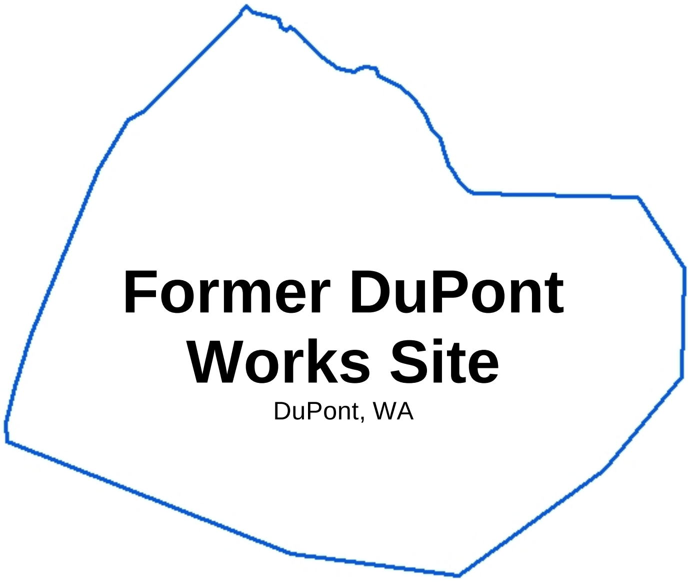
Final
Feasibility Study for the Former DuPont Works Site



Prepared For:

The Weyerhaeuser Company **and** **E.I. duPont de Nemours and Company**

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Preface

P.1 Introduction

These Volumes present information developed as part of the Final Remedial Investigation, Risk Assessment, and Feasibility Study (RI/RA/FS) for the Former DuPont Works Site (Site) located in DuPont, WA (See Figure P-1). These reports were stipulated in a Consent Decree, effective July 1991, between the lead agency, Washington State Department of Ecology (Ecology), and the principle responsible parties, Weyerhaeuser Company (Weyerhaeuser) and E.I. duPont de Nemours and Company, Inc. (DuPont). Per the Consent Decree, the reports were developed in accordance with the Model Toxics Control Act Cleanup Regulation (MTCA). Draft RI/RA/FS reports were completed in 1994 and 1995, submitted to Ecology, and underwent public review. The draft Final RI/RA/FS reports, presented here, have been developed to satisfy comments on the draft reports and to accurately reflect existing conditions and future land use at the Site. In addition, these reports incorporate a variety of agreements that have been reached with Ecology following completion of the draft studies in 1994 and 1995.

P.2 Property History

The Site property was originally used by Native Americans. European settlement began in 1832, when the Hudson’s Bay Company established a cabin/storehouse on nearby Puget Sound at the mouth of Sequalitchew Creek, northwest of the Site (City of DuPont, 1995). In 1833, Hudson’s Bay built Fort Nisqually, which was located in the northern portion of the Site. Ten years later, a new Fort Nisqually was built at a location adjacent to but outside the eastern edge of the Site.

The DuPont Company acquired the property in 1906 and constructed an explosives plant and the historical Village of DuPont as a company town for plant workers (the historical village area is located approximately 1 mile southeast of the Site). DuPont continued to manufacture explosives at the Site until the mid 1970s, when it sold the property and adjacent areas to the Weyerhaeuser Company. Weyerhaeuser and its subsidiary, Weyerhaeuser Real Estate Company (WRECO), still own the majority of the approximately 2,500 acres in the area, which they named Northwest Landing. Northwest Landing is a planned community in the City of DuPont and includes the Site. WRECO has begun to develop Northwest Landing on some of its lands within the City, but cannot develop the Site until the cleanup has been completed.

P.3 Site Regulatory History

The Site was used for the manufacture of commercial explosives from 1909 to 1976. Production of explosive material ceased and decommissioning of the buildings began in 1976, when Weyerhaeuser purchased the property from DuPont. As part of the cleanup process, asbestos was removed, salvageable materials were taken out, and structures were either burned or demolished. Actions taken at the Site subsequent to the shutdown in 1976 include the following:

- In 1985, Weyerhaeuser initiated studies to determine whether hazardous substances were present.

- In 1986, a Phase I Site Survey and Review was conducted to identify areas on Site that may be of environmental concern.

- In 1986, soil contamination was first documented and reported to Ecology.

- In 1987, a Phase II Site Characterization study was performed, which characterized the type, concentration, and distribution of constituents at 38 areas on the Site.

- In 1989, a Baseline Human Health Risk Assessment was performed using results of the Phase II survey.

- In 1991, Weyerhaeuser and DuPont signed a Consent Decree (No. 91 2 01703 1) with Ecology, where they agreed to study the Site and complete an RI, RA, and FS. The Site was divided into two main areas: Parcel 1 (approximately 636 acres); and Parcel 2 (approximately 205 acres).

- In 1994 and 1995, Draft RI, RA, and FS reports were submitted to Ecology and underwent public review.

- In 1996, based on the result of interim source removal actions, Ecology approved a Cleanup Action Plan (CAP) for Parcel 2 that provided for no further remediation activities except for the institutional controls to maintain the industrial use of Parcel 2.

- In 1997, Parcel 2 was deleted from the Consent Decree, and the deed requiring institutional controls to maintain the industrial use was recorded in the Pierce County Auditor's Office.

- Between 1990 and 2001, while studies and negotiations were ongoing, Weyerhaeuser and DuPont undertook numerous interim source removal actions to clean up soil and/or debris at the Site, in accordance with MTCA and the Consent Decree.

P.4 Description of Reports

In fulfillment of the provisions of the Consent Decree, RI, RA, and FS reports were prepared. A description of the contents of each of these reports is presented below.

- **RI** – The purpose of the RI was to collect sufficient information regarding the Site to enable the completion of the RA and FS. The RI characterizes the nature and extent of contamination based on the existing conditions at the Site. The RI Report presents the analytical data for the media that have been collected at the Site. The data are presented for each RI area, which was defined based on historical manufacturing and production operations at the Site.

- **RA** – In contrast to the RI, the RA evaluates Site conditions in relation to future land uses at the Site. The RA identifies default soil cleanup levels, and presents the methods used to derive Site-specific soil levels that are protective of human health and ecological receptors based on future land use. These cleanup levels and remediation levels are compared to Site constituent concentrations in order to identify which areas require additional evaluation in the FS.

- **FS** – The FS evaluates alternative potential cleanup methods designed to meet the remedial action objectives for the Site. The FS Report provides information for Weyerhaeuser and DuPont to recommend alternatives for remediation of selected areas, including both no action and action alternatives. Ecology will evaluate the FS and select the remedial measures it believes are appropriate. Weyerhaeuser and DuPont will complete the needed detailed design and implementation of the remedy selected by Ecology in the Cleanup Action Plan.

P.5 Report Organization and Documents

This RI/RA/FS report should be reviewed together to better understand the relationship between the Site study activities. The RI/RA/FS are interdependent Reports that are organized as follows:

Volume I – RI and Appendices
Appendix A - Field Procedures
Appendix B - Soil Quality Data
Appendix C - Groundwater, Surface Water and Freshwater Sediment Quality Data
Appendix D - Laboratory Physical Soils Testing

Appendix E - Data Quality Assessment

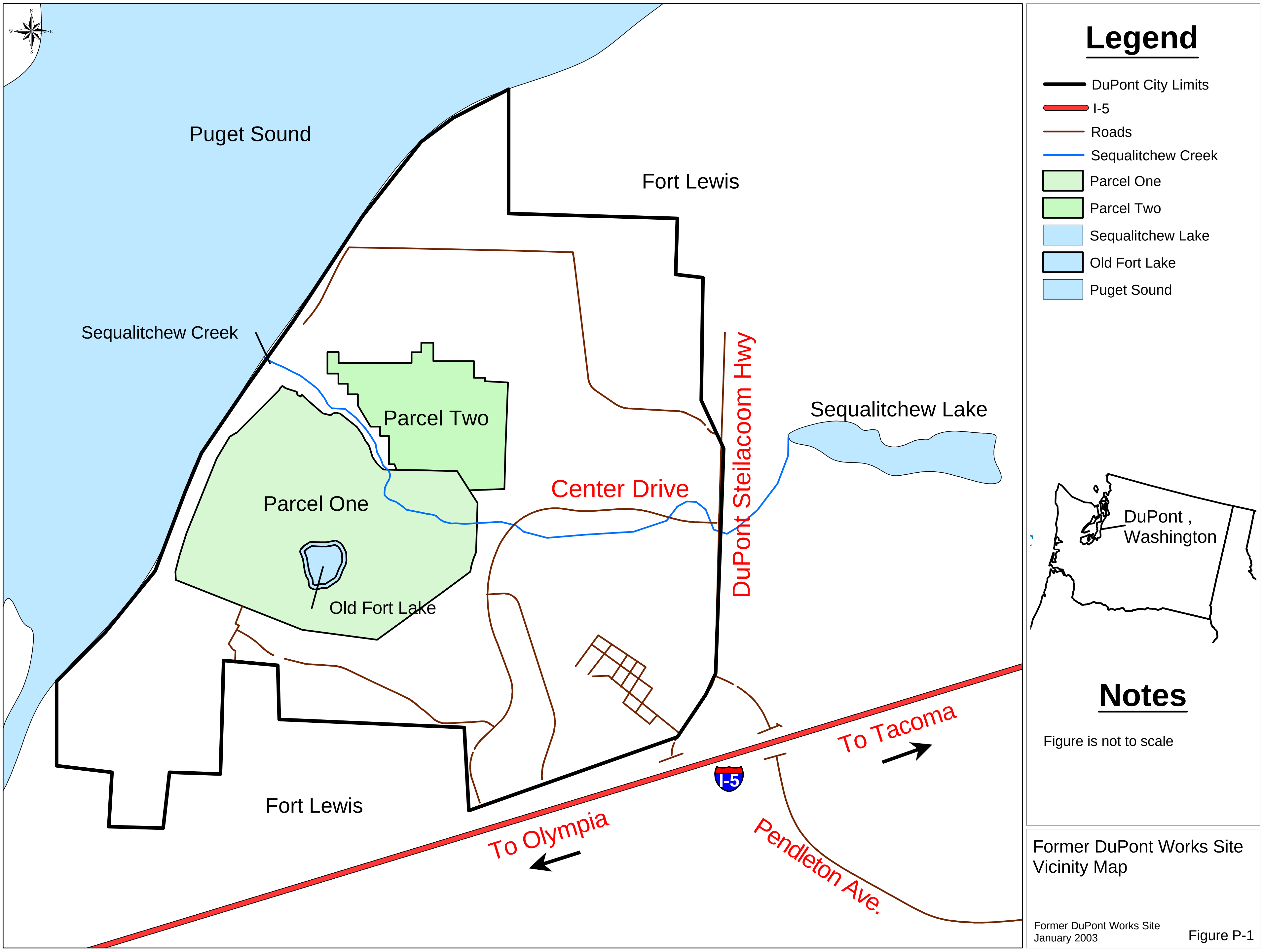
Volume II - RA and Appendices

- Appendix A – Ecological Risk Assessment Summary
- Appendix B – Evaluation Unit Sample Groupings
- Appendix C – Letters and Other Documentation of Site-Specific Determinations
- Appendix D – Toxicity Information For Select Constituents
- Appendix E – Cleanup Level and Remediation Level Calculations
- Appendix F – Summary Statistics and Comparison to Standards

Volume III - FS and Appendices

- Appendix A – Description of Remediation Technologies for Soil
- Appendix B – Overview of Soil Testing Procedures and Data Interpretation
- Appendix C – Lead and Arsenic Soil characterization and Treatability Studies
- Appendix D – Arsenic Wet Screening Study
- Appendix E – Ranking of Alternatives
- Appendix F – Cost Estimate for Remedial Alternatives Analyzed in Detail
- Appendix G – Estimation of Minimum Soil Volume Required for Cost-Effective On-Site Treatment
- Appendix H – Development of Soil Remediation Levels for the Golf Course Groundskeeper
- Appendix I – Impracticability of Groundwater Remediation at the Former DuPont Works Site, DuPont, Washington.

An Executive Summary is included with each Volume.



Notes

Figure is not to scale

Former DuPont Works Site
Vicinity Map

Former DuPont Works Site
January 2003

Figure P-1

P.6 References

City of DuPont. 1995 Comprehensive Plan. Adopted July 25, 1995.

MTCA (Model Toxics Control Act Cleanup Regulation). Chapter 173-340 WAC. Feb. 12, 2001. Ecology Publication 94-06.

Chapter 1 – INTRODUCTION

1.1 Introduction

This chapter presents the general scope, purpose, and organization of this report.

E.I. duPont de Nemours & Co. (DuPont), the Weyerhaeuser Company (Weyerhaeuser), and the Washington State Department of Ecology (Ecology) have agreed to complete a Remedial Investigation (RI), Health Risk Assessment (RA), and Feasibility Study (FS) for the Former DuPont Works Site (Site) under the terms and conditions defined in Consent Decree No. 91-2-01703-1.

The RI, RA, and FS were conducted according to provisions of the Washington State Model Toxics Control Act (MTCA) as administered by Ecology. Under MTCA, Ecology provides guidance and criteria for the selection of cleanup actions (WAC 173-340-360). MTCA specifies criteria for selecting cleanup actions, which include the permanence of the action, protectiveness, cost, long-term effectiveness, management of short-term risks, implementability and consideration of public concerns. Under MTCA, Ecology also provides general information on the content of a feasibility study (WAC 173-340-350). This FS follows that guidance.

This FS report is a companion document to the RI and RA and should be reviewed in conjunction with these reports.

1.2 Site Description and History

The Site is located in southwestern Pierce County, within the City of Dupont, as shown on Figure 1-1. The former DuPont Works occupied an 841-acre fenced area and included Parcel 1 and Parcel 2 areas, as referenced in the Consent Decree. Remediation of Parcel 2 has been completed and this parcel was released for development by Ecology in December of 1997. This FS only addresses Parcel 1 (i.e., The Site).

The Site is bordered by Weyerhaeuser property to the north and west and WRECO property on the east, and south (Figure 1-1). Burlington Northern railroad property is adjacent to the Weyerhaeuser open space to the west. Puget Sound is located to the west of the Burlington Northern Railroad property.

Activities at the Site during operation of an explosives manufacturing facility resulted in the accumulation of residual chemicals in soils:

- In areas associated with former building foundations;
- In areas where lead paint was used and/or stored;
- In areas where manufacturing materials were stored;
- Along the narrow gauge railroad tracks;
- In waste disposal areas; and
- In low concentrations Site-wide.

1.3 Interim Source Removal

In accordance with MTCA (WAC 173-340-430) and the Consent Decree for the Site (Sections D and E), interim source removal (also referred to as interim cleanup actions) has been conducted to remove soil and/or debris from discrete locations throughout the Site. This work was done between 1990 and 2001. Actions were conducted for five primary reasons:

- To minimize the potential for transport of residual constituents in soil by removing the sources, protect groundwater, and thereby minimize potential future environmental impacts;
- To remove soil and/or debris with high concentrations of constituents to improve the safety and environmental conditions at the Site;
- To remove debris (such as drums and other demolition material overlying fill and native soils) and facilitate a more complete and accurate RI;
- To minimize delays in the Site RI, RA, and FS process; and
- To prepare for the final remediation of the Site.

For each interim source removal (ISR), complete work plans were developed, reviewed by Ecology, and revised in accordance with their comments. Prior to the initiation of any ISR, Ecology's approval to start was obtained. In addition, Ecology was communicated with regularly during these activities either by regular Site visits, periodic telephone call and/or monthly reports.

The ISR was described in a series of Interim Source Removal Memoranda submitted to Ecology following work scope completion. These memoranda referenced in the RI, present the results and provided additional details of each activity.

The total volume of materials removed from the Site during ISR (through December, 2001) included: 60,900 tons of soil; 9,700 tons of debris; 1,540 tons of soil and debris mixtures; 4,836 drums; 69,204 gallons of liquids; and 170 cubic yards (CY) of asbestos-containing material. Materials were recycled off-Site, incinerated off-Site, or sent to an approved landfill.

As a result of these efforts, this is a focused FS, which addresses the residual constituents contained in soil and debris, and the contaminated stockpiled soil generated during ISR.

1.4 RI and RA Summary

The RI investigated four media (i.e., soil, surface water, groundwater, and sediment) and determined that only soil and groundwater were media of concern. The RA evaluated the soil information presented in the RI for compliance against Site-specific cleanup levels (CLs) and remediation levels (RLs). Because chemical constituents in media other than soil and groundwater meet Site-specific CLs and RLs, this FS will focus on these media only. Minor amounts of contaminated debris are also present on-Site and will be addressed in this FS.

The RA identified 25 areas to be addressed in the FS. The basis for determination of any area requiring no further action (NFA) is described in the RA. The RA also identified CLs and RLs associated with future Site land use. Chapter 6 of this FS further evaluates these risks and land uses to assess the value of engineering controls associated with the preferred alternatives to attain the RAOs.

1.4.1 Soil

The sample data collected during the RI indicated that soil on the Site initially contained lead, arsenic, mercury, 2,4-dinitrotolouene and 2,4-dinitrotoluene (DNT), 2,4,6-trinitrotoluene (TNT), total petroleum hydrocarbons (TPH), and carcinogenic polycyclic aromatic hydrocarbons (cPAH) above MTCA screening levels.

Interim Cleanup or Source Removal Actions remediated many of these locations. These interim actions were effective in reducing the potential for impacts to the groundwater by leachable constituents and by excavating, designating, and disposing of soil which would have been difficult to treat on the Site. This FS refers to conditions within each area after completion of these actions.

1.4.2 Debris

Contaminated debris generated during ISR was disposed of off-Site based on characterization sample analytical results. Additional debris remains in-situ and will be addressed in this FS and during final cleanup action.

1.4.3 Groundwater

The RI and RA reported that groundwater impacts (concentrations above drinking water standards) are limited to one contaminant, dinitrotoluene. These concentrations are very close to the drinking water standard and have slowly been slowing decreasing. Groundwater will be discussed further in Chapter 6.

1.5 Future Land Use

The RA and FS assume certain Site land uses. They are divided at Sequalitchew Creek, with industrial uses planned for the area north of the creek and commercial, historical, and recreational (golf course) land uses planned for the areas south of the creek. Open space will occur along Sequalitchew Creek, and will encompass Old Fort Lake and surrounding land. This land use configuration is presented in Figure 1-2. Land use was used as a basis to develop exposure scenarios in the RA to derive preliminary land use and chemical specific CLs and RLs. Further evaluation was done to assess the impacts of engineering controls associated with the alternatives chosen for further evaluation in Chapter 8. In some cases these engineering controls were used to modify the RLs used in the RA and to estimate the impacted soil volumes.

1.6 Identification of Remediation Units

The area of contamination (AOC) policy developed by Ecology (Ecology, 1991) clarifies the definitions of generation and disposal as they apply to waste soil and debris found on MTCA sites. In 1993, Ecology determined that an AOC, which includes all areas within the Consent Decree Boundary (Figure 1-1), would allow on-Site consolidation, handling, and treatment of soil from various Areas on the Site.

Remediation units (RU) are groupings of the Site locations with like land uses. Each RU grouping will be treated with similar technologies and, thus, can be addressed as a single entity for the purposes of the FS. Remediation units were developed to address the residual contamination and associated soil volumes remaining after ISR (as described in Section 1.2). This FS generally uses RUs based on land size and land use type rather than similar chemical types and concentrations, RI Areas, or where deposition of these chemicals is believed to have occurred by similar mechanisms (e.g., application of herbicides). This was done to address the public's concerns over the large variance in size between the RI areas and the lack of total Site coverage. These RUs are shown on Figure 1-2 and described in section 3.2. The exceptions are Miscellaneous Small RUs, which are either small in size or have similar and/or unique characteristics. These RUs are shown on Figure 1-3.

1.7 FS Purpose and Report Organization

The primary focus of this FS is to address soil impacted by lead and arsenic. Soils impacted by other contaminants and contaminated debris occur on Site but comprise relatively small volumes. These occurrences are referred to as “Miscellaneous Small RUs” throughout this FS. An evaluation of applicable remedial approaches for these RUs is contained in Chapter 7 and in Chapter 8.

The relationship between each section of this FS report and the process used for development and screening of remedial alternatives is presented on Figure 1-4.

This FS report is organized as follows:

- Chapter 2 summarizes RAOs designed to protect human health and the environment. The RAOs take into consideration remediation or cleanup levels identified in the RA and relevant state and federal regulations. The relevant cleanup or remediation levels form the basis of the estimated impacted soil volumes and are also used to assess the feasibility of potential remedial alternatives.

- Chapter 3 defines the RUs and summarizes the impacted soil volumes that will be addressed by the cleanup action.

- Chapter 4 describes applicable technologies and associated process options, and summarizes the screening of those technologies. Preliminary screening was performed based on professional judgment of the effectiveness of the technology and process options to remediate Site soil. Following the preliminary screening to eliminate technologies that are not suitable to remediate constituents at the Site, specific processes were assembled to represent a range of options for each technology. A qualitative screening of process options was then conducted based on effectiveness, implementability, and cost screening criteria. After this screening, at least one specific process was selected to represent each retained technology for combination into plausible remedial alternatives.

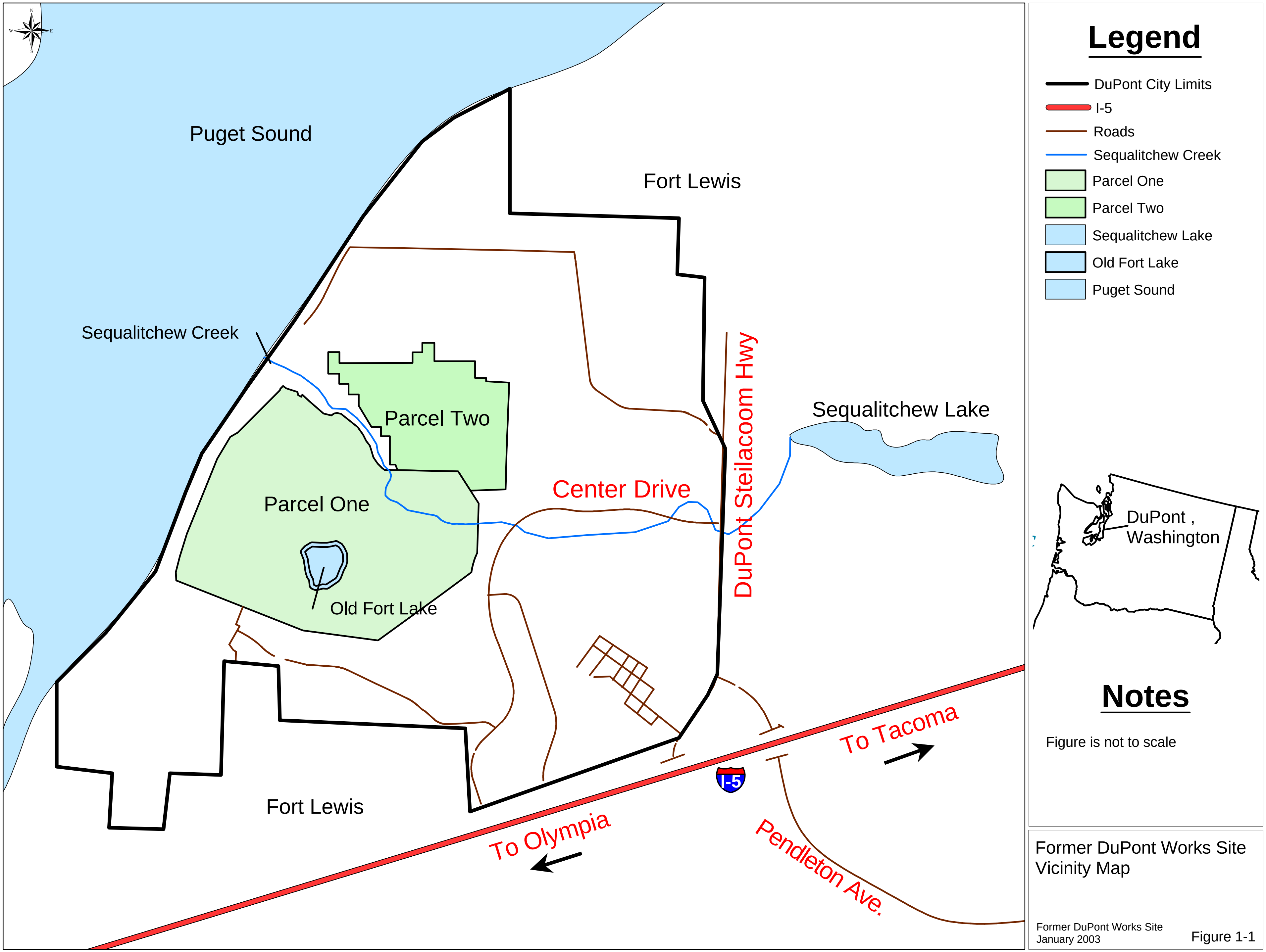
- Chapter 5 summarizes the scope, results, and recommendations from the treatability studies performed on various impacted soils.

- Chapter 6 describes and evaluates the application of remedial alternatives (groups of applicable technologies) to the cleanup action at the Site. Initially, groups of applicable technologies were assembled into alternatives that would be plausible for remediation of Site soils. Then, a quantitative screening of each alternative was conducted. The difference between this screening and the initial screening as discussed in Chapter 4 is that the criteria were weighted and the alternatives scored by the FS team (Appendix E), and the individual elements of each criterion were examined in detail.

- Chapter 7 describes the detailed analysis of remedial alternatives. This section includes an analysis and ranking of the remedial alternatives based on the same set of evaluation criteria used in Chapter 6 applied with greater detail. A comparative analysis identifies the performance of the retained remedial alternatives for each criterion. Cost is evaluated in detail using generic unit costs and recent vendor estimates for direct costs. Indirect costs associated with contingency, engineering design, administration, construction oversight, and community relations are also estimated. The recommended alternative for each RU grouping is selected in this section.

- Chapter 8 defines the recommended strategy for the Site cleanup action. The proposed steps for implementation of the selected alternative are described, pairing the selected alternatives with applicable remediation units and land use. Treatment alternatives for Miscellaneous Small RUs, containing other constituents and constituent mixtures, are also detailed.

Throughout this report, tables and figures are presented at the end of each chapter in which they are discussed. These chapters are supplemented by eight appendices, which provide supporting documentation of items discussed in the text.



Notes

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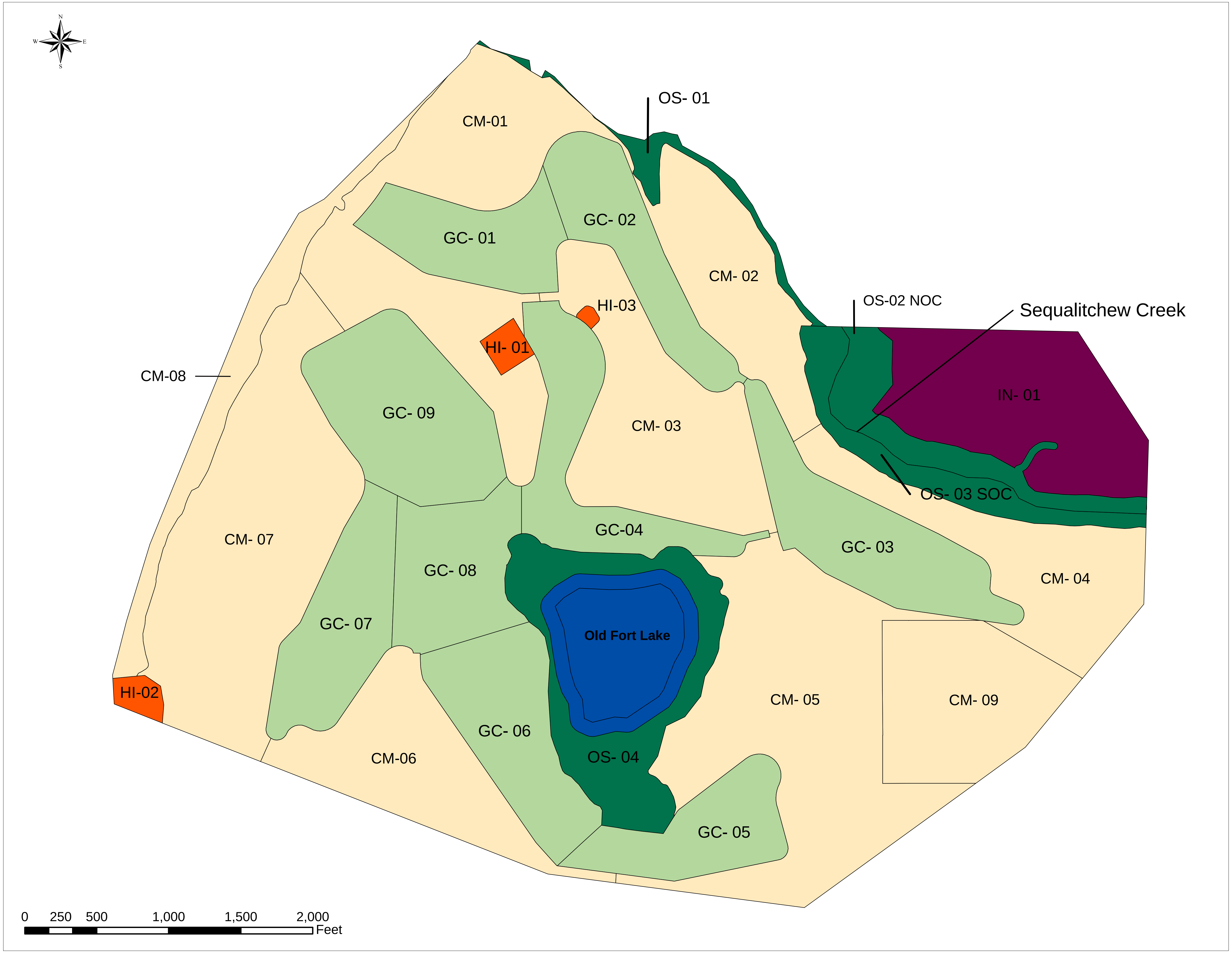
Former DuPont Works Site
Vicinity Map

Former DuPont Works Site
January 2003

Figure 1-1



Legend

- 🟨 Commercial
- 🟩 Golf Course
- 🟧 Historical
- 🟦 Old Fort Lake
- 🟪 Industrial
- 🟩 Open Space

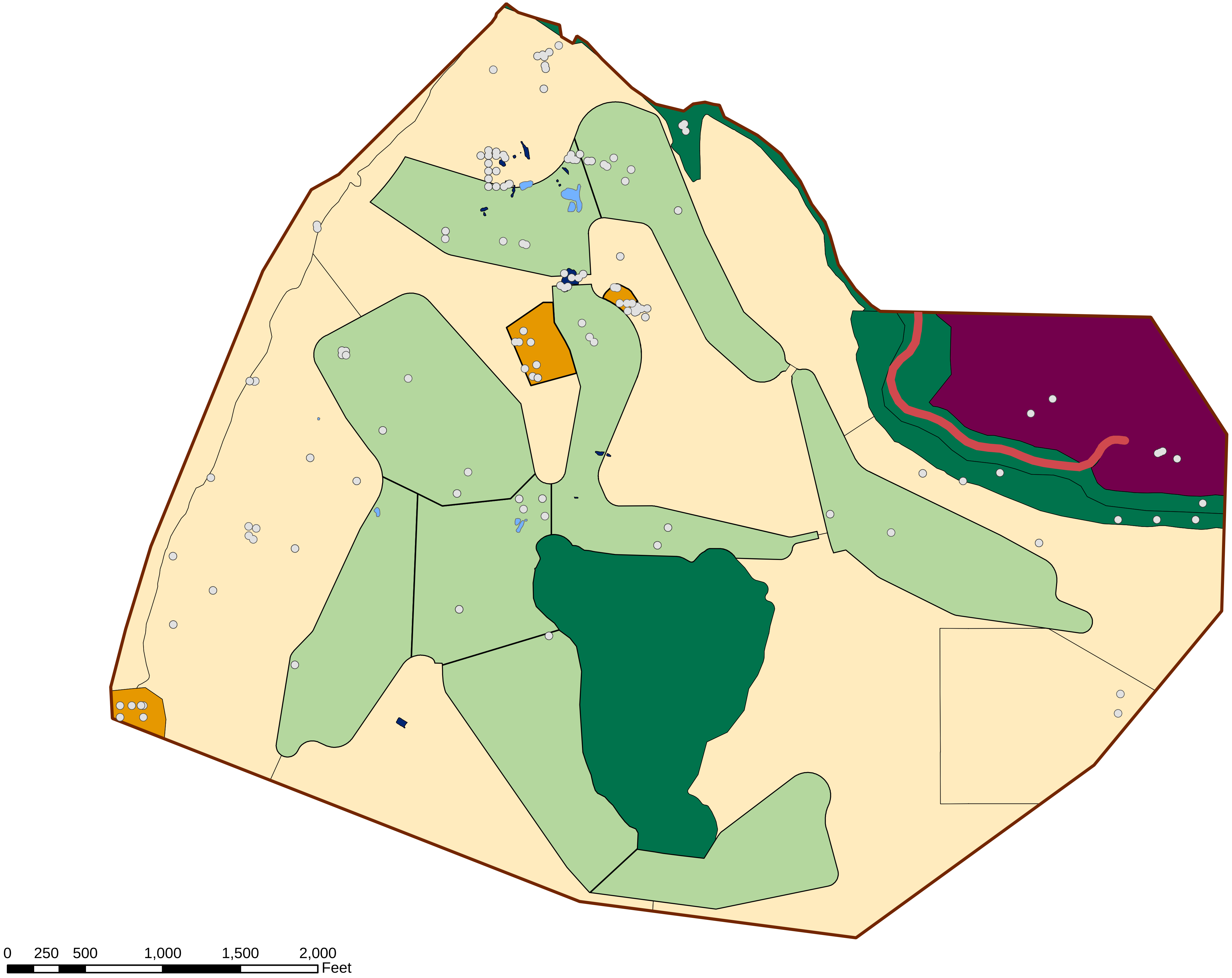
Notes

GC - Golf Course
CM - Commercial
HI - Historical
IN - Industrial
NOC - North of Creek
SOC - South of Creek

Land Use and Remediation Units

Former DuPont Works Site
September, 2002

Figure 1-2



Legend

Miscellaneous Small Units

- 🟦 Debris Areas
- 🟥 NGRR Miscellaneous Subunit
- 🟦 Stockpiles
- ⬜ Exceedence Locations

Evaluation Units

- ☐ Parcel One
- 🟪 Industrial EU
- 🟩 Open Space EU's
- 🟨 Commercial EU's
- 🟩 Golf Course EU's

Notes

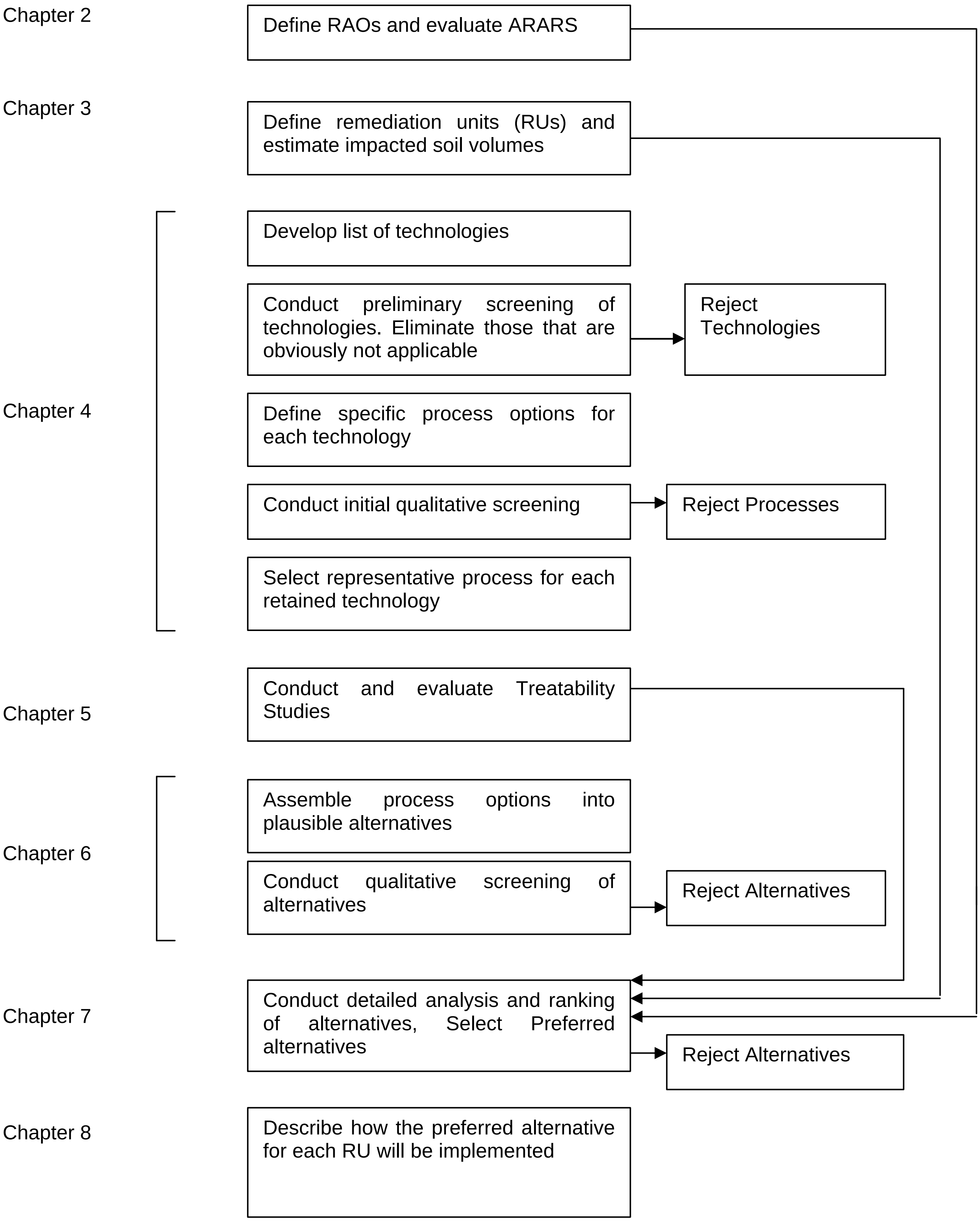
NGRR - Narrow Gauge Railroad

Miscellaneous Small Remediation Units

Former DuPont Works Site
July 2003

Figure 1-3

Figure 1-4 – Method for Screening Remedial Alternatives



1.8 References for Chapter 1

DuPont Environmental Remediation Services and Hart Crowser, 1994. Draft Risk Assessment, Former DuPont Works Site, Dupont, Washington. December 14, 1994.

Ecology, 1991. Inter-program Policy Memorandum on Contamination, Washington State Department of Ecology Toxics Cleanup Program, August 20, 1991.

EPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA.

Hart Crowser, 1994d. Remedial Investigation, Former DuPont Works Site, Dupont, Washington. June 30, 1994.

Chapter 2 – REMEDIAL ACTION OBJECTIVES

2.1 Introduction

The remedial action objectives (RAOs) of future cleanup actions at the Site are to provide remedial alternatives that protect human health and the environment (WAC 173-340-350). The proposed RAOs for the Site are designed to:

- Achieve CLs or RLs that will be protective of human health and the environment; and
- Comply with chemical-, location-, and action-specific applicable, relevant, and appropriate requirements (ARARs).

MTCA (Chapter 173-340 WAC) requires that cleanup actions meet Cleanup Standards at least as stringent as those under the Superfund Amendments and Reauthorization Act of 1986 (SARA), and WAC 173-340-710 requires that all cleanup actions be in compliance with applicable state and federal laws. Section 121 (d) of the SARA requires cleanup actions at Superfund sites to attain the "applicable or relevant and appropriate" requirements of federal and state environmental laws and regulations.

Because of the complexity of the Site, a Site-specific RA using land use specific exposure scenarios was used to develop CLs and RLs protective of human health and the environment (WAC 173-340-700 (3)(c)).

Section 2.2 discusses applicable or relevant and appropriate requirements (ARARs) for the cleanup action(s) at the Site, as specified under MTCA and federal regulations. Section 2.3 presents chemical-specific requirements based on ARARs and risk-based CLs or RLs. Sections 2.4 and 2.5 discuss the location and action-specific ARARs for the Site cleanup action(s). Section 2.6 summarizes the various RAOs identified from a consideration of ARARs and Site-specific risks. These RAOs form the basis for remediation alternatives presented in subsequent sections of this FS report.

2.2 Potentially Applicable State and Federal Requirements for the FS

2.2.1 Introduction

The specific standards that help to determine when RAOs have been met for Site cleanup under a MTCA consent decree are applicable state and federal laws. The selected remedies in the FS must be protective of human health and the environment and comply with these laws.

MTCA (Chapter 90.105D RCW) governs investigation and cleanup of the Site. Cleanup standards in the MTCA regulations (WAC 173-340) consist of the following:

- Cleanup or remediation levels for hazardous substances present at a site (constituent concentrations in affected media).
- Points of compliance (locations where cleanup levels must be met).
- Other regulatory requirements of applicable state and federal laws (requirements that apply to a site because of the type of action and/or the location of the site).

This section of the FS addresses the following: applicable state and federal laws for the cleanup action(s) at the Site, as specified under MTCA; chemical-specific CLs or RLs based on the MTCA regulations and the ARARs; and state and federal laws that apply to cleanup locations and cleanup actions.

2.2.2 Applicable State and Federal Laws

Under MTCA, “applicable state and federal laws” are all legally applicable requirements and those requirements that Ecology determines are relevant and appropriate. Therefore the definition is similar to the federal Superfund concept of “applicable or relevant and appropriate requirements” or ARARs. The term ARARs is used throughout the MTCA regulations and is also used here.

In WAC 173-340-710, MTCA defines legally applicable requirements as those cleanup standards, standards of control, and other environmental protection requirements, criteria, or limitations adopted under state or federal law that specifically address a hazardous substance, cleanup action, location, or other circumstances at a site.

MTCA defines “relevant and appropriate requirements” using the same words as those in Superfund guidance: *“those cleanup standards, standards of control, and other human health and environmental requirements, criteria, or limitations established under state or federal law that, while not applicable to the hazardous substance, cleanup action, location, or other circumstance at a site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to a particular site”* (italics added). The criteria used to make this determination are presented in WAC 173-340-710(4)(a)-(i).

Remedial actions conducted under a consent decree with Ecology must comply with the substantive requirements of the ARARs but are exempt from their procedural requirements (e.g., obtaining permits and approvals) (WAC 173-340-710(9)). Specifically, this exemption applies to requirements under the Washington State Water Pollution Control Act, Solid Waste Management Act, Hazardous Waste Management Act, Clean Air Act, State Fisheries Code, and Shoreline Management Act. It also applies to local laws requiring permits or approvals.

This section includes a discussion of the three types of ARARs: chemical-, location-, and action-specific. The definitions of these ARAR types and the potential ARARs for the Site that fall into these categories are presented in the following subsections.

2.3 Potential Cleanup Levels and Chemical-Specific ARARs

The remediation of contaminated Site media must meet the cleanup standards developed under MTCA and also meet chemical-specific ARARs. Chemical-specific ARARs include those requirements that regulate the acceptable amount or concentration of a constituent that may be found in or released to the environment.

MTCA requires that CLs or, if allowed, RLs be derived for contaminated media at hazardous waste sites. Ecology allows the use of site-specific data to determine risk-based CLs and RLs. If a calculated CL is less than the natural background concentration or the detection limit, the cleanup level would be set at background or the detection limit, whichever is higher (WAC 173-340-700(4)(d)). The RA used this approach to determine the appropriate CLs or RLs. Institutional controls, as defined by MTCA, can be used in conjunction with remedial actions in developing the cleanup alternatives. Table 2-1 summarizes the CLs and RLs approved for the Site by Ecology. This list was used in the RA to evaluate Site contamination. This list is not inclusive and will require re-evaluation based upon the preferred alternative.

MTCA also requires ecological evaluations at sites that may pose a threat to the terrestrial environment (WAC 173-340-7490 and 173-340-7491). These evaluations may be either simplified (WAC 173-340-7492) or site-specific (WAC 173-340-7493). The RA used Site-specific data to determine ecological soil screening level that is protective of ecological receptors. This screening level was used to screen the evaluation units (EUs).

2.4 Potential Location-Specific Requirements

Location-specific ARARs are those requirements that restrict the concentration of hazardous substances or the performance of activities solely because they occur in specific locations. For each of the following location-specific ARARs, a determination of whether they are applicable or are relevant and appropriate will be made after a detailed development of each FS alternative. A discussion of the location-specific ARARs that potentially apply to the Site follows.

Washington State Shoreline Management Act (Chapter 90.58 RCW; Chapters 173-18, 173-22, and 173-27 WAC): The substantive requirements of this statute and its implementing regulations apply to activities within 200 feet of shorelines in the state, which includes the shoreline of Sequalitchew Creek (WAC 173-18-310) and associated wetlands, but not the shoreline of Old Fort Lake (WAC 173-20-560) or Puget Sound which is over 200 feet from the Site. Proposed remedial actions must be consistent with the policies and goals of the approved Washington State coastal zone management program and with the policies and shorelands use designations of the local jurisdiction's shoreline master plan (Pierce County shoreline designation maps, WAC 173-22-0636).

Pierce County Shoreline Management Use Regulation (Title 20): Shorelines within Pierce County include all marine shorelines, shorelines and associated wetlands of streams with a mean annual flow of at least 20 cubic feet per second (cfs), and lakes and associated wetlands that are at least 20 surface acres (Old Fort Lake is approximately 13 acres). The flow rate of Sequalitchew Creek peaks in the spring and was measured in 1999 at approximately 25 cfs. Pierce County regulation provides constraints on "use activities" such as dredging and shoreline disposal of fill.

Pierce County Development Regulations—Critical Areas (Title 18E): This regulation protects critical areas by limiting any actions that are planned within 150 feet of a wetland or 35 feet of a stream, or near geologic hazard areas (steep slopes) or fish and wildlife habitat areas. Pierce County has mapped in an atlas, critical areas and wetlands in areas it has surveyed. This regulation establishes required buffer zones for actions adjacent to any of the above critical areas. Such actions could include any work along Sequalitchew Creek, and Old Fort Lake.

Washington State Hydraulic Projects Approval (Chapters 75.20.100 Through 75.20.160 RCW; Chapter 220-110 WAC): This statute and its implementing regulations apply to any work conducted in Puget Sound or within the designated shoreline that changes the natural flow or bed of the water body (and therefore has the potential to affect fish habitat). The requirements include bank protection (WAC 220-110-050), saltwater technical provisions, and prohibited work times in saltwater areas, such as juvenile salmon outmigration periods. Any work along Sequalitchew Creek will involve consultation with the Washington State Department of Fish and Wildlife (WDFW) to determine appropriate mitigation measures.

The Fish and Wildlife Coordination Act: The Fish and Wildlife Coordination Act requires actions that will result in the control or structural modification of any natural body of water for any purpose, to protect the fish and wildlife resources that may be affected by the action. The U.S. Fish and Wildlife Service (USFWS) and appropriate state agencies must be consulted to ascertain the means and measures necessary to mitigate, prevent, and compensate for project-related losses and to enhance resources. This regulation applies to any actions taken on Sequalitchew Creek. Fish species using Sequalitchew Creek include chum salmon (O*ncorhyncus keta)*, coho salmon (O*ncorhyncus kisutch*), and cutthroat trout (*Salmo clarki)*. Adult chum are reported to spawn in the lower 650 feet of the creek.

