not evident and may or may not be related to activities at the Drake Chemical Site.

Surface water samples contained inorganic analytes and the compound Fenac. Analytical values for these constituents do not exceed MCLs. The contaminants copper and zinc, however, do exceed the AWQC chronic toxicity values for aquatic organisms calculated form stream water hardness measurements. Both zinc and copper occur in upgradient sampling locations and are detected sporiously throughout the study area. Their presence in surface waters cannot be attributed specifically to activities at the Drake Site.

7.0 SUMMARY AND OBSERVATIONS TO GUIDE THE FS

This section summarizes the Phase III RI Report. Conclusions are also presented. The goal of this section is to set the stage for the FS and establish its direction and priorities.

The five specific project objectives (restated in Section 1.1) of the Phase III RI have been achieved and are documented in the body of the report. This report provides adequate basis for the FS to proceed. Information not presented in this report narrative can be obtained by consulting the RI appendices. It is probable that this will be necessary since all data collected has not been interpreted. In particular, additional hydrogeologic information, test-pit cross sections, and segments of the chemical-analytical base may have to be accessed during the FS and possibly in the design stage. It is with this concept in mind that full size drawings are provided in the Appendices.

7.1 EXTENT OF CONTAMINATION AND RAMIFICATIONS FOR THE FS

Following is a media by media summary of the occurrence and distribution of chemical contamination observed in the study.

Surface Waters and Sediments

Onsite lagoons, surface waters, and sediments were found to be contaminated with site-related contaminants, as expected. The relevance of this observation is minor since the two lined lagoons are slated for remediation during the forthcoming surface remediation project. Detection of site-related contaminants in the leachate lagoon, also expected, implies that this relatively small source of groundwater contamination needs to be factored into the overall site remedy strategy.

Fenac was the only site-related contaminant detected in offsite surface waters. Detection of fenac in offsite surface waters demonstrates that site-related contamination can migrate to these environs that are distant from the site. Other site-related compounds detected in offsite surface waters were limited to metals which, by comparison with results from background sampling locations, cannot be linked to wastes present at the site.

Detection of site-related compounds in downstream offsite sediments reinforces the observation that contaminants can migrate from the site to these offsite environs. The assessment of site-related impact on offsite sediments is obscured by the detection of site-related compounds in background samples.

Soils/Sludges

Based on the assessment in Section 4.0, it appears that more soils and sludges on the site are affected than was reported previously (NUS, 1987). Contamination with organic compounds

constitutes a major concern, but not an unexpected finding. Inorganic contamination appears to be less significant. It appears that only cadmium presents a problem. The detection of native inorganic soil, however, including iron and manganese, presents a matter of concern for any treatment strategy for organics. Issues of ash residue containing inorganic concentrates, in particular, are of concern if thermal process are considered for organics treatment. The soft sludges may not support heavy equipment and therefore present a physical constraint to the selection of remediation technologies.

The assessment indicates that the approximately 12.5 acres (by 12.5 feet deep) covered in the soil/sludge investigation is a homogenous mixture containing organics which cannot be discretized. This volume is approximately 3.6 times the quantity of material projected as candidate for remediation (Ebasco, December, 1987). If additional assessment and establishment of action levels in the FS indicates that the entire volume requires remediation, the soil/sludge budget cost estimates which parties may have derived from the Task 7 Report (Ebasco, December, 1987) should be adjusted.

Groundwater

Overburden groundwater beneath the site (Zone 1) is polluted with a variety of organics and several inorganics, some of which exceed water quality standards. The source of this contamination is most likely, the soils/sludges in the vadose zone. Depending on the overall source treatment, management of migration, and risk management strategy to be developed in the FS, substantial quantities of Zone 1 groundwater may require remediation. Groundwaters in the bedrock formation beneath the site (Zone 1) appear to be only marginally affected by site-related contamination. Depending on the overall site remedy strategy, including the assessment of risks, bedrock groundwater in Zone 1 may not be a candidate for remediation.