Endangered Species Act (16 USC 1531 et seq.; 50 CFR Parts 17, 225, and 402) : This act protects fish, wildlife, and plants species whose existence is threatened or endangered (T/E). The Coho salmon and the bald eagle are candidate T/E species in the Puget Sound ecologically significant unit. The requirements of this regulatory program apply to cleanup actions that may affect a listed T/E species or designated critical habitat. Applicability will be determined via discussions with the USFWS and the

National Marine Fisheries Service (NMFS), as appropriate. A biological assessment could be required by the agencies to evaluate whether the remedial action is likely to affect endangered species.

Native American Graves Protection and Repatriation Act (25 USC 3001 Through 3013; 43 CFR Part 10) and Washington's Indian Graves and Records Law (Chapter 27.44 RCW): These statutes prohibit the destruction or removal of Native American cultural items (human remains and associated funerary objects, graves, cairns, pictographs, glyptics, or other painted records) and require written notification of their inadvertent discovery to the appropriate agencies and Native American tribe. Because the Site area has been occupied or otherwise used by Native American tribes, remediation activities could uncover Native American graves or other protected items; therefore these programs are applicable to the Site cleanup, but only if the listed items are found. The remedial action must cease in the area of the discovery; a reasonable effort must be made to protect the items discovered before such activity is resumed; and notice must be provided as described above.

Archaeological Resources Protection Act (16 USC 470aa et seq.; 43 CFR Part 7): This program sets forth requirements that are triggered when archaeological resources are discovered. It requires that excavation of these resources be conducted under a permit by professional archaeologists. These requirements apply only if archaeological items are discovered during implementation of the selected remedy.

National Historic Preservation Act (NHPA) (16 USC 470 et seq.; 36 CFR Parts 60, 63, and 800): This regulatory program sets forth a national policy of historic preservation and provides a process that must be followed to ensure that impacts of actions on archaeological, historic, and other cultural resources are considered. NHPA requirements apply to federal sites but should be considered when evaluating location specific ARARs at the Site.

2.5 Potential Action-Specific Requirements

Action-specific ARARs are requirements that define acceptable management practices and are usually specific to certain kinds of activities that occur or technologies that are used during the implementation of cleanup actions.

Washington Dangerous Waste Regulations (Chapter 173-303 WAC): These requirements potentially apply to the identification, generation, accumulation, and transport of hazardous/dangerous (hazardous) wastes at the Site. Under Ecology's Area of Contamination (AOC) policy, if contaminated soil is managed within an AOC, it is not considered to be “generated” as a hazardous waste, even if constituent concentrations would cause it to exceed regulatory levels and ordinarily be called a hazardous waste. Ecology may set an AOC or AOCs for a site-undergoing cleanup under a MTCA Consent Decree. Hazardous waste requirements would therefore not apply unless the wastes resulting from the Site cleanup action were moved outside the boundary of the AOC.

Federal land disposal restrictions (LDRs) under 40 CFR Part 268 require that hazardous wastes be treated prior to being disposed of in a land-based disposal unit. EPA has developed special LDRs for contaminated soil and debris. The treatment standards for these substances are expressed as numerical limits and treatment methods, respectively. These standards would generally not apply to contaminated media disposed of within an AOC; however, they could be relevant and appropriate.

Solid Waste Management Act (Chapter 70.95 RCW; Chapter 173-304 and 173-351 WAC): Potential Site cleanup actions include on-Site treatment and consolidation of solid wastes. MTCA specifically includes the solid waste landfill closure requirements as a potential ARAR. If wastes or contaminated soil are to be disposed of on-site, the design requirements of the solid waste landfill regulations may be relevant and appropriate. These design standards include slope, cover, and other structural requirements.

Water Quality Standards for Surface Waters of the State of Washington (Chapters 90.48 and 90.54 RCW; Chapter 173-201A WAC): This regulation is an action-specific ARAR because the remedial actions at the Site (e.g., soil movement and disposal) must not result in any exceedance of surface water quality standards (unless a short-term modification of water quality has been approved by Ecology ahead of the activity; see WAC 173-201A-110). Surface water quality standards such as turbidity, temperature, and metal limits could apply to the remedial actions.

Ecology has designated Puget Sound as a Class A (excellent) water body; Sequalitchew Creek is also a Class A surface water body. Old Fort Lake would fall into the Lakes class. These classifications determine the beneficial uses that must be maintained for the surface water thus labeled and, therefore, the water quality standards as well (i.e., the higher the water quality, the more stringent the standard may be).

This regulation also governs the discharge of wastewater to surface water and groundwater, including discharges from municipal sewer systems to surface water or groundwater. Finally, it provides for use of best management practices for stormwater management on construction sites. Specifically, Chapter 173-216 WAC requires that all known, available, and reasonable treatment (AKART) be used to remove contaminants from wastewater prior to discharge to meet state surface water and groundwater quality standards.

Federal, State, and Local Air Quality Protection Programs: Regulations promulgated under the federal Clean Air Act (42 USC 7401) and the Washington State Clean Air Act (Chapter 70.94 RCW) governs the release of airborne contaminants from point and non-point sources. Local air pollution control authorities such as the Puget Sound Clean Air Agency (PSCAA) have also set forth regulations for implementing these air quality requirements.

Chapter 173-460 WAC, Controls for New Sources of Toxic Air Pollutants, requires that point-source emissions for major sources of regulated air toxics be treated using best available control technologies for toxics (T-BACT) prior to discharge, and that emissions do not cause ambient air concentrations of these chemical constituents to exceed established ambient source impact levels (ASILs). Chapter 173-460 WAC establishes ASILs for several of the chemical constituents at the Site, including arsenic, mercury, TNT, and PAHs. Similar requirements and ambient concentration limits have been adopted by PSCAA under Regulation III, and it is these local requirements, which are at least as stringent as the state and federal requirements, that apply to the Site.

Department of Transportation Hazardous Materials Regulations (40 CFR Parts 171 Through 180): The U.S. DOT has promulgated regulations that govern the transportation of hazardous materials, including packaging, labeling, placarding, and communications and emergency response requirements. The U.S. DOT and state regulations will apply to any hazardous materials transported off-site as part of the remediation.

Washington State Water Well Construction Act (Chapter 18.104 RCW; Chapter 173-160 WAC): This regulation governs the minimum standards for construction, maintenance, and abandonment of wells, including both water supply wells and resource protection wells (e.g., monitoring wells). These regulations will apply to any Site monitoring wells that are closed (abandoned) as part of the remedial action or new wells installed.

City of DuPont Regulations and Standards: The City of DuPont has established regulations and standards which governs the minimum standards for grading and setbacks from sensitive areas and wetlands. These substantive requirements of these regulations and standards, as they relate to the cleanup process, will be met and addressed as part of the remedial design process.

2.6 Screening of ARARs

A screening of ARARs was conducted to assess their applicability to the Site. Only those that were determined to be applicable were retained as an RAO. The following list identifies the ARARs that are potentially applicable to the Site.

Potential Cleanup Levels and Chemical-Specific ARARs

- The Model Toxics Control Act (Chapter 173-340 WAC).

Potential Location-Specific Requirements

- Washington State Shoreline Management Act (Chapter 90.58 RCW; Chapters 173-18, 173-22, and 173-27 WAC).
- Pierce County Shoreline Management Use Regulation (Title 20).
- Pierce County Development Regulations—Critical Areas (Title 18E).
- Washington State Hydraulic Projects Approval (Chapters 75.20.100 Through 75.20.160 RCW; Chapter 220-110 WAC).
- The Fish and Wildlife Coordination Act.
- Endangered Species Act (16 USC 1531 et seq.; 50 CFR Parts 17, 225, and 402).
- Native American Graves Protection and Repatriation Act (25 USC 3001 Through 3013; 43 CFR Part 10) and Washington's Indian Graves and Records Law (Chapter 27.44 RCW).
- Archaeological Resources Protection Act (16 USC 470aa et seq.; 43 CFR Part 7).

Potential Action-Specific Requirements

- Washington Dangerous Waste Regulations (Chapter 173-303 WAC).
- Solid Waste Management Act (Chapter 70.95 RCW; Chapter 173-304 and 173-351 WAC).
- Water Quality Standards for Surface Waters of the State of Washington (Chapters 90.48 and 90.54 RCW; Chapter 173-201A WAC).
- Federal, State, and Local Air Quality Protection Programs.
- Department of Transportation Hazardous Materials Regulations (40 CFR Parts 171 Through 180).
- Washington State Water Well Construction Act (Chapter 18.104 RCW; Chapter 173-160 WAC).
- City of DuPont Regulations and Standards.

Table 2-1 – Risk-Based Remediation Levels

Constituent	Site Specific Cleanup Levels[(1)] (mg/kg)	MTCA Method C Industrial Cleanup Level[(2)] (mg/kg)	Commercial Remediation Level (mg/kg)	Golf Course Land Use Remediation Level (mg/kg)	Historical Remediation Level (mg/kg)	Open Space Remediation Level (mg/kg)
Explosives						
Total DNT	3.0	–	–	–	–	–
2,4,6-Trinitrotoluene	1.75	1,750	1,230	1,230	172	172
Inorganics						
Arsenic	32	90	60	60	32[(4)]	32[(4)]
Lead[(3)]	–	1,000	2,100	2,100	1,500	1,500
Mercury	24	1,050	737	737	247	247
Pesticides						
Aldrin	–	7.7	5	5	0.3	0.3
TPHs and PAHs						
Bunker C	7,600	–	–	–	–	–
Benzo(a)Pyrene	–	18	13	13	0.7	0.7

Notes:

[(1)] Where remediation levels were calculated for both carcinogenic and noncarcinogenic effects, the value shown in the table is the lower of the two values.

[(2)] Industrial Cleanup levels were calculated using equations and exposure factors for MTCA Method C (WAC 173-340-745)

[(3)] Except for the Industrial lead soil level, which is the historical MTCA Method C industrial value, all other lead values were derived by Ecology using the lead biokinetic models for children and adults (Ecology, 1999a).

[(4)] Value is site-specific background level for arsenic. This level was approved for use by Ecology (Ecology, 1999b).

– = Not developed.

2.7 References for Chapter 2

URS Corporation (URS). 2000. *Cultural Resources Protection Plan, Remedial Investigation/Feasibility Study,* Appendix G. Former DuPont Works Site, Dupont, Washington.

Ecology (Washington State Department of Ecology). 1999a. Non-Residential Remediation Levels at the Former DuPont Works Site. Memo from Mike Blum to Vern Moore and Izzy Zanikos. May 3, 1999. (Memo is presented in Appendix C).

Ecology (Washington State Department of Ecology). 1999b. Soil Arsenic Non-Residential Remediation Levels. Memo from Mike Blum to Vern Moore and Izzy Zanikos. June 25, 1999. (Memo is presented in Appendix C).

EPA, 1992. Guidance on Risk Characterization for Risk Managers and Risk Assessors. Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant and Regional Administrators. February 26, 1992.

Pioneer Technologies Inc., 2002. Draft Risk Assessment, Former DuPont Works Site, Dupont, Washington. March 15, 2002.

Hart Crowser, 1992. Management Plan, Remedial Investigation/Feasibility Study, Former DuPont Works Site, Dupont, Washington. January 17, 1992.

Chapter 3 – ESTIMATED VOLUMES OF SOIL FOR REMEDIATION

3.1 Introduction

This chapter describes the following:

- Site remediation units are defined in Section 3.2;
- Section 3.3 describes the procedures that were used to estimate the impacted soil volumes, and present the volumes of in-place soils by RU type; and
- Section 3.4 summarizes the total estimated soil volume that is addressed in this FS.

3.2 Definition of Remediation Units

RUs are generally defined in this FS as areas of the Site with similar future land uses. The exception is the Miscellaneous Small RUs where the RUs were grouped by distinct constituent types, concentrations, or where deposition of those constituents is believed to have occurred by similar mechanisms. The names and descriptions of the remediation units that are used throughout this FS report are as follows:

Golf Course RUs: All property inside the golf course footprint. There are nine golf course RUs comprising 187 acres. The amount of remediation required in these RUs is related to the alternative selected and ranges from the entire 187 acres to less than 100 acres under a limited cap/cover scenario. Under a limited cap/cover scenario, roughly 73 acres would be used for soil placement and cap/cover.

Open Space RUs: These RUs represent the open space areas of the Site. Four open space RUs occur on-Site. They are North Sequalitchew Creek Canyon, South Sequalitchew Creek Canyon (broken into two RUs) and the Old Fort Lake Greenbelt. These RUs represent 73 acres.

Commercial RUs: All Site property planned for commercial development. There are nine Commercial RUs consisting of approximately 334 acres.

Historical RUs: These RUs make up the areas of the Site that have historic significance. Three historical RUs occur on-Site consisting of approximately 6 acres. They are the Fort Nisqually Cemetery (45PI404), the south Shell Midden (45PI72), and the 1833 Fort Nisqually Site (45PI55. An additional historic site, the small Shell Midden (45PI485) along Sequalitchew Creek, is included in the Sequalitchew Creek open space RU and will be addressed in the same manner as the remainder of that RU.

Miscellaneous Small Remediation Units: These remediation units are those that have unique characteristics and are small in size (less than 2 acres) and volume (requiring excavation of less than 5,000 CY). These unique characteristics could be any of the following:

- Similar mixture of contaminants;
- Similar deposition method (localized spill, localizes disposal site, etc.);
- Small occurrence(s) of a single contaminant;
- Contaminant “hot spots” discovered during final cleanup;
- Debris; and
- Location: An example would be sections of the Narrow Gauge Railroad track within Sequalitchew Creek Canyon. This RU is represented by the linear length of the track and the width of track bed from the toe of the uphill slope and the crest of the downhill slope.

3.3 Soil Volumes

Estimates of soil volume were based on interpretation of sample data collected during the RI and subsequent ISR or characterization efforts. Volumes reported below are pre-remedy estimates. The actual amount of soil to be excavated during the cleanup action will increase or decrease based on effectiveness of the remedy chosen as verified by the actual field sampling data (i.e., confirmation samples) obtained during the cleanup action, or the error inherent in the volume estimation process.

Only in-situ soils with lead and/or arsenic concentrations above the respective CLs or RLs are included in the estimated soil volumes for remediation. Additional volumes of non-lead and non-arsenic soils are associated with Miscellaneous Small RUs. Estimating the final volume of in-place impacted soil that must be addressed in miscellaneous small units with certainty is very difficult. These units are small and have many unique characteristics. For these units, an alternate approach based on Site knowledge and good technical judgment was developed that will provide reasonable estimates. This approach estimates the total volume associated with contamination discovered as a result of confirmation sampling as 0.5% of the total know volume of arsenic and lead impacted soil. As such, the total volume associated with Miscellaneous Small RUs equals the total known volume plus 0.5% of the total lead and arsenic impacted soil volume Site-wide.

3.4 Soil Volume Estimation Procedures

Soil volumes were estimated using the Pre-RI and RI analytical data and verification sample analytical data from the ISR and maps generated for the RI and RA reports. Excavated volumes are calculated by multiplying the in-place soil volumes by a “fluff” factor, which accounts for volume expansion that results from excavation. Based on laboratory and field measurements of Site soils, an excavation fluff factor of 1.25 was used. These volumes, in some cases, were converted to tons on a 1 CY = 1.4 tons basis. This conversion was developed from actual site data recorded during the 2001 Soil Screening Interim Cleanup Action.

Generally, the excavation depth used to estimate excavated soil volume was 1.25 feet. This estimate is based upon the 95% upper confidence level (UCL) of the actual vertical extent of lead and arsenic contamination statistically above the Site-specific RLs (determined to be 1 foot in depth) and a reasonable safety factor of 25%. The following assumptions/process were used to determine the 95% UCL.

- Each sample point was evaluated to assess the vertical extent of contamination. The depth of each constituent was determined by using the bottom of the sample interval above the RL in a test pit, boring, or hand auger exploration. (No interpolation was used when determining the depth). When surface samples only were above the RL, the depth was set at one foot.
- Once the sample evaluation was complete the sample data was evaluated using Ecology’s Threefold Statistical Process to determine at which depth compliance could be reached.

Due to the complexity of the Site and the difficulty in predicting the presence and location of isolated occurrences of lead and arsenic contamination above the Site-specific RLs, four separate methods were used to determine the lateral extent of contamination in each RU.

- For localized contamination, the lateral extent associated with a sample point above the RL was assumed to be 25 feet from the limit of the bermed area or limit of the former building foundation. This estimate was based on best professional judgment of a reasonable scenario for deposition of the constituent, such as construction material (lead sheeting on floors, workbenches). When no depositional constraints were present near the sample location, a 25-foot-square area centered over the sample location approximated the limit of impact. When two or more adjacent samples were above the RL and none of the depositional constraints were present, the area between the sample locations was included.
- The estimate of impacted soil volumes in the Narrow Gauge Railroad Tracks (NGRR) was based on sample analytical results which show that arsenic concentrations decreased significantly beyond 25 feet (see the RI). The length of impacted NGRR was interpolated between sampling locations with concentrations that are above and below the RL.
- For those areas of the Site where concentrations of lead and arsenic contamination approached the RLs, the prediction of the presence or absence of contamination becomes

difficult and impractical. In these areas the entire square footage of the RU was deemed to be contaminated.

- Debris volume was determined assigning an in-situ volume of 740 CY per known location. This estimate assumes a 50-foot by 50-foot lateral occurrence, which is 8 feet deep.

Note that these assumptions were used only for estimating impacted volumes. Actual volumes and limits of excavations will be determined by confirmation sampling conducted during the cleanup action.

3.4.1 In-Place Volumes of Impacted Soil

The following estimates of soil volume were calculated using the assumptions listed. Table 3-1 presents the estimates of in-situ volume of impacted soils by RU. They represent impacted volumes prior to the selection of any remedy. The selection of a remedy will change these volumes either upward or downward.

Golf Course RUs: The estimated in-place contaminated soil volume in the golf course RUs is 301,693 CY. Using the “fluff” conversion factor of 1.25, the excavated volume is 377,117 CY.

Open Space RUs: The estimated in-place contaminated soil volume in these RUs is 117,773 CY. Using the “fluff” conversion factor, the excavated volume is 147,217 CY.

Commercial RUs: The estimated in-place contaminated soil volume in these RUs is 554,987 CY. Using the “fluff” conversion factor, listed above, the excavated volume is 693,733 CY.

Historical RUs: The in-place contaminated soil volume in these RUs is 9,680 CY. Using the conversion factor, listed above, the excavated volume is 12,100 CY.

Miscellaneous Small RUs: The known volumes of the soil requiring remediation, for each Miscellaneous Small RU, are as follows:

- <u>Similar mixture of contaminants</u>: There are 3 locations where this type of occurrence is present. Using the criteria listed above this equates to approximately 173 CY excavated volumes of soil.
- <u>Similar deposition method:</u> There are 9 locations where this type of occurrence is present. Using the criteria listed above this equates to approximately 184 CY excavated volumes of soil.
- <u>Small occurrence(s) of a single contaminant</u>: There are 113 locations where this type of occurrence is present. Using the criteria listed above this equates to approximately 4,689 CY excavated volumes of soil.
- <u>Contamination “hot spots” discovered during final cleanup:</u> Since the impacted soil quantity in “discovered hot spots” is unknown, the impacted soil volume will be estimated at 0.5% of the total lead- and arsenic-impacted soil. As such, the in-situ contaminated soil volume in these RUs is 4,630 CY. Using the “fluff” conversion factor of 1.25, the excavated volume is 5,788 CY.
- <u>Debris:</u> Debris occurs both as stockpiled material and in-situ. Interim source removal/cleanup actions have discovered 20 discrete in-situ debris locations. Their depth and regulatory status is unknown. As such, it was assumed that each of these locations represent 740 CY excavated volume of contaminated debris for a total of 18,500 CY.
- <u>Sequalitchew Creek NGRR:</u> Approximately 2,000 linear feet of NGRR track bed remains in Sequalitchew Creek Canyon that will require remediation. This represents an estimated in-place volume of impacted soil of 1,852 CY. Using the “fluff” conversion factor of 1.25, the excavated volume is 2,315 CY. Estimated Soil Volumes Summary

Table 3-1 presents a summary of estimated in-place soil volumes above RLs for the Site organized by RU. The total excavated volume of soil associated with each remediation unit is also presented in the table. The total estimated volume of excavated soil and debris that may require remediation is approximately 1,261,815 CY. Figure 3-1 identifies the areas where mass excavation will occur.

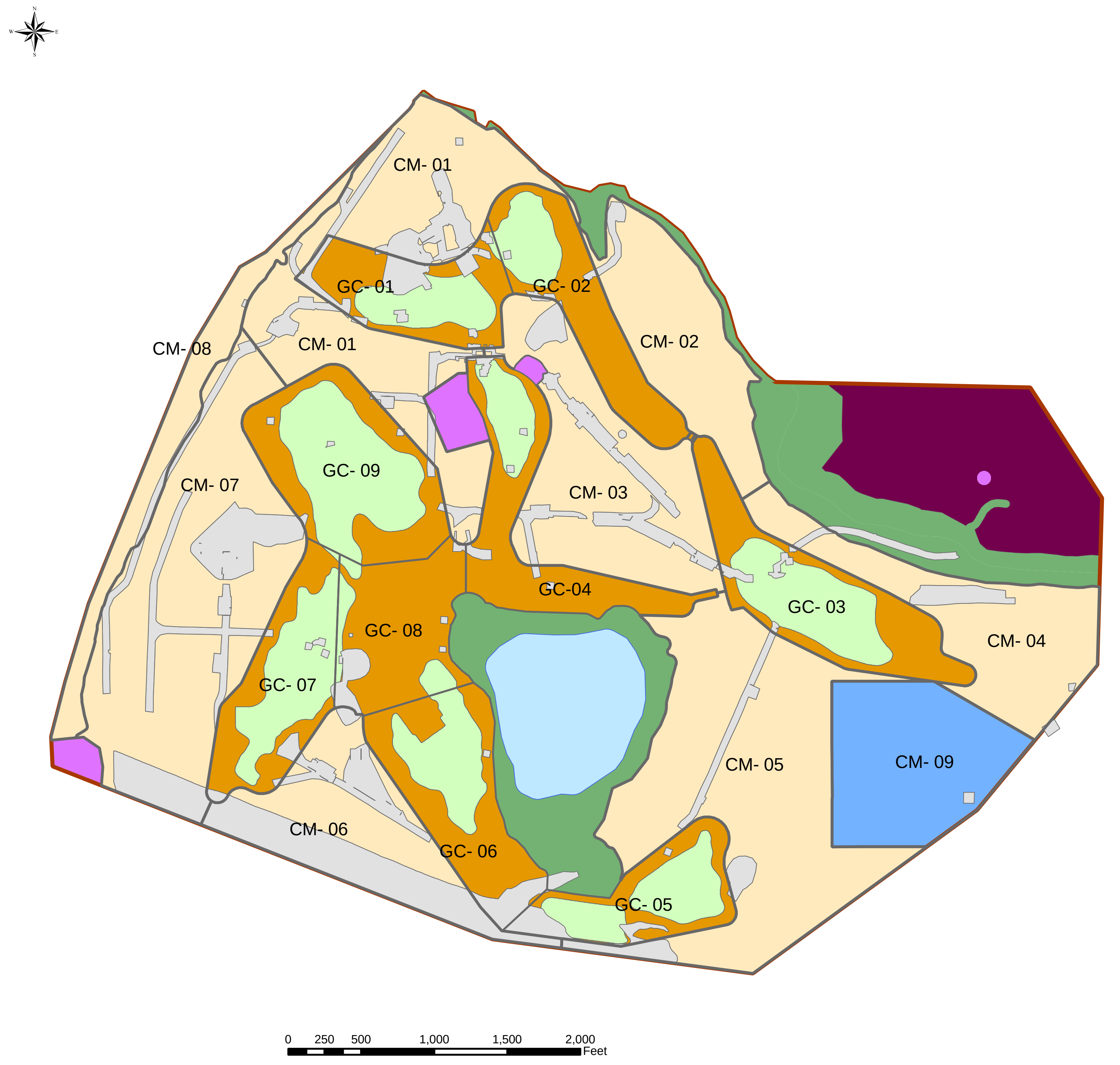
These estimated soil volumes are to be used as the basis for:

- The screening of technologies and process options (Chapter 4);
- Screening and analysis of alternatives (Chapters 6 and 7);
- Selecting the preferred alternative (Chapter 8); and
- The development of scope for treatability studies (Chapter 5).

Table 3-1 – Estimate of In-Situ Impacted Soil Volume for Each RU

Remediation Unit Type - Mass Excavation	Number of RUs	Acreage	In-situ Volume (CY)	Excavated Volume (CY)	Weight in Tons
Golf Course	8	187	301,693	377,117	527,963
Commercial	11	344	554,987	693,733	971,227
Open Space	3	73	117,773	147,217	206,103
Historic	3	6	9,680	12,100	16,940
Miscellaneous Small RUs	**Occurrences**				
Similar Mixtures	3		139	173	243
Similar Deposition	9		147	184	257
Single Contaminant	113		3,751	4,689	6,564
"Hot Spots"	NA		4,630	5,788	8,103
Sequalitchew Creek NGRR	2,000		1,852	2,315	3,241
TOTAL VOLUME - Soil			994,652	1,243,315	1,740,641
Debris	20		14,800	18,500	25,900
TOTAL VOLUME - Soil and Debris			1,009,452	1,261,815	1,766,541

Notes:
NA = Not applicable.



Legend

- 🟪 Historical Area
- 🟧 Golf course area to be scraped
- 🟨 Commercial area to be scraped
- 🟦 Old Fort Lake
- 🟩 Open Space
- ▭ Consent Decree Boundary
- ⬜ ISR Excavations SOC
- 🟦 Area in Compliance
- 🟪 Industrial Area
- 🟩 Placement Area

Notes

Scraped area omits Placement Area, ISR Excavations, Historical Areas, Open Space, and Industrial Areas in the calculation.

Total commercial acres to be scraped: 251.9 acres

Area scraped in each unit:
CM-01: 38.9 acres
CM-02: 23.8 acres
CM-03: 30.6 acres
CM-04: 26.3 acres
CM-05: 60.0 acres
CM-06: 12.4 acres
CM-07: 45.3 acres
CM-08: 14.6 acres

Total golf course acres to be scraped: 104.4 acres

Area scraped in each unit:
GC-01: 7.7 acres
GC-02: 13.2 acres
GC-03: 13.1 acres
GC-04: 15.6 acres
GC-05: 5.8 acres
GC-06: 13.2 acres
GC-07: 8.7 acres
GC-08: 15.2 acres
GC-09: 12.0 acres

ISR: Interim Source Removal
SOC: South of Creek

Historical location in the Industrial area is the Methodist Mission Marker. Actual location of the mission is unknown.

Scraped Units

Former DuPont Works Site

July 2003

Figure 3-1

Chapter 4 – IDENTIFICATION AND SCREENING OF TECHNOLOGIES

4.1 Introduction

This chapter summarizes the development of a list of preliminary screening of technologies and associated process options, and initial qualitative screening of technologies. Section 4.2 presents a list of databases reviewed in developing a list of potentially applicable technologies. Section 4.3 describes the technology screening process. Preliminary screening was performed using engineering judgment to assess the effectiveness of each technology in reducing potential Site risks. Technologies that passed through the preliminary screening were then further qualitatively screened, based on effectiveness, implementability, and cost. Tables 4-1 and 4-2 provide a synopsis of this information. Section 4.4 summarizes representative process options (at least one for each technology) that were selected following qualitative screening for compilation into remedial alternatives as presented in Chapter 6. Appendix A presents a detailed discussion of the general response actions, process options, or technologies, including limitations for cleanup of soils containing certain metals and mixtures of metals.

The screening of technologies and process options in this section focuses on the soil volumes defined in Chapter 3. Additionally, the RAOs summarized in Chapter 2 form the basis for the preliminary screening of technologies and process options.

4.2 Development of Candidate Technologies and Process Options

A list of potentially applicable technologies and process options was developed using the following resources:

- Vendor Information System for Innovative Treatment Technologies (VISITT) database, Version 2.0;
- EPA Risk Reduction Engineering Laboratory (RREL) database;
- EPA Superfund Innovative Technologies Evaluation (SITE) demonstrations;
- Remedial Technologies Screening Matrix and Reference Guide, USEPA and U.S. Air Force, July 1993;
- In-house DuPont Company experience;
- In-house consultant and contractor experience;
- Other consultant reports;
- Treatability studies for other sites; and
- Literature survey.

The technologies are grouped according to "general response actions." These are the broad categories of remedial measures that may be implemented alone or in combination to meet the RAOs. The potentially applicable technologies and process options are presented in the first three columns of Table 4-1. Note that process options are a subset of technologies and describe the different systems, equipment, or chemical processes that were considered as potentially applicable alternatives for remediation of the Site. The fourth column of the table includes a brief description of each process option. This description is included to aid the reader in understanding each process option.

4.3 Technology Screening

Screening of potentially applicable technologies was performed in two steps. First, a preliminary screening was performed to identify technologies that may be applicable to the Site. The preliminary screening was based on a technology's broad-based effectiveness in reducing Site risks. The technologies selected on the basis of preliminary screening then went through a second tier of screening, an initial qualitative screening.

4.3.1 Preliminary Screening

The preliminary screening eliminated technologies or process options, which, for technical reasons, could not be implemented or would not be effective (i.e., technically infeasible), including the following:

- Technologies that have been demonstrated only in a laboratory;
- Technologies that cannot achieve the Cleanup Standards required at the Site; and
- Technologies that are not applicable to the Site for practical reasons.

Table 4-1 summarizes the preliminary screening of technologies and process options. Technologies and process options deemed not applicable are indicated by shading. For example, cryogenic freezing was not a suitable immobilization technology since this process is not a permanent solution. The last column of Table 4-1 presents a brief comment on the applicability of the process option, based on the technology's ability to achieve RAOs. These comments provide explanation as to why a particular process option was retained for further evaluation or rejected.

4.3.2 Technologies That Rely On Stabilization/Solidification

Past interim source/cleanup actions have removed the majority of the known soil locations where lead and arsenic concentrations could potentially be above levels at which characteristic dangerous waste limits could apply. As such, technologies that rely on the mass stabilization of soils to reduce the leachability of lead and arsenic-impacted soils to below the hazardous designation were not retained. Stabilization was retained for further evaluation where the alternative concentrates the contaminants into a smaller volume (i.e. Wet Screening with Stabilization, On-Site Deposition and Cap/Cover).

4.3.3 Initial Qualitative Screening

The process options retained from the preliminary screening were evaluated in the initial qualitative screening. MTCA requires that technologies and processes are screened to determine if the alternatives selected for further evaluation represented those that were permanent to the maximum extent practicable (as defined by WAC 173-340-360 (3)(b)). For this phase of screening the MTCA required criteria were grouped in the following manner:

Effectiveness: Effectiveness contains those criteria that evaluate the state of development of the technology, the ability to protect human health and the environment, and identifies potential negative impacts associated with the technology. Under this heading are the following MTCA criteria:

- <u>Protectiveness:</u> This evaluation considers the degree of protection each technology provides to human health and the environment, the extent to which reductions in risk, toxicity, and/or mobility are expected to be achieved, the time required to reduce risk and obtain cleanup standards, the off-Site and on-Site risks resulting from the implementation of the alternative, and the degree of improvement of the overall environmental quality.
- <u>Permanence:</u> This evaluation considers the degree to which the alternative permanently reduces the toxicity, mobilization or volume of the contaminants. The evaluation considers the materials treated, quantity of material treated, degree of toxicity, mobility, and volume reduction, degree to which the treatment is irreversible, and residuals type and quantity.

- Long Term Effectiveness: This evaluation considers the effectiveness of the process during the time when contaminant concentrations remain on-Site that are greater than CLs or RLs, the magnitude of risk with the alternative in place, and the adequacy and reliability of any Site controls.

- Management of Short Term Risks: This evaluation considers the effectiveness of the process in dealing with the potential impacts to human health and the environment during the implementation phase.

- Consideration of Public Concerns: This evaluation considers any local community concerns over the alternative and how the alternative addresses those concerns.

Implementability: Implementability involves the technical and administrative feasibility of constructing, operating, and maintaining a particular remediation technology. Technical implementability has already been used in the preliminary screening. At this stage, the emphasis is placed on the institutional aspects of implementability, such as the ability to obtain the necessary permits; the availability of treatment, storage, and disposal services; and the availability of necessary equipment and skilled workers to implement the technology.

Cost: The cost for remediation work includes such items as installation and operation of process equipment, excavation, and disposal fees. The cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are high, medium, or low relative to other process options in the same technology category.

Table 4-2 summarizes the evaluation of the general response actions, technologies, and process options retained after the preliminary screening. In Table 4-2, process options that do not meet the screening criteria and were not considered acceptable based on this initial qualitative screening are indicated by shading. The remaining process options and technologies were retained for further development, assembly, and analysis as remedial alternatives in Chapter 6.

4.4 Representative Processes Selected for the Development of Alternatives

The technologies selected from the two-step screening process include several process options. The "cover" technology, for example, includes eight process options (clean soil cover, re-vegetation, synthetic membrane cap, clay cap, asphalt cap, asphalt/concrete cap, cement cap, and multimedia cap). Many of these process options are similar since they reduce potential exposure. To include all combinations of process options in the development of alternatives would result in the evaluation of hundreds of alternatives with limited benefit.

In some cases, the various process options are sufficiently different in their performance that one would not adequately represent the other. In these cases, more than one process option may be selected for a technology type. For example, under the volume reduction technology it was concluded that classification and screening were sufficiently different in performance and cost for both to be included in the remedial alternative development.

The following soil process options were selected as representative:

Technology	Representative Process Option(s)
Access Restrictions	• Deed Restrictions
Monitoring	• Soil Sampling
Cover	• Soil Cover
Cap	• Synthetic Membrane • Asphalt/Concrete Cap • Portland Cement Cap • Multimedia Cap
Cap/Cover	• Multimedia Cap • Soil and Gravel Cap
Dust Control	• Water Spraying • Plastic Cover
Immobilization	• None Selected
Excavation	• Conventional Equipment
Off-Site Disposal	• Hazardous Waste Landfill • Demolition Debris Landfill
Recycling	• None Selected
Thermal	• None Selected
Volume Reduction	• Solvent/Chelant Extraction • Acid or Base Extraction • Soil Classification • Sieving and Screening

These technologies and representative process options are discussed in greater detail in Appendix A. The actual process options to be used will be defined in the Cleanup Action Plan. The technologies and representative process options identified in this section are combined into alternatives in Chapter 6 and evaluated in more detail in the remainder of this FS.

Table 4-1: Preliminary Screening of Technologies and Process Options

Page 1 of 5

General Response Action	Technology	Process Options	Descriptions	Screening Comments
No Action	None	Not Applicable	No Action	Required as a baseline condition
Institutional Controls	Access Restrictions	▨ Fence	Fence site perimeter	Perimeter fence in place
		▨ Warning Signs	Post Signs indicating contamination and require safety gear	Warning Signs in place
		Deed Restrictions	Legally restrict land use on property deed	Deed restriction in place
		Health and Safety Equipment	Require Protective clothing for all site personnel	Applicable during cleanup
		▨ Fishing /Hunting Restrictions	Restrict Fishing and hunting for human consumption	Restrictions in place
	Monitoring	Groundwater	Test Groundwater for Contaminant levels	DNT in groundwater near or below drinking H2O standards
		▨ Surface Water	Test Surface Water for Contaminant levels	Surface water in compliance with MTCA
		Air	Test air for particulate levels	Applicable during cleanup
		Soil	Test soil for contaminant levels	Applicable during cleanup
		Tissue	Test animal tissue for contaminant levels	Not a major exposure pathway

▨ Eliminated from further Consideration

Table 4-1: Preliminary Screening of Technologies and Process Options

Page 2 of 5

General Response Action	Technology	Process Options	Descriptions	Screening Comments
Containment	Cover	Clean Soil	Layer of Clean Soil	Potentially Applicable
		Re-Vegetation	Vegetate exposed soil	Potentially Applicable
	Cap	Synthetic Membrane	Impermeable membrane	Potentially Applicable
		Clay Cap	Compacted Clay	Potentially Applicable
		▨ Asphalt Cap	Asphalt Membrane	Membrane will crack over time
		Asphalt/Concrete cap	Asphalt Pavement	Potentially Applicable
		Portland Cement Cap	Concrete over exposed soils	Potentially Applicable
		Multimedia Cap	Combine two of the above	Potentially Applicable
	Impermeable Liner	▨ Membrane & Clay	Impermeable liner & clay	Not Applicable: Pb & As not leachable
		▨ Grout Injection	Bentonite Slurry	Not Applicable: Pb & As not leachable
	Cap/Cover	Multimedia Cap	Combine two of the above	Potentially Applicable
		Soil/Gravel Cap	Soil and Gravel to restrict exposure	Potentially Applicable

To Dust Control

▨ Eliminated from further Consideration

Table 4-1: Preliminary Screening of Technologies and Process Options

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General Response Action	Technology	Process Options	Descriptions	Screening Comments
Containment	Dust Control	Water Spraying	Wet Exposed Soils to prevent dust	Potentially Applicable
		Dust Suppressants	Apply chemical binder to exposed Soils to prevent dust	Potentially Applicable
		▨ Wind Fence	Barrier to deflect wind	Irregular wind direction
		Plastic Cover	Plastic cover over exposed soils	Potentially Applicable
		▨ Vegetation	Temporary vegetation cover over exposed soils	Timeframe for growth inhibits production

▨ Eliminated from further Consideration

Table 4-1: Preliminary Screening of Technologies and Process Options

Page 4 of 5

General Response Action	Technology	Process Options	Descriptions	Screening Comments
Removal	Excavation and Off-site Disposal	Hazardous Waste Landfill	Dispose of soils in permitted HazWaste landfill	Applicable during cleanup
		Solid Waste Landfill	Dispose of soils in lined solid waste landfill	Applicable during cleanup
		Demolition Debris Landfill	Dispose of soils in unlined solid waste landfill	Applicable during cleanup
Immobilization	Solidification/ Stabilization	Portland Cement	Solidify soils with cement	Potentially Applicable during cleanup
		Silicate Based	Solidify soils with Flyash	Potentially Applicable during cleanup
		Thermoplastic	Solidify soils with asphalt	Applicable for TPH soils
		▨ Encapsulation	Contain soils in organic resin	Not applicable. Not proven on commercial scale
		▨ Cryogenic Encapsulation	Solidify soils by freezing in-place	Not applicable. Not proven on commercial scale
		▨ In-situ Vitrification	Solidify soils into glass using high voltage electricty	Not applicable. Not proven on commercial scale
		▨ Surfactant Fixation	Surfactants percolated through soils to bind contaminants	Not applicable. Not proven on commercial scale
		Surface Soil Fixation	Soil mixing and grinding with an additive for stabilization	Not applicable. Will not reduce contaminant levels.

▨ Eliminated from further Consideration

Table 4-1: Preliminary Screening of Technologies and Process Options

Page 5 of 5

General Response Action	Technology	Process Options	Descriptions	Screening Comments
Treatment	Recycling	To Lead Smelter	Layer of Clean Soil	Potentially Applicable
		To Cement Kin	Vegetate exposed soil	Potentially Applicable
	Thermal	▨ Thermal Desorption	Desorption of metal from heated soil	Not Applicable to Pb and As
		▨ Hydrogen Volatilization	High temperature distillation in hydrogen	Not Applicable - experimental
		▨ Slagging with Off Gas Treatment	Volatize Pb and As and condense as metal oxides	Insufficient capacity to treat large volume of soil
	Volume Reduction	Solvent or Chelant Extraction	Soils mixed with solvent or chelant to remove metals	Potentially Applicable
		▨ In situ Extraction	Solvent delivered to in-situ soils to leach out metals	Not applicable – shallow contamination
		Acid/Base Extraction	Soils mixed with acid or base to remove metals	Potentially Applicable
		▨ Electrical Separation	Direct current to transfer contaminants to cathodes	Not Applicable to sand and gravel
		Sieving and screening	Screening of soils into size fractions	Potentially Applicable
		Classification	Particle size classification into coarse gravels and contaminated fines	Potentially Applicable

▨ Eliminated from further Consideration

Table 4-2: Evaluation of Process Options

Page 1 of 2

General Response Action	Technology	Process Option	Effectiveness	Implementability	Cost
No Action	None	None	Not Effective, Unacceptable to Companies and Ecology	Easily Implemented	Very low
Institutional Controls	Access Restrictions	Deed Restrictions	Some effect in reducing exposure, does not reduce contamination	Easily Implemented	Low
		Health and Safety	Some effect in reducing exposure, does not reduce contamination	Easily Implemented	Low
	Monitoring	Groundwater	Useful for documenting conditions, does not reduce contamination	Easily Implemented	Low
		Air	Useful for documenting conditions, does not reduce contamination	Easily Implemented	Low
		Soil	Useful for documenting conditions, does not reduce contamination	Easily Implemented	Low
Containment	Cover	Clean Soil	Moderately effective in reducing exposure	Easily Implemented	Low
		Re-vegetation	Marginal effect in reducing exposure	Easily Implemented	Low
	Cap	Synthetic Membrane	Effective in reducing exposure	Easily Implemented	Moderate
		Clay Cap	Tends to crack over time	Clay not readily available	Moderate
		Asphalt/Concrete Cap	Effective in reducing exposure	Easily Implemented	Moderate
		Portland Cement Cap	Effective in reducing exposure	Easily Implemented	Moderate
		Multimedia Cap	Effective in reducing exposure	Easily Implemented	Moderate
	Cap/Cover	Multimedia Cap	Effective in reducing exposure	Easily Implemented	Moderate
		Soil/Gravel Cap	Effective in reducing exposure	Easily Implemented	Moderate
	Dust Control	Water Spraying	Effective in reducing dust during remediation	Conventional construction practice	Low
		Dust Suppressants	Effective in reducing dust during remediation	Conventional construction practice	Moderate
		Plastic Cover	Effective in reducing dust from stockpiles	Conventional construction practice	Low

▨ Eliminated from further consideration

Table 4-2: Evaluation of Process Options

Page 2 of 2

General Response Action	Technology	Process Option	Effectiveness	Implementability	Cost
Removal	Excavation and Off Site Disposal	To Hazardous Waste Landfill	Effective in eliminating contamination on site, does not reduce contamination.	Moderately easy to implement	High
		To Solid Waste Landfill	Not effective for contaminated soils	Easily implemented	Moderate
		To Demolition Debris Landfill	Not effective for contaminated debris Effective for clean debris	Easily implemented	Low
Immobilization	Solidification/Stabilization	Portland Cement	Effective for wide range of chemicals, does not reduce total concentration of contaminates in soils	Easily implemented	Moderate
		Silicate- Based	Effective for wide range of chemicals, does not reduce total concentration of contaminates in soils	Easily implemented	Moderate
		Thermoplastic	Effective for wide range of chemicals, does not reduce total concentration of contaminates in soils	Easily implemented	High
Treatment	Recycling	Recycle to Lead Smelter	Effective for Lead	Difficult to implement due to availability of smelters	High
		Recycle to Cement Kiln	Effective for chemical which pass TCLP	Difficult to implement due to availability of Kilns	Low
	Volume Reduction	Solvent/Chelant Extraction	Effective in reducing volume of contaminated soil	Easily implemented	High
		Acid/Base Extraction	Effective in reducing volume of contaminated soil	Easily implemented	High
		Sieving and Screening	Effective in reducing volume of contaminated soil	Easily implemented	Low to Moderate
		Classification	Effective in reducing volume of contaminated soil	Easily implemented	Moderate

▨ Eliminated from further consideration

Chapter 5 – TREATABILITY STUDIES

5.1 Introduction

This chapter describes treatability studies that were conducted to further evaluate the technical and economic feasibility of applying the selected technologies to Site soils impacted by lead and arsenic.

Section 5.2 describes the objectives of the treatability studies; Section 5.3 describes the approach taken and summarizes the treatability studies conducted; Section 5.4 summarizes the pertinent results and provides an interpretation to be used in the selection of alternatives (Chapter 6) and their subsequent detailed analysis (Chapter 7). Section 5.5 summarizes the conclusions of the treatability studies and provides recommendations for additional treatability work.

5.2 Treatability Study Objectives

Extensive treatability studies were mainly completed prior to 2000/2001. They were mainly used to help understand lead/arsenic distribution and interactions with Site soils. The studies were also used to investigate ways to address high concentrations of lead- and arsenic-impacted soil. The 2000/2001 ISR actions removed the high concentrations of lead and arsenic soil (above "dangerous waste limits").

Only small amounts of high concentrations of lead and arsenic soil now remain, after 2000/2001, and these soils are in the miscellaneous small RUs. Though the pre-2000/2001 treatability studies will not play a major role in selecting/evaluating preferred alternatives for final cleanup, since they were geared to high concentrations of soils, they are still presented in this Chapter. The treatability studies still provide background, understanding and insight into how remaining lead- and arsenic-impacted soils can be managed to meet RAOs.

Various treatability studies were conducted to aid in the evaluation of treatment technologies related to physical screening and/or soil washing with extraction. This group of technologies was identified in Chapter 4 as a key component in developing remedial alternatives (Chapter 6) and their subsequent detailed analysis (Chapter 7). These studies where also useful in the design and completion of the 2001 Wet Screening ISR Program. The focus of these studies was to obtain data to:

- Confirm the suitability of these technologies for Site-specific soils;
- Identify potential problems associated with these technologies for application at the Site; and
- Define additional treatability work that may be conducted prior to Site remediation.

Lead- and arsenic-impacted soil remediation technologies that take advantage of the concentration distribution of constituents between the different size fractions of the soil matrix were the primary technologies investigated. Typically, higher concentrations of metals are associated with the smaller grain size soil fractions. By physically segregating the soils into two or more fractions, the following would be obtained:

- A coarse fraction that contains metal concentrations below remediation or cleanup levels that can be returned to the Site as soil for backfill; and
- One or more fine fractions that contain metal concentrations above remediation or cleanup levels that will require further treatment.

Wet Screening and Classification processes were investigated for their ability to achieve physical segregation. Soil Washing with Extraction was examined for constituent extraction potential. Recycling to a Thermal Process was investigated to assess the potential for treating the finer separated soil fractions that would be expected to exceed the remediation or cleanup levels.

The principal objectives of the treatability studies were to:

- Determine the grain size distribution of soil present at the Site;
- Determine the constituent distribution by soil grain size;
- Determine the chemical nature of the constituent; and
- Evaluate volume reduction potential by removal of "clean" soil fractions.

Table 5-1 summarizes the relevant soil characterization parameters used to assess the viability of the above-referenced treatment technologies.

5.3 Treatability Study Approach

The treatability study program used comprehensive soil characterization and speciation studies and bench-scale treatability testing to obtain data on the fundamental physical and chemical properties of the impacted soils. An overview of the program and the pertinent results are summarized in Appendices C and D.

The soil characterization parameters, a description of how the parameters are used, and the specific test types are presented in Table 5-2. (More detailed definitions of the parameters and the testing procedures are summarized in Appendix B.) The soil characterization parameters are organized in Table 5-2 as follows:

Physical Properties that may impact materials handling (e.g., during excavation, stockpiling, treatment, and residuals management). These include particle size distribution and Atterberg limits (liquid limit, plastic limit, and plasticity index) that are used to determine the USDA soil classification. Other physical properties measured were moisture content and bulk density of both loose and packed soil.

Regulatory Analyses to determine regulatory classification of waste streams which provides information for management and disposal of treatment residuals in accordance with federal, state, and local regulations.

Chemical Analyses to gather information on soil chemistry, soil mineralogy, soil/constituent interactions, and the distribution, speciation, and mobility of the lead and arsenic constituents. The chemical analyses and the information they provide include the following:

- pH and Generalized Acid Neutralization Capacity (GANC) measure the alkalinity or acidity of the soil and indicate inherent buffering capacity;
- GANC and Reverse GANC (RGANC) are soil leaching tests that measure a soil’s capacity to buffer an acid or a base. This information can be used to design solidification/stabilization design mixes. It can also be an aid in designing acid or base extraction treatment processes;
- Organic carbon and anions analyses indicate the potential to provide bonding sites for heavy metals;
- Soluble cations analysis indicates the potential for competition with the heavy metals for bonding sites; and
- Scanning Electron Microscopy (SEM) and sequential extractions determine the specific chemical form of the metal in the soil matrix and the bonding mechanism. This information may be used when chemical reactions such as metals dissolution (in soil washing processes) and metals precipitation (removal of metals from solvent used in a soil washing process) are included in soil treatment.

Because of constituent concentrations for soil samples vary both vertically and horizontally, samples were analyzed for total constituents prior to conducting treatability testing. Thus, treatability study sample results were representative of the bulk of the Site soils likely to require cleanup action.

Table 5-3 lists the treatability studies conducted in support of lead and arsenic remediation at the Site. A detailed soil characterization program conducted by Hazen Research Inc. (Hazen), at its facility in Golden, Colorado, represents the majority of the treatability study work. Constituent speciation work, physical screening studies, and bench-scale technology evaluations were performed by Battelle Pacific Northwest Laboratories, Hart Crowser, State University of New York, and Weyerhaeuser Analytical and Testing Services.

The following sections briefly describe each treatability study and summarize the results. In addition, the results are evaluated in terms of the physical parameters (soils handling properties), technical feasibility of the remediation alternatives, and chemical parameters.

5.3.1 Lead- and Arsenic-Impacted Soils Characterization Study - Hazen Research Inc.

This study involved soil samples collected from Site areas impacted by lead and arsenic, and included detailed characterization and speciation analysis of the lead- and arsenic-impacted soils. Soil sampling for the characterization study used a statistical procedure based on EPA SW-846 guidance, recognized technical literature on sampling and analysis, and the experience of the Project Team. The sampling procedure enabled recovery of representative composite samples of impacted soils from randomly sampled grids in areas of the Site known to contain elevated concentrations of lead and arsenic.

Complete results for the lead and arsenic characterization are detailed in the final reports prepared by Hazen Research (1993a through 1993f and 1994a through 1994c). Six composite samples of lead-impacted soil and three composite samples of arsenic-impacted soil were collected from different Areas of the Site. The characterization results are summarized in Tables 5-4 and 5-5 for lead and arsenic, respectively. A full description of the Hazen Research soil characterization studies for lead and arsenic, and a discussion of the results obtained, is provided in Appendix C.

5.3.2 Arsenic Wet Screening Study - Hart Crowser, Inc.

Arsenic treatability studies were performed by Hart Crowser to better define the distribution of arsenic concentration with respect to soil particle size through the use of particle size distribution testing and associated arsenic analysis of sized soil fractions. Samples were collected in the Reference Grid Area, and the NGRR area to supplement the results of the Hazen arsenic characterization study completed on samples from Areas 18 and 36 and the NGRR. A summary of the results is provided in Table 5-6 and further details of the treatability study procedures and results are presented in Appendix D.

5.3.3 Arsenic Speciation Analysis - Battelle Pacific Northwest Laboratory (PNL)

Battelle PNL performed limited arsenic speciation analysis on soil samples collected from Areas 5, 25, and 38, and in the NGRR area. The purpose of this study was to identify ionic species of arsenic and investigate the presence of arsenic forms in Site soils potentially impacted by acid production (Areas 5 and 25), the use of arsenic-based herbicides (NGRR), or arsenic-based paint/ink (Area 38). The results are summarized in Table 5-7.

5.3.4 Bench-Scale Soil Leaching Study – State University of New York, Buffalo

A screening of non-proprietary soil leaching chemistries was performed by the Department of Civil Engineering at the State University of New York at Buffalo (UB) (State University of New York at Buffalo, 1994). The efficacy of various soil washing extraction agents and leaching conditions were evaluated for removing lead from a lead-impacted soil sample (-8 to +200 mesh fractions) from Area 40 of the Site. The results of this study are summarized in Table 5-8.

5.3.5 Bench-Scale Soil Leaching Study - Weyerhaeuser Analytical and Testing Services

To investigate the potential for using non-proprietary leaching chemistries to remove arsenic from the Site soils, a leaching study was carried out at the laboratories of Weyerhaeuser Analytical and Testing Services (Weyerhaeuser ATS). Several leaching solutions were applied to -1/4 inch by +200 mesh fractions of combined soil samples from Area 18 and the NGRR area. The effects of pH and liquid:solid ratio were investigated as well as performance under single-stage batch and multistage countercurrent extraction regimes. The results of the study are presented in Appendix C.

5.4 Interpretation of Results

In this section, the results of the treatability studies are discussed by treatment technology using the parameters relevant to each technology as presented in Table 5-1. For each parameter, the results that are applicable to handling and remediation of Site soils are discussed.

5.4.1 Physical Screening/Soil Washing

The relevant characterization test results for physical screening/soil washing with dissolution technologies (as shown in Table 5-1) are silt/clay content, constituent distribution with regard to particle size, surface area calculations, Atterberg Limits, organic carbon, GANC/RGANC, MANC/RMANC, and Sequential Extraction for speciation analysis.

The silt/clay (less than 200 mesh particle sizes) content of the Site soils ranged between 6% and 15 % for the samples tested, well below the 40% upper limit generally considered likely to limit the effectiveness of soil washing processes. The sand (greater than 200 mesh and smaller than 1/4 inch particle sizes) content of the Site soils varies between 26% and 53% and the gravel (greater than 1/4 inch particle sizes) content varies between 38% and 66% by weight.

The lead content in the silt/clay fraction of the Site soils is substantial at between 27% and 67% of total lead in soil, which suggests that significant volume reduction of lead-impacted soil could be achieved by separating the fine material from the whole soil. Classification to separate soil at the 100 mesh cut point would represent recovery of about 90% of whole soil mass suitable for on-Site deposition in appropriate land use areas.

Wet screen particle size distribution test results and corresponding chemical analyses results for separated size fractions indicate that between 84% and 97% of the soil lead is concentrated in the sand and silt/clay fractions. These fractions represent between 40% and 62% by weight of the whole soil. These results indicate that recovery of the cobbles and gravel fraction (representing between 38% and 60% of the whole soil) as "clean" material could be readily achieved using conventional wet screening or soil washing to achieve segregation of Site soils into different size fractions.

The arsenic content in the silt/clay fraction of the soils is between 51% and 71% of total arsenic in soil (corresponding concentrations range between 186 and 2,550 mg/kg), which suggests that significant volume reduction of arsenic-impacted soil could be achieved by separating the fine material from the whole soil. Classification to separate soil at the 100 mesh cut point would represent recovery of about 90% of whole soil mass suitable for on-Site deposition in appropriate land use areas.

Particle size distribution test results for Site soils and corresponding chemical analyses results for separated size fractions indicate that between approximately 79% and 92% of the soil arsenic is concentrated in the sand and silt/clay fractions. These fractions represent between 27% and 56% of the whole soil. These results indicate that recovery of the cobbles and gravels fraction (representing between 44% and 73% of the whole soil) as "clean" material could be readily achieved using conventional wet screening or soil washing to achieve segregation of Site soils into different size fractions.

For water-based soil washing processes, the wet screening and Sequential Extraction test results indicate that, because of the low aqueous solubility of lead or arsenic from Site soils, little or no water treatment provisions would be necessary.

The surface area calculations for each of the soil size fractions indicate, as expected, that the majority of the total soil surface area is contained in the silt and clay (64% to 83%), with less in the sands (17% to 36%), and least in the cobbles and gravel (<1% to 2%).

In the case of Areas 7 and 18, the lead distribution by size fraction increases with reducing size fraction and increasing surface area; these results indicate that lead bonding and binding is mostly surface-related. The lead distribution for Areas 36 and 40 in the sand and silt/clay fractions does not proportionally follow surface area distribution; this indicates that lead is not only surface bound but is also associated with other particulate matter present in the soil matrix. In the case of Area 36 soils, SEM confirmed the presence of particulate lead. The presence of metallic lead suggests that density separation techniques may need to be incorporated into the design of a soil washing system.

The arsenic distribution by size fraction for the Area 36 sample increases with reducing size fraction and increasing surface area; these results indicate that arsenic bonding and binding is mostly surface-related.

The very low silt/clay content and results of the Atterberg Limits testing show that the Site soils are non-plastic and should be both amenable to processing by physical screening equipment and easy to handle with conventional earth-moving equipment.

The organic carbon content of the Site soils (0.6% to 6.9%) is below the 10% upper limit generally considered to reduce removal efficiency in a soil washing system because of contaminant-carbon bonding. The inclusion of an organic carbon removal unit operation should not be necessary.

The GANC/RGANC results show that the Site soils have little buffering capacity and will not require the addition of large amounts of acid (to mobilize lead species) or base (to mobilize arsenic species) in a chemically enhanced soil washing system to achieve the desired pH change.

The ELP results (0.02 to 0.06 mg/L) demonstrate very low lead solubility with synthetic acid rain. The wet screening and Sequential Extraction test results also demonstrate that the lead species are relatively insoluble in water. The lead was more soluble in acetic acid solutions, as demonstrated by TCLP, GANC, and Sequential Extraction test data. These results indicate that lead is essentially immobile under normal environmental conditions, but can be mobilized under more rigorous leaching conditions.

The MANC/RMANC equilibrium lead concentrations in the aqueous phase occur between additions of 2 to 40 equivalents of acid/kg soil and between additions of 2 to 40 equivalents of base/kg. One stage acidic and alkaline leaching at 20:1 liquids:solids ratio can remove 45% to 75% of the lead using 2N acetic acid, or 13% to 40% lead using 2N sodium hydroxide. This indicates that acidic leaching has potential for use in conjunction with wet screening and other physical (gravity, density, and high-energy attrition) treatment techniques. Even under severe leaching, a maximum of 75% lead removal is achieved because of the presence of some extremely leach-resistant forms of lead.

In the consideration of MANC/RMANC equilibrium arsenic concentrations, high acetic acid concentrations (approximately 14 equivalents of acid/kg soil) were required to leach arsenic, whereas RGANC indicated that about two base equivalents/kg soil were required for optimum leaching. One stage acidic/alkaline leaching at 20:1 liquids:solids ratio can remove 2% to 4% of the arsenic using 2N acetic acid, but amounts of between 74% and 80% can be removed using 2N sodium hydroxide. These results indicate that chemical leaching using alkaline reagents has potential for use in conjunction with wet screening and other physical treatment techniques. Conversely, mildly acidic conditions might be employed in a soil washing with dissolution treatment scenario to ensure that arsenic remains concentrated in the fines fraction, which could subsequently be stabilized.

In the sized fractions examined, Sequential Extraction data show that lead is predominantly present as carbonate, specifically adsorbed and ion-exchangeable forms, as well as being associated with iron and manganese oxides and organic material. This speciation information also indicates that further lead removal could be achieved in a chemically enhanced (acidic) soil washing or leaching treatment system.

Sequential Extraction data show that arsenic is predominantly present, in the sized fractions examined, in association with iron and manganese oxides and organic material. Speciation analyses performed on selected sized fractions (gravity separated as appropriate) using SEM confirmed the Sequential Extraction test results. The Battelle PNL speciation analysis also indicates that, in the areas of the Site sampled (Areas 5, 25, 38, and NGRR), arsenic is largely present as As(5). This speciation information supports the conclusion that chemically enhanced (basic) soil washing or leaching treatment could be used to liberate arsenic from the soils.

The results of the UB soil washing with dissolution study provide further support for considering a chemically enhanced treatment application. The study shows that strong mineral acid extractants (specifically, hydrochloric and perchloric acid) at approximately pH 1 were effective at significantly reducing (by greater than 60%) lead concentrations by approximately 1,400 mg/kg in the sand fraction of Site soils. TCLP lead values for treated samples ranged from 0.3 to 0.5 mg/L. Less acidic conditions (pH 3) were also effective if a chelating agent (such as EDTA) was added.

The results of the Weyerhaeuser ATS leaching study confirm the leaching data generated under the Hazen study and further demonstrate that sodium hydroxide caustic solutions are effective in removing arsenic from the Site soils. In single-stage batch extractions, solutions of sodium hydroxide at approximately pH 11.5 removed up to 57% of arsenic from sand fractions containing initial concentrations of around 100 mg/kg; sodium carbonate solutions gave similar results but required significantly higher reagent doses. A strong dependency on pH was shown in the leaching tests and there was no evidence that leaching performance was constrained by arsenic solubility. A batch extraction test examining relative leaching efficiencies between subfractions of the tested soil showed a slightly better performance for the larger subfraction. No significant improvements in overall leaching performance were observed in simulated countercurrent tests. Further investigation of washing process configuration, solids hold-up times, temperature, and aqueous extract treatment/recycling will need to be completed to decide if a leaching step should be included as part of a soil washing treatment application.

5.5 Conclusions and Recommendations

This section summarizes the conclusions from the various treatability studies relating to the viability assessment of physical screening/soil washing with dissolution.

5.5.1 Soil Characterization

The TCLP results for lead and arsenic obtained for the treatability samples indicate that most Site soils do not exhibit a RCRA hazardous toxicity characteristic associated with these metals.

Physical analysis data show that the Site soils are moderately well sorted (i.e., more coarse fraction and a relatively low silt/clay content), non-plastic, and classify as sand and sandy-loam. Excavation and materials handling of the soils should be relatively easy using conventional equipment and methods, and the soils should be amenable to processing by physical screening and mixing equipment.

The Site soils are essentially neutral and possess little acidic or basic buffering capacity. This is advantageous for both solidification/ stabilization and soil washing with dissolution processes in that the amounts of binder or leaching chemical needed to achieve the desired treatment performance will be minimized. The unamended soils will not be corrosive to excavation, materials handling, or processing equipment.

Based on speciation analysis data, soil lead is present mainly as carbonate, specifically adsorbed and ion-exchangeable forms, and in association with iron and manganese oxides and organic material. Lead constituents are present both in association with soil surfaces (surface bonding/binding) and as free metallic particles within the soil matrix. Arsenic speciation analysis data show that soil arsenic exists predominantly as arsenate (+5 valence state) and occurs mostly in association with iron oxides and the organic portion of the soil. Arsenic bonding and binding is primarily associated with the smaller soil particles with a high surface area per unit mass.

Leaching data show that both lead and arsenic are essentially insoluble and immobile under normal environmental conditions. Under both acidic and basic leaching conditions, soil lead can be leached (more readily mobilized under the former), although some extremely leach-resistant forms of lead are indicated. Soil arsenic can be readily mobilized under moderately basic leaching conditions but is difficult to remove at low pH. This is consistent with the information yielded by the lead and arsenic speciation analyses.

The Site soils have a low organic carbon content and so no interference or inhibitory affects associated with potential carbon-heavy metal bonding/binding would be expected for either solidification/stabilization or physical screening/soil washing with dissolution treatment.

5.5.2 Volume Reduction

For both lead and arsenic, significant proportions of these constituents were measured in the silt/clay fraction of the soil. Separation of the fines from the whole soil would be effective in concentrating a substantial proportion of the metals into a relatively small soil volume. This will potentially reduce the volume of significantly impacted soils requiring subsequent treatment or disposal.

A comparison of soil particle distribution and associated chemical distribution data with remediation and cleanup levels was made. The results indicated that recovery, as “clean soil”, of the cobbles and gravel fraction (40% to 60% of soil by weight) can be achieved by dry and wet screening, respectively. More aggressive soil washing and secondary treatment can achieve recovery of the sand, cobble, and gravel fractions (90% or more of soil by weight) as "clean" material.

5.5.3 Metal Dissolution/Removal

Strong hydrochloric acid or perchloric acid solutions at low pH (approximately pH 1) are effective at significantly reducing lead concentrations in the Site soils. Similar leaching performances can be achieved with these acids at more moderate pH (approximately pH 3) if a chelant (EDTA) is added to the leaching solution.

In the case of arsenic-impacted soils, strong sodium hydroxide and sodium carbonate solutions (approximately pH 12 or greater) are able to effectively remove arsenic in a single-stage batch extraction regime. Leaching performance does not appear to be constrained by arsenic solubility, and might be improved under a multi-stage countercurrent leaching process configuration.

The use of acidic/caustic leaching in conjunction with physical screening processes is indicated to have potential for reducing concentrations of lead and arsenic in the sand fraction of the soil or in the sands and fines combined. This approach merits further evaluation.

Table 5-1 - Soil Characterization Parameters by Treatment Technology

Soil	Treatment Technology	Test Types
Whole Soil and Fractions	Stabilization/Solidification	GANC/RGANC MANC/RMANC Total Carbon, Inorganic and Organic Carbon RCRA Appendix IX SemiVOCs TCLP (inorganic and semiVOCs) Moisture Content Speciation Analysis of Fractions
	Physical Screening/Soil Washing for Dissolution	Constituent Distribution with Particle Size Surface Area Calculations Silt/Clay Content MANC/RMANC during GANC/RGANC Organic Carbon Speciation Analysis of Fractions Atterberg Limits
	Smelting/Thermal Recovery	Total Constituent Concentration Constituent Distribution with Particle Size XRF Scan (mineralogy) Silica Content (by XRF) Moisture Content Total Carbon RCRA F039 Listed Metals

Abbreviated terms used in this table are defined in Appendix B.

Table 5-2 - Soil Characterization Parameters by Category

Sheet 1 of 2

Soil	Category	Information Use	Test Types
Whole Soil	Physical Handling	Provides information on how soil will behave during excavation and in treatment processes.	Surface Area Calculations (Lead only) Particle Size Distribution Soil Plasticity (Atterberg Limits) USDA Soil Classification Density (loose and packed) Moisture Content
	Regulatory	Provides information to enable regulatory waste code classification.	Total Constituent Concentration TCLP Constituent Concentrations RCRA Appendix IX Total Metal Concentration TCLP (inorganics and semiVOCs) RCRA Appendix IX Inorganics RCRA Appendix IX SemiVOCs pH
	Soil Chemistry	Provides information on contaminant/soil interactions to further general understanding of soil properties and used in evaluating treatment technologies.	Bonding/Binding Anions Soluble Cations Carbon (total/inorganic/organic) GANC/RGANC
	▸ Anions	Provides an indication of availability of bonding/binding sites for heavy metals (anions can combine with metals to form low solubility salts)	Sulfide Sulfate Phosphate Carbonate/Bicarbonates
	▸ Soluble Cations	Can compete with heavy metals for bonding/binding sites (ion-exchange sites, anions).	Calcium Sodium Magnesium Potassium Manganese Iron
	▸ Carbon Balance	Organic carbon can bond/bind with metals.	Total Carbon Inorganic (fixed) Carbon (by TGA) Organic Carbon (by difference)

Table 5-2 - Soil Characterization Parameters by Category

Sheet 2 of 2

Soil	Category	Information Use	Test Types
Whole Soil, Continued	▸ Alkalinity/Acidity, Buffering Capacity	Provides indications of how soil will respond to acid/base changes.	pH Redox GANC/RGANC
	Mobility and Leachability	Provides information on mobility in, and availability to, the environment.	TCLP (inorganics and semiVOCs) Equilibrium Leaching Procedure (lead only) (SAR-F039 List Metals) MANC during GANC/RGANC GANC/RGANC
Soil Fractions	Regulatory	Provides information on metals of regulatory concern to enable proper management/disposal.	F039 List Metals
	Soil Chemistry	Provides information on contaminant/soil interactions to further general understanding of soil properties and used in evaluating treatment technologies.	Cation Exchange Capacity (CEC) (Lead only) Total Iron and Manganese Total Chloride
	Speciation	Provides information on what specific chemical forms of metals are present and how metals are bound within soil. Aids in determination of impact to environment and technology selection.	Sequential Extraction Scanning Electron Microscopy (SEM) X-Ray Diffraction (XRD) X-Ray Fluorescence (XRF) - Mineralogy

Abbreviated terms used in this table are defined in Appendix B.

Table 5-3 - Summary of Treatability Studies

Type of Study	Organization Performing Treatability Study	Location of Study	Target Constituent	Summary of Scope	Areas of Site Sampled
Soil Characterization	Hazen Research, Inc.	Golden, CO	Lead and Arsenic	Complete characterization (see Table 5-1 and Table 5-2)	7, 18, 36, 40, 18, 36, NGRR, Hot Spot Soils
Soil Washing/Leaching	Department of Civil Engineering, State University of New York	Buffalo, NY	Lead	Test various extraction agents and leaching conditions to remove lead	40
Constituent Speciation	Battelle Pacific Northwest Laboratories	Sequim, WA	Arsenic	Identify ionic and organic species of arsenic	5, 25, 36, NGRR
Wet Screening	Hart Crowser, Inc.	Seattle, WA	Arsenic	Determine distribution of arsenic between soil size fractions	18, 36, NGRR
Soil Leaching	Weyerhaeuser Analytical and Testing Services	Federal Way, WA	Arsenic	Test potential of non-proprietary leaching solutions for removal of arsenic	18, NGRR

Note: NGRR = Narrow Gauge Railroad Track

Additional Studies Performed but not considered during evaluation of technologies

Type of Study	Organization Performing Treatability Study	Location of Study	Target Constituent	Summary of Scope	Areas of Site Sampled
Solidification/ Stabilization	Center for GeoEnvironmental Science & Technology, University of Cincinnati	Cincinnati, OH	Lead and Arsenic	Evaluate ability of 3 types of binding mixes to stabilize lead and arsenic	36, 40

Table 5-4 Lead-Soil Characterization Study Summary of Test Results-Hazen Research [1]

Sheet 1 of 4

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
Sample Verification (Pulverized Head)						
Total Lead in mg/kg (avg. of three)	475	180	870	2,110	660	3,570
TCLP Lead in mg/L	1.7	0.3	4.6	1.3	1.2	21.4
RCRA Hazardous, D008	no	no	no	no	no	yes
Physical Materials Handling						
Particle Size Distribution in % (gravel, sand, silt)	56,32,12	38,53,9	61,32,7	43,42,15	60,32,8	53,37,10
Soil Plasticity (Atterberg Limits)	non-plastic	non-plastic	non-plastic	non-plastic	non-plastic	non-plastic
USDA Soil Classification	sand	sandy loam	sand	sand	sand	sand
Density (loose/packed) in g/cm^3	1.3/1.4	1.3/1.5	1.6/1.9	1.1/1.5	1.2/1.6	1.1/1.4
Moisture Content in %	12.2	9.8	5.0	20.5	11.7	17.0
pH (10% solids slurry)	4.4	6.0	6.3	7.3	5.4	5.8
Regulatory						
Total Lead in mg/kg (RCRA Appendix IX)	380	260	540	1,700	590	3,000
TCLP Lead in mg/L	2.0	0.3	4.7	1.4	0.9	18
RCRA Appendix IX Inorganics	none of concern	none of concern	none of concern	none of concern	none of concern	none of concern
RCRA Appendix IX SemiVOCs	none of concern	low level semiVOCs	low level semiVOCs	low level semiVOCs	none of concern	none of concern

Notes:

[1] Further description of the tests and interpretation of these results is provided in Section 5 text and in Appendix C.

Table 5-4 Lead-Soil Characterization Study Summary of Test Results-Hazen Research[1]

Sheet 2 of 4

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
Soil Chemistry						
Bonding/Binding Anions in mg/kg (total)	2,600	2,500	2,640	10,650	4,175	7,190
Soluble Cations in mg/kg (total)	81	24	77	261	66	94
Total/Inorganic/Organic Carbon in %	3.3/0/3.3	2.5/0.7/1.8	1.1/0.2/0.9	6.9/0/6.9	4.2/0/4.2	4.2/0/4.2
Net Acid/Base Potential in tons of $CaCO_3$/1,000 tons of soil	-10.9	-7.5	1.0	2.8	-24.4	-16.1
GANC/RGANC equivalents acid to reach pH<4 equivalents base to reach pH>10	unbuffered 2 2	unbuffered 2 2	unbuffered 2 2	unbuffered 4 2	unbuffered 2 2	unbuffered 2 2
Leaching and Mobility						
TCLP Lead in mg/L	2.0	0.3	4.7	1.4	0.9	18.0
Equilibrium Leaching Procedure leachate lead in mg/L equilib. partition coefficient (K)	 0.019 2.2E+04	 0.05 1.0E+04	 0.032 2.0E+04	 0.02 8.1E+04	 0.059 1.1E+04	 0.064 6.3E+04
MANC/RMANC equilib. lead conc. (acid/base) in mg/L	15/7	4/3	33/8	48/14	15/13	90/25
Speciation						
Sequential Extraction	majority of lead in carbonate, specifically adsorbed, and exchangeable forms	majority of lead in carbonate, specifically adsorbed, and exchangeable forms	majority of lead in carbonate, specifically adsorbed, and exchangeable forms	majority of lead associated with carbonates, iron and manganese oxides, and organic material	majority of lead associated with carbonates, iron oxides, and organic materials	majority of lead associated with carbonates, iron and manganese oxides, and organic material
SEM/XRD	positive ID of lead sulfate and lead sulfide	positive ID of lead carbonate, lead oxide, and lead-manganese oxide	positive ID of lead carbonate, lead silicate, metallic lead, and lead-iron oxide	positive ID of lead carbonate, lead silicate, lead oxides,	positive ID of lead silicate, lead oxides, lead phosphate,	positive ID of lead oxides (manganese, tin, aluminum,

Notes:

[1] Further description of the tests and interpretation of these results is provided in Section 5 text and in Appendix C.

Table 5-4 Lead-Soil Characterization Study Summary of Test Results-Hazen Research[1]

Sheet 2 of 4

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
				and lead-iron oxide	and lead-iron oxide	and iron)

Notes:

[1] Further description of the tests and interpretation of these results is provided in Section 5 text and in Appendix C.

Table 5-4 Lead-Soil Characterization Study Summary of Test Results-Hazen Research[1]

Sheet 3 of 4

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
Soil Chemistry						
Cation Exchange Capacity in meq/100g	34.6	84.2	49.6	98.1	111.0	95.9
Chloride in mg/kg	100	<100	<100	500	100	260
Iron/Manganese in mg/kg	23,350/620	34,238/838	39,979/775	63,630/990	30,050/1,150	95,820/1,090
Regulatory						
F039-List Metals	As, Pb, Ba, Cr	As, Pb, Ba, Cr	As, Pb, Ba, Cr	Pb, Ba, Cr, Zn	As, Pb, Zn	As, Pb, Ba, Cu, Zn
Physical Screening/Soil Washing						
Silt and Clay Content in %	12	9	7	15	8	10
Lead Distribution by Particle Size % of total lead in gravel/sand/silt	16/29/55	3/30/67	10/63/27	5/56/39	13/48/39	3/58/39
Total Lead Conc. in mg/kg by Particle Size (gravel/sand/silt)	130/420/2,170	50/310/3,970	180/2,100/3,980	195/2,310/4,350	130/950/3,320	130/4,260/10,600
Surface Area Calculations % of total surface area in gravel/sand/silt	<1/17/83	<1/36/64	2/22/76	<1/18/82	1/23/76	1/20/79
Organic carbon in %	3.3	1.8	0.9	6.9	4.2	4.2
GANC/RGANC equivalents acid to reach pH<4 equivalents base to reach pH>10	unbuffered 2 2	unbuffered 2 2	unbuffered 2 2	unbuffered 4 2	unbuffered 2 2	unbuffered 2 2
MANC/RMANC equilib. lead conc. (acid/base) in mg/L	15/7	4/3	33/8	48/14	15/13	90/25
% Lead Leached under MANC/RMANC (acid/base)	60/29	44/30	75/18	45/13	45/40	50/14

Notes:

[1] Further description of the tests and interpretation of these results is provided in Section 5 text and in Appendix C.

Table 5-4 **Lead-Soil Characterization Study Summary of Test Results-Hazen Research** [1]

Sheet 4 of 4

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
Stabilization/Solidification						
GANC/RGANC	unbuffered	unbuffered	unbuffered	unbuffered	unbuffered	unbuffered
MANC/RMANC Minimum Lead Concentration in mg/L/pH Range	<1/5.5 to 6.8	<1/4.6 to 6.1	<1/4.8 to 8.5	1/6.3 to 12.5	1/5.1 to 8.9	1/6.3 to 7.8
Total/Inorganic/Organic Carbon in %	3.3/0/3.3	2.5/0.7/1.8	1.1/0.2/0.9	6.9/0/6.9	4.2/0/4.2	4.2/0/4.2
RCRA Appendix IX SemiVOCs	none of concern	low level semiVOCs	low level semiVOCs	low level semiVOCs	none of concern	none of concern
TCLP Lead in mg/L	2.0	0.3	4.7	1.4	0.9	18
Moisture Content in %	12.2	9.8	5.0	20.5	11.7	17.0
Smelting/Thermal Recovery						
Total Lead in mg/kg	380	260	540	1,700	590	30,00
Lead Distribution by Particle Size % of total lead in gravel/sand/silt	16/29/55	3/30/67	10/63/27	5/56/39	13/48/39	3/58/39
Total Lead Conc. in mg/kg by Particle Size (gravel/sand/silt)	130/420/2,170	50/310/3,970	180/2,100/3,980	195/2,310/4,350	130/950/3,320	130/4,260/10,600
Silica Content in % (gravel/sand/silt)	-/69/59	-/-/33	-/-/45	-/56/28	-/-/28	-/50/29
Moisture Content in %	12.2	9.8	5.0	20.5	11.7	17.0
Total Carbon in %	3.3	2.5	1.1	6.9	4.2	4.2

Notes:

[1] Further description of the tests and interpretation of these results is provided in Section 5 text and in Appendix C.

Table 5-5 - Arsenic-Soil Characterization Study
Summary of Test Results
Hazen Research

Sheet 1 of 2

Whole Soil Procedures	Area 18	Area 36	RR Track Area
Physical Materials Handling			
Particle Size Distribution (PSD) in % (Gravel/sand/silt)	66/26/8	60/30/10	52/39/9
Arsenic Distribution with PSD in % (Gravel/sand/silt/slimes)	12/28/35/25	18/30/47/5	7/22/63/8
pH (10% solids slurry)		6.2	
Regulatory			
TCLP Arsenic in mg/L (conducted at 4.9 pH)	<0.03	<0.07	<0.03
RCRA Hazardous, D004	No	No	No
Soil Chemistry			
Total Arsenic in mg/kg	41	29	353
GANC/RGANC	Unbuffered	Unbuffered	Unbuffered
Equivalents acid to reach pH<4	>14	>14	2
Equivalents base to reach pH>10	2	<2	2
Leaching and Mobility			
TCLP Arsenic in mg/L	<0.03	<0.07	0.03
MANC/RMANC minimum arsenic Concentration (acid/base) in mg/L: pH	0.007:3.8/ 0.05:5.0	0.007:3.7/ 0.035:8.8	0.045:3.2/ 0.28:5.2
MANC/RMANC equilibrium Arsenic concentration (acid/base) in mg/L	0.25/2.7	0.06/1.5	2/22
% Arsenic Leached under GANC/RGANC (acid/base)	3/75	4/80	2/74

Table 5-5 - **Arsenic-Soil Characterization Study**
Summary of Test Results
Hazen Research

Soil Fraction Procedures	Area 18	Area 36	NGRR Track Area
Sequential Extraction	Majority of arsenic associated with the organic fraction and, to a lesser extent, with the non-crystalline iron oxide fractions.	Majority of arsenic associated with the organic and non-crystalline iron oxide fractions and, to a lesser extent, with the crystalline iron oxide fraction.	Majority of arsenic associated with the crystalline iron oxide and organic fractions and, to a lesser extent, with the non-crystalline iron oxide fraction.
SEM	Very little arsenic detected, but associated mainly with iron oxide. Also associated with silicates, and present as iron-arsenic-phosphate.	Arsenic associated mainly with iron oxide (including suspected goethite); arsenic also detected in particles (containing Fe, Al, Ca, and Si) attached to carbon-charcoal particles and with lead-manganese-oxide.	Arsenic associated mainly with iron oxide and organic material. Also positive identification of iron-arsenic-phosphate, lead-arsenic-sulfate and potassium-iron-sulfate.
XRF	Presence of silica-alumina-iron matrix	Presence of silica-alumina matrix	Presence of silica-alumina-iron matrix

Table 5-6 - Arsenic Wet Screening Study

Summary of Test Results and Statistical Evaluation

Hart Crowser Labs

Soil Fraction Type	Screen Size	Mass Distribution by Soil Size Fraction in % by wt.	Mean Arsenic Concentration in mg/kg	Cumulative Mean Concentration in mg/kg
Summary of Arsenic Data for Grid Samples from Lead Reference Area				
Gravel	+1	18.00	7.46	7.46
	-1+1/2	26.00	8.67	8.26
	-1/2+1/4	16.70	9.87	8.68
Sand	-1/4+8m	8.70	17.29	9.86
	-8m+16m	4.50	30.45	11.23
	-16m+30m	5.00	45.66	13.43
	-30m+60m	7.60	58.21	17.19
	-60m+100m	3.60	84.05	20.01
	-100m+200m	2.50	120.47	22.50
Silt	-200m	7.30	181.90	32.44
Summary of Arsenic Data for Samples from Narrow Gage Railroad Track Area				
Gravel	+1	18.00	21.15	21.15
	-1+1/2	21.50	32.06	28.26
	-1/2+1/4	17.50	49.45	35.25
Sand	-1/4+8m	11.80	81.37	43.13
	-8m+16m	5.40	110.75	47.96
	-16m+30m	7.50	158.45	57.68
	-30m+60m	7.80	249.18	74.72
	-60m+100m	2.30	602.18	88.47
	-100m+200m	1.90	876.61	105.03
Silt	-200m	6.30	1,689.61	203.32

Table 5-7 - Arsenic Speciation Tests

Summary of Test Results

Sample ID	Arsenic Concentration in $\mu g/g$			
	As +3	As +5[1]	MMA[2]	DMA[3]
25-As-SP-1	<1.6	71.9 (>93.7%)	<1.6	<1.6
LR-20	<1.6	75.3 (>94.0%)	<1.6	<1.6
LR-60	<1.6	228 (>97.9%)	<1.6	<1.6
LR-104	<1.6	358 (>95.7%)	<1.6	12.9
5D-VS-34	2.2	500 (>98.9%)	<1.6	<1.6
38-As-SP-1	1.9	567 (>99.1%)	<1.6	<1.6

Notes:

[1] The values in parenthesis indicate the proportion of the As +5 species

[2] MMA = Monomethyl arsinic acid

[3] DMA = Dimethyl arsinic acid

Table 5-8 Summary of UB Soil Washing Evaluation (State University of New York)

Extractant	pH	Temp in °C	Liquid:Solid Ratio	Remaining Soil Lead in mg/kg (Number of Readings)	TCLP Lead in mg/L (Number of Readings)
HCl	1	25	20:1	611 ± 166 (3)	
HCl	1	25	20:1	941 ± 951 (3)	0.50 ± 0.50 (3)
HCl	1	25	10:1	444 ± 24 (5)	0.47 ± 0.14 (3)
HCl	1	25	5:1	579 ± 61 (5)	1.47 ± 1.74 (3)
HCl	2	25	20:1	703 ± 627 (3)	0.20 ± 0.00 (3)
HCl	3	25	20:1	1359 ± 77 (5)	
HCl	3	25	20:1	1223 ± 382 (3)	
HCl	3	50	20:1	1259 ± 66 (5)	
H_2SO_4	1	25	20:1	720 (1)	
H_2SO_4	3	25	20:1	1111 ± 110 (5)	
$HClO_4$	1	25	20:1	449 ± 96 (5)	0.33 ± 0.14 (3)
$HClO_4$	3	25	20:1	1228 ± 116 (5)	
HCl/0.5M NaCl	3	25	20:1	1170 ± 130 (4)	
H_2SO_4/0.5M NaCl	1	25	20:1	851 ± 97 (5)	0.60 ± 0.25 (3)
HCl/0.005M EDTA	1	25	20:1	607 ± 145 (5)	0.37 ± 0.29 (3)
HCl/0.01M EDTA	3	25	20:1	644 ± 53 (5)	0.67 ± 0.14 (3)
HCl/0.01M EDTA	3	50	20:1	1045 ± 171 (4)	1.17 ± 0.14 (3)
HCl/0.01M Salicylate	3	25	20:1	1248 ± 147 (4)	

Notes:
The soil extractions were completed in a 24-hour batch extraction.

Remaining soil lead concentrations are given as the mean ± 95% CL (number of readings), after 24 hours of batch washing, with measurement outliers omitted. Readings were considered to be outliers if their values were greater than the initial lead concentration of 1,401 mg/kg.

The maximum proportion of lead released by soil washing during these experiments was 68 percent, achieved with HCl as the extractant at a pH = 1, at 25 degrees centigrade, and a 10:1 liquids:solids ratio.

5.6 References for Chapter 5

Hazen Research, Inc., 1993a. "Laboratory and Bench-Scale Studies for Characterizing Lead-Contaminated Soil from DuPont/Weyerhaeuser Remediation Site, Area 18 - Nitrator No. 1..” August 26, 1993.

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State University at New York at Buffalo, 1994. "Evaluation of Soil Washing Extraction Agents and Processes for Remediating Heavy Metal Contaminated Soil From Weyerhaeuser Area 40 Pulverizer (-8m +200m Tails)", March 2, 1994.

Chapter 6 – DEVELOPMENT AND SCREENING OF ALTERNATIVES

6.1 Introduction

This chapter combines the technologies and process options, retained from the Chapter 4 screening, into working remedial alternatives. These alternatives are further screened by evaluating to what degree the alternatives can reduce the potential for exposure identified in the RA. Each alternative was evaluated for all remediation units. Those alternatives that meet the screening criteria and can be effectively applied to Site soils were retained for detailed analysis in Chapter 7. The remedial alternatives applicable to Miscellaneous Small Remediation Units are described in Section 8.3.

Section 6.2 describes the alternative screening criteria. Section 6.3 assembles the technologies and process options retained from Chapter 4 into remedial alternatives. Section 6.4 describes and screens each alternative, and Section 6.5 ranks the alternatives based on the outcome of the screening process. Section 6.6 presents a summary of the alternatives retained for detailed analysis in Chapter 7.

6.2 Screening Criteria

Like the initial technology screening, alternative screening was based on three criteria: effectiveness, implementability, and cost (as described in Section 4.3.3). Figure 6-1 shows the relationship between these three screening criteria and the eight MTCA evaluation criteria used in the detailed analysis of alternatives in Chapter 7. Unlike the initial technology screening, the relative importance of the criteria are different, with more emphasis on the effectiveness of the alternative in attaining the RAOs and cleanup standards and less emphasis on implementability and cost. Effectiveness was emphasized because it encompasses five of the seven evaluation criteria used in Chapter 7 and because MTCA guidance places particular importance on permanence, one of the sub-criteria of effectiveness.

6.2.1 Effectiveness

For alternative screening, effectiveness is the primary criterion. Key sub-criteria (of effectiveness) used in the screening of alternatives are listed below. The protection of human health and the environment, and compliance with cleanup standards as listed in WAC 173-340-700 and/or WAC 173-340-7490(6)(f) are "threshold criteria" since they must be met by the alternative for it to be retained for further evaluation in Chapter 7. Those alternatives that did not meet these threshold criteria (with the exception of No Action) were not retained for further evaluation. The sub-criteria of effectiveness used to assess effectiveness are defined as:

Protectiveness: This evaluation considers the overall protection each technology provides to human health and the environment including the degree to which existing risks are reduced, the time required to reduce risk and obtain cleanup standards, the off-Site and on-Site risks resulting from the implementation of the alternative and the degree of improvement of the overall environmental quality.

Permanence: This evaluation considers the degree to which the alternative permanently reduces the toxicity, mobilization or volume of the contaminants including the adequacy of the alternative/technology in reducing or elimination of releases of the contaminant, degree to which the treatment is irreversible, and the characteristics and quantity of the treatment residuals generated. Since lead and arsenic are the contaminants of concern, one of the MTCA criteria, destruction, is not obtainable by any of the listed alternatives and will not be evaluated.

Long-Term Effectiveness: This evaluation considers the effectiveness and reliability of the process during the time when contaminant concentrations remain on site that are greater than cleanup levels including the magnitude of risk with the alternative in place, the degree of certainty that the alternative/technology will be successful, and the adequacy and reliability of any Site controls.

Management of Short-Term Risks: This evaluation considers the effectiveness of the process dealing with the potential impacts to human health and the environment during the construction and implementation phase and the effectiveness of the measures to manage such risks.

6.2.2 Implementability

Implementability includes both operational implementability and administrative feasibility. Operational implementability refers to the ability to construct and reliably operate the remediation alternative. It includes operation, maintenance, replacement, and monitoring of the technical components of an alternative. Administrative feasibility refers to the ability to obtain approvals from city/county/state officials/agencies, the availability of treatment, storage, and disposal services, and the availability of specific equipment.

6.2.3 Cost

The alternatives screening cost estimates were developed from a variety of sources including technology unit costs developed by the project team, vendor information, published cost-estimating guides, and prior experience with similar technologies. In this evaluation, treatment includes construction and treatment activities necessary for attaining the RAOs. The screening level cost estimates do not include the contingency, administration, maintenance, or long-term monitoring costs since these costs will not impact the relative cost differences between alternatives unless the alternative does not include long-term monitoring. These cost estimates are used for the screening of the alternatives only and should not be considered to represent the total remediation cost associated with the cleanup of the Site. Estimated costs presented in this chapter represent the direct cost that would be realized if the alternative being evaluated were implemented to address the total volume of contaminated soil listed in Chapter 3. Table 6-1 lists these costs. Chapter 7 presents the potential total costs for implementation of the alternatives that were retained for the detailed analysis.

6.2.4 Consideration of Public Concerns

MTCA calls for the evaluation of local community potential concerns over the alternative and how the alternative addresses those concerns. For this FS it has been determined that with the exception of the No Action Alternative, each of the remaining alternatives share the common public concerns of protection of cultural and historical sites and artifacts, long-term public health, and short-term public health. The latter two are key components of Long-Term Effectiveness and Management of Short-Term Risks and will be addressed under those headings. A cultural resource protection program has been in place at the Site for many years and will be followed during the cleanup. The cultural protection plan will also be a key component of the Cleanup Action Plan for this site. Since the same amount of soil excavation will be required, little, if any, difference exists between the action-related alternatives in addressing cultural resource concerns. As such, we will focus on concerns that are unique to each alternative but not those that are “global” in nature.

6.2.5 Ecology Cleanup Technology Preference

Ecology summarizes its cleanup technology preference guidance for the selection of remedial alternatives in WAC 173-340-350 (8)(c)(i)(C). The guidance sets a relative ranking for technologies. The following technologies are listed in order of descending preference by Ecology:

- Reuse or recycling;
- Destruction or detoxification;
- Separation or volume reduction, in combination with reuse, recycling, destruction, or detoxification;
- Immobilization;

- On-Site or off-Site disposal;
- On-Site isolation or containment; and
- Institutional controls and monitoring.

6.3 Assembly of Alternatives - Groundwater

Two alternatives have been selected for the remediation of groundwater; natural restoration and active groundwater treatment. Chapter 7 will further evaluate these alternatives and describe the preferred alternative.

6.3.1 Description and Screening of Alternatives – Groundwater

Active Groundwater Treatment: Available technologies for the active treatment of impacted groundwater are very limited and would require, for this Site, the pumping of very large quantities (up to 7,000 gallons per minute) of water. Groundwater pump and treat is the only active groundwater remediation technology which could be applied at the Site for the following reasons:

- Groundwater which would be targeted for remediation is deep (100 to 200 feet below surface) and laterally extensive. preventing use of impermeable barriers, gates, or other groundwater isolation techniques;
- DNT (the single contaminant) has low volatility, preventing use of sparging or other venting technologies ;
- Although DNT can be degraded through natural in situ processes, only biological degradation could potentially occur in Site aquifers and attempting to enhance this process as part of a remediation program would likely be infeasible;
- DNT readily degrades by photolysis (half-life on the order of days; Etnier, 1987), but this process will not occur in aquifers;
- DNT can be transformed to formic and acetic acids, but only at temperatures at which water would not persist (520°F; Etnier, 1987); and
- DNT in water degrades through biological processes under some aerobic and anaerobic conditions (Spanggord. 1980; Etniert 1987), but the metabolism of DNT is strongly dependent on environmental conditions and the presence of viable microorganisms (ATSDR, 1989). Biodegradation of DNT may be occurring naturally in Site aquifers, yet attempting to establish or enhance appropriate natural microorganism populations (e.g. , by introducing nutrients) in Site aquifers would likely be infeasible because of the size of the Site and the substantial depth of the aquifers.

Natural Restoration: Natural restoration is the process in which the source of the contamination is removed and the water is left to clean itself up naturally. Active monitoring is typically a part of natural restoration.

6.4 Assembly of Alternatives - Soil

This FS defines alternatives for soils as a collection of technology process options that can be combined to effectively address a given remediation unit. In general, technologies/process options that are effective for one remediation unit are also effective for other remediation units. There are some exceptions to this; for example, the alternate chosen in ecologically or historically sensitive areas may not be the same as those within industrial or commercial areas.

Based on the initial screening of technologies (presented in Chapter 4) and the results of the treatability studies (presented in Chapter 5), the following alternatives were formulated and ranked independently for all remediation units:

- No Action;
- Capping;
- Cover;
- Cap/Cover;
- On Site Deposition, Cap and Cover;
- Off-Site Disposal at a Landfill;
- Wet Screening, Classification, and Disposal of the Residual Soils at a Landfill;
- Wet Screening with On-Site Deposition, Cap and Cover and Disposal of the Residual Soils at a Landfill;
- Wet Screening with Stabilization and On-Site Deposition and Cover;
- Soil Washing with Wet Screening, Classification, Acid/Base Extraction, and Disposal of the Residual Soils at a Landfill; and
- Soil Washing with Wet Screening, Classification, Chelant Extraction, and Disposal of the Residual Soils at a Landfill.

Ten potential remedial alternatives, in addition to No Action, were developed for the Site. Each alternative will attain varying degrees of risk reduction under the proposed land use plan.

6.5 Description and Screening of Alternatives

This section presents a brief description of each alternative and discusses the performance of each alternative against the three screening criteria. Alternatives which are most likely to attain the RAOs are identified for further evaluation in Chapter 7.

6.5.1 No Action

No action means that no remedial activities will be implemented to clean up the Site.

Effectiveness:

- Protectiveness: The No Action alternative does not attain the Site ecological or human health standards. As such this alternative will not meet cleanup standards as listed in either WAC 173-340-700 or WAC 173-340-7490(6)(f). Since no action would occur there would be no reduction in risk.
- Permanence: No action does not reduce toxicity, mobility or volume and is not a permanent solution.
- Long Term Effectiveness: Since this alternative does not attain cleanup standards or reduce risk, toxicity or mobility it is not effective over the long-term.

- Management of Short Term Risks: Since no activities occur under this alternative, short-term risks associated with implementation would not occur.

- Consideration of Public Concerns: No action would result in denied access to the Site. Development of commercial, historical and golf course land use areas would not be allowed by this alternative.

Implementability: This alternative does not meet the needs of the current Site development plans or Ecology's cleanup standards. Development of commercial, historical and golf course land use areas would be limited by this alternative. Since no construction activities will be required as part of this alternative, it could be readily implemented.

Cost: There is no initial remediation cost associated with the implementation of this alternative since no activities are performed.

Considerations: No Action does not have the ability to meet RAOs consistent with Ecology's ecological and human health standards but has the lowest initial cost. It was retained during the detailed analysis to provide comparison with other remedial alternatives.

6.5.2 Capping

Capping consists of the installation of a layer of highly durable, impermeable, engineered materials over the Site soils containing contaminant concentrations above the CL but below the RL. No excavation of soils would occur as part of this alternative.

Effectiveness:

- Protectiveness: Both Site wide and discrete area capping could meet cleanup standards as listed in WAC 173-340-7490(6)(f). Preventing direct contact exposure with soil above the CL would significantly reduce risk. The time frame for this action would be dependant upon the size of the area capped. Capping of the entire Site would require approximately 3.3 years. Off-Site risk would be limited to implementation (see Management of Short Term Risks) and ongoing on-Site risks would be minimal. The reduction in exposure risk would improve the overall environmental condition of the Site.