Zone 2 overburden groundwaters are affected by site-related contaminants. The degree of contamination is mainly a function of distance from the source, as contaminant concentrations are observed to diminish with increasing distance from the site. Contaminant concentrations exceed water quality standards in some locations, particularly near the site. Consequently, depending on the overall site remedy strategy, including the assessment of risk, certain Zone 2 overburden groundwaters may require remediation. Bedrock groundwaters in Zone 2 do not appear to be appreciably affected. The need for remediation will hinge upon the overall site remediation strategy.

Groundwaters in the Zone 3 overburden appear to be much less affected than in Zone 2; however, some observed concentrations exceed water quality criteria. The need to remediate overburden groundwaters will have to be assessed along with a review of the attendant risks in the overall site remedy strategy.

Bedrock groundwaters in Zone 3 do not appear to be affected by site-related contamination. Zone 3 groundwaters, while subject to the overall site remediation strategy and an assessment of risks, do not appear to be a strong candidate for remediation.

7.2 REGULATORY AND RISK ASSESSMENT SUMMARY, RAMIFICATIONS FOR THE FS

Table 7-1 presents an overall regulatory and risk assessment summary based on the analyses detailed in Section 6.0. Typical (as opposed to worst-case) risks are presented. The remediation candidate designation is a subjective judgment based on the regulatory and risk assessment. It is intended to help focus the FS efforts under the fast-track approach.

The table indicates that MCLs are clearly exceeded in the overburden groundwater system in all three zones. MCLs, as qualified on the table, are not exceeded in the offsite surface waters or the bedrock in any of the zones. Strong candidates for remediation include the overburden in Zone 1 and portions of Zone 2. Remediation of the bedrock system is not clearly indicated for Zones 1 and 2. These must be considered in the overall site remedy strategy.

Based on this assessment it appears that offsite surface waters and groundwaters in Zone 3 are probably not strong candidates for remediation. This is because although some portions of the Zone 3 overburden system are observed to exceed MCLs, the portions are relatively small and typical carcinogenic and noncarcinogenic risks are not excessive. However, an important consideration which could effect the decision to remediate groundwaters particularly in Zone 3, is interpretion and application of the EPA's Guidelines for Groundwater CLassification under the EPA Groundwater Protection Strategy (EPA, December 1986) which emphasis compliance with MCLs rather than real or potential health effects.

Contaminant transport modeling results presented in Section 5.0 indicated that the maximum groundwater contaminant concentrations expected in Zones 2 and 3 should not occur for possibly several hundred years from the present. This consideration should be factored into an overall groundwater remediation strategy in the FS. The strategy should consider source remediation as well as migration dynamics within the overburden system. Considering the relatively long time period for peak concentrations to occur at locations distant from the site, and the further consideration that contaminant concentrations in Bald Eagle Creek should not exceed human or aquatic species exposure guidelines, it is possible that a phased remediation program can be implemented without imposing further adverse impact on groundwater or users and habitants at Bald Eagle Creek.

TABLE 7-1

REGULATORY AND RISK ASSESSMENT SUMMARY
DRAKE CHEMICAL SITE - PHASE III RI

	Offsite Downgradient Surface Water	Typical Zone 1 Overburden	Typical Zone 1 Bedrock	Typical Zone 2 Overburden	Typical Zone 2 Bedrock	Typical Zone 3 Overburden	Typical Zone 3 Bedrock
Exceeds MCLS	No	Yes	No	Yes	No	Yes	No
Exceeds Other Health-Based Criteria	No	Yes	No	Yes	No	Yes	No
Typical Total Carcinogenic Risk	0.0	0.8	3.43×10^{-7}	1.09×10^{-1}	3.77×10^{-4}	3.63×10^{-7}	4.13×10^{-7}
Typical Total Noncarcinogenic Risk	2.47(1)	13.6	4.7 x 10-2	3.0	4.4(3)	0	0
Remediation Candidate	Probably Not	Yes	Variable(2)	Yes	Variable(2)	Probably Not (4)	Probably Not

(1) Driven by observations of silver which are probably not site related.
(2) Variable depending on the overall site remedy strategy.
(3) Based on a single observation and not indicative of actual conditions.
(4) Exceedance of MCLs may trigger remediation under the Guidelines for Groundwater Classification under the EPA Groundwater Protection Strategy.

Onsite soil/sludge remediation strategies may affect groundwater remediation actions.

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