- Permanence: There would be no reduction in toxicity or volume. Mobility would be reduced due to the impermeable nature of the Cap material. Capping does not represent a permanent remedy.

- Long Term Effectiveness: Once complete, capping would greatly reduce residual risk. Long-term effectiveness of a capping remedy relies on an effective O&M program. Such programs can be effective with active management.

- Management of Short Term Risks: Since this alternative does not include the excavation of contaminated soils, short term exposure risk would be less than excavation related alternatives.

- Consideration of Public Concerns: Large scale capping would not meet the public's wish to return the property to viable use or Weyerhaeuser Real Estate's plans to develop the property. Lesser scale application could meet all concerns.

Implementability: Site wide capping could potentially result in limiting land use and development in the capping area. This alternative does not meet the current needs of the Site development plans. Capping is a common remedy and could be applied. Small-scale applications could be effectively implemented.

Cost: A direct cost range of $79 million (M) to $129.6M is estimated for implementation of this alternative. Long-term cap maintenance costs would also be incurred.

Considerations: Capping would be effective in meeting the RAOs for the Site but is not permanent. Capping also may restrict future Site development. It could be considered in small-scale areas where roads, asphalt trails, parking areas, or buildings are planned. It is also costly to apply. This alternative may have some limited use and will be retained for further evaluation in Chapter 7.

Adjustments to remediation levels: No adjustments to the remediation levels used in the RA are warranted for this alternative.

6.5.3 Cover

A cover involves the installation of a clean soil layer over areas of the Site that contain soil with concentrations of constituents above the CL but below the RL. The installation of a cover over these soils may meet the RAOs by reducing direct contact exposure. At a minimum the cover would equal 18 inches in depth for the protection of human health and 6 inches in depth (gravel only) for the protection of ecological receptors. No excavation of soils would occur as part of this alternative.

Effectiveness:

- Protectiveness: Both Site wide and discrete area cover could, depending on the thickness of the cover, meet cleanup standards as listed in WAC 173-340-7490(6)(f). Preventing direct contact exposure with soil above the CL would significantly reduce risk. The time frame for this action would be dependent upon the size of the area covered. Covering of the entire Site would require approximately 2.4 years. Off-Site risk would be limited to implementation (see Management of Short Term Risks) and ongoing on-Site risks would be minimal. The reduction in exposure risk would improve the overall environmental condition of the Site. The placement of a topsoil cover in golf course, treeless open space, and historical land use areas could, depending on thickness, be an effective exposure barrier.

- Permanence: Cover, in itself, does not represent a permanent remedy. There would be no reduction in mobility, toxicity or volume.

- Long Term Effectiveness: The residual risk would be greatly reduced once a complete cover was in place. Long-term effectiveness of a cover remedy relies on an effective O&M program. Such programs can be effective with active management.

- Management of Short Term Risks: Since this alternative does not include the excavation of contaminated soils, short term exposure risk would be less than excavation related alternatives.

- Consideration of Public Concerns: Total Site cover would not meet the public's wish to return the property to viable use or Weyerhaeuser Real Estate's plans to develop the property. Lesser scale applications could meet all concerns.

Implementability: This alternative can meet the current needs of the Site development plans in areas where treeless open space, historical, or golf course land uses are planned. Installation of a soil cover across broad areas may be difficult to implement because of development restrictions in the covered area and the availability of cover material. Cover over smaller areas can be easily completed since smaller quantities of soils are readily available on Site and can be placed easily because of the typically flat topography of the Site.

Cost: A direct cost range of \$43M to \$72M is estimated for implementation of this alternative. Clean soil from on-Site sources makes the cost less for installation of soil cover in selected areas.

Considerations: Cover would be effective in meeting the RAOs for the Site, but is not permanent. Cover would also restrict future Site development. It could be considered on a small-scale in areas of environmental or historic sensitivity. As such, it was retained for further evaluation in Chapter 7.

Adjustments to remediation levels: No adjustments to the remediation levels used in the RA are warranted for this alternative.

6.5.4 Cap/Cover

Cap/Cover consists of the placement of 18 inches of soil over the Site soils containing contaminant concentrations above the CL but below the RL. The cap would consist of a layer of high durability, engineered materials or layer of gravel. A 12-inch to 18-inch soil cover would then be placed on top of the cap to further prohibit exposure to the underlying soils. The installation of the cap/cover would meet the RAOs by preventing direct contact exposure with soil above the CL. This combination would act as an exposure barrier to both ecological receptors and humans. No excavation of soils would occur as part of this alternative.

Effectiveness:

- <u>Protectiveness:</u> Cap/Cover could meet cleanup standards as listed in WAC 173-340-7490(6)(f) in both Site wide and smaller applications. Since cap/cover incorporates the best of both the cap and cover alternatives risk would be further reduced. The time frame for this action would be dependent upon the size of the area capped. Cap/Cover of the entire Site would require approximately 2.8 years. Off-Site risk would be limited to implementation (see <u>Management of Short Term Risks</u>) and ongoing on-Site risks would be minimal. The reduction in exposure risk would improve the overall environmental condition of the Site.

- <u>Permanence:</u> There would be no reduction in toxicity or mobility. This alternative does not represent a permanent remedy.

- <u>Long Term Effectiveness:</u> The residual risk would be greatly reduced once a complete cover was in place. Long-term effectiveness of a capping remedy relies on an effective O&M program. Such programs can be effective with active management.

- <u>Management of Short Term Risks:</u> Since this alternative does not include the excavation of contaminated soils, short term exposure risk would be less than excavation related alternatives

- <u>Consideration of Public Concerns:</u> Large-scale cap/cover would not meet the public's wish to return the property to viable use or Weyerhaeuser Real Estate's plans to develop the property. Restricting the use of this alternative to the golf course, open space, and historical land use areas would meet all concerns.

Implementability: Large scale capping could potentially result in limiting land use and development in the capped area. This alternative does not meet the current needs of the Site development plans. Isolated use of this alternative could be useful in preventing exposure to soil with contaminant concentrations above CLs. Capping is a common remedy and could be applied.

Cost: A direct cost range of $26.6M to $41.5M is estimated for implementation of this alternative. Long-term cap maintenance costs would also be incurred.

Considerations: Cap/Cover would be effective in meeting the RAOs for the Site, but is not permanent. Cap/Cover would also restrict future Site development and could be considered in golf course, historical areas and open space areas where exposure prevention and protection of habitat are desired. As such, it was retained for further evaluation in Section 7.

Adjustments to remediation levels: The risk-based remediation or cleanup levels used in the RA for soil located within the golf course and open space land use areas are based on frequency of exposure and do not consider the installation of a soil cover over impacted soil. The application of an engineered cap/cover will further reduce the potential risk of exposure thereby increasing the effective RL. Ecology has determined that the effective remediation levels for lead- and arsenic-contaminated soils in areas of the Site that will have a cap/cover are 4,100 mg/kg and 530 mg/kg, respectively. Justification of this decision is included in Appendix H.

6.5.5 On Site Deposition, Cap and Cover

On-Site Deposition, Cap and Cover includes the excavation of soils containing contaminant concentrations above the RL in one land use, transferring it to a land use area within the area of contamination (AOC) where it is below the RL for that land use, and using a cap/cover combination to prevent exposure. The cap would consist of a layer of high durability, engineered materials or layer of gravel over the deposited soils. A soil cover would then be placed on top of the cap to further prohibit exposure to the underlying soils. The installation of the cap/cover would meet the RAOs by preventing direct contact exposure with soil above the CL. Implementation of this alternative allows integration of the deposition of soil with the design of the golf course.

Effectiveness: On-Site deposition with cap/cover is allowed under MTCA and may be effective in meeting site cleanup standards and RAOs. Although volume and toxicity are not modified, soil would be placed in a land use area where the exposure risks are reduced based on restricted access and the protection afforded by the cap/cover.

- <u>Protectiveness:</u> This alternative would meet cleanup standards as listed in WAC 173-340-7490(6)(f). Risk would be reduced in two ways. The cap/cover would prevent direct exposure and the consolidation of the contaminated soils in a smaller area would lessen the probability of direct contact. The timeframe necessary to complete this action is approximately 2.8 years.

- <u>Permanence:</u> There would be no reduction in toxicity, or mobility. This alternative does not represent a permanent remedy.

- <u>Long Term Effectiveness:</u> Once complete this alternative would greatly reduce residual risk. Long-term effectiveness of a capping remedy relies on an effective O&M program. Such programs can be effective with active management. This alternative is particularly applicable within the golf course land use areas since the operations of a golf course would ensure the competence of the cap/cover.

- <u>Management of Short Term Risks:</u> Since this alternative includes excavation, it represents an increased risk when compared to non-excavation alternatives. It does represent the least risk of the alternatives that involve excavation. An aggressive dust control program and air monitoring could minimize short-term risks. These efforts have been successful in the past in controlling potential risks.

- <u>Consideration of Public Concerns:</u> This alternative would meet the public's wish to return the property to viable use and WRECO's plans to develop the property. Restricting the use of the alternative to the golf course land use areas would meet all concerns.

Implementability: If restricted to the golf course this alternative can meet the current needs of the Site development plans and can be easily implemented using conventional soils excavation, handling, and transportation equipment. Since the AOC has been defined by Ecology as the land inside the Consent Decree Boundary, soil could be deposited in areas where future Site development would not be restricted.

Cost: An approximate direct cost of $13M to $21.6M is estimated for implementation of this alternative. Clean soil from on-Site sources makes the cost of installation of a soil cover low.

Considerations: This alternative provides for placing soil in land use areas associated with lower exposure risks. This alternative would also consolidate the contaminated soils into discrete areas, and thus is more effective than wholesale covering or capping of the Site. Soil cover may restrict future Site development but not to the degree that whole cover or capping would. The volume of impacted soil would not be reduced.

Adjustments to remediation levels: A key component of this alternative is the installation of an 18-inch soil cap/cover (as described in Section 7.2.3) The risk-based remediation or cleanup levels used in the RA for soil located within the golf course and open space land use areas are based on frequency of exposure and do not consider the installation of a soil cover over impacted soil. The application of an engineered cap/cover will further reduce the potential risk of exposure thereby increasing the effective RL. Ecology has determined that the effective remediation levels for lead- and arsenic-contaminated soils in areas of the Site that will have a cap/cover are 4,100 mg/kg and 530 mg/kg, respectively. Justification of this decision is included in Appendix H.

6.5.6 Offsite Disposal at a Landfill

This option involves excavation of soil above the CLs, transport, and off-Site disposal. Soil would be characterized based on RI and confirmation sample results.

Effectiveness:

- <u>Protectiveness:</u> Off-Site disposal would be effective in meeting the cleanup standards for the Site as listed in WAC 173-340-700. The timeframe necessary to complete this action is approximately 7.6 years.

- <u>Permanence:</u> Since no soil exceeding the cleanup standards would remain on-Site, volume and toxicity would be reduced on-Site but not at the disposal facility. This alternative represents a permanent solution.

- <u>Long Term Effectiveness:</u> This alternative is effective for the Site. Soil would have to be managed at the disposal facility over the long-term.

- <u>Management of Short Term Risks:</u> This alternative would involve the greatest amount of excavation and hauling of any of the retained alternatives. As such, the risks from dust and truck traffic would increase proportionally. An aggressive dust control program and air monitoring could minimize short-term risk to dust exposure. These efforts have been successful in the past in controlling potential risks. The high volume of truck traffic could cause a significant amount of added risk.

- <u>Consideration of Public Concerns:</u> Trucking of the soil off-Site would require approximately 44,000 truckloads over 5.6 years. Truck traffic has been an issue with the public in the past.

Implementability: This alternative can meet the current needs of the Site development plans. It can be implemented using standard excavation practices.

Cost: A direct cost range of $181M to $248.8M is estimated for implementation of this alternative.

Considerations: This alternative represents the highest reasonable cost for remediation of the Site. Implementing more costly alternatives to remediate the Site would not be warranted. No volume reduction would be attained by this alternative. It is, however, the most permanent and will be retained for further evaluation in Chapter 7.

Adjustments to remediation levels: No adjustments to the remediation levels used in the RA are warranted for this alternative.

6.5.7 Wet Screening, Classification, and Disposal of the Residual Soils at a Landfill

This option includes the excavation of soil above CLs, wet screening the soil into at least two soil fractions, and deposition of the clean coarser fraction on the Site. The concentrated finer fractions would be disposed of at a landfill. The results of the 2001 Screening Program and an evaluation of the treatability study data, presented in Chapter 5, indicates that the cut point for generating a clean coarse fraction and a concentrated finer fraction will depend on the initial contaminant concentration in the soil. For the purposes of evaluation, this FS considered this cut point to be ½ inch. As such, total volume of soil requiring off-Site disposal is likely to be approximately 76 percent. The residual soil could require stabilization at the landfill. No on-Site deposition of soils above the CLs would occur under this alternative. No cover or cap would be used.

Effectiveness:

- <u>Protectiveness:</u> Classification and off-Site disposal could be effective in meeting the cleanup standards for the Site as listed in WAC 173-340-700. The timeframe necessary to complete this action is approximately 4.4 years.

- <u>Permanence:</u> Since no soil exceeding the cleanup levels would remain on Site, volume and toxicity would be reduced on-Site but not at the disposal facility. This alternative represents a permanent solution.

- <u>Long Term Effectiveness:</u> Since all soil contaminant concentrations on-Site would not exceed cleanup standards, this alternative would be effective long-term. Soil shipped off-Site would have to be managed at the disposal facility over the long-term.

- <u>Management of Short Term Risks:</u> All wet screening and soil washing alternatives represent an increase in materials handling compared to other retained alternatives. As such, the risks from dust increase proportionally. An aggressive dust control program and air monitoring could minimize short-term risk to dust exposure. These efforts have been successful in the past in controlling potential risks.

- <u>Consideration of Public Concerns:</u> Trucking of the soil off-Site would require approximately 34,000 truckloads over 4.0 years. Truck traffic has been an issue with the public in the past.

Implementability: This alternative could be implemented using existing soil treatment and handling technologies. Disposal of contaminated fines soil at a landfill could be implemented but would require up to 34,000 truckloads. Based on data from 2001 Screening Program, water generated by the wet screening process could be filtered to remove suspended contaminants and recycled.

Cost: A direct cost range of $61.9M to $110.6M is estimated for implementation of this alternative. As a conservative approach, it was assumed that the residual material would require stabilization at the landfill. Wet screening and a classification cut point of ½ inch (24 percent volume reduction) were used in the cost evaluation.

Considerations: This alternative has the potential for significant soil volume reduction, is permanent and uses conventional soil handling technologies. It is, however, a time consuming and expensive process that would cause significant public concern (truck traffic). Since the time, benefit and increased public concern outweigh the benefits (vs. similar volume reduction alternatives) it will not be retained for further evaluation.

Adjustments to remediation levels: No adjustments to the remediation levels used in the RA are warranted for this alternative.

6.5.8 Wet Screening with On Site Deposition, Cover and Cap and Disposal of the Residual Soils at a Landfill

This option includes the excavation of soil above Site-specific RLs, wet screening the soil to separate it into "clean" and contaminated fractions, off-Site disposal of the contaminated fines, and the deposition and cover/cap of the clean, coarser fraction on the Site.

Wet screening the soil into two soil fractions, one larger and one smaller than about -200 mesh, will generate a clean coarser fraction and a concentrated finer fraction which could be disposed of at a landfill. Since the finer fraction of soil from the wet screening operation will contain higher concentrations of lead or arsenic than the excavated, untreated soil, stabilization may be required at the landfill. The results of the 2001 Screening Program indicates that the total volume of soil requiring off-Site disposal is likely to be less than 10 percent.

The coarse "clean" fraction would be transferred to discrete locations within the golf course land use areas and covered with an 18-inch thick cap/cover combination to prevent exposure. The cap would consist of a layer of high durability, engineered materials or layer of gravel placed over the deposited soils or soils which contain contaminant concentrations above the CL but below the RL. A soil cover would then be placed on top of the cap to further prohibit exposure to the underlying soils. The installation of the cap/cover would meet the RAOs by preventing direct contact exposure with soil above the CL.

Effectiveness:

- Protectiveness: This alternative could be effective in meeting the cleanup standards for the Site as listed in WAC 173-340-700. Although mobility and toxicity are not modified, volume would be reduced and the soil would be placed in a land use area where the exposure risks are reduced. The timeframe necessary to complete this action is approximately 3.6 years.

- Permanence: There would be no reduction in toxicity or mobility. This alternative is not a permanent remedy.

- Long Term Effectiveness: Once complete, this alternative would greatly reduce residual risk. Long-term effectiveness of a cap/cover remedy relies on an effective O&M program. Such programs can be effective with active management. This alternative is particularly applicable within the golf course land use areas since the operations of a golf course would ensure the competence of the cap/cover.

- Management of Short Term Risks: All wet screening, and soil washing alternatives represent an increase in materials handling compared to other retained alternatives. As such, the risks from dust increase proportionally. An aggressive dust control program and air monitoring could minimize short-term risk to dust exposure. These efforts have been successful in the past in controlling potential risks.

- Consideration of Public Concerns: No additional public concerns are anticipated.

Implementability: If on-Site deposition is restricted to discrete areas within the golf course land use area, treeless open space, and historical land use areas this alternative can meet the current needs of the Site development plans and can be easily implemented using conventional soils excavation, handling, and transportation equipment.
Cost: A direct cost range of $59.9M to $99M is estimated for implementation of this alternative.

Considerations: This alternative has the potential for significant soil volume reduction, and uses conventional soil handling technologies. It is a less time consuming and expensive process than similar volume reduction alternatives and would reduce public concern over truck traffic. This alternative provides for placing soil in land use areas associated with lower exposure risks. Future Site development restrictions due to soil covers may be limited to the golf course areas only. Since this alternative has benefits in time, cost and decreased public concern (vs. similar volume reduction alternatives) it will be retained for further evaluation.

Adjustments to remediation levels: A key component of this alternative is the installation of an 18-inch soil cap/cover (as described in Section 7.2.3) The risk-based remediation or cleanup levels used in the RA for soil located within the golf course and open space land use areas are based on frequency of exposure and do not consider the installation of a soil cover over impacted soil. The application of an engineered cap/cover will further reduce the potential risk of exposure thereby increasing the effective RL. Ecology has determined that the effective remediation levels for lead- and arsenic-contaminated soils in areas of the Site that will have a cap/cover are 4,100 mg/kg and 530 mg/kg, respectively. Justification of this decision is included in Appendix H.

6.5.9 Wet Screening with Stabilization and On-Site Deposition and Cap/Cover

This option includes the excavation of soil above the RL, wet screening of the soil, stabilization of the contaminated fraction, and deposition and cover/cap of the clean, coarser fraction on the Site.

Wet screening the soil into two soil fractions, one larger and one smaller than about -200 mesh, will generate a clean coarser fraction and a concentrated finer fraction which would require stabilization prior to deposition. The results of the 2001 Screening Program indicate that the total volume of soil requiring stabilization is likely to be less than 10 percent.

Both the coarse “clean” fraction and the stabilized material would be transferred to discrete areas within the golf course land use areas and covered with an 18-inch thick cap/cover combination to prevent exposure. The cap would consist of a layer of high durability, engineered materials or a layer of gravel over the deposited soils or soils which contain contaminant concentrations above the CL but below the RL. A soil cover would then be placed on top of the cap to further prevent exposure to the underlying soils. The installation of the cap/cover would meet the RAOs by preventing direct contact exposure with soil above the CL.

Effectiveness:

- Protectiveness: Wet screening would be effective in reducing the volume of contaminated soil on Site. It would not lower contaminant concentrations in the fines (the concentration would increase) and thus would not meet the cleanup standards for Site soils. Stabilization of the finer fraction would reduce leachability/mobility and, if placed into a monolithic unit, would reduce the total surface area available for direct contact. The timeframe necessary to complete this action is approximately 3.7 years.

- Permanence: Mobility and volume would be reduced. Toxicity would not be addressed. Since this alternative would not meet cleanup standards, this is not a permanent solution.

- Long Term Effectiveness: This alternative is effective long-term in reducing leachability and, since it is combined with a cover, somewhat reduces the risk of long-term exposure. Long-term effectiveness of a cap/cover remedy relies on an effective O&M program. Such programs can be effective with active management. This alternative is particularly applicable within the golf course land use areas since the operations of a golf course would ensure the competence of the cap/cover.

- Management of Short Term Risks: All wet screening and soil washing alternatives represent an increase in materials handling compared to other retained alternatives. As such, the risks from dust increase proportionally. An aggressive dust control program and air monitoring could minimize short-term risk to dust exposure. These efforts have been successful in the past in controlling potential risks.

- Consideration of Public Concerns: No additional public concerns are anticipated.

Implementability: Both stabilization and wet screening are conventional technologies and the implementation of these technologies in combination would not require special considerations. This alternative can meet the current needs of the Site development plans. Monitoring of the stabilized soil may be required.

Cost: A direct cost range of $46.6M to $84M is estimated for implementation of this alternative.

Considerations: This alternative does not meet cleanup standards and will not retained for detailed analysis.

Adjustments to remediation levels: No adjustments to the remediation levels used in the RA are warranted for this alternative.

6.5.10 Soil Washing with Wet Screening, Classification, Acid/Base Extraction, and Disposal of the Residual Soils at a Landfill

This option includes the excavation of soil above the RL, wet screening the soil at about 4 mesh (6 mm), deposition of the clean coarser fraction on the Site, further classification of the -10 mesh soil to separate a concentrated fine residual fraction (approximately -200 mesh), acid or base extraction of metals from the -10 mesh to +200 mesh fraction, deposition of the cleaned fraction on-Site, and disposal of the -200 mesh fraction at a landfill. Treatability studies indicate that acid extraction of soil containing lead can be attained using an acid mixture with a pH range from 1 to 3. Arsenic is more leachable under base conditions between pH 10 and pH 12. These extraction methods, in combination with classification, may be effective in cleaning impacted soil, and returning about 90 percent of the soil to the Site. Note that a lower classification cut point of 200 mesh (vs. 100 mesh) was selected to enhance metals recovery in the -10 mesh +200 mesh fraction using extraction chemicals. Metals extracted by this alternative would be precipitated and disposed of at a landfill along with non-metal sludge that may accumulate.

Effectiveness:

- Protectiveness: This alternative could be effective in meeting the cleanup standards for the Site as listed in WAC 173-340-700. Soil Washing would be effective in reducing the volume of contaminated soil. Acid extraction would be effective for soils containing lead only, and base extraction would be effective for soils containing arsenic only. No soil above CLs would remain on the Site. The timeframe necessary to complete this action is approximately 5.5 years.

- Permanence: Since no soil above CLs would remain on the Site, this is a permanent solution.

- Long Term Effectiveness: This alternative is effective long-term.

- Management of Short Term Risks: All wet screening and soil washing alternatives represent an increase in materials handling compared to other retained alternatives. Soil washing adds an additional risk associated with the handling of treatment chemicals. As such, the risks from dust increase proportionally. Aggressive chemical handling and dust control programs and air monitoring could minimize short-term risk. These efforts have been successful in the past in controlling potential risks.

- Consideration of Public Concerns: No additional public concerns are anticipated.

Implementability: Soil washing technologies (wet screening, classification, and acid/base extraction) use common processes, and the implementation of these technologies in combination would not require special considerations. This alternative can meet the current needs of the Site development plans and no soil above the RLs would remain on Site. Handling of acids and bases during the treatment process would require special precautions. No commercial application of base extraction of soils containing arsenic is known.

Cost: A direct cost range of $76.9M to $120M is estimated for implementation of this alternative. The -200 mesh soil and precipitated concentrates (10% of whole soil) would be disposed of off-Site as a characteristic hazardous waste.

Considerations: This alternative has the potential to reduce volume, toxicity, and mobility. Additionally, a low volume of material would require off-Site disposal. Acid/base handling on the Site may reduce the short-term effectiveness. It is, however, a time consuming and expensive process that could also be ineffective short-term due to acid/base handling on the Site. Since these factors outweigh the benefits (vs. similar volume reduction alternatives) it was not retained for further evaluation.

Adjustments to remediation levels: No adjustments to the remediation levels used in the RA are warranted for this alternative.

6.5.11 Soil Washing with Wet Screening, Classification, Chelant Extraction, and Disposal of the Residual Soils at a Landfill

This option includes the excavation of soil above the RL, wet screening the soil at about 4 mesh (6 mm), deposition of the clean coarser fraction on the Site, further classification of the -10 mesh soil to separate a concentrated fine residual fraction (approximately -200 mesh), chelant extraction of metals from the -10 mesh to +200 mesh fraction, deposition of the cleaned finer fraction in the excavation or other on-Site area, and disposal of the -200 mesh fraction at a landfill. Note that a lower classification cut point of 200 mesh (vs. 100 mesh) was selected to enhance metals recovery in the -10 mesh +200 mesh fraction using extraction chemicals. Metals extracted by this alternative would be precipitated and disposed of at a landfill along with any non-metal sludge that may accumulate. Recycling of the extracted metals and -200 mesh fraction may be implemented if this material can meet the strict requirements of the thermal recycling vendors (smelters).

Effectiveness:

- Protectiveness: Soil Washing may be effective in reducing the volume of contaminated soil on site. Chelant extraction has been implemented effectively on soil containing lead. Recent research being performed with soil washing technology indicates that arsenic extraction using a chelant is questionable. The effectiveness of this alternative in treating Site soils with lead or arsenic is therefore uncertain. No soil above cleanup standards would remain on the Site. The timeframe necessary to complete this action is approximately 5.5 years.

- Permanence: Since no soil above CLs would remain on the Site, this is a permanent solution.

- Long Term Effectiveness: This alternative is effective long-term.

- Management of Short Term Risks: All wet screening and soil washing alternatives represent an increase in materials handling compared to other retained alternatives. Soil washing adds and additional risk associated with the handling of treatment chemicals. As such, the risks from dust increase proportionally. Aggressive chemical handling and dust control programs and air monitoring could minimize short-term risk. These efforts have been successful in the past in controlling potential risks.

- Consideration of Public Concerns: No additional public concerns are anticipated.

Implementability: Wet screening and classification can be readily implemented using common soil treatment and handling technologies. This alternative can meet the current needs of the Site development plans and no soil above the CLs would remain on the Site. The implementation of this alternative on soil impacted by arsenic would be considered innovative and the implementation would require significant effort during the start-up period. Handling of chelants could require special precautions.

Cost: A direct cost range of $75.3M to $120M is estimated for implementation of this alternative. The -200 mesh soil and precipitated concentrates (10% of whole soil) will be disposed of off-Site as a hazardous waste.

Considerations: This alternative may be effective in treating lead soil, but is has questionable effectiveness and implementability for arsenic only soil. It is also a time consuming and expensive process that could also be ineffective short-term due to chelant handling on the Site. As such, it will not be retained for further analysis.

Adjustments to remediation levels: No adjustments to the remediation levels used in the RA are warranted for this alternative.

6.6 Ranking of Alternatives

Ranking of the alternatives, described and discussed in Section 6.4, was conducted using the criteria defined in Section 6.2. The project team independently ranked the alternatives and the results were compiled into a single ranking for each alternative (Appendix E). This allowed the semi-quantitative ranking of the best and least favorable alternative for the particular criterion.

Different weightings were applied to the criteria to examine the sensitivity of the ranking results as the weightings were varied. For lead- and arsenic-impacted soils, the weighting factor had a small effect on the overall ranking of the alternatives. The alternatives were close in each case and the highest ranked alternatives still ranked high following the application of different weightings.

6.7 Summary of Selected Alternatives

No Action and three remedial alternatives of the eleven described and evaluated in this chapter were retained for further detailed analysis in Chapter 7. The alternatives retained for detailed analysis were:

- No Action;
- Off-Site Disposal at a Landfill;
- On Site Deposition, Cap and Cover; and
- Wet Screening with On-Site Deposition, Cap and Cover and Disposal of the Residual Soils at a Landfill

Four additional alternatives were retained for small scale or “spot” applications. These were:

- Cap;
- Cover;
- Cap/Cover; and
- Off-Site Disposal at a Landfill.

The selection of each of the alternatives was based on the ability of the alternative to provide a higher level of effectiveness, implementability, and/or lower cost than other alternatives that use similar technologies. This results in the best alternatives for each technology being retained for the detailed analysis. Two of the alternatives (No Action and Off-Site Disposal at a Landfill) were retained for cost comparison.

A summary of why each of the alternatives was retained is presented below.

6.8 Retained Alternatives: Large Scale Applications

No Action: Even though it does not meet cleanup standards by either the criteria listed in WAC 173-340-700 or WAC 173-340-7490(6)(f), the No Action alternative was retained for comparative purposes. It represents the low cost alternative.

Off-Site Disposal at a Landfill: This alternative meets cleanup standards and is permanent (for the Site). It was, therefore, retained for further evaluation. This alternative also represents the highest reasonable cost, which would be incurred by a cleanup action. This alternative represents the high cost option.

On Site Deposition, Cap and Cover: This alternative meets cleanup standards, meets RAOs, minimizes risks, is easily implemented, and represents reasonable costs. It is the most protective of the containment (cap or cover) alternatives and was, therefore, retained for further evaluation.

Wet Screening with On-Site Deposition, Cap and Cover and Disposal of the Residual Soils at a Landfill: This alternative represents the most practical of the volume reduction alternatives. It is effective (meets cleanup standards), is easily implemented, has been proven to be successful (2001 Screening Program), has the lowest overall cost and represents the lowest short-term risk of this group of technologies. For these reasons this alternative was retained for further evaluation.

6.9 Retained Alternatives: Small Scale Applications

Even though large-scale applications of the following technologies may be either ineffective (do not meet RAOs) or are overly expensive for the benefit they offer, they may be appropriate for Miscellaneous Small Units. They will be evaluated further in Section 8.3.

- **No Action:** No Action may be appropriate in locations where special considerations apply. These areas could include those areas of environmental sensitivity, special cultural significance or locations of contaminants that meet certain criteria.

- **Cap:** Asphalt capping may be appropriate where trails, or parking lots are planned. Limited use of this technology would meet cleanup standards, be protective long-term (with active maintenance) and is cost effective.

- **Cover:** A thick soil cover may be appropriate where disturbance of in-situ soils could cause significant harm to areas of environmental sensitivity, or special cultural significance.

- **Cap/Cover:** The application of a cap/cover (as described in Section 7.2.3) may be appropriate where an exposure barrier is desired. This technology is as appropriate for in-situ soils as it is for areas of soil deposition especially in areas of special cultural significance.

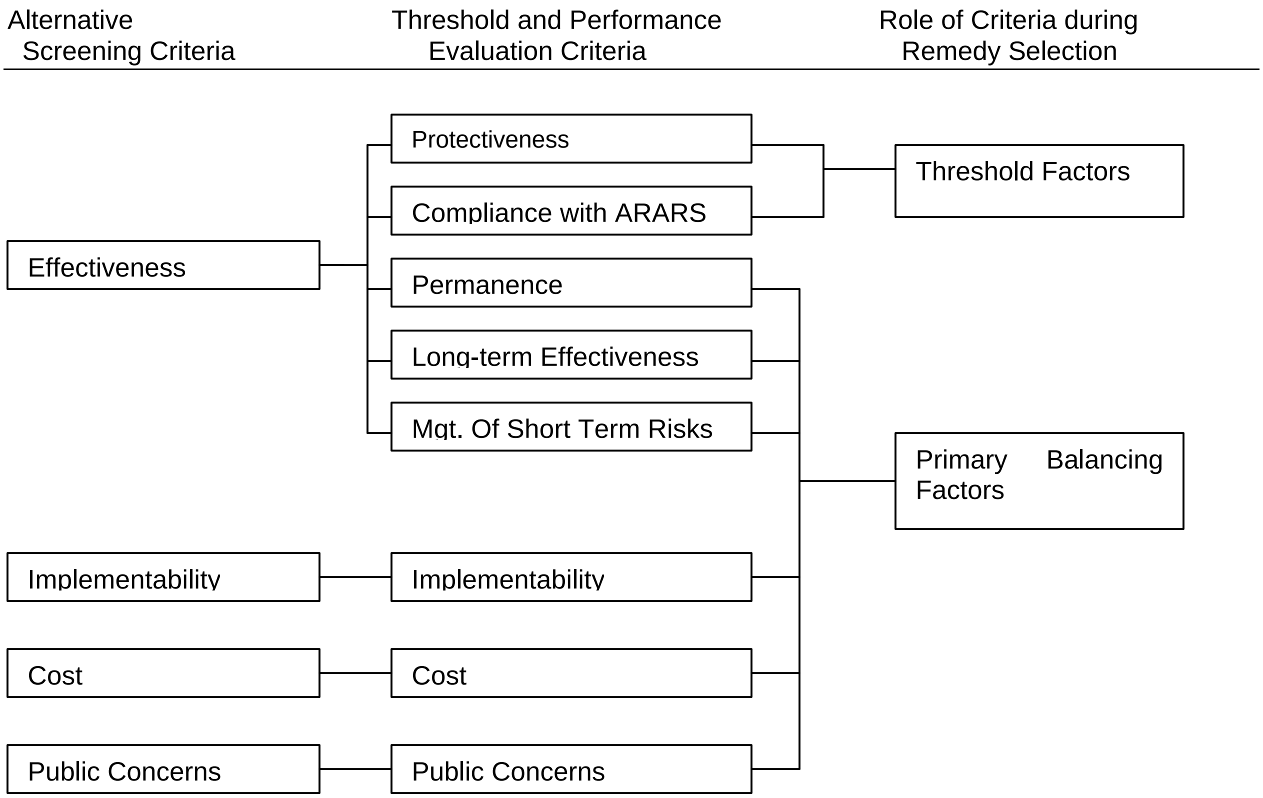
- **Off-Site Disposal at a Landfill:** Excavation and disposal of small volumes of contaminated soils could be appropriate. This technology has particular value in remediating “Miscellaneous Small RUs”.

TABLE 6-1 - ESTIMATED LOW AND HIGH RANGE UNIT COSTS

LOW RANGE UNIT COSTS ALTERNATIVE	APPROX. TOTAL COST ($)
No Action	$0
Cover	$43,200,000
Capping	$79,200,000
Cap/Cover	$21,600,000
On-site Deposition with Cap/Cover	$13,248,000
Off-site Disposal at Landfill	$181,296,000
Soil Washing with chelants and offsite disposal	$75,312,000
Soil Washing with acid and offsite disposal	$76,896,000
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	$46,656,000
Wet Screening, Classification and Disposal at Landfill	$61,920,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$59,904,000

HIGH RANGE UNIT COSTS ALTERNATIVE	APPROX. TOTAL COST ($)
No Action	$0
Cover	$72,000,000
Capping	$129,600,000
Cap/Cover	$41,472,000
On-site Deposition with Cap/Cover	$21,600,000
Off-site Disposal at Landfill	$248,832,000
Soil Washing with chelants and offsite disposal	$120,096,000
Soil Washing with acid and offsite disposal	$120,096,000
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	$84,096,000
Wet Screening, Classification and Disposal at Landfill	$110,592,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$99,216,000

Figure 6-1 – Relationship of Screening Criteria to the Evaluation Criteria



Chapter 7 – DETAILED ANALYSIS OF ALTERNATIVES AND SELECTION OF PREFERRED ALTERNATIVES

7.1 Introduction

This chapter evaluates how each alternative, retained from the screening of alternatives in Chapter 6, would be applied to each RU at the Site and presents a comparative analysis of these alternatives. Some alternatives evaluated in Chapter 6 are not appropriate for smaller scale applications (less than 2 acres in size or 5,000 cubic yards in volume). As such, this section will be include both the evaluation of the preferred alternative for larger scale (ranging from greater than 2 acres in size to total Site remediation) and the alternatives that may be used for small scale applications less than 2 acres.

In addition to the No Action alternative, which is retained as a baseline, the three primary remedial alternatives (to be used on a large scale basis) considered in the detailed analysis are as follows:

- On-Site Deposition, Cap and Cover;
- Off-Site Disposal at a Landfill; and
- Wet Screening with On-Site Deposition, Cap and Cover and Disposal of the Residual Soils at a Landfill.

In addition to the No Action alternative, which may have limited applications, the four primary remedial alternatives (to be used on a small-scale basis) considered in the detailed analysis are as follows:

- Cap;
- Cover;
- Cap/Cover; and
- Off-Site Disposal at a Landfill.

The details of how each alternative is able to successfully treat soils from different RUs are crucial to evaluating the alternatives. Not all RUs can be treated by each alternative; an alternative may be selected as the preferred alternative based on its effectiveness in treating a particular RU. The applicability of the alternatives to each specific RU is discussed in Chapters 5 and 6.

Section 7.2 describes the alternatives being retained for detailed analysis and identifies the large-scale RUs and volumes of soil which these alternatives may treat. Section 7.3 is the comparative detailed analysis of these alternatives. It also describes the evaluation criteria and rates each alternative. Section 7.4 summarizes the analysis of the alternatives. Section 7.5 describes the preferred alternatives for large-scale RUs, and any adjustments that implementation of the alternative would have on Site-specific RLs.

Section 7.6 describes the alternatives being retained for detailed analysis and for use in small-scale applications and Miscellaneous Small RUs. Section 7.7 is the comparative detailed analysis of these alternatives. It also describes the evaluation criteria and rates each alternative. Section 7.8 summarizes the analysis of the alternatives. Section 7.9 describes the preferred alternatives.

The detailed analysis of alternatives presents comparative results on the performance of each alternative for each RU. The most consistently performing alternatives are described in detail in Chapter 8.

7.2 Description of the Alternatives Retained for Detailed Analysis – Large Scale Applications

The following descriptions of alternatives are presented as they would be implemented for the RUs described in Section 3.2. These descriptions define how the alternative achieves the RAOs.

7.2.1 No Action

This alternative is retained for the purpose of comparing the current Site condition to the result of implementing any of the other remedial alternatives. No Action does not meet cleanup standards and will not be used for large-scale applications.

7.2.2 Common Activities

Certain common activities will be required for remediation of Site soils when the remedial alternatives involve excavation of in-place soil. These common activities include excavation, stockpiling, characterization and verification sampling and analysis, and regulatory classification of stockpiled soils prior to off-Site disposal, treatment, or on-Site deposition.

Analytical Field Screening: Where necessary (e.g., debris areas), field-screening samples will be collected to guide the cleanup action and allow for more cost-effective excavation of the impacted soil.

Site Preparation: Clearing and grubbing would be done once approval to proceed is given by Ecology. During this task, all vegetation would be removed from the areas to be excavated. Vegetation would be chipped and deposited on-Site. The work areas will be inspected by trained archeologists to determine if cultural or archeological artifacts are present. If any artifacts are found they will be treated in the manner described in the Cultural Resource Protection Plan that will be part of the Cleanup Action Plan (CAP) for the Site.

Excavation: Soil above the RL will be excavated to a depth of one foot of soil in impacted areas as delineated by the RI or by additional sample data, except in specific areas where soils are impacted at depths greater than one foot.

Verification Sampling and Analysis: Verification soil samples (i.e., 5-point composites) will be collected from the excavated area and analyzed. Analytical results will be evaluated to determine compliance. If soil remaining in the excavation does not meet Site RLs or, if applicable, CLs, additional excavation and verification sampling and analysis will be performed.

Haul/Stockpile: Excavated soil will be transported directly to either a low exposure risk area (e.g., golf course areas) for deposition or transported to a central area and stockpiled in preparation for treatment or disposal.

7.2.3 On-Site Deposition, Cap and Cover

General Process: In general, this alternative would involve the mass excavation of the top one foot of soil in targeted areas of the project Site, followed by the transfer of the excavated soil, and the consolidation of these soils in selected locations on-Site. Additional excavation would be required for soil greater than one foot below current ground surface if either confirmational or RI testing showed that they contained contaminant concentrations greater than CLs. Each of these consolidation locations would be capped and lie beneath the planned golf course.

Excavation Methods: Excavation of soils greater than the Site-specific RLs for lead and arsenic would occur by the following methods. All excavation work done within the first three feet of the current ground surface will be monitored by trained archeologists to determine if cultural or archeological artifacts are present. If any artifacts are found they will be treated in the manner described in the Cultural Resource Protection Plan that will be part of the Cleanup Action Plan (CAP) for the Site.

Method 1) Scraping: The majority of the shallow soils (up to 1.0 foot deep) will be excavated using self-loading pan scrapers. This method would be used on those areas within Parcel 1 that are not historical or open space RUs. Some selected excavation could occur within the golf course areas. The general scraping process would be:

- Phase I – The upper six inches of soil would be removed, using a self-loading pan scraper.
- Phase II - The remaining six inches of soil would be graded into a windrow and picked up by the pan scraper. If gravel were encountered prior to reaching the target depth, further excavation would be terminated at the gravel layer. The gravel represents a natural barrier to penetration of the subsurface by burrowing organisms. GPS will be used confirm the initial depth, followed by a complete survey to confirm the depth excavated.

Method 2 – Selected Excavation:

- In those areas not accessible to the pan scrapers (because of topography or other reasons), an excavator will be used to selectively excavate the soil in six to eight inch lifts until the desired depth of one foot. The excavated soil will be loaded into off-road haul trucks and transported to the PAs for placement. Direct pushing of soils into the PA is also possible for areas adjacent to the PAs. GPS will be used to confirm the initial depth, followed by a complete survey to confirm the depth excavated.

All of the material excavated, by either method, will be placed in the placement/consolidation areas (PAs) within the golf course areas and rough-graded.

Cap Construction: A golf course would be constructed on the project Site as an engineered cover (cap) for contaminated soils and, if necessary, contaminated debris. The majority of this material would be imported from the commercial land use areas of Parcel 1 and consolidated in roughly 73 acres of the approximately 180-acre golf course footprint. These 73 acres would constitute the PAs. Only soils and debris that contain contaminant concentrations equal to or less than the golf course remediation levels would be placed in the PAs. Each PA would be capped with 18 inches of clean soil by one of the following two methods listed below. This cap would also be placed on any areas within the golf course with in-situ contaminant concentrations (if not excavated) less than the golf course remediation level but greater than the Site-specific commercial remediation level.

- **Method One:** Six inches of clean soil would be placed over 12 inches of pit run gravel. In this process, the gravel would act as an exposure barrier to ecological receptors. The six inches of clean soil would act as an additional exposure barrier to individuals most likely to be exposed—the golf course worker, who on occasion may find it necessary to install drainage ditches or repair irrigation pipe.
- **Method Two:** Eighteen inches of “pit run” soil would be placed over a geotextile. In this case, the 18 inches of soil would act as the human health exposure barrier and the geotextile will act as the ecological exposure barrier.

Application: This alternative is potentially applicable to the following RUs:

- Golf Course RUs, and
- Commercial RUs

The volume of impacted soil associated with these RUs is approximately 714,000 CY.

7.2.4 Off-Site Disposal at a Landfill

General Process: This alternative would involve the excavation of a minimum of one foot of soil in targeted areas of the project Site. Since the planned golf course would not be constructed under this option the acreage excavated and, thus, the volume would be larger than other retained alternatives. Additional excavation would be required for soil greater than one foot below current ground surface if either conformational or RI testing showed that they contained contaminant concentrations greater than CLs. The excavated soils would be stockpiled, sampled, and transported to an approved off-Site disposal facility.

Application: This alternative is potentially applicable to the following RUs:

- Golf Course RUs;
- Commercial RUs ; and

The volume of impacted soil associated with these RUs is approximately 1,190,500 CY.

7.2.5 Wet Screening with On-Site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill

General Process: This alternative would involve the excavation of a minimum of one foot of soil in targeted areas of the project Site. Additional excavation would be required for soil greater than one foot below current ground surface if either confirmational or RI testing showed that they contained contaminant concentrations greater than CLs. These soils would be stockpiled prior to wet screening. Wet screening, as described in Chapter 6, is an effective technology for reducing the total volume of soil needing treatment. Based on the treatability study conclusions and the results of the 2001 Screening Program, it is assumed that wet screening will concentrate the lead and arsenic in the soil into 10 percent of the original soil volume. The residual soils would be loaded into 30-ton haul trucks, transported to and disposed of at an approved landfill. The process soil that met Site-specific golf course remediation levels would be transported to the golf course PAs for on-Site deposition and contained under a cap/cover. Section 7.2.3 describes the cap construction methods.

Application: This alternative is potentially applicable to the following RUs:

- Golf Course RUs;
- Commercial RUs; and

The volume of impacted soil associated with these RUs following wet screening is approximately 714,000 CY.

7.3 Comparative Detailed Analysis of Alternatives – Large Scale Applications

The following analysis provides information for the selection of a preferred alternative for each RU. This detailed analysis of alternatives will be comparative. The advantages and disadvantages of each retained alternative are identified and compared against the other alternatives to determine their relative performance according to each criterion.

The threshold criteria—protection of human health and the environment and compliance with cleanup standards—are those criteria that must be met for the alternative to have been retained from the screening described in Chapter 6. Each retained alternative meets the threshold criteria for lead and arsenic soils, with the exception of No Action, which is retained for comparison with the current Site condition.

The comparative analysis describes the evaluation criteria and presents the most favorable alternative first and includes the remaining alternatives in decreasing order of ability to satisfy the criteria.

The criteria to be used for the comparative detailed analysis of alternatives include the following:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability;
- Cost; and
- Consideration of Public Concerns.

7.3.1 Long-Term Effectiveness and Permanence

Long-term effectiveness measures the effectiveness of the cleanup action after the cleanup standards have been met. The primary focus of this comparison is to weigh the controls that may be necessary to manage the treatment residuals or untreated soil. This is done in two ways: by assessing the magnitude of the residual risk; and by assessing the adequacy of the individual controls to manage the treatment residuals or untreated soil. This long-term effectiveness comparison does not consider the residual risk or controls that may be associated with the off-Site landfill alternatives. The evaluation of "certainty of success" was omitted from this evaluation since each of the cleanup alternatives being evaluated will need to attain cleanup standards before demobilization can occur. The cleanup of the Site will be performed over a period of time during which "success" can be measured with a high degree of certainty for each process.

Magnitude of Residual Risk on Site: Each remedial alternative will have low residual risk since each will leave only acceptable concentrations of constituents (below either cleanup or remediation levels) on Site. Some alternatives have less residual risk than others. Excavation of soil above the RL means that the Site meets the remediation levels, which are based on acceptable levels of risk. The following discussion relates to the relative magnitude of low residual risk from residual soils generated by each alternative.

- The least residual risk on Site will be associated with Off-Site Disposal at a Landfill. Implementation of this alternative will result in no soil above the CL remaining on the Site.
- Slightly more residual risk will be associated with the Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill and On-Site Deposition with Cap and Cover alternatives, which include off-Site disposal of soils exceeding the golf course RL. Risk is further reduced by minimizing the potential for direct contact exposure routes with the use of a Cap/Cover.
- The No Action alternative would not modify the current Site condition and residual risk would be similar to the current risk. Future land uses would be restricted and current access restrictions would be maintained.

Adequacy and Reliability of Controls: The adequacy and reliability of controls relate to future land uses at the Site. Long-term development plans would impact only the No Action alternatives.

- Off-Site Disposal at a Landfill will require the lowest degrees of long-term management. Environmental audits of appropriate off-Site landfill facilities have determined that current controls implemented at those facilities are acceptable.

- Both On-Site Deposition with Cap/Cover and Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill rely on the Cap/Cover to reduce the potential for exposure to humans and ecological receptors. The Site development plans support the long-term management of these soils if they are located under the golf course.

- No Action would require that general access to impacted areas be restricted. Application of various institutional controls may be required to prevent exposure.

7.3.2 Reduction of Toxicity, Mobility, and Volume

This evaluation criterion addresses Ecology's preference for selecting remedial alternatives that use treatment technologies that permanently and significantly reduce toxicity, mobility, and volume of the constituents in Site soils. This evaluation focuses on the ability of alternatives to reduce the total volume of impacted soils, and irreversibly reduce mobility and toxicity of the constituents.

Implementation of any of the alternatives, except No Action, will address the highest concentrations of constituents in the soil.

Total Volume Reduction: Reduction of the volume of impacted soils is compared in this evaluation. Because metals are present in Site soils, destruction/reduction of the elemental constituents is not an option; thus, only soil volume reduction is considered.

- Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill has the potential to reduce the total impacted soil volume by up to 90 percent. As such, it represents the alternative that results in the highest amount of volume reduction.

- Off-Site Disposal at Landfill, On-Site Deposition with Cap/Cover and No Action would not reduce the volume of impacted soil. Off-Site Disposal would result in the material being transported from the Site and placed in an engineered landfill.

Mobility Reduction. The reduction of mobility is based on the alternative's ability to permanently prevent constituents from transport along potential exposure pathways. Since stabilization and other technologies that reduce leachability do not meet cleanup standards, the pathway considered is direct contact. Alternatives that involve excavation of soil above the RLs would permanently reduce the potential for direct contact exposure in the excavation area by removing the source of constituents.

- Off-Site Disposal at a Landfill would result in all soil above CLs being transported to a controlled landfill, where the mobility of the constituents would have to be controlled with liner and cap containment for the long term.

- Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill would indirectly reduce the mobility of the constituents because this treatment results in a smaller portion of the impacted Site soils being available as a potential future source for migration. The coarse material returned to the Site would not be a significant source for direct contact exposure. This alternative also reduces the possibility of direct contact with contaminated soil by using a Cap/Cover.

- The On-Site Deposition with Cap/Cover alternative also reduces the possibility of direct contact with contaminated soil by using a Cap/Cover. Developing and following health and safety procedures could limit exposure to workers during future subsurface construction or maintenance at deposition locations.

- No Action would not reduce the mobility of the constituents at the Site.

Toxicity Reduction: This evaluation is based on the ability of the alternative to destroy or convert the Site constituents to a less toxic form. Lead and arsenic in Site soils are elemental, and their destruction is not practical. None of the retained alternatives are intended to reduce the toxicity of lead or arsenic in soil.

7.3.3 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phases of the cleanup action. Each alternative is evaluated with respect to the potential impact on human health of the surrounding community, site workers, and the environment.

Potential Community Exposure during Implementation: This aspect of short-term effectiveness addresses any risk that results from implementation of the proposed alternative, such as dust generation during materials handling and transportation, and air emissions resulting from equipment operation. Dust generation would require monitoring so that the level of dust generated during soil handling does not exceed allowable levels in downwind areas. Dust control methods (i.e. applying water to work areas prior to and during excavation) would be required. The air quality impacts would be monitored to protect both Site workers' health and safety. In addition, work done within 500 feet of the southern boundary of the Site would require perimeter dust monitoring and dust prevention measures. Transportation of soils off-Site may have a very low potential for exposure. As a result the quantity of material being treated on-Site and/or transported to an off-Site landfill is the basis for this evaluation.

- No Action has the lowest risk associated with implementation since no soil is treated or removed from the Site.

- On-Site Deposition with Cap/Cover will require management of dust generation associated with the blending and amendment of soil or excavation and deposition. Only a small volume of soil would be transported off-site with this alternative.

- Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill, since it would be concentrating contaminants, would generate a greater volume of soil that requires off-site disposal than On-Site Deposition with Cap/Cover. It also requires a greater degree of soil handling since not only is the same volume of soil excavated, as On-Site Deposition, but it is also screened. This alternative will require management of dust generation associated with the excavation and handling of the soil, and during any subsequent deposition of treated soils on the Site.

- Off-Site Disposal at a Landfill will require the most controls to minimize risk associated with dust generation. Dust generation associated with the excavation of the soil and transportation will require management because all soils above CLs will be transported to an appropriate landfill.

Potential Worker Exposure during Implementation: This factor assesses potential threats that may be posed to the workers and the effectiveness and reliability of protective measures that would be taken during implementation of the cleanup action.

Personal protective equipment (PPE) appropriate for the type of potential exposure would be worn to reduce worker exposure. Workers would be trained in the health and safety procedures appropriate for their respective tasks, and operation of equipment (trucks, backhoes, and other heavy equipment) and would comply with the appropriate safety regulations.

Several alternatives would generate dust and/or require transportation to a landfill during implementation. Dust generation will be managed by wetting the soil during handling, paving the centralized treatment area, and/or covering stockpiles when not adding or removing material. Transportation of soil to the landfill will be managed by conforming to applicable Department of Transportation regulations.

The total volume of material handled and the use of water or extraction solutions are the leading criteria for this evaluation.

- Since no excavation, transport or processing of contaminated soils occur, No Action has the lowest potential for worker exposure.
- On-Site Deposition with Cap/Cover requires management of dust generated during the excavation, transport and on-Site placement of soils, and the construction of the Cap/Cover.
- Off-Site Disposal at a Landfill requires management of dust generated during the excavation, transportation and off-Site disposal of the soils.
- Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill will require management of dust generated during excavation, processing, transport and on-Site placement of soils, construction of the Cap/Cover, and transportation and off-Site disposal of the soils. In addition, workers will require additional PPE to prevent injury from the moving parts of the screening plant.

Potential Environmental Impacts: This factor addresses the potential adverse environmental impacts that may result from the implementation of the alternative and evaluates the mitigation measures which could be implemented to prevent or reduce these impacts. Potential environmental impacts include but are not limited to: dispersion of constituents; treatment water releases; spills; and wildlife exposure. All alternatives (except No Action) are believed to have the same impacts during the initial excavation of soils.

- Since no remedy would be implemented No Action has the lowest potential for adverse impacts on the environment during the implementation. It does, however, represent the alternative with the highest residual risk since no cleanup would have taken place.
- Off-Site Disposal at Landfill will have the lowest potential for adverse impacts on the environment during the implementation.
- On-Site Deposition with Cap/Cover will have a low potential for environmental impacts. The lead and arsenic constituents contained in soils amenable to cleanup action by these methods do not readily leach. If soil spills occur from the loading of trucks, they will be re-excavated. The underlying soils will be sampled to ensure the completeness of the cleanup.
- Since the screening plant would be placed upon a containment pad designed for the containment of soil and water spills, the Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill alternative will have a low potential for adverse impacts. It will have greater potential for impacts (vs. the above alternatives) due to increased handling of the soil. Process water is expected to contain only low to negligible metal concentrations, so the impact of a release of process water, if it occurred, would be low.

Time to Achieve RAOs: This factor estimates the time required to achieve the RAOs for the Site. The reduction of the constituent concentrations in the Site soil or the exposure risk to meet RAOs will be achieved by each alternative except the No Action alternative. The alternatives could be implemented in a timeframe that is principally limited by the time to complete excavation, verification sampling and analysis and, for the Off Site Disposal at a Landfill alternative, the time required to load and transport the contaminated soil off site. For the purposes of the cost evaluation the following was assumed:

- No Action would be completed immediately.
- On-Site Deposition with Cap/Cover was the fastest active alternative with a duration of 2.8 years.

- Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill alternative would require approximately 3.6 years to complete. This duration is based on a processing rate of about 1,250 tons per day, a six-month mobilization and start-up period, and a six-month demobilization and cleanup period.

- Off-Site Disposal at a Landfill will have the longest duration, 7.6 years, since the number of available trucks and the maximum truckloads per day limit the process. Table 7-1 lists the timeframes of each retained alternative.

7.3.4 Implementability

The Implementability criterion addresses the technical feasibility of implementing the alternative and the availability of materials and services. This evaluation will focus on the following criteria: ability and reliability of the technology to operate as would be required by the design and implementation schedule; ease of undertaking additional cleanup actions; and availability of services and materials. Additional criteria, such as availability of equipment, availability of commercially demonstrated technologies, administrative and regulatory requirements, scheduling, availability of appropriately sized equipment, construction access, and monitoring access, are considered to have minor impacts on the retained alternatives being evaluated in this section.

Ability and Reliability of Technology: This evaluation relates to the technical difficulties and unknowns associated with the alternative. Technical problems associated with the implementation of the alternative may prevent attainment of the remediation or cleanup levels or result in delays in the cleanup schedule.

- No technical difficulties or problems would be associated with the No Action alternative.

- On-Site Deposition with Cap/Cover would be readily implementable.

- Off-Site Disposal at a Landfill would be readily implementable. Capacity of the landfill is not a limiting factor and only small transportation problems are anticipated. No delays in the excavation and disposal process are anticipated.

- Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill could be readily implemented. Wet screening technologies have been proven on large scales at several sites and have been successfully used on the Site. Only minor delays associated with the startup of a process containing a number of mechanical operations are anticipated.

Ease of Undertaking Additional Actions: This evaluation discusses what, if any, future cleanup actions may be necessary and how difficult it would be to implement such additional actions after soil treatment by one or more of the alternatives.

- No Action would not modify existing Site conditions so that additional actions would be easy to implement.

- Off-Site disposal would be considered a permanent solution. Further cleanup actions would not be anticipated following the implementation of these permanent disposal and/or treatment alternatives.

- Any additional actions associated with the On-Site Deposition with Cap/Cover and Wet Screening with On-site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill would be associated with the placement areas. As long as permanent structures, such as buildings, are not constructed on top of PAs in the golf course land use area, subsequent action, if required, could be readily implemented in these areas.

Availability of Services and Materials: This evaluation considers the availability of the materials and equipment to implement the alternative, as well as the availability of contractors to provide competitive bids. Cleanup actions directed toward soil impacted with lead and arsenic have been and are currently being implemented throughout the Northwest, North America, and Europe. Many vendors were questioned regarding the technology they use, and the information they provided was used in the screening of alternatives. These same vendors continue to provide updates on their activities and new developments in the technologies as a result of field demonstrations of soil treatment. The screening of alternatives also identified remedial technologies that are not complex to operate and use common construction processes and equipment. Based on these considerations, the availability of services and the necessary materials to achieve the RAOs are not anticipated to be a limiting factor and are unlikely to impact schedule for any of the remedial alternatives.

7.3.5 Cost

This evaluation includes an assessment of costs that may be incurred during the cleanup action. The evaluation considers three cost categories: direct cost; indirect cost; and long-term operation and maintenance (O&M) cost and present the sum for each alternative.

Direct Capital Costs: Direct capital costs are considered to be those costs associated with the implementation of the remedial alternative for impacted soil at the Site. These costs are associated with construction, equipment, Site preparation, operation/maintenance, and disposal. Direct costs were obtained from several sources, including vendor solicitations, previous experience, and actual costs for disposal of soil generated during interim source removal at the Site. The ranges of direct costs compiled from these sources are presented in Tables 7-2.

Indirect Capital Costs: Indirect capital costs are those costs associated with administration, community relations, engineering design, construction oversight, and contingency for the alternative. These costs were estimated based on previous experience during interim source removal. Detailed tables of the cost estimates are provided in Appendix F. Tables 7-3 presents a summary of estimated indirect remediation costs.

Total Costs: Table 7-4 presents a summary of the total costs estimated for each alternative. They are:

- No Action represents the "no cost" option.
- On-Site Deposition with Cap/Cover represents the second lowest cost, ranging between $ 13.2 MM and $ 21.6MM.
- Based upon the costs associated with the 2001 Screening program costs for Wet Screening with On-Site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill would range between $46.6MM and $ 79.6MM. The average of this range is approximately 4.6 times higher than the average cost for On-Site Deposition with Cap/Cover.
- Off-Site Disposal at a Landfill represents the high cost estimate ranging between $ 181.3MM and $ 248.8MM. The average of this range is approximately 12.6 times higher than the average cost of On-Site Deposition with Cap/Cover and approximately 2.7 times higher than the average cost of Wet Screening with On-Site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill

Accuracy of Estimate: The estimates used on Tables 7-2 through 7-4 present the range of estimated total costs. These estimates of remedial action cost are assumed to be accurate to within -30 percent and +30 percent of the estimate where both estimates could vary by –30 to +30 percent of the listed value. In effect, the estimated "Best Estimate" remedial action cost would be defined as average of the high and low estimate. Additionally, cost estimates, which overlap by about 50 percent, should be considered equal for the purpose of this evaluation.

Note that the estimated total cost of Site remediation based on the preferred alternatives and the cost of completed ISR work at the Site is presented in Chapter 8.

7.3.6 Consideration of Public Concerns

MTCA calls for the evaluation of any local community concerns over the alternative and how the alternative addresses those concerns. Concerns over protection of cultural and historical sites and artifacts, long-term public health, and short-term public health have been addressed above. Concerns related to any additional short-term impacts, not covered above, are focused on the danger of truck traffic during off-Site disposal.

- On-Site Deposition with Cap/Cover represents the least public health and safety concerns since it represents the alternative with the least volume of soil leaving the Site and, with the installation of the Cap/Cover, minimizes the potential for exposure.

- Public concerns associated with Wet Screening with On-Site Deposition, Cap and Cover and Disposal of Residual Soil at a Landfill would be slightly higher than On-Site Deposition with Cap/Cover since more truck traffic would occur due to the greater volume of soil requiring off-Site disposal.

- Off-Site Disposal at a Landfill would require approximately 44,000 truckloads over 5.1 years and, thus, would cause great public concern.

- Public health and safety concerns should be highest under the No Action alternative since there would be no reduction in contaminant concentrations or potential for exposure.

7.4 Summary of the Detailed Analysis

Table 7-5 summarizes each alternative based on the results of comparative detailed analysis. For each evaluation criteria, each alternative was discussed in descending order of performance according to that criterion. Table 7-5 was prepared by giving the highest performing alternative a score of 1 and the weakest performing alternative a score of 5. In cases where it was not possible to distinguish performance given between alternatives, those alternatives were discussed together and given equal scores.

The subtotal scores for each evaluation criteria category (e.g. long-term effectiveness, Implementability, etc.) and the overall score for the sum of all criteria are presented in Table 7-5. Note that the lowest score indicates the best performance. The results obtained using this method are based on an equal weighting of each sub-criteria. This approach is consistent with MTCA guidance, which emphasizes the permanence of the selected remedial alternatives.

7.5 Preferred Alternative for Large Scale Applications

Based on the best overall score, On-Site Deposition with Cap/Cover is the preferred alternative followed by the Wet Screening alternative. Off-Site Disposal at a Landfill received the highest score making it the least attractive alternative. No action also received a good score because of its low cost but does not meet cleanup standards and, thus, cannot be used except in special circumstances (areas of ecological sensitivity).

This summary of the ranking of each alternative based on the comparative detailed analysis is further developed in Chapter 8, which describes the preferred alternatives in more detail.

7.6 Retained Alternatives: Small Scale Applications

7.6.1 No Action

No action may have some applicability to some land use areas that are highly ecologically sensitive and isolated occurrences of chemicals. The Sequalitchew Creek Canyon (excluding railroad tracks), and the open space setbacks surrounding Old Fort Lake, require special consideration to the impacts required to cleanup existing contamination (largely low concentrations) vs. impacts to the local ecology if no action was taken. This net environmental benefit evaluation indicates that no action is a positive approach for these areas.

No action may also be appropriate for small isolated occurrences of chemicals that were not used or generated as part of the manufacturing activities or decommissioning of the buildings at the Site. For No Action to be an appropriate alternative the following conditions must be met:

- The contaminant must not have been detected in groundwater;
- Their concentrations are low (near the cleanup level);
- The average/mean concentration is below the cleanup level;
- The number of exceedances (less than 5%) of the cleanup level are low in comparison to the number of detections and/or samples collected; and
- No known sources for these contaminants are associated with activities at the Site.

7.6.2 Cap

General Process - Cap Construction: In general, this alternative would involve the construction of an impermeable cap over existing soils containing contaminant concentrations above the CL but below the RL for a particular area. An example would be the use of an asphalt cap. In this case, the asphalt and subbase would act as the human health exposure barrier and the geotextile will act as the ecological exposure barrier. No excavation of underlying soils would occur.

Applicable: This alternative is potentially applicable to the following RUs:

- Open Space RUs; and
- Commercial RUs.

7.6.3 Cover

General Process - Cover Construction: In general, this alternative would involve the construction of a thick (> 3 feet) soil cover over existing soils containing contaminant concentrations above the CL but below the RL for a particular area. A key component of this alternative is the required thickness of the cover necessary to create an effective barrier to human and ecological exposure. No excavation of underlying soils would occur.

Applicable: This alternative is potentially applicable to the following RUs:

- Historical Areas;
- Golf Course RUs; and
- Open Space RUs.

7.6.4 Cap/Cover

General Process – Cap/Cover: This alternative involves the same cap/cover process described in Section 7.3 above but on a smaller scale. No excavation of underlying soils would occur.

In general this includes the construction of an engineered cap/cover 18 inches in thickness using one of the two methods listed below. This cap would be placed on any golf course land use areas with in-situ contaminant concentrations less than the golf course remediation level but greater than the Site-specific commercial remediation level.

Method One: Twelve inches of clean soil would be placed over six inches of gravel. In this process, the gravel would act as an exposure barrier to ecological receptors. The 12 inches of clean soil would act as an additional exposure barrier to humans.

Method Two: Eighteen inches of "pit run" soil would be placed over a geotextile. In this case, the 18 inches of soil would act as the human health exposure barrier and the geotextile will act as the ecological exposure barrier.

Applicable: This alternative is potentially applicable to the following RUs:

- Historical Areas;
- Golf Course RUs; and
- Open Space RUs.

7.6.5 Off-Site Disposal at a Landfill

General Process – Cap/Cover: This alternative involves the same process described in Section 7.3 above but on a smaller scale. Soils above Site-specific CLs for non-lead and arsenic contaminated soils would be excavated, loaded into 30-ton trucks and hauled to and disposed of at an off-Site landfill.

Applicable: This alternative is potentially applicable to the following RUs:

- Miscellaneous Small RUs;
- Historical Areas;
- Golf Course RUs; and
- Open Space RUs.

7.7 Comparative Detailed Analysis of Alternatives – Small Scale Applications

The following analysis uses the same criteria as listed in Section 7.2 above and provides information for the selection of a preferred alternative for each grouping of Miscellaneous Small Remediation Units.

The threshold criteria—protection of human health and the environment and compliance with cleanup standards—remain the same as those for large scale applications. Each retained alternative meets the threshold criteria for lead and arsenic, with the exception of No Action, which is retained for special considerations only.

The criteria to be used for the comparative detailed analysis of alternatives, as described in section 7.3 above, include the following:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;

- Implementability; and
- Considerations on Public Concerns.

7.7.1 Long-Term Effectiveness and Permanence

Magnitude of Residual Risk on-Site: Each remedial alternative will have low residual risk since each will leave only acceptable concentrations of constituents (below the RL) on-Site. Some alternatives have less residual risk than others. Excavation of soil above the RL means that the Site meets the remediation levels, which are based on acceptable levels of risk. The following discussion relates to the relative magnitude of low residual risk from treated soil residuals generated by each alternative.

- The least residual risk on-Site will be associated with Off-Site Disposal at a Landfill. Implementation of this alternative will result in no known soil above chemical-specific CLs.
- Since they will meet clean up standards residual risk will be associated with the Cap, Cover or Cap/Cover alternatives be within limits acceptable to Ecology. Of these three alternatives, the least amount of residual risk is associated with the Cap and Cap/Cover alternatives. The effectiveness in reducing residual risk for the Cover alternative is associated with the thickness of the cover. A thick cover (>3 feet) represents the same degree of residual risk as the other two alternatives.
- The No Action alternative would not modify the current Site condition and residual risk would be similar to the current risk.

Adequacy and Reliability of Controls: The adequacy and reliability of controls relate to future land uses at the Site. Long-term development plans could impact three of the alternatives: Cap, Cover and Cap/Cover.

- The Off-Site Disposal at a Landfill alternative will require the lowest degrees of long-term management.
- The Site development plans support the long-term management of the Cap, Cover and/or Cap/Cover alternatives.
- No Action would require that general access to some impacted areas be restricted. Application of various institutional controls may be required to prevent exposure.

7.7.2 Reduction of Toxicity, Mobility, and Volume

Volume Reduction: Because metals are present in Site soils, destruction/reduction of the elemental constituents is not an option. Thus, only soil volume reduction can occur. None of the retained alternatives reduces the volume of impacted soils; off-Site Disposal at a Landfill transfers the volume of impacted soil to the landfill.

Mobility Reduction: The pathway considered is direct contact. Alternatives, which involve excavation of soil above the RL, would permanently reduce the potential for direct contact exposure in the excavation area by removing the source of contamination.

- Off-Site Disposal at a Landfill would result in all soil above CLs being transported to a controlled landfill, where the mobility of the contaminants would have to be controlled by containment in the long-term.
- Capping, Cover and Cap/Cover result in constituents being placed in a controlled land use area. The potential for constituents in the soil to become available for direct contact is reduced by these

controls. Developing and following health and safety procedures could limit exposure to workers during future subsurface construction or maintenance at deposition locations.

- No Action would not reduce the mobility of the contaminants at the Site.

Toxicity Reduction: No alternatives are intended to reduce the toxicity of lead or arsenic in soil.

7.7.3 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phases of the cleanup action. Each alternative is evaluated with respect to the potential impact on human health of the surrounding community, Site workers, and the environment.

Potential Community Exposure during Implementation: Dust generation would be the primary concern during implementation and would need to be monitored so that the level of dust generated during soil handling does not exceed allowable levels in downwind areas. Dust control methods (i.e. applying water to work areas prior to and during excavation) would be required. Work done within 500 feet of the southern and eastern boundaries of the Site would require perimeter dust monitoring and dust prevention measures. The air quality impacts would be monitored to protect Site workers' health and safety. Transportation of soils off-Site may have a very low potential for exposure. As a result the quantity of material being excavated on-Site and/or transported to an off-Site landfill is the basis for this evaluation.

- No Action has the lowest risk associated with implementation since no soil is treated or removed from the Site.

- Cap, Cover and Cap/Cover will require management of dust generated during any excavation of soils and with the construction of the cap, cover or cap/cover. Since no contaminated materials will be used to construct these features no additional exposure risk is represented by one alternative vs. another. No off-Site transportation of soil would occur with these alternatives.

- Off-Site Disposal at a Landfill will require the most controls to minimize risk associated with dust generation. Dust generation associated with the excavation of the soil and transportation will require management because all soils above CLs will be transported to an appropriate landfill.

Potential Worker Exposure during Implementation: Personal protective equipment (PPE) appropriate for the type of potential exposure would be worn to reduce worker exposure. Workers would be trained in the health and safety procedures appropriate for their respective tasks, and operation of equipment (trucks, backhoes, and other heavy equipment) and would comply with the appropriate safety regulations.

The total volume of material handled and the use of water or extraction solutions are the leading criteria for this evaluation.

- No Action has the lowest worker exposure associated with implementation.

- Cap, Cover and Cap/Cover require management of dust generated during any excavation of soils and the construction of the cap and/or cover. Since no contaminated materials will be used to construct these features no additional exposure risk is represented by one alternative vs. another.

- Off-Site Disposal at a Landfill requires management of dust generated during the excavation of the contaminated soil, and management of transportation because all soils above the CL would be transported to the appropriate landfill.

Potential Environmental Impacts: All alternatives (except No Action) are believed to have the same impacts during the initial excavation of soils.

- No Action and Off-Site Disposal at Landfill will have the lowest potential for adverse impacts on the environment during the implementation.

- Cap, Cover and Cap/Cover will have a low potential for environmental impacts. The lead and arsenic constituents contained by these alternatives do not readily leach into the environment and represent very low potential for environmental impact. The Cap alternative, using an impermeable material, would further lower the already low potential by preventing water infiltration through the impacted soils.

Time to Achieve RAOs: Due to the small volumes associated with the remaining alternatives there is no difference in time to meet RAOs, with the exception of No Action which will require no time but does not meet RAOs.

7.7.4 Implementability

Due to the small-scale nature of this evaluation factors that impact implementability are, generally, comparable.

Ability and Reliability of Technology: No Action would not pose technical difficulties or problems. All remaining alternatives would be readily implementable.

Availability of Services and Materials: The availability of services and the necessary materials to achieve the RAOs are not anticipated to be a limiting factor and are unlikely to impact schedule for any of the remedial alternatives.

7.7.5 Cost

Cost will not be used as a evaluation criteria for small-scale applications. This decision was made for the following reasons:

- Costs associated with small-scale applications vary little between alternatives; and

- The majority of the applications that would use these alternatives have either special considerations (historic or ecological sensitively) or will only be defined (volume, time, etc.) once remediation occurs (Miscellaneous Small RUs).

7.7.6 Consideration of Public Concerns

Due to the small-scale of these applications there is little difference between alternatives. An exception occurs in areas of the Site that have great public interest (such as Sequalitchew Creek Canyon). As such, a detailed description of the processes that will be used to address these “special concerns” will be presented in Section 8.1.

7.8 Summary of the Detailed Analysis – Small Scale Applications

Due to the small volumes associated with small scale applications an analysis involving weighting of criteria was not done. Selection of the preferred alternative was weighted toward permanence, net environmental benefit and impact to historical sites.

7.9 Preferred Alternative for Small Scale Applications

Since cost was not considered in this evaluation, Cap/Cover and Off-Site Disposal are the preferred alternatives for small-scale applications. Capping could have limited applications. No action is applicable in areas of ecological sensitivity and for small isolated occurrences of chemicals that were not used or generated as part of the manufacturing activities or decommissioning of the buildings at the Site.

This summary of the ranking of each alternative based on the comparative detailed analysis is further developed in Section 8.1 and Section 8.3, which evaluates the preferred alternatives against Small RUs and the Miscellaneous Small Units, respectively.

7.10 Comparative Detailed Analysis of Alternatives – Groundwater

The following analysis uses the same criteria as listed in Section 7.2 above and provides information for the selection of a preferred alternative for groundwater. This detailed analysis of the two alternatives (Natural Restoration and Active Groundwater Treatment) will be comparative; the advantages and disadvantages of each retained alternative are identified and compared against the other alternative to determine their relative performance according to each criterion.

7.10.1 Long-Term Effectiveness and Permanence

Magnitude of Residual Risk on-Site: Each remedial alternative will have low residual risk since each would be conducted until groundwater reaches drinking water standards. As such, there is no difference between the alternatives.

Adequacy and Reliability of Controls: Both Active Treatment and Natural Restoration would rely upon deed restrictions to restrict the use of groundwater to non-potable uses. As such, there is no difference between the alternatives.

7.10.2 Reduction of Toxicity, Mobility, and Volume

Volume Reduction: Secondary treatment associated with the Active Groundwater Treatment alternative would destroy/reduce a small quantity of DNT that may be recovered. It would not, however, destroy/reduce residual DNT concentrations below the drinking water standard; the target of the treatment process. Natural Restoration would not destroy/reduce DNT.

Mobility Reduction: The pathway considered is direct contact. Each remedial alternative would limit transport since each would be conducted until groundwater reaches drinking water standards. As such, there is no difference between the alternatives.

Toxicity Reduction: Secondary treatment associated with the Active Groundwater Treatment alternative would destroy a small amount DNT that could be captured as part of the process. Natural Restoration would not destroy DNT.

7.10.3 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phases of the cleanup action. Each alternative is evaluated with respect to the potential impact on human health of the surrounding community, Site workers, and the environment.

Potential Community Exposure during Implementation: This aspect of short-term effectiveness addresses any risk that results from implementation of the proposed alternative, such as direct contact with contaminated groundwater, exposure to treatment chemicals, if any, during transport and air emissions resulting from equipment operation.

- Natural Restoration has the lowest risk associated with implementation since no actions, other than monitoring, occur.

- Active Groundwater Treatment involves the pumping, processing and treating up to 7,000 gallons of groundwater per minute (gpm). The storage of water and transportation of any treatment chemicals would require management especially during off-site transport.

Potential Worker Exposure during Implementation: This factor assesses potential threats that may be posed to the workers and the effectiveness and reliability of protective measures that would be taken during implementation of the cleanup action.

- Natural Restoration has the lowest risk associated with implementation since no actions, other than monitoring, occur.

- Active Groundwater Treatment, due to the magnitude of the process, involves a significant increase in risk associated with mechanical and safety hazards. Chemical hazards associated with any treatment chemicals would require special care.

Potential Environmental Impacts: Potential environmental impacts include but are not limited to: dispersion of constituents; erosion control in case of a release of treated water; spills of treatment chemical, if any; and wildlife exposure.

- Natural Restoration has the lowest risk associated with implementation since no groundwater is stored and treated.

- Active Groundwater Treatment, due to the magnitude of the process, involves a significant increase in the potential risk of releases stored or treated water. Treatment ponds would have to be created causing an attractive nuisance to wildlife, chemical hazards could exist due to treatment chemicals.

Time to Achieve RAOs: The time to complete either alternative is unknown. Gradually declining terms in DNT concentrations indicate that groundwater will eventually be naturally restored. Active Treatment will require up to 20 years, or longer, (Appendix I) to reach RAOs. Pump and treat systems poor historical performance in achieving drinking water standards could indicate that RAOs may never be reached.

7.10.4 Implementability

The Implementability criterion addresses the technical feasibility of implementing the alternative and the availability of materials and services.

- Natural Restoration requires no implementation.
- Active Groundwater Treatment involves the construction, operations and maintenance of an extremely large treatment facility. Successfully implementing this alternative would be very difficult. The historical performance of groundwater pump and treat systems in restoring aquifers to drinking water standards has been poor suggesting that groundwater pump and treat to achieve drinking water standards everywhere in an aquifer may be technically infeasible (Appendix I).

Ability and Reliability of Technology: This evaluation relates to the technical difficulties and unknowns associated with the alternative.

- Natural Restoration is reliable and poses no technical difficulties.

- Pump and treat systems (Active Groundwater Treatment) have a poor historical performance in achieving drinking water standards. Concentrations in Site groundwater are already low enough that active groundwater pump and treat would likely be little or no more effective than natural restoration in removing the last residual DNT from Site aquifers

Availability of Services and Materials: Natural Restoration requires no services or materials. Pump and treat systems are readily available for small applications but not for the size required to treat the large volumes of groundwater at the Site. The treatment facility would have to be custom made. As such, materials would not be readily available.

7.10.5 Cost

Cost is a major factor in the determination of the preferred alternative of groundwater remediation.

- Natural Restoration involves the monitoring of groundwater until drinking water standards are met. The cost of this activity is roughly $ 9,000 per year.
- Active Groundwater Treatment will require between $33,000,000 and $58,000,000.

7.10.6 Consideration of Public Concerns

Since the goal of each alternative is groundwater concentrations below drinking water standards there is little difference between alternatives.

7.11 Summary of the Detailed Analysis

Analysis of the alternatives results in the following conclusions:

- Both Natural Restoration and Active Treatment will reach the same goal; drinking water standards; and thus, represent the same residual risk of exposure;
- Both Natural Restoration and Active Treatment will use deed restrictions to control future groundwater use;
- Active Groundwater Treatment could reduce/destroy a small amount of DNT;
- Active Groundwater Treatment represents a significantly greater risk for potential community, worker, and environmental exposure during implementation;
- Active Groundwater Treatment would be much more difficult to implement and may not be effective in reaching RAOs;
- Active Groundwater Treatment is much more costly; and
- Both Natural Restoration and Active Treatment address public concerns.

7.12 Preferred Alternative for Groundwater

The cost for Active Groundwater Treatment at the Former DuPont Works Site (Site) to meet the DNT drinking water screening level would be substantial and disproportionate to the degree of risk reduction which could be achieved. Therefore, in accordance with MTCA (WAC 173-340-360), it is impractical to consider active groundwater remediation at the Site for an end use (drinking water) that is not planned. Appendix I discusses the impracticability of this alternative. This conclusion is based on the following:

- Site groundwater poses no risk to human health or the environment.
    - o Because off-Site drinking water supplies will supply more than double the full projected population of DuPont through the year 2020 , Site groundwater is not currently and will not in the future be used as a drinking water source (due to a deed restriction).
    - o Future Site development plans will include deed restrictions as necessary to prevent drilling of drinking water supply wells;
    - o Even assuming a hypothetical drinking water exposure that does not and will not exist at the Site, the highest DNT concentrations currently in Site aquifers (less than 0.5 μg/L) represent a worst-case risk of less than 4 x 10^{-6}, which meets a risk threshold of $l0^{-5}$;

  - Current DNT concentrations pose no risk to golfers, other visitors, or golf course maintenance workers who would be most likely to encounter Site groundwater on a regular basis when it is used for golf course irrigation; and

  - Site groundwater poses no risk to any Site ecological environment (including Sequalitchew Creek and Old Fort Lake) or off-Site ecological environment (e.g. Puget Sound).

- Natural groundwater recovery will occur following the completed interim DNT source removal. Removal of more than 40,000 cubic yards of DNT-impacted Site soils has been completed, thus the source of DNT to Site groundwater has been removed;

- Already low DNT concentrations in Site groundwater may decline further because Site aquifers are highly permeable and DNT is mobile, allowing natural flushing of DNT from the groundwater system and further reductions over time in the already low risk under a hypothetical drinking water scenario; and

- The current Site groundwater monitoring program will continue to document the DNT concentrations over time,

- Acknowledging groundwater pump and treat systems poor historical performance in achieving drinking water standards, the existing DNT concentrations in Site groundwater would represent a reasonable remediation endpoint at sites where active remediation is under consideration or underway.

- The cost to implement active groundwater remediation would be excessive, with preliminary estimates ranging between 33 and 58 million dollars. Consistent with the intent of MTCA and CERCLA, resources should be directed toward making substantive reductions in overall Site risk, which will be best accomplished at this Site by addressing other contaminants remaining in soils.

Considering the above, Natural Restoration is the preferred alternatives for groundwater.

TABLE 7-1 - ESTIMATED TIMEFRAMES BY ALTERNATIVE
FORMER DUPONT WORKS SITE
DUPONT, WASHINGTON

Estimate of Time to Completion (Work days)	Pre/Post-Construction		CONSTRUCTION				
Alternative	Design	Permitting and Reporting	Work Days (WD)	Additional WD: Screening	Additional WD: Disposal	Total Work Days	Total Years
No Action	0	0	0	0	0	0	0
On-Site Deposition, Cap and Cover;	100	303	306			709	2.8
Off-Site Disposal at a Landfill; and	100	303	415		1,083	1,902	7.6
Wet Screening with On-Site Deposition, Cap/Cover and Disposal of the Residual Soils at a Landfill.	170	303	306	100	10	889	3.6

TABLE 7-2 - ESTIMATED LOW AND HIGH RANGE DIRECT COSTS
FORMER DUPONT WORKS SITE
DUPONT, WASHINGTON

LOW RANGE UNIT COSTS ALTERNATIVE	APPROX. TOTAL COST ($)
No Action	$0
On-site Deposition with Cap/Cover	$9,200,000
Off-site Disposal at Landfill	$125,900,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$41,600,000

HIGH RANGE UNIT COSTS ALTERNATIVE	APPROX. TOTAL COST ($)
No Action	$0
On-site Deposition with Cap/Cover	$15,000,000
Off-site Disposal at Landfill	$172,800,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$68,900,000

Table 7-3 – Estimated Low and High Range Indirect Costs

LOW RANGE COSTS BY ALTERNATIVE	APPROX. DESIGN COSTS	APPROX. PUBLIC RELATIONS	APPROX. OVERSIGHT	APPROX. ADMIN & REPORTING	APPROX. Contingency	APPROX. TOTAL INDIRECT COSTS
	5%	1%	10%	3%	25%	
No Action	$0	$0	$0	$0	$0	$0
On-site Deposition with Cap/Cover	$460,000	$92,000	$920,000	$276,000	$2,300,000	$4,048,000
Off-site Disposal at Landfill	$6,295,000	$1,259,000	$12,590,000	$3,777,000	$31,475,000	$55,396,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$2,080,000	$416,000	$4,160,000	$1,248,000	$10,400,000	$18,304,000

HIGH RANGE COSTS BY ALTERNATIVE	APPROX. DESIGN COSTS	APPROX. PUBLIC RELATIONS	APPROX. OVERSIGHT	APPROX. ADMIN & REPORTING	APPROX. Contingency	APPROX. TOTAL INDIRECT COSTS
	5%	1%	10%	3%	25%	
No Action	$0	$0	$0	$0	$0	$0
On-site Deposition with Cap/Cover	$750,000	$150,000	$1,500,000	$450,000	$3,750,000	$6,600,000
Off-site Disposal at Landfill	$8,640,000	$1,728,000	$17,280,000	$5,184,000	$43,200,000	$76,032,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$3,445,000	$689,000	$6,890,000	$2,067,000	$17,225,000	$30,316,000

Table 7-4 – Estimated Low and High Range Total Costs

	LOW RANGE BY ALTERNATIVE	HIGH RANGE BY ALTERNATIVE	"BEST ESTIMATE" BY ALTERNATIVE
	TOTAL COST	TOTAL COST	TOTAL COST
	($)	($)	($)
No Action	$0	$0	$0
On-site Deposition with Cap/Cover	$13,248,000	$21,600,000	$17,424,000
Off-site Disposal at Landfill	$181,296,000	$248,832,000	$215,064,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$59,904,000	$99,216,000	$79,560,000

Table 7-5 – Summary of Detailed Analysis

Alternative		Long-Term Effectiveness and Permanence					Short-Term Effectiveness				
	Residual Risk	Adequacy and Reliability of Controls	Reduction of Volume	Reduction of Mobility	Reduction of Toxicity	**Subtotal**	Community Exposure	Worker Exposure	Environmental Impacts	Time to Achieve RAOs	**Subtotal**
No Action	4	4	4	4	4	**20**	4	4	4	4	**16**
On-site Deposition with Cap/Cover	2	1	3	3	2	**11**	1	1	2	1	**5**
Off-site Disposal at Landfill	1	2	3	3	2	**11**	3	3	3	3	**12**
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	2	1	2	3	2	**10**	2	2	1	2	**7**

	Implementability				**Cost**	**Overall Total Score**
Alternative	**Ability and Reliability of Technology**	**Additional Actions**	**Availability Services/ Materials**	**Subtotal**		
No Action	1	1	1	**3**	**1**	**40**
On-site Deposition with Cap/Cover	2	3	1	**6**	**2**	**24**
Off-site Disposal at Landfill	2	2	1	**5**	**4**	**32**
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	4	4	1	**9**	**3**	**29**

Chapter 8 – CONCEPTUAL DESIGN OF THE PREFERRED ALTERNATIVES

8.1 Introduction

The previous chapters of this FS report provide a description of the processes, which have been used to select appropriate remedial alternatives. Chapter 2 defines the objectives of the cleanup action (RAOs). Chapter 3 identifies the soil volumes, which require treatment. Chapter 4 identifies applicable technologies and process options, which can effectively treat the soils to meet the RAOs. Chapter 5 presents the findings of treatability studies performed on Site soil to better define the applicability of various technologies. Chapters 6 and 7 evaluate and compare alternatives and select a preferred alternative that can be used to cleanup the Site.

This section describes how the Site cleanup can be achieved using the preferred alternatives. Section 8.2 describes how the preferred alternative will be used in each RU to achieve cleanup goals. Section 8.3 describes the alternative to be used for Miscellaneous Small RUs. Section 8.4 summarizes an estimate of the total remediation cost for the entire Site.

8.2 Conceptual Design by Remediation Unit (Large Scale Applications)

This section describes the preferred alternatives and how they may be applied to each remediation unit.

Golf Course RUs: Golf Course RUs are defined by the property inside the golf course footprint, other than Miscellaneous Small Units. They consist of the following four sub-units:

- <u>Golf Course Placement/Deposition Areas (PA):</u> These are discrete areas within the golf course footprint that will be used to deposit soils from other RUs. Each PA will be capped with the Cap/Cover described in Section 7.2.3. No excavation is planned in these areas unless soils occur that that have arsenic or lead concentrations above the golf course remediation levels (i.e., 530 mg/kg for arsenic and 4,100 mg/kg for lead). These soils will be treated as “Hot Spots” as described in Section 8.3.
- <u>Non-PA Areas within Golf Course RUs:</u> This is the property within the Golf Course RUs that is not a PA. Soils in these areas will be excavated and placed within the PAs. Following the excavation of these soils, the resulting surface soils will be sampled (i.e., 5-point composite samples collected on a 75 foot grid) and if found to be above the golf course remediation level, re-excavated. In the unlikely event that confirmation sampling identifies soils that have arsenic or lead concentrations above the golf course remediation levels, they will be treated as “Hot Spots” as described in Section 8.3.
- <u>Foundations within Golf Course RUs:</u> Foundations of the former manufacturing building remain within the non-PA areas of the golf course. Elevated levels of lead contamination can occur in the vicinity of these foundations if the buildings were lined with lead sheeting or were either painted with or stored lead-based paint. The lead concentrations decrease significantly with increased distance from the foundation. As such, an excavation limit of 25 feet from the foundation wall will be used. No excavation will be done outside the 25-foot excavation limit. An excavator will be used to complete all the planned work. No bulldozers or scrapers will be used to excavate these soils. Excavated soils will be hauled by truck. All excavated soils will be placed in a PA **if their concentrations do not exceed golf course remediation levels**. In the unlikely event that confirmation sampling identifies soils that have arsenic or lead concentrations above the golf course remediation levels (i.e., 530 mg/kg for arsenic and 4,100 mg/kg for lead), these soils will be treated as “Hot Spots” as described in Section 8.3. Water will be used within the work area and on haul roads to control dust. All decisions on the need for further excavation will be based upon a “pass/fail” system in which if a sample exceeds screening concentrations the excavation will be deepened. No statistics will be used. Excavation and sampling will

continue until cleanup goals are met. Foundations that are located within placement areas will not be excavated.

- <u>NGRR within Golf Course RUs:</u> NGRR sections occur within the GC land use area. Past sampling determined that soils within 25 feet of NGRR centerlines can contain elevated arsenic concentrations. All soils within the 25 feet the NGRR centerline will be excavated to a depth of 1.5 feet. The sides of the rail bed will be excavated first, followed by the rail bed itself. The excavated soil will be hauled, by truck, to the nearest placement area and deposited unless, in the unlikely event that confirmation sampling identifies soils that have arsenic concentrations above the golf course remediation levels (i.e., 530 mg/kg for arsenic). These soils will be treated as "Hot Spots" as described in Section 8.3. Water will be used within the work area and on haul roads to control dust. All decisions on the need for further excavation will be based upon a "pass/fail" system in which if a sample exceeds screening concentrations the excavation will be deepened. No statistics will be used. Excavation and sampling will continue until cleanup goals are met. NGRR tracks that are located in PAs will not be excavated.

Open Space RUs: Open Space RUs consist of all Site property that will be left in its current condition. There are four open space RUs on-Site. Sequalitchew Creek NGRR has been excluded and will be considered a Miscellaneous Small Unit. They are Sequalitchew Creek Canyon (OS-01), open space north of Sequalitchew Creek (OS-02 NOC), open space south of Sequalitchew Creek (OS-3 SOC) and Old Fort Lake (OS-03).

The OS-1 RU is adjacent (i.e., south of) to Sequalitchew Creek. There are three locations where the lead concentrations exceed the ecological screening level and these three locations are classified as Miscellaneous Small Units (MSUs) and will be excavated.

There are several locations in OS-2 and OS-3 RUs where the arsenic or lead concentrations exceed the open space cleanup or remediation levels. These exceedances (including the former LR-68 hot spot which is the only location where remediation will occur on a side hill) are associated with former roads, hot spots, or are included in the Sequalitchew Creek NGRR MSUs.

The OS-4 RU is the open space surrounding Old Fort Lake. There are no lead exceedances, but there are four locations that have arsenic concentrations marginally above the area background concentration of 32 mg/kg.

No Action (other than MSU excavation) is proposed for Open Space RUs due to their special ecological sensitivity. The justification for this proposal is centered on the following five factors:

- <u>Habitat:</u> These RUs consist of vibrant ecological communities. Such habitat is important to the local ecosystem considering the amount of habitat that will be eliminated due to the remediation of all areas surrounding them.
- <u>Low Contaminant Concentrations:</u> Contaminant concentrations in these areas are low, with few locations where the Site-specific human health CLs are exceeded.
- <u>Proximity to surface water:</u> These RUs contain or are located within 100 feet of a surface water body. As such, excavation in these areas could cause significant impact, such as slope instability and potential sedimentation.
- <u>Topography:</u> These RUs have steep topological conditions. As such, containment of runoff from excavation activities could be problematic.
- <u>Accessibility:</u> Due to the steep topography, human exposure in these RUs will be limited to established travel routes.

Commercial RUs: Commercial RUs are defined by the property inside the Site that is planned for commercial land use applications, other than Miscellaneous Small Units. Soils in these RUs will be excavated to a depth of 1.0 foot, and placed within the Golf Course land use PAs. Following the excavation of these soils, the resulting surface soils will be sampled, (i.e., 5-point composite samples collected on a 75 foot grid) and if found to be above the remediation level for the golf course land use, re-excavated. In the unlikely event that confirmation sampling identifies soils that have arsenic or lead concentrations above the golf course land use RLs, they will be treated as "Hot Spots" as described in Section 8.3.

Historical RUs: These RUs make up the areas of the Site that have historic significance, as defined by a listing with the Office of Archaeology and Historic Preservation. At this time three historical RUs are known to exist on-Site. They are:

- Fort Nisqually Cemetery: (45PI404)
- Shell Midden: (45PI72)
- 1833 Fort Nisqually Site (45PI55)
- Each of these areas are small in size (less than 2 acres) and could contain discrete locations where arsenic or lead concentrations above the Site-specific remediation levels (i.e., 60 mg/kg for arsenic and 118 mg/kg for lead) occur. As such, these RUs and/or the discrete areas they contain will be treated as either "small-scale applications" or "Hot Spots" as described in Section 8.3. Mass excavation will not be done in these RUs.

8.3 Conceptual Design (Small-Scale Applications and Miscellaneous Small RUs)

The selected remedy for each historical RU will be protective of human health and the environment and will be dependent on how the land is going to be used in the future. A different remedy may be selected for an area depending on who is going to use the land (e.g., children versus adults). Stakeholders' concerns regarding the cultural resources associated with each historical RU will also be a consideration in the remedy selection process. For example, based on cultural resource concerns, capping may be appropriate for one site (e.g., Fort Nisqually Cemetery) and inappropriate for another (e.g., Shell Midden).

The selection of the preferred alternative for these RUs was performed in Chapter 7. This section summarizes how each alternative will be applied to each remediation unit.

Historical RUs: Each of these areas are small in size (less than 2 acres) and could contain discrete locations where arsenic or lead concentrations above the Site-specific remediation levels (i.e., 60 mg/kg for arsenic and 118 mg/kg for lead). As such, these RUs and/or the discrete areas qualify as either a "small-scale application" or a "Hot Spot." They are:

- Fort Nisqually Cemetery (45PI404);
- Shell Midden (45PI72); and
- 1833 Fort Nisqually Site (45PI55).

RI and other characterization data show that discrete locations within the boundary of these RUs contain lead concentrations greater than CLs. These sites are of important historical significance and should be left undisturbed to the highest degree possible. To do this, no excavation will take place, and a Cap/Cover (as described in Section 7.6.5) will be installed over the contaminated soils to prevent direct contact. A deed restriction, prohibiting excavation in the areas covered by the Cap/Cover, will be necessary to ensure the long-term effectiveness of the Cap/Cover.

Golf Course Land Use RUs: No excavation will occur unless Site-specific RLs are exceeded. Soils with contaminant concentrations exceeding RLs are considered miscellaneous small remediation unit "Hot Spots" and will be remedied by the methods described in the following section.

Miscellaneous Small Remediation Units: Miscellaneous Small Remediation Units are defined as soils impacted by contaminants or contaminant mixtures that have an in-situ volume believed to be smaller than 5,000 CY. This volume was determined to be the limit below which extensive evaluation of remedial alternatives or implementation of specialized on-Site treatment technologies would not be cost effective. Appendix G presents the procedures and assumptions used in defining the "small" remediation units.

- Similar mixture of contaminants: Soils above Site-specific CLs or RLs would be excavated, loaded, and hauled to an off-Site landfill for disposal, using 30-ton trucks.
- Similar deposition method: Soils above Site-specific CLs or RLs would be excavated, loaded, and hauled to an off-Site landfill for disposal, using 30-ton trucks.
- Small occurrence(s) of a single contaminant: The preferred alternatives for these MSUs is Excavation and Off-Site Disposal, where soils with selected contaminant concentrations above Site-specific CLs or RLs would be excavated, loaded, and hauled to an off-Site landfill for disposal, using 30-ton trucks, and No Action. No action would be appropriate for small occurrences of cadmium which has not been detected in groundwater, occurs in very low concentrations, has an average/mean concentration below the cleanup level, has a low number of exceedances (less than 5%) of the cleanup level in comparison to the number of detections and/or samples collected, and has no known source associated with activities at the Site.
- Contamination “hot spots” discovered during final cleanup: Soils above Site-specific CLs or RLs would be excavated, loaded, and hauled to an off-Site landfill for disposal, using 30-ton trucks.
- Debris: Debris with contaminant concentrations above Site-specific CLs or RLs would be excavated, loaded, and hauled to an off-Site landfill, using 30-ton trucks.
- Sequalitchew Creek NGRR: This RU is represented by the linear length of the track and the width of track bed from the toe of the uphill slope and the crest of the downhill slope. Soil with contaminant concentrations above Site-specific CLs or RLs would be excavated, loaded, and hauled to an off-Site landfill, using 30-ton trucks. The remainder of the track bed will be covered with a gravel subbase and capped with asphalt. This Cap will act as an exposure barrier to both human and ecological receptors.

8.4 Groundwater

Natural Restoration has been selected as the preferred alternative for the remediation of residual DNT in groundwater. Groundwater monitoring would be required on an annual basis until the monitoring wells reach compliance (represented by four consecutive sampling rounds showing DNT concentrations in the groundwater represented by that well are below the drinking water standard of 0.13 µg/L). Once this has been achieved the well will be closed by the proper methods (Chapter 18.104 RCW; Chapter 173-160 WAC) after approval from Ecology. Sampling of the remaining wells will continue until they reach compliance. Seep 1 will be sampled during the annual groundwater monitoring event after the surface soil mass excavation remediation work has been completed.

The highest DNT concentration in groundwater ever detected at the Site was 3.8 ug/L in MW-27 in January of 1995. If any of the results from future groundwater sampling is greater than 3.8 ug/L Weyerhaeuser and DuPont will meet with Ecology to discuss the results.

8.5 Estimate of Total Site Remediation Cost

The estimate of cost for the preferred alternative in this FS is based upon the application of the large-scale alternative (On-Site Deposition with Cap/Cover) for the majority of the Site and a combination of small-scale alternatives for small-scale and Miscellaneous Small RUs. The preferred alternative for each RU or small unit is summarized below:

Remediation Unit Type:	***Preferred Alternative***
Large Scale Applications	
Golf Course Land Use RUs	On-Site Deposition with Cap/Cover
Commercial RUs	On-Site Deposition with Cap/Cover
Open Space RUs	No Action

Small Scale Applications	
Historical RUs	Cap or Cap/Cover, On-Site Deposition with Cap/Cover
Golf Course Fill Areas	Cap or Cap/Cover
Small Miscellaneous RUs	
Similar mixture of contaminants	Off-Site Disposal at a Landfill
Similar deposition method:	Off-Site Disposal at a Landfill
Small occurrence(s) of a single contaminant	Off-Site Disposal at a Landfill, No Action
Contamination “hot spots” discovered during final cleanup	Off-Site Disposal at a Landfill
Debris (contaminated)	Off-Site Disposal at a Landfill
Sequalitchew Creek NGRR	Off-Site Disposal at a Landfill of “Hot Spots” and Cap (with asphalt) of NGRR track bed
Groundwater	
Site Wide	Natural Restoration

8.5.1 Cost for Remediation: Preferred Alternative – Large and Small Scale Applications

The costs for remediation of both large scale (the golf course land use RUs (excluding fill areas), commercial RUs and open space RUs) and small scale applications (Historical RUs, Golf Course Land Use fill areas and Miscellaneous Small RUs) are presented in Table 8 -1.

8.5.2 Cost of Groundwater Remediation

The cost for total Site remediation is approximately $ 9,000.00 per year. For this FS a 10-year period is estimated bringing the total to $ 90,000.00.

8.5.3 Cost for Total Site Remediation

The cost for total Site remediation, for the preferred alternatives, is presented in Table 8-2.

Table 8-1 – Summary of Remediation Costs: Preferred Alternative – Large and Small Scale Applications

Estimated Low and High Remediation Costs for Large Scale Applications

PREFERRED ALTERNATIVE:	LOW RANGE TOTAL COST	HIGH RANGE TOTAL COST	"BEST ESTIMATE" TOTAL COST
On-site Deposition with Cap/Cover	$13,248,000	$21,600,000	$17,424,000

Estimated Low and High Remediation Costs for Miscellaneous Small Remediation Units

RU TYPE	LOW RANGE TOTAL COST	HIGH RANGE TOTAL COST	"BEST ESTIMATE" TOTAL COST
Similar Mixtures	$ 63,370	$ 63,926	$ 68,833
Similar Deposition	$ 63,370	$ 63,926	$ 68,833
Single Contaminant	$ 63,370	$ 63,926	$ 68,833
"Hot Spots"	$ 636,965	$ 642,550	$ 691,876
Debris	$ 759,684	$ 766,344	$ 825,174
Sequalitchew Creek NGRR	$ 633,704	$ 639,259	$ 688,333
Total	$ 2,220,635	$ 2,240,103	$ 2,411,884

Table 8-2 – Summary of Site Remediation Costs

Item		"Best Estimate" of Cost
Proposed Remediation in FS (1)	$	17,424,000
Miscellaneous Small RUs	$	2,411,884
Groundwater(2)	$	90,000
Total Cost of Site Remediation	$	19,925,884

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(1) Based upon preferred alternative listed in Section 8 and costs in Appendix F
(2) Based upon preferred alternative listed in Section 8 and costs listed in Appendix I

APPENDIX A – *DESCRIPTION OF REMEDIATION TECHNOLOGIES FOR SOIL*

A.1 Introduction

This appendix describes the remediation technologies and corresponding process options associated with each general response action listed in Section 4.3. The information in this appendix forms the basis for the screening of the technologies presented in Tables 4-1 and 4-2. The general response actions, technologies, and process options are organized in this appendix in the same order they are arranged on the tables.

The general response actions identified for the remediation of metals- impacted soils at the Former DuPont Works Site (Site) include:

- No Action;
- Institutional controls;
- Containment;
- Removal;
- Treatment; and
- Stabilization.

The technology performance is compared with the chemical concentrations observed at the Site and the remediation or cleanup level considered appropriate for the land use are presented on the figures. All the technologies are able to meet the RAOs.

A.2 No Action

The No Action alternative is retained throughout the feasibility study process. It provides a baseline to compare the other alternatives to evaluate their effectiveness. The no action response literally means leaving the Site exactly as it exists at the time of preparation of the FS.

A.3 Institutional Controls

Institutional Controls are physical or legal restrictions used to prevent exposure to Site constituents. Typically, exposure is prevented or reduced by restricting access to the Site or to potential constituent receptors—such as groundwater or wildlife. The toxicity, volume, and mobility of the constituents are not reduced.

For these restrictions to be effective, they require understanding and compliance by the population being protected. Two types of institutional controls (technologies)—access restrictions and monitoring—are described below.

A.3.1 Access Restriction

Access restriction falls into two basic types: physical restrictions and legal restrictions. The physical restrictions are usually easy to implement and very cost-effective. The legal restrictions are also easy to implement and restrict future use of the property.

Fence: Fencing a site is an inexpensive and effective method for restricting access. Simple fences (such as chain-link) accomplish significant reduction of potential human exposure. If required, special fences can be constructed to keep out wildlife. Fencing does not prevent access to small burrowing animals or birds. Well-constructed fences may last many years with little maintenance. Since the Site will be developed as recreational, commercial, and industrial areas, fences will have little applicability. They are currently used to restrict access to the Site during the RI and interim source removal and will continue to be used during future cleanup actions.

Warning Signs: Warning signs are also very effective at restricting access at very little cost. They are most effective when used with fencing. Since the Site will be developed as recreational, commercial, and industrial areas, warning signs will have little applicability. They are currently used to restrict access to the Site during ongoing activities.

Deed Restrictions: Deed restrictions may be useful in preventing accidental exposure due to activities of future property owners. The deed restriction notifies future owners of specific Site conditions to prevent activities that may release constituents or increase exposure. Generally, Site-wide deed restrictions would reduce the value of the Site.

Fishing/Hunting Restrictions: These restrictions reduce human exposure by reducing the consumption of potentially impacted tissues. Since zoning prohibits hunting on the Site and no fish-bearing surface water body is present on the Site, this restriction is effectively in-place.

Health and Safety Equipment: Using appropriate health and safety equipment and supplies is essential for individuals working on the Site during the cleanup action and Site development. When used properly, equipment such as protective clothing, boots, and a respirator can prevent exposure.

A.3.2 Monitoring

Monitoring can be used to prevent exposure by detecting contaminant migration. Early detection of the contaminant allows corrective action to be taken prior to exposure. At this Site, monitoring may be relevant to the following media:

- Groundwater;
- Air (during cleanup action only); and
- Soil.

Air monitoring is particularly useful during remedial construction because of the greater risk of exposure from dust. Verification sampling of the soil can be used during construction to verify that the contamination has been addressed.

Groundwater and surface water monitoring is useful in situations where there is uncertainty as to how a constituent might migrate to and in the aquifer, or in the surface water.

Since groundwater or surface water has not been impacted by lead and arsenic during the operation of the facility there is little chance that groundwater will be impacted following cleanup action. Groundwater and surface water monitoring may be required in association with stabilization or related to existing DNT-impacted groundwater contamination.

A.4 Containment

Containment uses physical barriers to either prevent direct exposure to the constituent or prevent migration of the constituent into the environment. Migration may be prevented by either preventing movement of the impacted medium or preventing a transport agent—such as water—from contacting the impacted medium. Containment technologies do not change the nature of the constituent but reduce risk by preventing exposure to the constituent.

Four containment technologies for soil are discussed below; cover, cap, liner and cap/cover.

A.4.1 Cover

Covers are characterized by a physical barrier between the impacted medium and the atmosphere. Usually, the purpose of a cover is to prevent or reduce contact between the impacted medium and precipitation. Covers also serve to prevent exposure to wind and to prevent direct contact by humans or animals.

Covers are used when there is extensive subsurface contamination that is difficult to remove or remediate in-place. Covers are often used over stabilized material or residues from other treatment technologies. Covers may also be used over soil with constituent concentrations below remediation levels, but still above cleanup levels, to prevent direct contact and further reduce residual risk.

Clean Soil Cover: A clean soil cover consists of the placement of imported clean soil on top of the soil to be covered. It prevents direct contact with the covered soil and provides a good substrate for vegetation. As vegetation will prevent erosion, little maintenance of the soil cover may be required. It is an effective low cost option when no leachable constituents of concern are present.

Re-vegetation: Although it can be used alone, re-vegetation is usually associated with some form of soil cap. The vegetative cover protects the cap from wind and rain erosion. It can also prevent direct contact with uncapped impacted soil during the cleanup action process and reduce windblown dust. Re-vegetation does not, however, prevent direct contact to plants or burrowing animals.

A.4.2 Cap

Engineered Cap (Synthetic Membrane, Clay, Asphalt, Asphalt Concrete, Portland Cement Concrete, Multimedia): Low permeability caps can be constructed from a variety of materials, or combinations of several materials. Materials that may be used in cap design, either individually or in combination, include synthetic polymer membranes, clay, asphalt, asphalt concrete, or Portland cement concrete. These materials are subject to damage so that engineered caps require long-term maintenance. Engineered caps are the most effective covers to reduce percolation of rain through the covered soil. Since lead and arsenic in low concentrations are not leachable, engineered caps have some limited use at the Site.

A.4.3 Liner

Liners are characterized by a physical barrier between the impacted medium and the underlying soil or groundwater. The main purpose of the liner is to reduce water movement from an impacted zone to clean zones. Usually, the impacted soil is placed in a prepared, lined basin and eventually capped. Liner materials include **synthetic membrane** and **clay** although often a combination of the two is used (**multimedia liner**) (EPA, 1985). Unless a nearby source of clay is available, clay is not usually economical. There is no ready source of clay near the Site. DNT is the only constituent at the Site that is leachable and it has been almost entirely removed during interim source removal. Consequently, a liner would have limited use as a containment technology. A lined basin may be considered for on-Site placement of stabilized concentrated fines but an engineered cap over the stabilized soil would prevent infiltration and leaching more cost effectively. Liners will not be retained for further analysis.

***In Situ* Liner** can be created using **grout injection**. In this process, low permeability grout is injected in a grid pattern across the Site. The grout permeates the soil underlying the impacted zone creating a continuous layer of very low permeability material. The biggest advantage of this method is that the impacted soil does not have to be excavated. This can be important if the contamination extends to a great depth. Disadvantages include expense and ensuring that the grout layer is continuous. This method is not appropriate for the Site where most of the constituents are located in the upper foot of soil.

A.4.4 Cap/Cover

Cap/Cover is the combination of an engineered cap or liner and soil cover. It prevents direct contact with the covered soil and provides a good substrate for vegetation. As vegetation will prevent erosion, limited/little maintenance of the soil cover may be required. It is an effective low cost option when no leachable constituents of concern are present.

A.5 Dust Control

Dust control is typically important only during cleanup action (excavation, screening). There are two basic types of dust control: binding agents and barriers.

Water Spraying: This is the most common binding agent used for dust control. It is used on virtually all construction jobs. It has the disadvantage that it is temporary and requires frequent reapplication. Applied at the correct flow rate, the water will not infiltrate to the groundwater.

Dust Suppressants: Chemicals or binding agents such as liquid asphalt last longer. These have the disadvantages that they may be toxic and are more expensive than water. Biodegradable dust suppressants are available, such as wood fiber suspended in water. This material is sprayed over the surface, as for water, to form a protective crust, although it does not dry as quickly. Because the dust suppressant caps are typically thin, they are susceptible to cracking, especially under traffic loading.

Wind Fences: A wind fence is a barrier that is placed around the perimeter of the area to be protected. It deflects the wind from the susceptible area preventing it from entraining dust particles. Wind fences are useful when constant activity prevents covering of susceptible areas and the wind blows from a constant direction. These are unlikely conditions at the Site; therefore, this option will not be considered in further analyses.

Plastic Covers: Plastic covers are another form of barrier. When soil piles sit for long periods of time, they can be covered with plastic. Plastic covers are effective regardless of the direction the wind is blowing. Plastic covers are currently used on the soil stockpiles at the Site.

Vegetation: One type of permanent dust control is vegetation. Vegetation can work both as a binding agent and as a barrier. Plant roots bind soil particles to the surface at the same time that the plant above the ground reduces near-surface wind speeds. Site development is expected to include landscaping and vegetation. Hydro-seeding may be used to establish a grass-type vegetation after cleanup action and before landscaping. Since vegetation is already part of the Site development plan, it will not be carried into further analyses.

A.6 Removal

Removal is a rapid method to move the soil from the uncontrolled environment of the impacted site to a controlled treatment or disposal area. Except for *in situ* methods, removal is required for all remedial alternatives.

Removal technologies do not change the nature of the constituent but reduce risk when combined with treatment or disposal technologies.

Excavation of impacted soils can normally be accomplished with conventional construction equipment such as scrapers, backhoes, bulldozers, and front-end loaders. Some excavation is required for virtually all remedial alternatives except No Action. In some special situations, such as on steep slopes, or near buildings and utilities, special equipment may be necessary.

A.6.1 Excavation and Off-Site Disposal

Off-site disposal is a proven, effective remedial technology. Sites can be quickly and permanently cleaned up, although the nature and toxicity of the constituent is not changed. The main disadvantage of off-site disposal is the potential liability associated with mismanagement of the contained waste in the receiving landfill.

Hazardous Waste Landfill: Disposal in a hazardous waste landfill is a proven technology. This type of management is usually reserved for wastes that have been characterized as state dangerous or RCRA (federal) hazardous wastes based on their properties or characteristics or because they have been explicitly listed in state and federal hazardous waste regulations (e.g., Chapter 173-303 WAC and 40 CFR Parts 260 through 270). Thus the properties, characteristics, or constituents of these hazardous wastes warrant special, RCRA landfill disposal requirements.

The EPA Land Disposal Restrictions (LDRs) require that hazardous wastes be subjected to minimum levels of treatment and/or contain minimum concentrations of hazardous constituents before they, or residues from their treatment, can be land disposed of. Off-site land disposal of soils that are hazardous wastes may require treatment of concentrations that are above LDR concentrations.

Solid Waste Landfill: This technology involves disposal in a lined landfill with a leachate collection system. Solid waste landfills are the prime repository for municipal trash and garbage. Some solid waste landfills also accept industrial waste including problem waste.

Chapter 173-304 WAC defines problem wastes as "(a) soils removed during the cleanup of a remedial action site, or a dangerous waste site closure or other cleanup efforts and actions and which contains harmful substances but are not characterized dangerous wastes, or (b) dredge spoils..." Regulations that deal specifically with problem waste (PW) management and disposal have not yet been developed (as of March 1994). Disposal as a PW may be suitable for stabilized soil which passes the toxicity characteristic leaching procedure (TCLP) tests or for mixture of non-hazardous impacted soils with constituent concentrations above the Cleanup Standard.

Demolition Debris Landfill: Demolition debris landfills are unlined. Debris landfills have been used for debris disposal during interim source removal and additional disposal of non-hazardous debris is anticipated as part of future cleanup action. Disposal of the Site soils in this type of landfill would not be appropriate.

A.7 Immobilization

Immobilization is a response action designed to accomplish at least one of the following (EPA, 1986):

- Improve the handling and physical characteristics of the soil;
- Decrease the surface area available for the transfer of constituents from the soil; and/or
- Limit the solubility of the constituents in the soil.

Immobilization is often used in conjunction with disposal of material in a commercial landfill (EPA, 1985).

Immobilization encompasses two technologies: solidification and stabilization (or fixation). The emphasis of the first is to create a high strength material which will reduce the exposure to the impacted soil by direct contact. The second technology focuses on reducing the constituents mobility within the matrix. Those two technologies overlap as some solidification reagents also have a fixation effect and vice versa. Often, both effects are desired. Consequently, solidification and stabilization will be considered as one technology.

A.7.1 Solidification/Stabilization

Common solidification reagents include **Portland cement** and **silicate-based** materials like fly-ash and polysilicate mixtures. These reagents have been used for many years in road construction and also provide stabilization for certain metals. Portland cement is effective to fix lead, and arsenic has been successfully stabilized with a polysilicate mixture.

Arsenic chemistry is complex, involving a variety of valence states and ionic species, and both inorganic and organic species. Arsenic oxides and sulfides can be stabilized but not the organic species (contained in herbicides). The arsenic oxide (found in flue dust from non-ferrous smelting operations) is soluble in both acid and basic environments. Lead is soluble mostly in an acid environment. The range of pH in which both lead and arsenic oxide will be stabilized is narrow. The stabilization of arsenic oxide and lead-impacted soil is difficult.

Mix design for solidification must be determined by bench-scale testing with the actual Site soil.

Other, innovative techniques include **thermoplastic** solidification and **encapsulation**. In thermoplastic solidification, the soil is sealed in a matrix such as asphalt bitumen. This technique requires specialized equipment. Asphalt incorporation is a thermoplastic solidification method which is also a recycling process for the impacted soil. It can be applied only to soil passing TCLP tests and therefore is unlikely to be an option for most soils above the statistical action levels (SALs). Encapsulation uses an organic binder or resin to physically contain waste materials either by containing individual soil particles or a cluster of particles. The encapsulation processes are generally proprietary and expensive.

Cryogenic encapsulation is a temporary solidification process only. A large power supply is required to keep the ground frozen. No temporary solidification is required at the Site; therefore, this process will not be further analyzed.

One common method of fixation is to use **sorbents,** such as fly-ash or bentonite, to absorb free liquid and produce a solidified waste. Other additives can be use to chemically fix constituents by forming an insoluble precipitate or complex. Many proprietary mixes exist to fix various constituents. This technology is not applicable at the Site since the impacted soils do not contain free liquids.

Fixation can be also be achieved *in situ* or *ex situ* by **surfactant fixation**, often a proprietary process. This technology utilizes the application of specific inorganic and organic reagents which readily percolate through the impacted soils. They reduce heavy metals to their lowest valence state and render them insoluble as stable organometallic complexes. The detoxified soils achieve the TCLP requirements and are no longer leachable. This technology has been demonstrated only for low metal concentrations (lead and cadmium: 10 to 15 mg/kg) and may require toxic amounts of surfactant at higher concentrations. This technology will not be retained for further analysis.

Surface Soil Fixation employs soil mixing and grinding with addition of a fixating agent to homogenize concentrations in the surficial soil and stabilize the metals. The homogenization action results in a reduction of isolated elevated concentrations in the surficial 6 inches of soil. The fixating agent may be a constituent modifying the pH of the soil thus lowering the leachability potential of the metal or a proprietary additive forming a chemical bond with the metal for stronger fixation. Proprietary additives for strong fixation may not be necessary since none of the TCLP results for arsenic were above the limit of 5 mg/L. Surface soil fixation could be applied to mitigate direct contact risk by aggregating the fines. The addition of cement can result in the formation of a granular material that could be used as a subgrade under areas such as parking lots.

In situ **Vitrification (ISV)** is a process whereby impacted soils are melted with a high electrical current and then allowed to cool to form a stable glass-like material. ISV is a patented process developed by Battelle Pacific Northwest Laboratory for the U.S. Department of Energy as an in-place stabilization technique (Hansen, 1988). At the high temperatures created (over 1,700 degrees Celsius), organic material undergoes chemical change by pyrolysis (thermal destruction in the absence of oxygen). The products of pyrolysis rise to the surface as off-gases which must be collected, monitored, and treated. Inorganics are immobilized by chemical incorporation in the melt and solidified with the residual product. The residual ISV product offers 20 to 45 percent volume reduction, and excellent structural, weathering, and biotoxicity properties.

Full scale tests with ISV have been conducted on a variety of soil types (Fitzpatrick et al., 1986; Timmons, 1989). The full scale unit has four electrodes spaced about 18 feet apart. This results in a melt zone about 30 feet wide.

Buried metal in the soil can cause short-circuiting problems for the ISV process depending on the physical state of the objects. Fitzpatrick et al. (1986) states that soil with up to 5 percent metal, by weight, can be vitrified. In recent tests, soils with up to 15 percent metal, by weight, have been successfully melted (Timmons, 1989).

In situ vitrification is not an appropriate process for the Site since most of the metal contamination is distributed in the first foot of soil.

A.8 Treatment

Treatment technologies permanently reduce the toxicity and/or volume of the constituent or impacted material. The cleaned soil can then be returned to the site, disposed of as clean fill, or placed in a landfill. Treatment technologies for metals-impacted soils include recycling, and thermal and soil washing processes.

A.8.1 Recycling

Lead Smelter: Recycling lead-impacted soil to a smelter involves recovery of lead from the soil by the same process which extracts lead from ore. A minimum soil lead content of 10 percent by weight is expected to be required for acceptance by the smelter. The presence of other metal constituents may be problematic as they would volatilize, remain in the slag as a waste product, or impact the quality of the lead metal product.

Cement Kiln: Impacted soil could also be recycled to a cement kiln where the volatile metals would be removed in the off-gas and recovered in the baghouse, and the heavy metals incorporated into the cement at low concentrations. The soil would have to pass the TCLP tests before being accepted by the cement kiln. This is an unlikely option for Site soils.

A.8.2 Thermal Treatment

Thermal treatment does not destroy metals. Lighter metals will volatilize, heavy metals will remain in the soil. Important concerns are potential air emissions and the liability associated with the residuals.

In general, thermal treatments are characterized by high costs based on energy consumption.

Slagging with Off-Gas Treatment: This process is a two-stage, high temperature system. The temperature inside the reactor section is between 1,400 and 1,850°C. In the high-temperature reducing atmosphere, metals such as lead, arsenic, and cadmium are vaporized from the waste. Less volatile metals such as copper, nickel, and cobalt, if present in sufficient quantities, coalesce as a molten alloy phase. The remaining components of the waste, which may include metal oxides such as those of iron, melt in a molten slag.

Products from the reactor are passed to a slag separator. The process gases are drawn from the slag separator through the off-gas system where the vapors are post-combusted with ambient air and condensed as metal oxides. The gases are subsequently cooled, and the mixed metal oxide particulate is collected in a baghouse before discharge to the atmosphere. This process significantly reduces the volume of impacted material. The metal oxide particulates and the slag are withdrawn from the reactor and recycled or disposed of according to their toxicity.

Fixed and transportable full-scale treatment units exist. Their maximum treatment rate is 2.5 tons per hour, which will not be adequate to treat all the impacted soils within a reasonable time frame. This process will not be retained for further analysis.

Thermal Desorption: As mercury is fairly volatile compared to other metals (boiling point 356.9°C), thermal desorption can be used to recover it from soil. The impacted soil is heated to the point where mercury begins to volatilize; the vapors are collected and treated to recover the mercury. This process is only applicable to mercury and would leave other metals in the soil. As only small amounts of mercury contaminated soils occur on the Site, this technology was not retained for further analysis.

Hydrogen Volatilization: Hydrogen volatilization is a process in which lead is recovered by high temperature distillation in hydrogen. It is an experimental technology demonstrated only in the laboratory and will not be retained for further analysis.

A.8.3 Physico-Chemical Separation

Physico-chemical separation removes the constituent from the medium with a combination of physical (scrubbing, classifying) and chemical processes (solvent extraction, solubilization).

Solvent or Chelant Extraction: Soil is placed in a tank with a solvent or chelant. The mixture is agitated, and the solvent or chelant is used to extract the constituent from the soil matrix. Clean soil is returned to the Site and the solvent or chelant is treated to remove the constituent and is recycled. Concentrated residues from the solvent/chelant recovery process are then further treated or disposed of. EDTA, citric acid, and other solvents and chelants have been used with various metals. Solvent/chelant extraction is site-specific and generally requires a pilot study prior to system design. It has the advantage of returning most of the soil, clean, to the Site.

Solvent/chelant extraction is generally done in a batch process, where a volume of soil is placed in a mixing tank in one batch, treated, and then removed. Each batch of soil may be washed more than once with fresh solvent.

***In Situ* Extraction:** In this process, lagoons are constructed over the impacted area. Water is allowed to infiltrate through the impacted soil into the underlying groundwater. The groundwater is then extracted for treatment and recycled back to the lagoons. This is a very simple process that is most useful when groundwater contamination already exists. If not, there is a risk of not capturing all of the infiltrating water and causing a groundwater problem. Another disadvantage is that fine-grained soils can greatly slow the process. Because contamination at the Site is shallow and water is a poor solvent for metals, this technology was not retained for further analysis.

Acid or Base Extraction: Impacted soils are washed with an acid or base leaching solution to concentrate the metals in solution. Other chemicals can be added to facilitate metals solubilization. The washed soil is then separated from the leaching solution and the soil may require neutralization before being backfilled on the Site. The solution is treated to recover the metals, by precipitation, reverse osmosis, or ion exchange. Precipitation produces a sludge containing the metals which can be recycled or disposed of at a RCRA landfill. Selective ion exchange can recover individual metals but is only cost-effective for recovery of precious metals. Reverse osmosis produces a concentrated solution of metals which requires further treatment. Acid extraction has been demonstrated as effective for lead. Most arsenic chemical constituents are not removed by acid. Basic solutions are more effective. As for solvent or chelant extraction, acid/base extraction has the advantage of returning most of the soil, clean, to the Site.

Electrical Separation: Electrokinetic soil processing is an *in situ* semi-continuous process for the removal of heavy metals, radionuclides, and organic bases from fine-grained silty clays. The application of a low intensity, direct current applied across the impacted soil, results in removal of the constituents through mass transfer mechanisms of diffusion, and ion migration. The pollutants present in the soils are removed in cycles. One cycle will typically capture 75% to 95% of the original constituent and will require 2 to 3 months. Each cycle involves application of direct current, removal of the constituents at the cathodes in either soluble or precipitated forms, and replacement of the lost soil moisture.

This technology is not cost-effective in sands and gravels and therefore not applicable to the Site.

Screening: Screening is a common pretreatment process for other types of treatment since oversized particles cannot be processed by equipment associated with soil washing and thermal treatment methods. In this process, soil is fed into a wire mesh screen to remove oversized particles. Most metal constituents in soil are bound up in the finer fraction of soil particles so screening also reduces the volume of impacted soil by removing the larger particles which do not exceed the Site-specific remediation levels.

Screening can be a dry or wet process depending on the degree of separation sought. Dry screening will not remove all the fines from the cobbles/gravel, especially if the soil is moist. Its advantage is that water handling is avoided. Wet screening uses water spray to wash the fines off the gravel and improve the degree of separation. The wash water will be carried with the fines and may require treatment. Wet screening generally allows separation to a finer mesh than dry screening.

Classification: Classification is a group of water-based processes which typically uses mineral processing technology (jigs, spirals, flotation, hydrocyclones, attritioning). The process generates a clean soil fraction, an impacted sludge or cake consisting of soil fines, other concentration material, and process water. The waste and concentrates may require treatment prior to recycling. The sludge may be recycled to a lead smelter (if the lead is highly concentrated) or a cement kiln, or disposed of in a RCRA landfill. A pilot-scale test is necessary to determine the feasibility of this technology for a given soil. Classification has the advantage of returning a large fraction of the soil, clean, to the Site while not involving the handling and treatment of chemicals (solvent, acid, or base). Classification may be a more or less complex process depending on the concentration rate desired and the equipment required to achieve that concentration.

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APPENDIX B – *OVERVIEW OF SOIL TESTING PROCEDURES AND DATA INTERPRETATION*

B.1 Whole Soil Procedures

Sample Preparation: Upon receipt, the soil sample was coned and quartered, and blended and split to produce a more homogeneous head sample.

Stage Crushing: Throughout the course of this program, samples assayed for chemical constituents were crushed prior to analysis. The fines were separated out and the oversize was crushed again. The entire process was repeated until the desired particle size was achieved. This helped to ensure that a representative sample was assayed.

Sample Verification Testing: After sample preparation, three grab samples were collected. Each sample was analyzed for total lead. The TCLP was performed on a composite of the three samples, with leachate analysis for total lead. These analyses were performed on a rush or priority basis to check whether the lead sample collected was representative of the lead concentrations at the Site, based on the results of previous sampling events.

Moisture Content: The sample was air dried and the moisture content was reported as a percent weight loss. This provided an indication of how wet or sticky a soil was and how dry that soil can be made by stockpiling in a dry area. This information was useful for materials handling and technology selection.

Soil Bulk Density: This parameter, measured as kilograms soil per cubic meter, provided an exact conversion from volume to weight. Loose density was representative of soil in an excavated condition, while packed density was representative of *in situ* conditions. The sample for packed density measurement was not compressed, but was prepared by tapping the container so that the soil settled.

Soil Plasticity (Atterberg Limits): The liquid and plastic limits, and plasticity index are qualitative measurements indicating soil plasticity. This information provides an indication of how sticky the soil is, and how it deforms and flows (rheology). The information was used for identification and classification of fine-grained soil and clays. It was useful for materials handling, when choosing excavation and mixing equipment for implementation of treatment technologies.

Particle Size Distribution: Soil was divided into approximately nine size fractions ranging from cobbles/gravel, coarse to fine sands, and silt/clay by wet screening. The particle size distribution was used in determining the USDA soil classification. Each size fraction and the residual water were then analyzed for total lead. The weight and lead distributions were reviewed to determine which particle size fractions contained the lead and which fractions are "clean". This information was used to evaluate the effectiveness of soil washing and the quality of the wash water. Highly contaminated fractions may be further analyzed for lead species.

Standard USDA Soil Classification: The soil classification was determined from the soil particle size distribution, plasticity information, and visual observation. The various groupings of this classification system was devised by the ASTM committee to correlate in a general way with the geotechnical engineering behavior of soils. The classification was useful in understanding the behavior of the soil in materials handling and treatment processes.

RCRA Appendix IX Semivolatile Organic Compounds: This information was needed for regulatory purposes and constituent screening. Information on concentrations of semivolatile organic compounds is also important when evaluating treatment technologies, since they may interfere with performance or may be released as emissions. Samples were not assayed for volatile organic compounds, since many of the sample homogenization and preparatory procedures permit volatilization. Additionally, samples were not assayed for pesticides, herbicides, PCBs, dioxins, and furans, since historical evidence and prior analyses do not indicate the presence of these constituents at the areas studied at the Site.

RCRA Appendix IX Inorganic Compounds: This information was needed for regulatory purposes and constituent screening. While this study was primarily concerned with lead-affected soils, the soils in the study contained other metals of regulatory concern. Treatment processes which concentrate lead or extract/leach lead in a particular soil fraction (soil washing) may also concentrate or extract other heavy metals.

Soluble Cations: Calcium, sodium, magnesium, and potassium were measured. These soluble cations can impact the system solubility and compete with heavy metal constituents for binding/bonding sites and anionic species. In general, cations are retained in soil types with higher clay content and surface area. Cations exhibit relatively low mobility in clay and silty clay soils and moderate to high mobility in sandy, loamy sand, and sandy loam soil.

Anions: Sulfide, sulfate, phosphate, carbonates, and bicarbonates are naturally occurring anions in soil which provide bonding and binding sites for heavy metals and soluble cations. In general, anions exhibit relatively low mobility in clay and silty clay soils and moderate to high mobility in other soil types.

Carbon Content: Total carbon is measured from the carbon dioxide evolved during combustion of a sample in an oxygen atmosphere. Inorganic or fixed carbon is determined by thermal gravimetric analysis (TGA). TGA involves heating a sample under an argon atmosphere at a known rate until first the moisture and then the volatile matter are driven out of the soil. Air is then introduced to oxidize any remaining material (fixed carbon) until only the ash remains. Inorganic (fixed) carbon is reported as a weight percent of the original sample. Organic carbon is determined to be the difference between the total and inorganic carbon. Organic carbon content is another indication of the soil's natural ability to bond and bind with constituents. Carbon content information was useful in evaluating both stabilization and soil washing technologies.

pH: This is a measure of the acidity or alkalinity of the soil. This information was used to determine whether the soil is RCRA hazardous because it exhibits the RCRA characteristic of corrosivity. Initial pH of the soil is a useful piece of information needed in calculating stabilization mix designs or in determining the effectiveness of acidic or basic soil washing.

Redox Potential: This is a measure of whether the soil is in an oxidizing or reducing state. Several elements can exist as part of the structure of soil minerals in more than one oxidation state. For example, manganese (Mn) can exist in soil as Mn+2, Mn+3, or Mn+~. Arsenic (As) can exist as As+5, or As+3. The particular species which will be present depends upon the oxidation-reduction (i.e., redox) status of the soil.

Acid-Base Potential: This is a quantitative measure of the soil's buffering capacity. The amount of neutralizing bases present in the soil are reported as tons of calcium carbonate per 1,000 tons of soil. A positive number indicates that the soil is basic. Conversely, a negative number indicates that the soil is acidic. A close relationship exists between the total sulfur content of the soil and the net potential acidity. This information was useful in calculating stabilization mix designs or in determining the effectiveness of acidic or basic soil washing.

Generalized Acid Neutralization Capacity (GANC) and Reverse GANC: This test is a single-batch leaching procedure that utilizes a series of dried samples extracted for a 48-hour time period with an increasingly acidic leachant (or an increasingly basic leachant for the reverse GANC). A 20:1 liquid to solids ratio was used to duplicate the conditions of the TCLP. Equivalents of 2N acetic acid (or 2N sodium hydroxide per kilogram of dried solids) are plotted versus final solution pH. This information indicates the buffering capacity of the material, and can be used to calculate stabilization mix designs or to determine the effectiveness of acidic or basic soil washing.

Metals with Acid Neutralization Capacity (MANC) and Reverse MANC: This test quantifies the concentration of a metal released when an amount of acetic acid (or sodium hydroxide) in equivalents is used to reduce (or increase) the pH of a solution. For each acidity (or alkalinity) value of the GANC (or reverse GANC), the concentration of a metal released was measured after a 48-hour time period. Equivalents of 2N acetic acid (or 2N sodium hydroxide) per kilogram of dried solids are plotted versus the concentration of a metal. While the GANC plot depicts the relationship between acid (or base) addition and pH (buffering capacity), the MANC plot depicts the relationship between acid (or base) addition and metal concentration (solubility). When the GANC and MANC are plotted on the same figure, the minimum solubility point for a metal is shown to correspond to a specific pH range. This information was used in calculating stabilization mix designs and in determining the effectiveness of acidic or basic soil washing (based on solubility of metals).

Toxicity Characteristic Leaching Procedure (TCLP): The TCLP is designed to determine the mobility of constituents in a waste. A solid waste exhibits the RCRA characteristic of toxicity if, using the TCLP test procedures, the extract from a representative sample of the waste contains any of a set list of constituents at or above certain concentrations. This information was required for regulatory classification, and proper handling and disposal of the waste soil. The TCLP and associated criterion may be used to set the remediation cleanup goals. The TCLP was used as a measure of the chemical performance of treatment technologies. Since the TCLP is an extremely aggressive acid equilibrium leaching procedure (20:1 liquid to solid ratio, small solid particle size, and 18-hour contact time), the TCLP results may also be used to calculate distribution coefficients, if the initial constituent concentrations are known.

Equilibrium Leaching Procedure (ELP): This is a leaching procedure that uses synthetic acid rain (SAR) to simulate weathering conditions at a site. It uses the same solid particle size and liquid to solid ratio (20:1) as the TCLP; however, it provides a more realistic leaching scenario since it uses 60% sulfuric acid/ 40% nitric acid SAR (instead of acetic acid) and a contact time of 96 hours (instead of 18 hours) to further ensure that the leaching is more realistic of site conditions and has been given time to achieve equilibrium. Lead assays are performed on both the leachate and solids to provide a complete mass balance for the calculation of distribution coefficients.

Surface Area Calculations: For each soil fraction or particle size range, the amount of surface area was calculated in square meters per kilogram. The smaller the particle size, the larger the surface area. Based on the weight distribution of the various soil fractions, the surface area distribution was calculated. In general, the majority of the surface area are associated with the fines or silt/clay fraction. The fine particles often exhibit adsorption, cation exchange capacity, and other binding and bonding properties.

B.2 Soil Fraction Procedures

FO39 List Metals: Treatment processes which concentrate lead or extract/ leach lead in a particular soil fraction (soil washing) may also concentrate or extract other heavy metals. This information was needed for constituent screening and regulatory purposes, to ensure proper handling and disposal of the soil.

Chloride: This is a naturally occurring inorganic anion which can affect the mobility of constituents. Chloride compounds are very soluble and therefore very mobile. This information was useful in determining the species and mobility of metals and, therefore, the impact to the environment.

Iron and Manganese: Heavy metals can bond and bind with iron-manganese oxide surfaces in the soil. This information was useful in determining the species and mobility of metals and, therefore, the impact to the environment.

Cation Exchange Capacity (CEC): The CEC is defined as the total amount of water soluble cations adsorbed by negative charges on a unit mass of soil. In general, the silt/clay fraction exhibits the highest CEC, since it has the most surface area. The adsorption process is reversible, and the equilibrium relationship can be expressed by K_d, the distribution coefficient. CEC is one component of the soil that is responsible for the soil's buffer capacity. Buffering mechanisms that involve metal cations in solution are affected by the extent of adsorption to cation exchange sites on soil particle surfaces. In arid regions, the accumulation of calcium, sodium, magnesium, and potassium salts may result in the saturation of a soil's cation exchange capacity with these cations. The tendency for these cations to produce hydroxide ions is the factor controlling the amount of hydrogen ions in the water phase of the soil (and thus the pH). Carbonate minerals (calcium carbonates, sodium carbonates, and magnesium carbonates) can buffer the hydrogen ion content (pH) of water in a soil system.

Sequential Extraction: This procedure is a wet chemical method in which a series of specific reagents is sequentially applied to a soil sample, and the lead content is measured in each extractant. Each reagent selectively removes lead that has been bound or adsorbed to the soil matrix in a specific way. The sequence of reagents is such that each reagent is more aggressive than the previous one. The results of this test indicate the species of lead present and the way in which the lead is bound to the soil. This information was valuable in determining impact to the environment and in evaluating treatment technologies.

Scanning Electron Microscopy (SEM): SEM is a sophisticated technique to determine constituent species by viewing the material under extremely high magnification. SEM analyzes individual soil particles and can identify both crystalline and amorphous structures. This information on constituent species was valuable in determining mobility and impact to the environment, and in evaluating treatment technologies.

X-Ray Fluorescence (XRF): This scan is performed to determine soil mineralogy. While the results are reported as compounds (mainly oxides and metals), the scan actually identifies major, minor, and trace elements (approximately 40). Results are reported as a weight percentage of the total sample. Carbon dioxide is also analyzed by a coulometric method, to aid in the material balance. The difference between the total weight of the soil and the weight percentage of minerals may be attributable to water. Information on soil mineralogy aids in the understanding of soil/ contaminant interactions including contaminant species, binding/bonding and mobility.

APPENDIX C – *LEAD AND ARSENIC SOIL CHARACTERIZATION AND TREATABILITY STUDIES*

C.1 INTRODUCTION

Treatability studies were performed to assist in the selection of appropriate Cleanup Actions for impacted soils at the former DuPont Works Site (the "Site"). The studies were selected to address constituents impacting significant soil volumes; these constituents were lead and arsenic. This document will address: the requirements for treatability studies; the basis for treatability study selection and design; the treatability study approach and initiatives taken; a summary description of the treatability studies completed and the study results; a summary of interpretations made; and finally, conclusions drawn from the treatability studies and recommendations for additional treatability work.

C.2 TREATABILITY STUDY REQUIREMENTS

The specific requirements of the treatability studies were determined based on the need to generate technical data to assist with the screening and selection of potential soil remediation technologies for lead- and arsenic-impacted soils. The lead and arsenic studies were designed with regard to the principal candidate technology categories identified through preliminary Feasibility Study (FS) screening. Chapter 4 provides an overview of the type of data required to assess the effectiveness of these types of technologies. The constituent-specific portions of Chapter 5 (5.3 and 5.4) contain a discussion of the treatability study results and their relevance to the evaluation of each technology category.

The treatability studies were carried out to meet the objectives described in Chapter 3. They include characterization studies performed by Hazen Research, Inc. (Hazen), in addition to speciation work, screening studies, and bench-scale technology evaluations performed by Hart Crowser, Battelle Pacific Northwest Laboratories, the State University of New York, the University of Cincinnati, and Weyerhaeuser Analytical and Testing Services.

C.3 BASIS FOR TREATABILITY STUDY SELECTION AND DESIGN

C.3.1 Treatability Study Objectives

The general objectives of the overall treatability study program, together with specific objectives with respect to soil characterization, are set out below.

- Provide sufficient information necessary to fully define the soil remediation problems presented and determine the specific requirements of the candidate technologies.

- Expedite the evaluation process prescribed by Model Toxics Control Act (MTCA) and so assist the selection of appropriate Cleanup Action Alternatives (CAA's) for soils impacted by the major constituents of concern, i.e.,
    - Provide information/data on treatment technology effectiveness;
    - Enable CAA's to be compared and evaluated on an equal basis;
    - Provide, in conjunction with available relevant literature, sufficient characterization and performance data to allow treatment alternatives to be developed and evaluated during FS detailed analysis;

  - Help reduce performance uncertainties for treatment alternatives to acceptable levels to enable remedy selection; and
  - Support the Interim Source Removal program.
- Provide preliminary supporting data for the design of selected CAA's and help define further data requirements needed prior to Cleanup Action implementation.

Specific soil characterization objectives are:

- To help fill gaps in physical and chemical Site characterization data pertinent to soil handling and to the treatment options developed;
- To determine, in detail, the physio-chemical nature of constituent/soil matrix interactions and thereby answer basic questions regarding constituent distribution and speciation, soil bonding/binding characteristics, and constituent leachability/mobility; and
- To provide information on the prospects for reducing volumes of significantly impacted soils through the use of physical screening techniques to segregate soils by particle size.

C.3.2 Rationale and Constraints

The rationale for the selection and design of the treatability study program was based on several basic criteria. These criteria, which in some cases represent constraints on the scope of the program, are summarized below.

- The treatability studies should address the major constituents of concern under the FS, i.e., those impacting significant (greater than 5,000 yds^3) soil volumes at levels exceeding the Working Hypothesis screening levels. These constituents of concern are lead and arsenic.
- The studies should be tailored to obtain appropriate data to assist in the determination of the technical viability of the principal candidate remediation technology categories identified through preliminary FS screening (see Chapter 2). The range of data obtained via the studies should reflect the broad range of innovative technology types and treatment approaches under consideration.
- The studies should be capable of fully characterizing the impacted soil matrices and the complex soil/chemical interactions (this criterion is further addressed in the opening discussion under Section C.4 below).
- The scope and duration of the studies should be consistent with the schedule for completion of the Remedial Investigation (RI) and FS activities.

C.4 TREATABILIITY STUDY APPROACH AND INITIATIVES

U.S. Environmental Protection Agency (EPA) analytical protocols are widely used in environmental remediation programs to determine the appropriate designation of potential 'waste' materials. These protocols include measuring the total or leachable concentrations of chemical constituents in the subject material (e.g., using SW-846 and Toxicity Characteristic Leaching Procedure (TCLP) methods), as well as testing the material for the characteristics of ignitability, corrosivity, reactivity, and toxicity. The protocols are designed to assist in determining whether any regulatory waste classification is applicable, so that the material may be managed, treated, and disposed of appropriately.

However, when dealing with a complex matrix such as soil impacted by chemical constituents, additional characterization information regarding physical and chemical properties and constituent/soil interactions is needed. In addition to assisting the assessment of regulatory classification, potential impact to human health and the environment, and decisions regarding cleanup goals, this information is necessary to thoroughly evaluate which treatment technologies and processing conditions are applicable.

In this case, the treatability study approach principally involved a series of carefully devised laboratory tests directed at detailed characterization of representative soil samples impacted by the major chemical constituents of concern. The characterization testing program was designed with emphasis placed on the examination of complex soil/constituent (metal) interactions. The types of soil characterization information obtained relate to how constituents are held/bound in the soil matrix, what chemical form (speciation) constituents exist, and in what soil fractions (distribution) they reside. Associated information was also obtained to describe the soil composition (chemical and mineral content as well as particle size distribution) and assess the mobility/leachability of the bound constituents. The overall intent of the soil characterization studies was to provide a wide range of physical and chemical data giving insight into the viability and suitability of the principal candidate remediation technology categories referenced in Chapter 2, and to provide an efficient and cost-effective means of narrowing the field of potential Cleanup Action Alternatives. The physical analyses were primarily aimed at providing data, which will indicate how the soils will behave physically during materials handling, and physical treatment steps, while the chemical and speciation analyses were directed more towards identification of technological applicability.

The soil characterization methods and procedures described, by category, in the following paragraphs were selected for use in the lead and arsenic constituent initiatives, based on their ability to physically and chemically characterize metals-impacted soils. Further information is provided in Tables C-1 and C-2, “Soil Characterization Procedures”, which lists each of the analyses included in the characterization studies (performed by Hazen), and specifies the type of information that can be determined from each analysis. The three categories presented below are used as the basis for the presentation and discussion of the treatability study results in Section C.5.

C.4.1 Regulatory Analyses

Regulatory analyses are designed to determine the regulatory classification of the waste, so that the waste may be managed, treated, and disposed of properly. Regulatory analyses include the RCRA Appendix IX list inorganics and semi-volatile organics. The Toxicity Characteristic Leaching Procedure (TCLP) was performed to determine whether the soil exhibited the RCRA characteristic of toxicity, and therefore should be assigned an EPA Characteristic Hazardous Waste Number.

C.4.2 Physical Analyses

Physical analyses are aimed at gathering data to indicate how the soil will behave physically during excavation, materials handling, and treatment processes. The physical analyses include particle size distribution and Atterberg limits (liquid limit, plastic limit, and plasticity index) that are used to determine the standard USDA soil classification. Other physical properties measured are moisture content and bulk density of both loose and packed soil.

C.4.3 Chemical Analyses

Chemical analyses are aimed at gathering information on soil chemistry, soil mineralogy, soil/constituent interactions, and constituent distribution, speciation, and mobility. The pH and Generalized Acid Neutralization Capacity (GANC) are measured of the soil’s alkalinity or acidity and inherent buffering capacity. GANC and Reverse GANC data can also be used to assist the potential effectiveness of stabilization and soil washing/leaching treatments. The TCLP and Equilibrium Leaching Procedure (ELP) are both measures of leaching or mobility of the constituent. Organic carbon and anions can bond with heavy metals, reducing their mobility. Soluble cations can compete with heavy metals for bonding sites, increasing heavy metal solubility. X-ray diffraction, scanning electron microscopy, and sequential extractions are all used to determine which specific chemical form of the metal is present in the soil and how it is bound

The data quality objectives under the characterization studies were primarily to generate high quality technical data for use in performing evaluations and supporting positions developed under the FS. Only those procedures intended to determine the regulatory classification of the soil were performed strictly according to EPA SW-846 protocols. Under subcontract to Hazen, Evergreen Analytical, Inc. performed the regulatory analysis for the RCRA Appendix IX total inorganics (including lead, arsenic, and mercury) and semi-volatile organics, TCLP, and TCLP leachate organics and semi-volatile organics. The remainder of the analyses, performed by Hazen, was not completed according to strict SW-846 analytical protocols; however, every effort was made to ensure high quality data were generated. This approach was consistent with the main goal of this program, to generate high quality analytical information for technology screening purposes, rather than to produce legally defensible regulatory classification data. All procedures are documented and commercially available.

To supplement the laboratory characterization testing outlined above, additional speciation screening studies, and bench-scale treatability work was carried out to assist with a more detailed examination of the viability of soil washing and solidification/stabilization technologies.

C.5 SUMMARY DESCRIPTION AND RESULTS OF TREATABILITY STUDIES COMPLETED

C.5.1 Introduction

The majority of the treatability study work is represented by the laboratory and bench-scale soil characterization studies performed under contract by Hazen at their facility in Golden, Colorado. These studies involved soil samples from Site Areas known to be impacted by lead and arsenic, and include detailed characterization and speciation analysis of the lead- and arsenic-impacted soils. Soil sampling for the characterization studies utilized a statistical procedure based on EPA SW-846 guidance, recognized technical literature on sampling and analysis, and the experience of the Project Team. The sampling procedure enabled recovery of representative composite samples of impacted soils from randomly sampled grids in designated Areas of the Site determined, from pre-RI and RI information, to contain elevated concentrations of lead and arsenic.

The Hazen studies were supplemented by several additional specific initiatives performed by other commercial organizations and Universities, as outlined in Section C.5.2 below. Sections C.5.3 and C.5.6 present summaries of the constituent-specific work, focusing on the Hazen characterization studies, and include interpretations of the treatability study data generated. In the case of the lead-impacted soils characterization study (included in Section C.5.3), the work was part of a broader multi-site program conducted by DuPont to characterized company-wide lead remediation needs. The scope and detail of the DuPont study were greater than necessary for the purposes of this FS; only pertinent parts of the study and results are summarized here.

C.5.2 Other Initiatives Supporting Hazen Studies

Hazen's work was supplemented with subsequent treatability study initiatives performed by other commercial organizations and Universities. These are listed below with a brief description of the study scope for each.

BENCH-SCALE SOIL LEACHING STUDY – STATE UNIVERSITY OF NEW YORK, BUFFALO

A screening evaluation of the non-proprietary soil leaching chemistries was performed by the Department of Civil Engineering at the State University of New York at Buffalo (UB). The efficacy of various soil washing extraction agents and leaching conditions were evaluated for removing lead from a lead-impacted soil sample (-8 to +200 mesh fractions) from Area 40 (Pulverizer) of the Site, provided by Hazen. The results of this soil leaching study are contained in the final report prepared by UB researchers entitled Evaluation of Soil Washington Extraction Agents ad Processes for Remediating Heavy Metal Contaminated Soil from Weyerhaeuser Area 40 Pulverizer," March, 1994.

SOLIDIFICATION/STABILIZATION SCREENING STUDY – UNIVERSITY OF CINCINNATI

The University of Cincinnati Center for GeoEnvironmental Science and Technology (CGEST) conducted solidification/stabilization screening tests on soil fines (-200 mesh) samples from Areas 36 and 40 (Glazemill and Pulverizer) of the Site provided by Hazen to evaluate the ability of three non-proprietary binder mixes to solidify and stabilize lead-impacted soils. The effects of lead-designed solidification/stabilization binder mixes on arsenic contained in the Area 36 sample were also investigated. The results of this screening study are contained in the final report prepared by CGEST researchers entitled “Solidification/Stabilization Screening for Integrated Lead Remediation Program”, 1993.

BENCH-SCALE SOIL LEACHING STUDY – WEYERHAEUSER ANALYTICAL & TESTING SERVICES

To investigate the potential for utilizing non-proprietary leaching chemistries to remove arsenic from the Site soils, a leaching study was carried out at the laboratories of Weyerhaeuser Analytical and Testing Services (Weyerhaeuser ATS). Under this three-phase study, several leaching solutions were applied to -1/4” by +200 mesh fractions of combined soil samples from Area 18 and the Narrow Gage Railroad area. The effects of pH and liquid:solid ratio were investigated as well as performance under single-stage batch and simulated multistage countercurrent extraction regimes.

ARSENIC SPECIATION ANALYSIS – BATTELLE PACIFIC NORTHWEST LABORATORY

Battelle Pacific Northwest Laboratory (Battelle PNL) performed limited arsenic speciation analysis on soil samples from Areas 5, 25, 38, and the Narrow Gage Railroad area. The purpose of this study was to identify ionic species of arsenic and investigate the presence of organic arsenic forms in Site soils potentially impacted by acid production (Areas 5 and 25), the use of arsenic-based herbicides (Narrow Gage), or arsenic-based paint/ink (Area 38).

WET SCREENING TESTING ON ARSENIC-IMPACTED SOIL – HART CROWSER

Additional arsenic treatability studies were performed by Hart Crowser to better define the distribution of arsenic concentration with respect to soil particle size, through the use of particle size distribution testing and associated arsenic analysis of sized soil fractions. Samples were taken in the 250/500 – foot arsenic soil sampling grid area (including Areas 18 and 36) and the Narrow Gage Railroad area to supplement the results from the Hazen arsenic characterization study completed on samples from the same areas.

C.5.3 Lead-Impacted Soils

Fifty-five gallon composite soil samples were collected from each of the following Consent Decree Areas, one sample per Area: Area 7 (Kettle), Area 18 (Nitrator Number 1), and Area 36 (Lead Melting). Three soil samples were also collected from Area 40, one each from the Pulverizer, Glazemill, and Packhouse locations. The method of sample collection was detailed in the sampling plan for each Area; a brief summary is described below.

Previous sampling results were used as a basis for establishing sampling grids in each Area. For each grid area (containing 100 nodes), a random number generator was used to select 25 discrete sample locations. Sub-areas, within the identified Consent Decree Areas, shown by previous sampling results to exhibit lead concentration below the MTCA Method A screening level of 250 mg/kg were not included in the sampling regime. Only soils that contained lead concentrations greater than 250 mg/kg were included (i.e., “hot spots” were in effect, sampled).

The soil samples for each grid area were taken from shallow depth intervals that were chosen to represent the soil to be potentially remediated based on previous vertical delineation. Approximately two gallons of soil were collected from each of the 25 selected sampling locations. The 25 samples were then composited into one 50-gallon samples from each area samples were shipped to Hazen in 55-gallon drums.

Composite sampling was chosen to adequately represent each area because the resulting soil homogenization is a simulation of the mixing that would occur during full-scale excavation and ex-situ treatment. It is not significant that this sampling approach did not allow a thorough evaluation of lead concentration variability on technology performance, since these issues will be addressed in any future pilot testing.

Upon receipt of the soil samples, Hazen personnel prepared and tested the samples as outlined in Figure C-1,"Flow sheet for Sample Preparation and Testing". Portions of the samples from Areas 36 and 40 (Glazemill and Pulverizer) were sent to CGEST for the solidification/stabilization screening study, and portions of the sample from Area 40 (Pulverizer) were sent to UB for the bench-scale soil washing evaluation.

C.5.4 Test Results

Complete results for all of the procedures conducted under the lead characterization study are detailed in the final reports prepared by Hazen for each of the six samples tested. The reports are entitled "Laboratory and Bench-Scale Studies for Characterizing Lead-Contaminated Soil from DuPont/Weyerhaeuser Remediation Site", (August-October, 1993). The characterization results are summarized in Table C-3, "Summary of Lead-Soil Characterization Test Results"; the results are presented according to the information categories indicated in Section 4.0. An expanded summary of selected results is presented below in the same format as Table C-3, with limited interpretation.

REGULATORY ANALYSIS

The total lead concentrations, as determined by Method 6010 as part of the RCRA Appendix IX metals analysis, ranged from 260 mg/kg to 3,000 mg/kg for the six composite soil samples tested. The TCLP lead analyses results indicate that the soil samples from Areas 7, 18, 36, and 40 (Pulverizer and Glazemill) were not RCRA D008 hazardous, based on the regulatory limit of 5 mg/1. However, the soil sample from the Packhouse area of Area 40 exceeded the RCRA D008 regulatory threshold with a TCLP lead result of 18 mg/l; the corresponding total lead assay for this sample was 3,000 mg/kg.

TCLP analysis for the other metals and organics was also conducted. The results indicate that the Site soil does not exhibit the RCRA toxicity characteristic for any of these constituents.

There were other RCRA Appendix IX metals present, but these were at very low concentrations in all cases (the highest values were in the Packhouse and Pulverizer areas of Area 40, with zinc concentrations up to 2,500 mg/kg and moderate concentrations of copper and barium). No RCRA Appendix IX semi-volatile organics were present in the soil samples from Areas 7 and 40 (Glazemill and Packhouse). Extremely low levels (ppb) of semi-volatiles were present in the samples from Areas 18, 36, and 40 (Pulverizer). The semi-volatile constituents were polynuclear aromatic hydrocarbons (PAHs), which appear to be related to petroleum-based materials previously identified at the Site.

PHYSICAL ANALYSIS

Physical testing determined that the USDA standard soil classification was "sand" for the samples from Areas 7, 36, and 40, and "sandy loam" for the sample from Area 18. The results of the Atterberg Limits tests indicate that all six-soil samples were non-plastic, suggesting that soil excavation and processing can be managed in a straightforward manner.

The particle size distribution test results for the soil samples ranged from 38 to 61% cobbles/gravel (greater than 4 mesh), 32 to 53% sands (less than 4 and greater than 200 mesh), and 7 to 15% silt/clay (less than 200 mesh). This data indicates that the soil is amendable to standard physical screening or size classification-type soil washing treatment.

The moisture content results ranged from approximately 5 to 20%; loose and packed densities ranged from 1.1 to 1.6 grams/cubic centimeter (g/cm3) (or approximately 0.9 to 1.3 tons/cubic yard (tons/yd3)) and from 1.4 to 1.9 g/cm3 (or approximately 1.2 to 1.6 tons/yd3), respectively. The density data is given to represent ex-situ and in-situ soils, respectively, and reflects typical ambient moisture.

The pH of the soil samples ranged from 4.4 to 7.4 in a slurry (10% solids) of soil and demineralized water. Since the soil is mildly acidic to neutral, it will not be corrosive to excavation, materials handling, and other treatment equipment.

The physical analyses data collectively indicate that materials handling of the Site soils, including provisions for dust control should be uncomplicated and accomplished using conventional equipment and methods.

CHEMICAL ANALYSIS

Lead assays performed using Method 7420 on pulverized heads of whole soils for each of the six samples determined total lead concentrations (average of three readings) in the range of 180 to 3,600 mg/kg.

Anions considered likely to produce metal salts of low solubility were investigated in the soil samples. Those found to be present were sulfide, sulfate, phosphate, and carbonates. Total concentrations of these low solubility bonding/binding anions present in the samples from Areas 7, 18, and 36 ranged from approximately 2,500 to 2,650 ppm. The total concentrations of these anions in the samples from Area 40 ranged from approximately 4,200 to 10,700 ppm. In general, the level of anions in the soils is substantially greater (up to 10X) than the total lead concentration, indicating that low solubility metal salts can potentially form. Evidence of such compounds in the soils was provided using more sophisticated speciation techniques, as discussed in later sections.

The presence of soluble cations, which can compete with any soluble lead species for soil adsorption sites, soil ion exchange sites and binding anions, was also screened. Competing cations investigated were calcium, sodium, magnesium and potassium. The total leachable concentration of these cations present in the soil sample from Area 18 was very low at less than 50 ppm. The total leachable concentrations of cations present in the samples from Areas 7, 36, and 40 (Glazemill and Packhouse) were low, ranging from 50 to 100 ppm. The total leachable concentration of cations present in the soil sample from the Pulverizer area of Area 40 was also low at less than 300 ppm. These results indicate that soluble lead should be able to bind with soil at adsorption and ion exchange sites since competition is not severe. The results are consistent with sequential extraction speciation results discussed later.

Organic carbon (organic matter) content is important as it can bind with heavy metals and can potentially interfere with soil treatment processes. The organic carbon present in the soil samples from Areas 7, 18, and 36 ranged from 0.9 to 3.3%; no detectable levels of inorganic (fixed) carbon were reported for these samples. The organic carbon present in the samples from Area 40 ranged from 4.2 to 6.9%; the inorganic carbon content of these samples ranged from non-detect to 0.7%. These levels are considered moderately low from a soil treatment perspective and should not interfere with implementation or performance of soil washing, solidification/stabilization and other technologies. Sequential extraction was used to determine how much lead was associated with organic matter in the soil.

The results of X-Ray Fluorescence analysis (XRF) indicate the presence of a soil matrix comprising silica, alumina and iron oxide, with minor amounts of sodium, magnesium, potassium, phosphorus, sulfur, titanium and calcium. These results are to be expected for the type of soils present at the Site.

The Generalized Acid Neutralization Capacity (GANC), Reverse GANC (RGANC), and pH analyses data indicate that the soil samples ranged from slightly acidic to neutral and had little acidic or basic buffering capacity.

Results of the Sequential Extraction tests performed on selected sized fractions indicate that the majority of the lead was present in carbonate, specifically adsorbed, and in ion-exchangeable forms in samples from Areas 7, 18, and 36. For the Area 40 samples, the majority of the lead was shown to be associated with carbonates, iron and manganese oxides, and organic material.

Speciation analyses performed on selected sized fractions (gravity separated as appropriate) using Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) gave positive identification of lead in the following forms: lead carbonate, lead oxide, lead-iron oxide, lead-manganese oxide, lead-tin oxide, lead-aluminum oxide, lead sulfate, lead sulfide, lead silicates, lead phosphates, and metallic lead.

LEACHING/MOBILITY

The TLCLP lead analytical results are summarized in the Regulatory Analysis section, above.

The Equilibrium Leaching Procedure (ELP) results demonstrate very low lead solubility with synthetic acid rain (0/02 to 0.06 mg/l). The wet screening and Sequential Extraction test results also demonstrate that the lead species are relatively insoluble in water. However, the lead was more soluble in acetic acid solutions, as demonstrated by TCLP, GANC, and Sequential Extraction test data. These results indicate that lead is essentially immobile under normal environmental conditions, but can be mobilized under more rigorous leaching conditions.

Under the GANC and RGANC tests, one stage acidic and alkaline leaching at 20:1 liquid/solids ratio removed a range of 45 to 75% of the lead using 2N (normal) acetic acid, and a range of 13 to 40% of the lead using 2N sodium hydroxide. This indicates that lead is more readily mobilized under acidic, as opposed to basic, leaching conditions, but also indicates the presence of some extremely leach-resistant forms of lead.

SOLIDIFICATION/STABILIZATION SCREENING – UNIVERESITY OF CINCINNATI (CGEST)

Three non-proprietary binding mixes (two containing Portland cement and one containing a combination of cement kiln dust and fly ash) were used to screen solidification/stabilization technology, using -200 mesh fractions of soil samples from Areas 36 and 40 (Glazemill and Pulverizer) supplied to CGEST by Hazen. The following are the main results after 28 days of curing:

- All three design mixes passed TCLP, with lead leachate results ranging from 0.29 to 1.5 mg/l;
- The amount of lead that leached in the TCLP tests ranged from 0.44 to 2.73% of the total lead in the treated sample (initial untreated soil lead concentrations ranged from 2,900 to 3,200 mg/kg);
- The end point pH in the TCLP tests ranged from 5.2 to 8.2; and
- Unconfined Compressive Strength (UCS) data for the prepared samples of fine material with Portland cement binder ranged between 18 and 96 pounds per square inch. The fine material treated with kiln dust/fly ash did not set within the 28-day curing time and strength analysis could not be completed.

BENCH-SCALE SOIL WASHING STUDY – STATE UNIVERSITY OF NEW YORK, BUFFALO (UB)

The Department of Civil Engineering at the UB examined soil leaching through laboratory and bench-scale experiments. The efficacy of various soil leaching extraction agents and conditions was evaluated for removing lead from a lead-impacted soil sample (-8 to +200 mesh fractions) from Area 40 (Pulverizer). The results relevant to the evaluation of treatment technologies are summarized below:

- Soil lead was reduced to less than one-half the initial mean concentration of 1,401 +/- 244 mg/kg (95% confidence interval) in approximately one-third of the soil leaching experiments conducted.
- The lowest soil lead concentration (444 +/- 24 mg/kg) was achieved using hydrochloric acid at a pH of 1 with a liquids/solids ratio of 10:1, and at 25 deg C;
- Strong mineral acid extractants containing the chloride ion (HC1, HC1O4) were the most effective at removing lead from the soil;

- Significant lead removal (>50%) was achieved with an HC1 extraction solution at more moderate pH (~3) with the addition of EDTA as a complexing (chelating) agent; and

- TCLP lead values for the treated soil samples ranged from 0.3 to 0.5 mg/l.

C.5.5 Interpretation of Results

The Hazen soil characterization results which bear most significantly on the viability and effectiveness of solidification/stabilization, physical screening/soil washing, and smelting/thermal recovery technologies for remediating lead-impacted soils are listed in Table C-3. A brief discussion of key results from the characterization study, including implications for technology selection, is provided below. Results of the UB bench-scale soil washing tests and the CGEST solidification/stabilization screening tests are also discussed briefly, as appropriate.

SOLIDIFICATION/STABILIZATION

As indicated in Table 3, the characterization test information most relevant for the evaluation of solidification/stabilization remediation technology are GANC/RGANC, Metals Acid Neutralization Capacity (MANC)/Reverse MANC, organic carbon, RCRA Appendix IX semi-volatiles, TCLP, and moisture content.

As previously mentioned, the GTANC, RGANC, and pH analyses indicate that the Site soils sampled are mildly acidic to neutral and have little acidic or basic buffering capacity. The low buffering capacity is advantageous for a solidification/stabilization process because a minimum amount of binder would need to be added to buffer the soil, add reserve alkalinity, and drive lead solubility to low values. Based on the GASNC and MANC plots, the optimal pH (corresponding with the minimum lead solubility) for the Site soils for solidification/stabilization treatment lies in the range of moderately acidic to moderately basic (pH 4-10).

The carbon analysis results indicate that the organic carbon content in the Site soils (0.9 to 6.9%) is typically below levels (<10%) that would be expected to inhibit curing in a solidification/stabilization process. However, with regard to the stabilization of soil fines (-200 mesh), the CGEST study indicates that fly ash/kiln dust binders require longer curing times than Portland cement binders.

The RCRA Appendix IX semi-volatiles results indicate that semi-volatiles are either absent in the Site soils or present only in very low concentrations. These results indicate the application of a straightforward solidification/stabilization treatment. Some semi-volatile organics (sugars, alcohols) can be difficult to solidify/stabilize and may inhibit curing of treated material.

Only one of the six samples analyzed for TCLP exceeded the RCRA D008 regulatory threshold of 5 mg/l, the Area 40 (Packhouse) soil sample (18 mg/l). No other constituents exceeded TCLP threshold levels. These results indicate that if solidification/stabilization treatment were applied to the Site soils, the TCLP lead leachability criterion would be readily met. The solidification/stabilization screening performed by CGEST further supports this conclusion. Here, several conventional binding mixes were tested on soil fines from Areas 36 and 40 (Glazemill and Pulverizer) and yielded TCLP results well below the 5 mg/l RCRA Land Disposal Restriction (LDR) treatment standard, on the stabilized soils (0.29 to 1.5 mg/l).

The moisture content results for the Site soils were variable, ranging from approximately 5 to 20%. Moisture content is the most sensitive input variable in solidification/stabilization system design and requires careful control during implementation. At the levels measured in this case, based on the CGEST solidification/stabilization screening work where moisture contents were in the range of 40 to 50%, a requirement for make-up water is indicated.

PHYSICAL SCREENING/SOIL WASHING

The characterization test results of most relevance for the evaluation of physical screening/soil washing remediation technologies (as shown in Table C-3) are silt-clay content, lead distribution with regard to particle size, surface area calculations, Atterberg Limits, organic carbon, GANC/RGANC, MANC/RMANC, and Sequential Extraction.

The silt/clay content of the Site soils, ranging between 7% and 15% for the samples tested, is quite low, and well below the 40% upper limit generally considered likely to limit the effectiveness of soil washing processes. The lead content in the silt/clay fraction of the Site soils is substantial at between 27% and 67% (corresponding concentrations range from 2,170 mg/kg to 10,600 mg/kg). These results suggest that significant beneficial volume reduction of lead-impacted soil could be achieved by separating the fine material from the whole soil.

Wet screen particle size distribution test results and corresponding chemical analyses results for separated size fractions indicate that between 84% and 97% of the soil lead is concentrated in the sand and silt/clay fractions. These fractions represent between 40% and 62% by weight of the whole soil. These results indicate that recovery of the cobbles/gravel fraction (representing between 38% and 60% of the whole soil) as “clean” material could be readily achieved using conventional wet screening or classification-type soil washing.

For water-based soil washing processes, the wet screening and Sequential Extraction test results indicate that, due to the low aqueous solubility of lead in Site soils, little or no water treatment provisions would be necessary.

The surface area calculations for each of the soil size fractions indicate, as expected, that the majority of the total soil surface area is contained in the silt/clay (64% to 83%), with less in the sands (17 to 36A%), and least in the cobbles/gravel (<1% to 2%). In the case of Areas 7 and 18, the lead distribution by size fraction increases with reducing size fraction and increasing surface area; these results indicate that lead bonding and binding is mostly surface related. The lead distribution for Areas 36 and 40 in the sand and silt/clay fractions does not proportionally follow surface area distribution; this indicates that lead is not only surface bound but is also associated with other particulate matter present in the soil matrix. In the case of Area 36 soils, SEM confirmed the presence of particulate lead.

The Atterberg Limits results show that the “sand” and “sandy loam” soil is non-plastic and should be both amenable to processing by physical screening equipment and easy to handle with conventional earth-moving equipment.

The organic carbon content of the Site soils (0.6% to 6.9%) is below the 10% limit generally considered as the value above which complications in a soil washing system can arise due to contaminant-carbon bonding. The inclusion of an organic carbon removal unit operation should not be necessary.

The GANC/RGANC results, as mentioned previously, show that the Site soils have little buffering capacity and would not require the addition of large amounts of acid in a chemically enhanced soil-washing scenario, to achieve a desired pH change.

The MANC/RMANC equilibrium lead concentrations in the aqueous phase occur between additions of 2 to 40 equivalents of acid/kg soil and between additions of 2 to 40 equivalents of base/kg. One stage acidic and alkaline leaching at 20:1 liquids/solids ratio can remove 45% to 75% of the lead using 2N acetic acid, or 13% to 40% lead using 2N sodium hydroxide. This indicates that acidic leaching has potential for use in a soil washing system to clean the Site soils, possibly in conjunction with wet screening and other physical (gravity, density, and high-energy attrition) treatment techniques. It is important to note, however, that even under severe leaching, lead removal is not complete as can be explained by the presence of some extremely leach-resistant forms of lead.

Sequential Extraction data show that lead is predominantly present, in the sized fractions examined, as carbonate, specifically adsorbed, and non-exchangeable forms, as well as being associated with iron and manganese oxides and organic material. This speciation information, which is supported by the SEM and

XRD results, also indicates that further lead removal could be achieved in a chemically enhanced (acidic) soil washing or leaching treatment scenario.

The results of the UB soil washing study provide further support for considering a chemically enhanced soil washing or leaching treatment application. The study showed that strong mineral acid extractants (specifically, hydrochloric and perchloric acid) at approximately pH 1 were effective at significantly reducing (by greater than 60%) lead concentrations of approximately 1,400 mg/kg in the sand fraction of Site soils. TCLP lead values for treated samples ranged from 0.3 to 0.5 mg/l. Less acidic conditions (pH 3) were also effective if a chelating agent (such as EDTA) was added. Other conclusions drawn from this study, such as those relating to the detailed behavior of complexing compounds and the effects of temperature and liquid/solids ratio, as well as aqueous extract treatment/recycling, will be essential issues to consider when deciding on whether to include leaching in a soil washing treatment approach.

SMELTING/THERMAL RECOVERY

The characterization test results of primary importance for the evaluation of smelting/thermal recovery remediation technology are total lead concentrations, moisture content, RCRA F039 listed metals, and soil mineralogy results.

Cost effective treatment of RCRA D008 wastes by smelters requires that lead content in the feed soils be on the order of 6 to 8% by weight or that the soil contain at least 80% silica (silica is a flux agent used in smelting). Since total average lead concentrations in the Site soils lie in a range of only 180 to 3,600 mg/kg (i.e. 0.4% maximum), and even the highest measured concentration in the silt/clay fraction is only 1.1%, the soils would not be suitable for smelting without intensive pre-processing to concentrate lead into the finer soil fractions. Silica content for Site soils ranges from 30 to 60%, which also indicates that the soil is not suitable as a silica flux replacement in smelting. Though the possibility of using smelting to treat concentrated soil-washing residuals does still exist, the technical and economic viability would require further investigation.

The maximum acceptable moisture content of a smelter feed soil is 10%. This may place a further constraint on the smelting application for the Site soils; concentrated fines/residuals from a soil washing process would likely need to be passed through an advanced dewatering step.

The RCRA F039 metals analyses indicate the present of other metals including: antimony, arsenic, barium, chromium, copper, nickel, selenium, vanadium, and zinc. Though present at low concentrations, these metals are potential impurities in certain smelter products that may restrict the facilities that could potentially handle the soils or treatment residuals.

The XRF analysis results indicate the presence of a silica-alumina-iron oxide matrix, with minor amounts of sodium, magnesium, potassium, phosphorus, sulfur, titanium, and calcium. The presence of these elements is expected in sandy and silty soils. They could, however, adversely affect the viability of smelting/thermal recovery as impurities in the system.

C.5.6 Arsenic-Impacted Soils

Soil samples for the Hazen study were collected from each of the following areas of the Site (one sample per area): Area 18, Area 36, and the Narrow Gage Railroad area. In addition to the characterization work performed by Hazen, Hart Crowser performed a laboratory wet screening study to better define the concentration distribution in relation to soil particle size on samples from these same areas. An additional five soil samples from the 250/500-foot arsenic sampling grid area (including Areas 18 and 36), and five samples from the Narrow Gage Railroad area were collected for the Hart Crowser study. The sample collection methods are summarized in the following paragraphs.

Previous sampling results were used as a basis for establishing sampling grids in each area. For the Area 18 and 36 grids, a random number generator was used to select 25 discrete sample locations. Some parts of the Site, within targeted areas, shown by previous sampling results to exhibit arsenic concentrations below the Site background level of 32 mg/kg were not included in the sampling regime. The Narrow Gage area was segregated into 100 linear segments along the railroad track; 25 segments were randomly selected for collection of three-point composite samples, which were composited into a 55-gallon sample. For the Hart Crowser screening study, ten five-point composite samples were collected at locations identified during the RI (including the December 1993, Phase I Arsenic Sampling) as areas of elevated arsenic.

The soil samples for each grid area were taken from a shallow depth interval (0-1 foot) chosen to represent the soil to be potentially remediated based on previous vertical delineation. Composite sampling was chosen to adequately represent each area because the resulting soil homogenization is a simulation of the mixing that would occur under full-scale excavation and ex-situ treatment operations. Arsenic concentration variability issues will be more specifically addressed in any future pilot testing.

Approximately two gallons of soil were collected from each of the 25 selected sampling locations for the Hazen study. The 25 samples were then composited into one representative 50-gallon sample for each area and shipped to Hazen in 55-gallon drums. Upon receipt of the soil samples, Hazen personnel prepared and tested the samples. Portions of the samples from Area 18 and the Narrow Gage Railroad area were sent to Weyerhaeuser ATS for the bench-scale soil leaching study.

C.5.7 Test Results

Complete results for all the procedures conducted under the arsenic characterization study are detailed in the final report prepared by Hazen for each of the three samples tested. The reports are entitled "Laboratory and Bench-Scale Chacterization Studies for Arsenic-Contaminated Soil from DuPont/Weyerhaeuser Remediation Site," (March-April, 1994). The characterization results are summarized in Table 4, "Summary of Arsenic-Soil Characterization Test Results". The results are presented according to the information categories indicated in Section 4.0. An expanded summary of selected results is presented in the following sections, with limited interpretation. Further data interpretation, as applicable to specific remediation technology categories, is provided in Section 5.4.2.

REGULATORY ANALYSIS

The TCLP arsenic analyses results for each of the soil samples were less than 0.07 mg/l and indicate that the samples were not RCRA D004 hazardous, based on the regulatory limit of 5 mg/l. TCLP analysis for the other metals and organics was also conducted on the sample from Area 36; the results indicate that the soil does not exhibit the RCRA hazardous toxicity characteristic for any of these constituents.

PHYSICAL ANALYSIS

Physical testing determined that the USDA standard soil classification was "sand" for the soil samples from each of the three Areas. The results of the Atterberg Limits tests indicate that the samples from Areas 36 and 18 (by inference from analysis performed on a different composite sample from Area 18) were non-plastic.

The particle size distribution test results for the soil samples ranged from 52% to 66% cobbles/gravel, 26 to 39% sands, and 8 to 10% silt/clay.

For the Area 36 sample, the moisture content measured 5% and the loose and packed densities measured 1.6 and 1.9 g/cm3 (or approximately 1.3 and 1.6 tons/yd3), respectively. Also, the pH of a soil slurry measured 6.3, which indicates that the soil will not be corrosive to excavation, materials handling, or other treatment equipment.

Many of the physical analyses performed on the lead samples were not considered necessary when studying arsenic-impacted soils because much of the general information gathered from the lead characterization/treatability studies could be applied to soils across the Site for the purposes of evaluating potential treatment technologies. The physical analyses data collectively indicate that materials handling of the Site soils will not be complicated.

CHEMICAL ANALYSIS

Arsenic assays performed using Method 7060 on pulverized heads of whole soils for each of the three samples tested determined total arsenic concentrations in the range of 29 to 353 mg/kg.
Concentrations of low solubility bonding/binding anions and soluble cations, and organic carbon content for the Area 36 sample were measured at 2,640 ppm, 77 ppm, and 0.9%, respectively as reported under the lead characterization study. Although these analyses were not performed on the Area 18 sample, existing data from the lead characterization study composite sample from Area 18 indicates that the soils from Areas 18 and 36 have similar chemical characteristics.

The XRF analyses data indicate the presence of a silica=alumina-iron matrix with lesser amounts of sodium, magnesium, potassium, and calcium. These results are to be expected for the type of soils present at the Site and are consistent with the results from the lead characterization study.

The GANC/RGANC and pH analyses data show that the soil samples were essentially neutral and had no appreciable acidic or basic buffering capacity.

Sequential Extraction test results for selected sized fractions indicate that, for all samples, the occurrence of arsenic in the selected sized fractions examined was mostly in association with iron oxides and the organic portion of the soils.

Speciation analyses performed on selected sized fractions (gravity separated as appropriate) using SEM confirmed and Sequential Extraction test results that arsenic as associated with iron oxides and with the organic portion of the soil. SEM also gave positive identification of arsenic in the following forms or associations: iron-arsenic-phosphate, potassium-iron-sulfate, silicates, manganese oxides, and lead-arsenic-sulfate. An overall assessment of the SEM results suggests that arsenic exists predominantly in the +5 valence state.

LEACHING/MOBILITY

The TCLP arsenic analytical results are summarized in the Regulatory Analysis section, above.

Under the GANC and RGANC tests, one stage acidic/basic leaching at 20:1 liquids/solids ratio removed a range of two to four percent of the arsenic using 2N (normal) acetic acid, and 74% to 80% using 2N sodium hydroxide, respectively. This indicates that arsenic is more readily mobilized under basic, rather than acidic, leaching conditions. In general, the solubility of arsenic in the RGANC test was ten times higher than the corresponding solubility in the GANC test. This can be explained by reference to the sequential extraction results, which indicate the predominant arsenic forms and associations identified in the Site soils. Arsenic compounds in the +5 valence state are soluble under oxidizing conditions and at high pH.

The arsenic was more soluble in weak sodium hydroxide solutions than under moderate acetic acid leaching conditions, as demonstrated by TCLP, GANC, and Sequential Extraction test data. These results indicate that arsenic is essentially insoluble and immobile under normal environmental conditions, but can be mobilized under more rigorous high pH (caustic) leaching conditions.

BENCH-SCALE SOIL LEACHING STUDY – WEYERHAEUSER ATS

The potential of solutions of sodium hydroxide and sodium carbonate (at varying strengths, with and without phosphate addition) to extract arsenic from -1/4” to +200m fractions of the Site soil were investigated in single-stage batch extraction experiments under a study performed by Weyerhaeuser ATS. The effect of changes in liquid/solids ratio was evaluated, and the relative leaching efficiencies achieved for several sub-fractions of the soil sample examined. A simulation of a potential multi-stage countercurrent field extraction process was also conducted. The principal finds of this study are as follows:

- Soil arsenic concentrations were reduced by a maximum of 57% from a starting concentration of between 103 and 113 mg/kg in a single-stage batch extraction at an end point pH of 11.5 with 0.02 N sodium hydroxide and a liquid/solids ratio of 20:1. Similar performance was achieved with a sodium carbonate solution, although asignificantly higher reagent dose (e.g. 0.33 N) was necessary.

- A phosphate solution at near neutral pH was able to reduce arsenic concentrations by up to 10%. Extraction efficiencies of up to 25% were achieved in experiments evaluating the performance of phosphate in conjunction with alkali; appreciable pH buffering by phosphate was, however, seen, particularly in solutions including sodium carbonate.

- Leaching performance was shown to vary as a function of end point pH under the extraction experiments (increased sharply with increasing pH over the range of reagent strengths tested).

- Caustic leaching performance was not constrained by arsenic solubility under tests involving liquid/solids ratios of between 5:1 and 20:1.

- A somewhat greater percentage reduction in soil arsenic concentration was seen for the larger sub-fraction in a single-stage batch extraction examining relative leaching efficiencies for three sub-fractions of the tested soil.

- The overall leaching performances achieved under single stage batch and simulated multi-stage countercurrent extractions were comparable.

WET SCREENING TESTING – HART CROWSER

A total of five composite soil samples from the 250/500-foot arsenic sampling grid area and five samples from the Narrow Gage Railroad area were taken for wet screening analysis. The analysis involved separation of the whole soil into a series of size fractions for subsequent total arsenic analysis. The data generated were combined with the wet screening data derived for arsenic-impacted soil samples from Area 18, Area 36 and the Narrow Gage Railroad area under the Hazen study, the presence of higher arsenic concentrations in the smaller size fractions was consistently shown by these results. The combined results were subjected to a statistical evaluation (involving calculation of cumulative mean arsenic concentrations with reducing size fraction) to allow various “cut points” to be examined in consideration of potential remediation scenarios featuring soil size separation.

SPECIATION ANALYSIS – BATTELLE PACIFIC

Data from the Battelle Pacific speciation study indicate that, in the areas of the Site sampled (Areas 5, 25, 38, and Narrow Gage Railroad), arsenic is largely present as As(V). As(III), the common reduced form, accounts for less than one percent of the total soil arsenic. One sample in the Narrow Gage Railroad area contained about four percent organic (methylated) arsenic, which indicates the possible use of organic arsenic-based herbicides on the Site.

SOLIDIFICATION/STABILIZATION SCREENING – UNIVERSITY OF CINCINNATI (CGEST)

Three non-proprietary binding mixes (two featuring Portland cement and one featuring a combination of cement kiln dust and fly ash) were used to stabilize the -200-mesh fraction of a soil sample from Area 36 supplied to the University by Hazen. The initial arsenic concentration in the soil fraction was 205 mg/kg. All three design mixes passed TCLP following a 28-day curing period, with arsenic leachate results below the method detection limit (<0.1 mg/l).

C.5.8 Interpretation Results

The soil characterization results which bear most significantly on the viability and effectiveness of solidification/stabilization, physical screening/soil washing, and smelting/thermal recovery technologies for remediating arsenic-impacted soils are listed in Table C-2. A brief discussion of key results from the characterization study, including implications for technology selection, is provided in the following sections. The results of the CGEST solidification/stabilization screening tests, the Hart Crowser wet screening testing, and the Weyerhaeuser ATS bench-scale soil leaching study are also discussed briefly, where appropriate.

SOLIDIFICATION/STABILIZATION

The characterization test information most relevant for the evaluation of solidification/stabilization remediation technology are GANC/RGANC, organic carbon, RCRA Appendix IX semi-volatiles, TCLP (inorganic and semi-volatiles), and moisture content.

As previously mentioned, the GANC/RGANC and pH analyses indicate that the Site soils sampled are neutral and have essentially no acid or basic buffering capacity. The low buffering capacity is advantageous for a solidification/stabilization process because it minimizes the amount of solidification/stabilization binder that would need to be added to buffer the soil and maintain the arsenic solubility at low values. Based on the GANC and RGANC plots only, the optimal pH for the Site soils (corresponding to minimum solubility) for solidification/stabilization treatment of arsenic is in the acidic range (pH 3 to 4). This is consistent with the speciation results since As(V) species are known to be very insoluble in acid. To ensure a practical treatment and sensible pH conditions, the target end point pH under TCLP testing should be only a slightly acidic pH 5 to 7.

The carbon analysis results indicate that the organic carbon content in the Area 36 Site soils (<1%), which is a measure of the soil's natural ability to bond and bind with arsenic and other constituents, is typically below levels (<10%) that would be expected to inhibit curing in a solidification/stabilization process. With regard to the stabilization of soil fines (-200 mesh), the CGEST study indicates that fly ash/kiln dust binders require longer curing times than Portland cement binders.

The RCRA Appendix IX semi-volatile organics results (produced for the Area 36 soil sample) indicate that semi-volatiles are either absent in the Site soils or present only in low concentrations. These results support the application of solidification/stabilization treatment since semi-volatiles can be difficult to stabilize/solidify and may inhibit curing of the treated material.

None of the TCLP results exceeded the RCRA D004 regulatory threshold of 5 mg/l and no other constituents exceed TCLP threshold levels. These results indicate that if solidification/stabilization were to be applied to the Site soils, the TCLP arsenic leachability criterion would be readily met. The solidification/stabilization screening performed by CGEST further supports this conclusion. Here, several conventional binding mixes were tested on soil fines (-200 mesh) from Area 36 and yielded TCLP results well below the 5 mg/l RCRA LDR treatment standard on the stabilized soils (measured levels were less than the method detection limit, 0.1 mg/l). It is important to note that the Area 36 soils analyzed in the CGEST study were also impacted with lead. Typically, lead stabilization requires alkaline conditions, while arsenic stabilization is best performed under more neutral to slightly acidic conditions. For the binders tested, the study showed that a slightly alkaline "balance" can be struck (end point pH's in the range 5.2 to 8.2 under TCLP testing) that will stabilize lead and also will not leach excessive arsenic. This is an important finding, warranting further consideration in the event that fines generated from a soil washing system campaigning a mixture of lead- and arsenic-impacted soils require further solidification/stabilization treatment.

The moisture content results for the Site soils were fairly variable, ranging form approximately 5% to 10% for Area 18 (by inference from results for the lead characterization study sample from the same Area) and Area 36. Moisture content is the most sensitive input variable in solidification/stabilization system design and requires careful control during implementation. At the levels measured in this case, based on the CGEST solidification/stabilization screening work where moisture contents were in the range of 40% to 50%, a requirement for make-up water is indicated.

PHYSICAL SCREENING/SOIL WASHING

The characterization test results of most relevance for the evaluation of physical screening/soil washing remediation technologies are silt/clay content, arsenic distribution with regard to particle size, surface area calculations, Atterberg Limits, organic carbon, GANC/RGANC, MANC/RMANC, and Sequential Extraction.

The silt/clay content of the Site soils, ranging between eight and ten percent for the samples tested, is well below the 40% limited generally considered likely to limit the effectiveness of soil washing processes. The arsenic content in the silt/clay fraction of the soils is substantial at between 51% to 71% (corresponding concentrations range between 186 and 2,550 mg/kg) and suggests that significant beneficial volume reduction of arsenic-impacted soil could be achieved by separating the fine material from the whole soil.

Particle size distribution test results and corresponding chemical results for separated size fractions under the Hazen and Hart Crowser wet screening studies indicate that between approximately 79% and 92% of the soil arsenic is concentrated in the sand and silt/clay fractions. These fractions represent between 27% and 56% of the whole soil. These results indicate that recovery of the cobbles and gravel fraction (representing between 44% and 73% of the whole soil) as “clean” material could be readily achieved using conventional wet screening or classification-type soil washing.

For water-based soil washing processes, the wet screening and Sequential Extraction test results indicate that, due to the low aqueous solubility of arsenic in Site soils under near-neutral pH conditions, little or no water treatment provisions would be necessary.

The surface area calculations for each of the soil size fractions of the Area 36 sample show, as expected, that the majority of the total soil surface area is contained in the silt/lay (~80%), with less in the sands (~20%), and least in the cobbles/gravel (<2%). The arsenic distribution by size fraction for the Area 36 sample increases with reducing size fraction and increasing surface area; these results indicate that arsenic bonding and binding is mostly surface related.

The Atterberg Limits results for the Area 36 soil sample show (as seen generally for all other Site samples tested) that the “sand” soil is non-plastic and should be amenable to processing by physical screening equipment and easy to handle by conventional earth-moving equipment.

The organic carbon content of the Area 36 soils is 0.9%, significantly below the 10% limit generally considered as the value above which complications in a soil Washington system can arise due to contaminant/carbon bonding. Although organic carbon data for the other arsenic characterization soil samples are not available, information from the lead characterization study (Section 5.3) indicates that the organic content of soils across the Site does not vary significantly. The inclusion of an organic matter removal unit operation in a soil washing process to address soil organic carbon should not be necessary.

The GANC/RGANC results show that the Site soils have little buffering capacity and will not require the addition of large amounts of base in a soil-washing scenario to achieve a desired pH change.

In the consideration of MANC/RMANC equilibrium arsenic concentrations, high acetic acid concentrations (approximately 14 equivalents of acid/kg soil) were required to leach arsenic, whereas RGANC indicated that about two base equivalents/kg soil were required for optimum leaching. One stage acidic/alkaline leaching at 20:1 liquids/solids ratio can remove two to four percent of the arsenic using 2N acetic acid, but amounts of between 74% and 80% can be removed using 2N sodium hydroxide. These results indicate that chemical leaching using alkaline reagents has potential for use in a soil washing process to clean the Site soils, possibly in conjunction with wet screening and other physical treatment techniques. Conversely, mildly acidic conditions might be employed in a soil washing treatment scenario to ensure that arsenic remains concentrated in the fines fraction, which could subsequently be stabilized.

Sequential Extraction data show that arsenic is predominantly present, in the sized fractions examined, in association with iron and manganese oxides and organic material. The results indicate that arsenic species are not soluble in water or under acidic conditions, but can be solubilized under caustic conditions (the organic matter sequential extraction step uses sodium hydroxide and phosphate as the leachant). This speciation information supports the conclusion that chemically enhanced (basic) soil washing or leaching treatment could be used to liberate arsenic from the soils.

The results of the Weyerhaeuser ATS leaching study corroborate the leaching data generated under the Hazen study, and further demonstrate the potential for a chemically enhanced soil washing application, in that they show alkaline solutions to be effective in removing arsenic from the Site soils. In single-stage batch extractions, solutions of sodium hydroxide at approximately pH 11.5 removed up to 57% of arsenic from sand fractions containing starting concentrations of around 100 mg/kg; sodium carbonate solutions gave similar results but required significantly higher reagent doses. A strong dependency on pH was shown in the leaching experiments and there was no evidence that leaching performance was constrained by arsenic solubility. A batch extraction examining relative leaching efficiencies between sub-fractions of the tested soil showed a somewhat greater performance for the larger sub-fraction, and no significant improvements in overall leaching performance were seen in simulated multi-stage countercurrent tests. These various issues will require further investigation before decisions can be made for including leaching in a soil washing treatment application. Similarly, issues including solids hold-up times, temperature and aqueous extract treatment/recycling will need to be addressed.

SMELTING/THERMAL RECOVERY

The characterization test results of chief importance for the evaluation of smelting/thermal recovery remediation technology are total arsenic concentrations, moisture content, RCRA F039 listed metals, and soil mineralogy results.

Cost effective treatment of RCRA D004 waste by secondary smelters requires that arsenic content in the feed soil be on the order of that for lead recovery, i.e., 6-8% by weight. Since total average arsenic concentrations in the Site soils lie in a range of only 29 to 353 mg/kg (i.e., 0.035% maximum), and even the highest measured concentration in the silt/clay fraction is only 0.25%, the soils would not be suitable for smelting without intensive pre-processing to concentrate arsenic into the finer soil fractions. Because of the relatively low arsenic concentrations, the likelihood that smelting would be suitable to treat concentrated soil washing residuals is low.

The maximum acceptable moisture content of a smelter feed soil is 10%. This may place a further constraint on the smelting application for the Site soils; concentrated fines/residuals from a soil washing process would probably need to be passed through a dewatering step.

The RCRA F039 listed metals analyses indicate the presence of antimony, barium, chromium, copper, nickel, selenium, vanadium, zinc, and lead. Though present at low concentrations, these metals are potential impurities, which could adversely impact smelting/thermal recovery processes.

The XRF analysis indicates the presence of a silica-alumina-iron oxide matrix with minor amounts of sodium, magnesium, potassium, phosphorus, sulfur, titanium, and calcium. The presence of these elements is expected in sandy and silty soils. They could, however, adversely affect the viability of smelting/thermal recovery as impurities in the system.

Table C-1 – Soil Characterization Procedures by Category

Category	Test Group	Information Use	Test Types
Whole Soil	PHYSICAL HANDLING	Provides information on how soil will behave during excavation and in treatment processes.	Surface Area Calculations (Lead only) Particle Size Distribution Soil Plasticity (Atterberg Limits) USDA Soil Classification Density (loose and packed) Moisture Content
	REGULATORY	Provides information to enable regulatory waste code classification.	Total Constituent Concentration TCLP Constituent Concentrations RCRA Appendix IX Total Metal Concentration TCLP (inorganics and semiVOCs) RCRA Appendix IX Inorganics RCRA Appendix IX SemiVOCs pH
	SOIL CHEMISTRY	Provides information on contaminant/soil interactions to further general understanding of soil properties and to be used in evaluating treatment technologies.	Bonding/Binding Anions Soluble Cations Carbon (total/inorganic/organic) GANC/RGANC

Table C-1 – Soil Characterization Procedures by Category (Continued)

Category	Test Group	Information Use	Test Types
Whole Soil (Continued)	SOIL CHEMISTRY (Continued) -Anions	Provides an indication of availability of bonding/binding sites for heavy metals (anions can combine with metals to form low solubility salts).	Sulfide Sulfate Phosphate Carbonates/Bicarbonates
	-Soluble Cations	Can compete with heavy metals for bonding/binding sites (ion-exchange sites, anions).	Calcium Sodium Magnesium Potassium Manganese Iron
	-Carbon Balance	Organic carbon can bond/bind with metals.	Total Carbon Inorganic (fixed) Carbon (by TGA) Organic Carbon (by difference)
	-Alkalinity/Acidity, Buffering Capacity	Provides, and indications of, how soil will respond to acid/base changes.	pH Redox GANC/RGANC

Table C-1 – Soil Characterization Procedures by Category (Continued)

Category	Test Group	Information Use	Test Types
Whole Soil (continued)	MOBILITY AND LEACHABILITY	Provides information on mobility in, and availability to, the environment.	TCLP (inorganics and semiVOCs) Equilibrium Leaching Procedure (Lead only) (SAR-F039 List Metals) MANC during GANC/RGANC GANC/RGANC
Soil Fractions	REGULATORY	Provides information on metals of regulatory concern to enable proper management/disposal.	F039 List Metals
	SOIL CHEMISTRY	Provides information on contamination/soil interactions to further general understanding of soil properties and to be used in evaluating treatment technologies.	Cation Exchange Capacity (CEC) (Lead only) Total Iron and Manganese Total Chloride
	SOIL CHEMISTRY -Speciation	Provides information on what specific chemical forms of metals are present and how metals are bound within soil. Aids in determination of impact to environment and technology selection.	Sequential Extraction Scanning Electron Microscopy (SEM) X-Ray Diffraction (SRD) X-Ray Fluorescence (SRF) - Mineralogy

Table C-2 – Soil Characterization Procedures by Treatment Technology

Category	Treatment Technology	Test Types
Whole Soil and Fractions	Stabilization/Solidification	GANC/RGANC MANC Total Carbon, Inorganic and Organic Carbon RCRA Appendix IX SemiVOCs TCLP (inorganic and semiVOCs) Moisture Content Speciation Analysis of Fractions
	Physical Screening/Soil Washing	Constituent Distribution with Particle Size Surface Area Calculations Silt/lay Content MANC during GANC/RGANC Organic Carbon Speciation Analysis of Fractions
	Smelting/Thermal Recovery	Total Constituent Concentration Constituent Distribution with Particle Size XRF Scan (mineralogy) Silica Content (by XRF) Moisture Content Total Carbon

Table C-3 – Lead-Soil Characterization Study-Hazen Research-Summary of Test Results

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
Sample Verification (Pulverized Head)						
Total Lead, mg/kg (avg. of three)	475	180	870	2,110	660	3,570
TCLP Lead	1.7	0.3	4.6	1.3	1.2	21.4
RCRA Hazardous, D008	no	no	no	no	no	yes
Physical Materials Handling						
Particle Size Distribution (cobbles/gravel, sand, silt/clay), %	56/32/12	38/53/9	61/32/7	43/42/15	60/32/8	53/37/10
Soil Plasticity (Atterberg Limits)	non-plastic	non-plastic	non-plastic	non-plastic	non-plastic	non-plastic
USDA Soil Classification	sand	sandy loam	sand	sand	sand	sand
Density (loose/packed), g/cm3	1.3/1.4	1.3/1.5	1.6/1.9	1.1/1.5	1.2/1.6	1.1/1.4
Moisture Content, %	12.2	9.8	5.0	20.5	11.7	17.0
pH (10% solids slurry)	4.4	6.0	6.3	7.3	5.4	5.8
Regulatory						
Total Lead, mg/kg (RCRA Appendix IX)	380	260	540	1,700	590	3,000
TCLP Lead, mg/l	2.0	0.3	4.7	1.4	0.9	18
RCRA Appendix IX Inorganics	none of concern	none of concern	none of concern	none of concern	none of concern	none of concern
RCRA Appendix IX Semi-VOCs	none of concern	low level semi-VOCs	low level semi-VOCs	low level semi-VOCs	none of concern	none of concern

Table C-3 – Lead-Soil Characterization Study-Hazen Research-Summary of Test Results (Continued)

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
Soil Chemistry						
Bonding/Binding Anions, ppm total	2,600	2,500	2,640	10,650	4,175	7,190
Soluable Cations, ppm total	81	24	77	261	66	94
Carbon (total/inorganic/organic), %	3.3/0/3.3	2.5/0.7/1.8	1.1/0.2/0.9	6.9/0/6.9	4.2/0/4.2	4.2/0/4.2
Net Acid/Base Potential, tons of CaCO3/1000 tons of soil	-10.9	-7.5	1.0	2.8	-24.4	-16.1
GANC/RGANC	unbuffered	unbuffered	unbuffered	unbuffered	unbuffered	unbuffered
Equivalents acid to reach pH,4	2	2	2	4	2	2
Equivalents base to reach pH>10	2	2	2	2	2	2
Leaching and Mobility						
TCLP Lead, mg/l	2.0	0.3	4.7	1.4	0.9	18.0
Equilibrium Leaching Procedure						
Leachate lead, mg/l	0.019	0.05	0.032	0.02	0.059	0.064
Equilibrium partition coefficient, K	2.2E+04	1.0E+04	2.0E+04	8.1E+04	1.1E+04	6.3E+04
MANC/RMANC equilibrium lead conc. (acid/base), mg/l	15/7	4/3	33/8	48/14	15/13	90/25

Table C-3 – Lead-Soil Characterization Study-Hazen Research-Summary of Test Results (Continued)

Whole Soil Procedures	Area 7 (Kettle)	Area 18 (Nitrator)	Area 36 (Lead Melt)	Area 40 (Pulverizer)	Area 40 (Glazemill)	Area 40 (Packhouse)
Speciation						
Sequential Extraction	Majority of lead in carbonate, specifically adsorbed, and exchangeable forms	Majority of lead in carbonate, specifically adsorbed, and exchangeable forms	Majority of lead in carbonate, specifically adsorbed, and exchangeable forms	Majority of lead associated with carbonates, iron and manganese oxides, and organic material	Majority of lead associated with carbonates, iron oxides, and organic materials	Majority of lead associated with carbonates, iron and manganese oxides, and organic material
SEM/XSD	Positive ID of lead sulfate and lead sulfide	Positive ID of lead carbonate, lead oxide, and lead-manganese oxide	Positive ID of lead carbonate, lead silicate, metallic lead, and lead-iron oxide	Positive ID of lead carbonate, lead silicate, lead oxides, and lead-iron oxide	Positive ID of lead silicate, lead oxides, lead phosphate, and lead-iron oxide	Positive ID of lead oxides (manganese, tin, aluminum, and iron)
Soil Chemistry						
Cation Exchange Capacity, Meq/100g	34	84.2	49.6	98.1	111.0	95.9
Chloride, mg/kg	100	<100	<100	500	100	260
Iron/Manganese, mg/kg	23,350/620	34,238/838	39,979/775	63.630/990	30,050/1,150	95,820/1,090
Regulatory						
F039-List Metals	As, Pb, Ba, Cr	As, Pg, Ba, Cr	As, Pb, Ba, Cr	Pb, Ba, Cr, Zn	As, Pb, Zn	As, Pb, Ba, Cu, Zn

Table C-3 – Lead-Soil Characterization Study-Hazen Research-Summary of Test Results (Continued)

Whole Soil & Fraction Procedures	**Area 7 (Kettle)**	**Area 18 (Nitrator)**	**Area 36 (Lead Melt)**	**Area 40 (Pulverizer)**	**Area 40 (Glazemill)**	**Area 40 (Packhouse)**
Physical Screening/Soil Washing						
Silt/Clay Content, %	12	9	7	15	8	10
Lead Distribution by Particle Size (% of total lead in cobbles/gravel, sand, silt/clay)	16/29/55	3/30/67	10/63/27	5/56/39	13/48/39	3/58/39
Total Lead Conc. By Particle Size (cobbles/gravel, sand, silt/clay), mg/kg	130/420/2,170	50/310/3,970	180/2,100/3,980	195/2,310/4,350	130/950/3,320	130/4,260/10,600
Surface Area Calculations (% of total surface area in cobbles/gravel, sand, silt/clay)	<1/17/83	<1/36/64	2/22/76	<1/18/82	1/23/76	1/20/79
Organic carbon, %	3.3	1.8	0.9	6.9	4.2	4.2
GANC/RGANC	Unbuffered	Unbuffered	Unbuffered	Unbuffered	Unbuffered	Unbuffered
Equivalents acid to reach pH<4	2	2	2	4	2	2
Equivalents base to reach pH>10	2	2	2	2	2	2
MANC/RMANC equilib. lead Conc. (acid/base), mg/l	15/7	4/3	33/8	48/14	15/13	90/25
% Lead Leached under MANC/RMANC (acid/base)	60/29	44/30	75/18	45/13	45/40	50/14

Table C-3 – Lead-Soil Characterization Study-Hazen Research-Summary of Test Results (Continued)

Whole Soil & Fraction Procedures	**Area 7 (Kettle)**	**Area 18 (Nitrator)**	**Area 36 (Lead Melt)**	**Area 40 (Pulverizer)**	**Area 40 (Glazemill)**	**Area 40 (Packhouse)**
Stabilization/Solidification						
GANC/RGANC	Unbuffered	Unbuffered	Unbuffered	Unbuffered	Unbuffered	Unbuffered
MANC/RMANC Minimum Lead Concentration (mg/l)pH Range	<1/5.5 to 6.8	<1/4.6 to 6.1	<1/4.8 to 8.5	1/6.3 to 12.5	1/5.1 to 8.9	1/6.3 to 7.8
Carbon (total/inorganic/organic), %	3.3/0/3.3	2.5/0.7/1.8	1.1/0.2/0.9	6.9/0/6.9	4.2/0/4.2	4.2/0/4.2
RCRA Appendix IX SemiVOCs	none of concern	low level semiVOCs	low level semiVOCs	low level semiVOCs	none of concern	none of concern
TCLP Lead, mg/l	2.0	0.3	4.7	1.4	0.9	18
Moisture Content, %	12.2	9.8	5.0	20.5	11.7	17.0
Smelting/Thermal Recovery						
Total Lead, mg/kg	380	260	540	1,700	590	3,000
Lead Distribution by Particle Size (% of total lead in cobbles/gravel, sand, silt/clay)	16/29/55	3/30/67	10/63/27	5/56/39	13/48/39	3/58/39
Total Lead Conc. By Particle Size (cobbles/gravel, sand, silt/clay), mg/kg	130/420/2,170	50/310/3,970	180/2,100/3,980	195/2,310/4,350	130/950/3,320	130/4,260/10,600
Silica Content (weight % in Cobbles/gravel, sand, silt/clay)	-/69/59	-/-/33	-/-/45	-/56/28	-/-/28	-/50/29
Moisture Content, %	12.2	9.8	5.0	20.5	11.7	17.0
Total Carbon, %	3.3	2.5	1.1	6.9	4.2	4.2

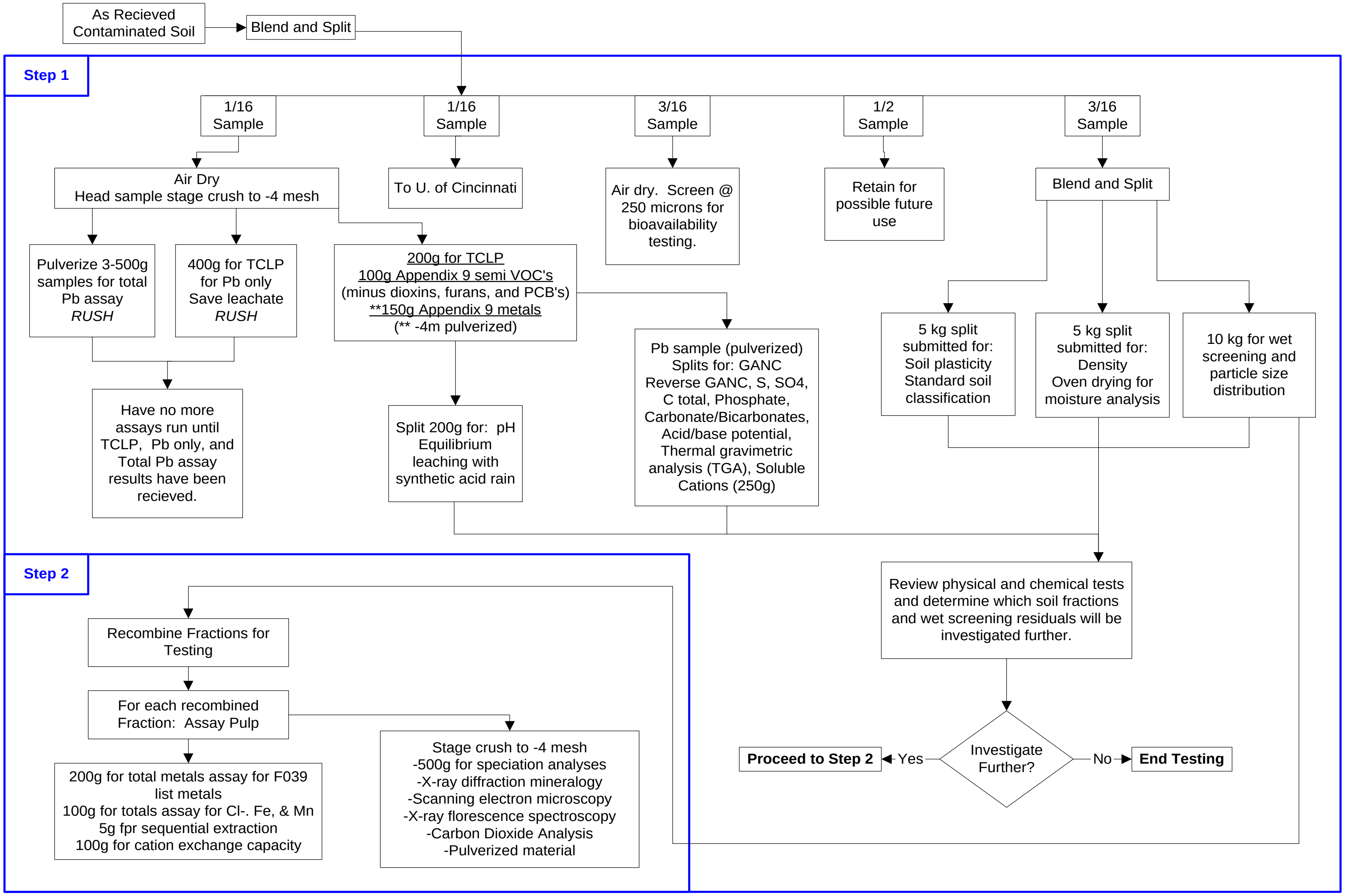
Table C-4 – Arsenic-Soil Characterization Study-Hazen Research-Summary of Test Results

Whole Soil Procedures			
Physical Materials Handling	**Area 18**	**Area 36**	**RR Track Area**
Particle Size Distribution (cobbles/gravel, sand, silt/clay), %	66/26/8	60/30/10	52/39/9
Arsenic Distribution by Particle Size (% of total arsenic in cobbles/gravel, sand, silt/clay, slimes)	12/28/35/25	18/30/47/5	7/22/63/8
pH (10% solids slurry)		6.2	
Regulatory			
TCLP Arsenic, mg/l (conducted at 4.9 pH)	<0.03	<0.07	<0.03
RCRA Hazardous, D004	no	no	no
Soil Chemistry			
Total Arsenic, mg/kg	41	29	353
GANC/RGANC	unbuffered	unbuffered	unbuffered
Equivalents acid to reach pH<4	>14	>14	2
Equivalents base to reach pH>10	2	<2	2
Leaching and Mobility			
TCLP Arsenic, mg/l	<0.03	<0.07	0.03
MANC/RMANC minimum arsenic Concentration (acid/base), mg/l: pH	0.007:3.8/ 0.05:5.0	0.007:3.7/ 0.035:8.8	0.045:3.2/ 0.28:5.2
MANC/RMANC equilibrium arsenic Concentration (acid/base), mg/l	0.25/2.7	0.06/1.5	2/22
% Arsenic Leached under GANC/RGANC (acid/base)	3/75	4/80	2/74

Table C-4 – Arsenic-Soil Characterization Study-Hazen Research-Summary of Test Results (Continued)

Soil Fraction Procedures			
Speciation	**Area 18**	**Area 36**	**RR Track Area**
Sequential	Majority of arsenic associated with the organic fraction and, to a lesser extent, with the non-crystalline iron oxide fractions.	Majority of arsenic associated with the organic and non-crystalline iron oxide fractions and to a lesser extent, with the crystalline iron oxide fraction.	Majority of arsenic associated with the crystalline iron oxide and organic fractions and, to a lesser extent, with the non-crystalline iron oxide fraction.
SEM	Very little arsenic detected, but associated mainly with iron oxide. Also associated with silicates, and present as iron-arsenic-phosphate.	Arsenic associated mainly with iron oxide (including suspected goethite); arsenic also detected in particles (containing Fe, Al, Ca, & Si) attached to carbon-charcoal particles and with lead-manganese-oxide.	Arsenic associated mainly with iron oxide and organic material. Also positive identification of iron-arsenic-phosphate, lead-arsenic-sulfate and potassium-iron-sulfate.
XRF	Presence of silica-alumina-iron matrix	Presence of silica-alumina matrix	Presence of silica-alumina-iron matrix

Figure C-1 – Flow sheet for Sample Preparation and Testing



APPENDIX D – *ARSENIC WET SCREENING STUDY*

D.1 Objective and Overview

The objective of performing additional arsenic treatability studies was to better define the distribution of arsenic concentration relative to soil particle size. Distribution data can be used to select a particle size "cut point" for remedial action that corresponds to the cleanup or remediation level for arsenic.

We analyzed soil samples from two areas of the Site, the Narrow Gage Railroad (NGRR) and the 250/500-foot arsenic soil sampling grid (Grid), to determine if the differences in average arsenic concentration are likely to impact the distribution with grain size. We combined the results of the Hart Crowser arsenic treatability studies with the previously performed Hazen arsenic treatability studies to determine the average arsenic concentration associated with different grain sizes.

A total of three Hazen arsenic study analyses were included in this evaluation. Hazen arsenic study results from the Area 36 - Melt Shop and the Area 18 - Hot Spot were incorporated in the evaluation of the Grid soil data. Hazen arsenic study results from the NGRR area were incorporated in the evaluation of the NGRR soil data.

Hart Crowser samples were collected close to locations identified during the RI sampling as areas of elevated arsenic concentrations. The RI sampling concentrations for the Grid and the NGRR, as well as concentrations for the whole sample and the pulverized whole sample from the treatability study, are presented in Table D-1.

The whole sample result represents the analysis of an aliquot of soil from the treatability study samples collected and analyzed using the same procedure used for the RI samples.

The pulverized whole sample result is the concentration in an aliquot of soil from the treatability study following pulverization of the entire soil sample.

D.2 Treatability Sample Collection

A total of ten 5-point composite samples were collected at selected locations that were previously sampled during the RI. Five samples were collected from the NGRR locations to provide samples that contained relatively high concentrations (400 to 950 mg/kg) of arsenic. The remaining five samples were collected from the 250/500-foot RI sampling grid; these were intended to provide treatability study samples containing lower arsenic concentrations (82 to 360 mg/kg). The ten samples were collected using the same procedure. A four-gallon sample was collected from a depth of 0 to 6 inches at each sampling location, using the same sampling procedure as for RI sample collection. Each 5-point composite sample was collected immediately adjacent to the previously sampled RI location. The sample was placed into a clean/lined bucket and appropriately labeled with the same RI sample number as used previously. Table D-1 summarizes the results from the treatability study sample locations and the associated total arsenic concentrations from previous RI analyses.

Several observations can be made by comparison of these data:

- The RI sample results have generally higher arsenic concentrations compared to the treatability study whole sample results.

- The results for the pulverized whole samples are all lower than the results of the non-pulverized whole sample. These results indicate that the higher concentration of arsenic is confined to smaller soil size fractions.

D.3 Treatability Study Procedure

The ten samples were analyzed using the same physical and chemical testing procedures. Physical testing of the samples was performed in the Hart Crowser Physical Laboratory. Chemical analysis for total arsenic was performed at Analytical Technologies, Inc. (ATI) in Renton.

D.3.1 Physical Testing

The following sample preparation and physical testing procedures were performed prior to the total arsenic analysis. Figure D-1 presents a schematic flow diagram of the procedure:

1) Initially, the entire 4-gallon sample was thoroughly mixed to improve homogeneity.

2) The sample was coned and quartered into four portions (approximately 1-gallon each). Three of the quarters were combined into one 3-gallon sieve sample.

3) A 4-oz sample aliquot was collected from the remaining 1-gallon sample and analyzed the aliquot for total arsenic at ATI. This sample is identified as a "whole sample". The remainder of this sample was crushed and pulverized until 50 percent of the sample passed the 100 mesh sieve. A 4-oz aliquot was collected from the pulverized sample and submitted for total arsenic analysis at ATI. This sample is identified as "pulverized whole sample."

4) The whole sample from Step 3 was dried, crushed, and pulverized to 50% passing the 100 mesh sieve.

5) A 4-oz aliquot of the material from Step 4 was collected and submitted to ATI for total arsenic analysis.

6) The 3-gallon sample was dry screened at 10 mesh.

7) The +10 mesh material from Step 6 was wet screened at 10 mesh (-10 mesh to Step 12).

8) The +10 mesh material from Step 7 was dried and sieved with screen sizes of 1", 1/2", 1/4" and 8 mesh.

9) The material retained was then weighed on the 1", 1/2", 1/4" and 8 mesh screens and calculated the >8 mesh percent.

10) After screening and weighing the dried +10 mesh material through 1", 1/2", 1/4", and 8 mesh sieves (Steps 4 and 7) the material retained on each sieve was pulverized so 50 percent of the material was <100 mesh. A 4-oz sample of the pulverized material was collected and sent to ATI for total arsenic analysis.

11) A 4-oz aliquot of each sample was collected and sent to ATI for total arsenic analysis.

12) The -10 mesh material from the wet screening and the -10 mesh from the initial dry screening were combined and dried.

13) The -10 mesh material was weighed for the >8 mesh percent calculation.

14) The -10 mesh material was homogenized and quartered, to produce one 1,000 gram sample aliquot. The remaining sample was held in the original sample container.

15) The 1,000 gram aliquot was wet screened at 200 mesh. (The -200 mesh water and slimes to Step 18). Two samples of the slime water were collected and analyzed for total arsenic (RR-545 and RR-528).

16) The dry +200 mesh material was weighed and then sieved through 16, 30, 60, 100, and 200 mesh sieves.

17) The material retained on these sieves was weighed and the <8 mesh percent was calculated.

18) The material retained on each sieve was pulverized so that at least 50 percent of the sample was <100 mesh. A 4-oz sample of the pulverized material was collected and sent to ATI for total arsenic analysis.

19) A sample of water and slimes from Step 15 was submitted to ATI for total arsenic analysis.

20) The -200 mesh water and slimes from Step 15 were dried and combined the -200 mesh material from Step 15 with the -200 mesh material from Step 16.

21) The dried -200 mesh material was weighed and sampled for total arsenic analysis at ATI.

The above procedures were followed for each of the samples. However, in two cases, modifications occurred during the analysis as noted below.

- Step 18 was not implemented as described above for sample RR-546. The temperature in the oven used to dry the -200 mesh samples from Step 13 was inadvertently increased to 430°C. Typical oven temperatures were approximately 80°C. The higher temperature may have reduced the total arsenic concentration in the sample because of the sublimation of the arsenic from the soil. As a result the -200 mesh material from sample RR-546 from Step 15 was sampled for analysis at ATI. This result will probably be more representative of the -200 mesh material.

- The +8 mesh material was coned and quartered following crushing and prior to pulverizing in order to expedite sample submittal to the lab for analysis. This resulted in about 250 grams of material being pulverized. Large samples of the -8 mesh material were also coned and quartered prior to pulverizing to expedite sample submittal. The reduction of sample size during this process should not impact the analytical result obtained for the particular sieve size because the soil is more uniform following crushing and splitting of the sample and is likely to include equal ratios of each grain size.

D.3.2 Chemical Testing

A total of 130 soil samples were submitted to ATI for total arsenic analysis. Since each sample was dried prior to screening and collecting the sample, the analytical results were reported on a wet weight basis. The differences between the treatability study and RI laboratory methods were compared. The treatability study and RI samples were prepared using SW-846 Method 3050 and, according to the QAPP in the Site Management Plan, analyzed by graphite furnace/atomic absorption (SW-846 Method 7060). This is a similar method used by ATI for all RI arsenic analyses. This is not the method used for the treatability studies performed by Hazen Research. Hazen used an American Society for Testing of Materials (ASTM) Method D 4606-86 which used a slightly more rigorous extraction procedure than was used by ATI. This may have resulted in the Hazen method extracting different amounts of arsenic from each soil sample relative to the amount extracted from a similar sample analyzed at ATI. Hazen used a hydride atomic absorption analysis method different from the graphite furnace analysis method used by ATI. We are unable to predict the impact that these differences may have on the analytical results without a detailed evaluation of these two analytical methods.

Two water samples were submitted to ATI for total arsenic analysis to determine potential dissolution of arsenic during the wet screening process. Samples were analyzed using SW-846 Method 7060, the same analytical procedure used when analyzing the soil samples.

D.3.3 Treatability Study Results

The results of the physical and chemical analysis for the Grid and NGRR soils are presented in Attachment D-1. Table D-2 presents the mean arsenic distribution and cumulative mean arsenic distribution with respect to grain size for both grid samples and railroad samples. A total of 7 samples (2 Hazen, 5 Hart Crowser) were analyzed to assess the arsenic distribution with respect to grain size in grid soil.

Grid Soil: Evaluation of the data generated during the analysis of grid soil is summarized below.

- For the 7 samples analyzed, the average grain size distribution was 60.7% Gravel, 32.0% Sand, and 7.3% Silt. The mean arsenic concentration for each grain size is presented in Table D-2. Based on the data for all of the grid soil samples presented in Attachment D-1, the range of arsenic distribution by soil type is presented below.

Size Fraction	Range of Total Arsenic Distribution in %
+1/4-inch (gravel)	8.4 to 21.4
-1/4-inch to +200 mesh (sand)	28.4 to 55.7
-200 mesh (silt)	22.9 to 47.0

- The calculated pulverized whole sample arsenic concentration and the result for the pulverized whole sample analysis was compared for each sample (see Attachment D-1). The percent difference of these concentrations ranged from +50 percent (Area 18 - Hazen Sample) to -20.0 percent (18R-461). This level of accuracy is attributed to the high degree of variation expected with the high concentrations of arsenic in the matrix.

Narrow Gage Railroad (NGRR) Soil: Evaluation of the data generated during the analysis of NGRR soil are summarized below. A total of 6 samples (1 Hazen, 5 Hart Crowser) were analyzed to assess the arsenic distribution with respect to grain size in NGRR soil.

- For the 6 samples analyzed the average grain size distribution was 57% Gravel, 36.7% Sand, and 6.3% Silt. The mean arsenic concentration for each grain size is presented in Table D-2. Based on the data for the NGRR soil samples presented in Attachment D-1, the range of arsenic distribution by soil type is presented below.

Size Fraction	Range of Total Arsenic Distribution in %
+1/4-inch (gravel)	7.1 to 12.7
-1/4-inch to +200 mesh (sand)	22.0 to 70.7
-200 mesh (silt)	17.4 to 62.8

- The calculated pulverized whole sample arsenic concentration and the result of the pulverized whole sample analysis was compared for each sample (Attachment A). The percent difference of these concentrations ranged from +83 percent (RR-545) to -13 percent (RR-528). This level of accuracy is attributed to the high degree of variation expected with the high concentrations of arsenic in the matrix.

D.3.4 Conclusion

The application of soil washing may be effective when applied to Site soil impacted by arsenic. This treatability study shows that a coarser low concentration fraction and a finer high concentration fraction can be readily attained. The determination of the particle size "cut point" for impacted soils is likely to vary with the initial concentration of the feed soil. A lower "cut point" may be attained by implementing higher energy particle separation technologies, such as attrition scrubbing.

Table D-1 – Whole Samples Total Arsenic Results 250/500-Foot Grid and Narrow Gage Railroad Track

Sample Number	Total Arsenic Concentration in mg/kg		
	RI	Treatability Study	
	Whole Sample (ATI Result)	Whole Sample (ATI Result)	Pulverized Whole Sample (ATI Result)
250/500-Foot Grid			
LR-125E	110	71	34
LR-157	82	48	23
LR-207	140	54	31
LR-311	360	110	60
18R-461	100	74	35
Narrow Gage Railroad Track			
RR-515	550	370	220
RR-528	400	490	190
RR-536	480	550	120
RR-545	530	150	100
RR-546	950	340	81

TABLE D-2 - ARSENIC DISTRIBUTION WITH GRAIN SIZE
ARSENIC TREATABILITY STUDY
FORMER DUPONT WORKS SITE

AVERAGE ARSENIC DISTRIBUTION IN GRID SAMPLES

Screen Size	Mean Dist. in Percent by weight		Mean Conc. in mg/kg	Cumulative Mean Conc. in mg/kg*
+1	18.0%			
-1+1/2	26.0%	Gravel	7.46	7.46
-1/2+1/4	16.7%		8.67	8.26
	60.7%		9.87	8.68
-1/4+8m	8.7%			
-8m+16m	4.5%		17.24	9.86
-16m+30m	5.0%	Sand	30.45	11.23
-30m+60m	7.6%		45.66	13.43
-60m+100m	3.6%		58.21	17.19
-100m+200m	2.5%		84.05	20.01
	32.0%		120.47	22.50
-200m	7.3%	Silt		
	7.3%		181.90	32.44
	100.0%			

AVERAGE ARSENIC DISTRIBUTION IN NGRR SAMPLES

Screen Size	Mean Dist. in Percent by weight		Mean Conc. in mg/kg	Cumulative Mean Conc. in mg/kg*
+1	18.0%			
-1+1/2	21.5%	Gravel	21.15	21.15
-1/2+1/4	17.5%		32.06	28.26
	57.0%		49.45	35.25
-1/4+8m	11.8%			
-8m+16m	5.4%		81.37	43.13
-16m+30m	7.5%	Sand	110.35	47.96
-30m+60m	7.8%		158.45	57.68
-60m+100m	2.3%		249.18	74.72
-100m+200m	1.9%		602.18	88.47
	36.7%		876.61	105.03
-200m	6.3%	Silt		
	6.3%		1,689.61	203.32
	100.0%			

* The cumulative mean concentration is the sum of the products of the weight percent and the concentration divided by the cumulative coarser weight percents.

ATTACHMENT D-1
WET SCREENING PROCESS DATA FOR HART CROWSER AND HAZEN RESEARCH ARSENIC TREATABILITY STUDIES

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic Calculate Head, mg/	Distrib. %
18R-461	+1"	35.6		6.5		16.6
	-1"+1/2"	26.2	gravel	9.0		16.9
	-1/2"+1/4"	11				0.0
		72.8			6.4	33.5
	-1/4"+8m	5.5				0.0
	-8m+10m	0.7				0.0
	-10m+16m	2.3				0.0
	-16m+30m	4.8	sand			0.0
	-30m+60m	6.6				0.0
	-60m+100m	2.3				0.0
	-100m+200m	1.8		160.0		20.6
		24			12.0	20.6
	-200m	3.2	silt/clay	200.0		45.9
		3.2			200.0	45.9
	Total	100.0	TOTAL		14.0	100.0

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	74

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic Calculate Head, mg/	Distrib. %
LR-125E	+1"	13.9		6.0		#DIV/0!
	-1"+1/2"	28	gravel	9.0		33.8
	-1/2"+1/4"	20.3				0.0
		62.2			5.4	67.0
	-1/4"+8m	9.6				0.0
	-8m+10m	0.9				0.0
	-10m+16m	2.2				0.0
	-16m+30m	2.7	sand			0.0
	-30m+60m	7.2				0.0
	-60m+100m	5.1				0.0
	-100m+200m	2.8		90.0		41.3
		30.5			8.3	41.3
	-200m	7.3	silt/clay	160.0		91.7
		7.3			160.0	91.7
	Total	100.0				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	71

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic Calculate Head, mg/	Distrib. %
LR-157	+1"	13.9		7.2		
	-1"+1/2"	33.6	gravel	7.1		
	-1/2"+1/4"	18.4				
		65.9				
	-1/4"+8m	8.2				
	-8m+10m	1.2				
	-10m+16m	2.4				
	-16m+30m	3.8	sand			
	-30m+60m	6.5				
	-60m+100m	2.8				
	-100m+200m	2.8		100.0		
		27.7				
	-200m	6.4	silt/clay	120.0		
	Total	100.0				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	48

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic Calculate Head, mg/	Distrib. %
LR-207	+1"	9.9		5.8		
	-1"+1/2"	21.2	gravel	6.1		
	-1/2"+1/4"	13				
		44.10				
	-1/4"+8m	9.8				
	-8m+10m	2.3				
	-10m+16m	4.6				
	-16m+30m	9.4	sand			
	-30m+60m	12.2				
	-60m+100m	3.4				
	-100m+200m	3		89.0		
		44.7				
	-200m	11.2	silt/clay	120.0		
	Total	100.00				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	54

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic Calculate Head, mg/	Distrib. %
LR-311	+1"	13.8		16.0		
	-1"+1/2"	22.8	gravel	9.3		
	-1/2"+1/4"	16.7				
		53.30				
	-1/4"+8m	10.5				
	-8m+10m	1.1				
	-10m+16m	3.4				
	-16m+30m	6.1	sand			
	-30m+60m	10				
	-60m+100m	4.4				
	-100m+200m	3.9		200.0		
		39.4				
	-200m	7.3	silt/clay	300.0		
	Total	100.0				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	110

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic Calculate Head, mg/	Distrib. %
RR-528	+1"	21.3		15.0		
	-1"+1/2"	19.6	gravel	36.0		
	-1/2"+1/4"	18.7				
		59.60				
	-1/4"+8m	11.3				
	-8m+10m	1.1				
	-10m+16m	3.6				
	-16m+30m	7.8	sand			
	-30m+60m	9.8				
	-60m+100m	2.4				
	-100m+200m	2.8		1500.0		
		38.8				
	-200m	1.6	silt/clay	1800.0		
			slime/water	0.32 mg/l		
	Total	100.00				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	490

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic	
					Calculate Head, mg/	Distrib. %
RR-536	+1"	22.2		23.0		
	-1"+1/2"	22.2	gravel	50.0		
	-1/2"+1/4"	16.3				
		60.70				
	-1/4"+8m	10.9				
	-8m+10m	1.2				
	-10m+16m	3.1				
	-16m+30m	4.7	sand			
	-30m+60m	6.2				
	-60m+100m	2.4				
	-100m+200m	2.1		610.0		
		30.6				
	-200m	8.7	silt/clay	1200.0		
	Total	100.0				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1- gal before crushing	550

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic Calculate Head, mg/	Distrib. %
RR-545	+1"	14		11.0		
	-1"+1/2"	22.7	gravel	26.0		
	-1/2"+1/4"	21				
		57.7				
	-1/4"+8m	11				
	-8m+10m	1.1				
	-10m+16m	2.9				
	-16m+30m	4.7	sand			
	-30m+60m	7.9				
	-60m+100m	3.5				
	-100m+200m	3.3		700.0		
		34.4				
	-200m	7.9	silt/clay	1100.0		
			slime/water	0.41 mg/l		
	Total	100.0				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	150

FORMER DUPONT WORKS SITE
J-3534-14
TREATABILITY STUDY
Revised : 14-Mar-02
WET SCREENING DATA FOR ARSENIC

Sample Identification	Screen Size	Distribution Wt. %	Solids Classification	Assay mg/kg	Arsenic	
					Calculate Head, mg/	Distrib. %
RR-546	+1"	23.5		18.0		
	-1"+1/2"	22.6	gravel	24.0		
	-1/2"+1/4"	14.3				
		60.4				
	-1/4"+8m	10.5				
	-8m+10m	1.5				
	-10m+16m	4.2				
	-16m+30m	8.5	sand			
	-30m+60m	8				
	-60m+100m	1.3				
	-100m+200m	0.9		790.0		
		34.9				
	-200m	4.7	silt/clay	1600.0		
	Total	100.0				

Sample Identification	Total As mg/kg
Pulverized Head A	
Whole sample; 1-gal before crushing	340

APPENDIX E – *RANKING OF ALTERNATIVES*

Chapter 6 defines the performance of the alternatives against the alternatives screening criteria (effectiveness, implementability, and cost). Ranking of these alternatives using these criteria was conducted. All members of the FS project team independently ranked the alternatives and the results were compiled into a single ranking for each alternative. A semi-quantitative comparative method was adopted whereby each participant gave each alternative a score of "-2" for very poor "-1" for poor, "0" for average, "+1" for good or "+2" for very good performance according to a given criterion. The score of each participant was normalized to bring each person's average criterion ranking to "0" prior to compiling the results into a single ranking for each alternative and criterion. The comparative analysis allows the evaluation of all the alternatives against the single screening criterion. This allows the ranking mechanism to be used to assess the best and least favorable alternative for the particular criterion. Table E-1 summarizes the compiled results using weighting factors that place equal emphasis on each effectiveness criterion, implementability, and cost.

Different weighting factors were applied to the three screening criteria to examine the sensitivity of the ranking results as preference is given to different screening criteria. Four different weighting factor scenarios were applied to the alternatives to assess relative performance. These four scenarios emphasize the following criteria preferences.

- **Equal:** Effectiveness, implementability, and cost carry the same weight.
- **Favoring Cost:** Effectiveness and implementability are the same weight while cost carries twice the weight.
- **Favoring Effectiveness:** Implementability and cost have the same weight while effectiveness has five times the weight.
- **Favoring Effectiveness and Cost:** Effectiveness carries a total weight of five, one for each sub-criterion, cost carries a weight of three, and implementability carry a weight of two.

The sensitivity of ranking results to the weighting factor set used is presented in Table E-2.

The weighting of the screening criteria had a small effect on the overall ranking of the alternatives. The alternatives were close in each case and the highest ranked alternatives ranked high following the application of different weightings. The ranking of alternatives did not directly influence the selection of alternatives for further analysis. The ranking was performed as a preliminary step in the screening process and was only used as guidance. Table E-3 illustrates this point.

Table E-1 - Screening of Alternatives

Alternative	EFFECTIVENESS					IMPLEMENTABILITY	COST	SUM
	Protection of Human Health and the Environment	Compliance with ARARs	Reduction of Toxicity Mobility and Volume	Short Term Effectiveness	Long Term Effectiveness	Implementability	Cost	
No Action	-2	-2	-2	-1	-2	2	2	▨ -5
Cover	0	0	0	0	-1	-1	1	-1
Capping	0	0	0	0	-1	-1	1	-1
Cap/Cover	0	1	0	0	0	0	0	1
On-site Deposition with Cap/Cover	1	2	0	0	1	1	1	▨ 6
Off-site Disposal at Landfill	2	2	2	-1	2	-1	-2	▨ 4
Soil Washing with chelants and offsite disposal	1	2	1	0	1	-1	-1	3
Soil Washing with acid and offsite disposal	1	2	1	-1	1	-2	-1	1
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	1	-2	2	-1	1	-1	-1	-1
Wet Screening, Classification and Disposal at Landfill	2	2	1	-1	2	-1	-2	3
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposa	1	2	1	1	1	0	0	▨ 6

Score

-2 Very Poor
-1 Poor
0 Average
1 Good
2 Very Good

Retained for further analysis ▨

Table E-2 - Weighting Factors Used for Ranking of Alternatives

Former DuPont Works Site
DuPont, Washington

	Effectiveness					Implementability	Cost
Emphasis of Weighting Factors	Protection of Human Health and the Environment	Compliance with ARARs	Reduction of Toxicity, Mobility, and Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost
Equal Weighting for Effectiveness, Cost, and Implementability	0.2	0.2	0.2	0.2	0.2	1	1
Favoring Cost	0.1	0.1	0.1	0.1	0.1	0.5	1
Favoring Effectiveness	1	1	1	1	1	1	1
Favoring Effectiveness and Cost	1	1	1	1	1	2	3

Table E-3 - Comparative Analysis of Alternatives Using Selected Weighting Factors

Weighting: 0.2, 0.2, 0.2, 0.2, 0.2, 1, 1 **Equal**	WEIGHTED SCORE
No Action	2.2
Cover	-0.2
Capping	-0.2
Cap/Cover	0.2
On-site Deposition with Cap/Cover	2.8
Off-site Disposal at Landfill	-1.6
Soil Washing with chelants and offsite disposal	-1
Soil Washing with acid and offsite disposal	-2.2
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	-1.8
Wet Screening, Classification and Disposal at Landfill	-1.8
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	1.2

Weighting: 0.1, 0.1, 0.1, 0.1, 0.1, 0.5, 1 **Favoring cost**	WEIGHTED SCORE
No Action	2.1
Cover	0.4
Capping	0.4
Cap/Cover	0.1
On-site Deposition with Cap/Cover	1.9
Off-site Disposal at Landfill	-1.8
Soil Washing with chelants and offsite disposal	-1
Soil Washing with acid and offsite disposal	-1.6
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	-1.4
Wet Screening, Classification and Disposal at Landfill	-1.9
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	0.6

Weighting: 1, 1, 1, 1, 1, 1, 1 **Favoring effectiveness**	WEIGHTED SCORE
No Action	-5
Cover	-1
Capping	-1
Cap/Cover	1
On-site Deposition with Cap/Cover	6
Off-site Disposal at Landfill	4
Soil Washing with chelants and offsite disposal	3
Soil Washing with acid and offsite disposal	1
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	-1
Wet Screening, Classification and Disposal at Landfill	3
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	6

Weighting: 1, 1, 1, 1, 1, 2, 3 **Favoring effectiveness and cost**	WEIGHTED SCORE
No Action	1
Cover	0
Capping	0
Cap/Cover	1
On-site Deposition with Cap/Cover	9
Off-site Disposal at Landfill	-1
Soil Washing with chelants and offsite disposal	0
Soil Washing with acid and offsite disposal	-3
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	-4
Wet Screening, Classification and Disposal at Landfill	-2
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	6

APPENDIX F – *COST ESTIMATE FOR REMEDIAL ALTERNATIVES ANALYZED IN DETAIL*

This appendix describes the procedures used in estimating capital costs. The estimating process generally follows the guidance provided by EPA for CERCLA sites, *Remedial Action Costing Procedures Manual*, although the Site is not being administered under the EPA CERCLA process. This guidance was selected as being appropriate because of the number of constituents identified during the RI.

F.1 Capital Cost

Capital costs are those costs that are incurred during the construction and implementation of the cleanup action. These include: unit price for each process element (e.g., excavation, treatment, disposal); engineering design; contingency allowance; construction oversight; administration; and community relations. Direct and indirect capital costs were developed separately since several of the indirect costs are estimated as a percentage of the direct costs.

F.1.1 Direct Capital Costs

The direct capital costs include estimates of the construction, implementation, and disposal costs. These costs were gathered from vendors who provided budgetary estimates based on specific Site information generated from the RI and the treatability studies. In general, the vendors responded with a range of costs that may be applicable for the remedial action of Site soils. The average low and high vendor unit cost estimates are presented in Table F-1. The variability between the low and high cost was expected since the vendors were not asked to provide a bid for services, which in many cases would require a pilot study or bench-scale treatability studies on Site soils.

Using the unit costs presented in Table F-1, estimated costs were assembled by summing the unit costs for each activity that are combined to comprise each alternative. Table F-2 presents an activity-by-activity cost estimate and a low and high total and overall direct costs for each of the alternatives analyzed in detail in Section 6.0. These estimates of remedial action cost are assumed to be accurate to within -30 percent and +30 percent of the estimate where both estimates could vary by –30 to +30 percent of the listed value. In effect, the estimated "Best Estimate" remedial action cost would be defined as average of the high and low estimate.

Several assumptions, listed below, were necessary to complete the direct capital cost estimates:

- Estimate of soil volumes is based on RI and ISR data, which are assumed to be accurate and complete;

- Cleanup or remediation levels for all constituents are assumed;

- Estimate of soil volumes was conducted according to the procedures and assumptions described in Section 3.0, and are the basis for the direct cleanup action costs; and

- Direct costs are based on the technology unit costs developed from vendor solicitation, engineering estimation, treatability study results, and past experience with similar technologies.

EPA guidance also recommends that the direct cost estimates include the estimated costs for equipment, land and site development needed to implement the cleanup action, buildings and services, and relocation costs. These costs were not included in the estimated direct cost for the following reasons:

- **Equipment**. At this time we anticipate that the remedial action will be done as by a contractor to Weyerhaeuser or DuPont. Subsequently, the cost for the purchase of equipment will likely be small in relation to the total cleanup action cost.

- **Land and Site Development**. Expenses associated with the preparation of the Site prior to implementing the remedial action are likely to be small in relation to the total cleanup action cost.

- **Buildings and Services Cost**. Buildings used by the contractors during interim source removal will again be utilized by the remedial action contractor, and no new facilities are anticipated. Services including electricity, garbage, sewer, and other utilities, which are not included in the unit cost of the remedial alternative, will be small in relation to the total action cost. The unit costs presented in Table F-1 are assumed to include the costs associated with this direct cost.

F.1.2 Indirect Capital Costs

Indirect capital costs are those costs associated with engineering design, contingency, construction oversight, administration, and community relations. These costs were estimated based on previous experience during interim source removal and the remedial investigation of the Site. Tables F-3 presents a breakdown of the estimated indirect costs by alternative.

The following assumptions were incorporated into the estimates for indirect cost for each alternative:

- Implementation will be directly related to the amount of soils handling;
- Engineering design costs are estimated at 5 percent of the direct costs;
- Construction oversight costs are estimated at 10 percent of the direct costs;
- Administrative and reporting costs are estimated at 3 percent of the direct costs;
- Contingency allowances are estimated at 25 percent of the direct costs; and
- Four public meetings may be held during the design, construction, operation, and closure of the selected cleanup action. The costs of this effort are estimated at 1 percent of the direct costs.

The following assumptions for developing indirect costs were also developed and are applicable to each remediation unit and remedial alternative:

- Construction oversight is provided by a third party contractor;
- Community relations will be provided by company representatives and a third party contractor; and
- Ecology oversight, administration, and public meeting costs are not included in the estimated costs.

EPA guidance also recommends that the license and permitting costs be included. These costs were not included in the estimated indirect capital cost since obtaining permits for remediation activities under a state cleanup action is not required. The cleanup must otherwise conform to the substantive requirements of the regulation.

F.2 Total Estimated Cost

The preceding cost estimates are the basis for the estimated total cost for all remediation units of the Site. The sum of the direct costs and indirect costs are presented for each remediation alternative in Table F-4. The range of low and high total costs represent the range of direct costs and the corresponding contingency and engineering design ranges which are based on a percentage of the direct costs. Costs for the remediation of Miscellaneous Small RUs are listed on Table F-5.

Based on the preferred alternatives presented in Chapter 8 for remediation of in-place and stockpiled Site soils, and the completed interim source removal described in Chapter 1, the best estimate of total cost for Site remediation was prepared and is presented in Table F-6. Including accrued costs for studies, sampling, legal fees, and communications etc., the total cost of Site remediation is approximately $64,000,000.

Table F-1 – High and Low Range Estimated Costs

TABLE F-1 - HIGH AND LOW RANGE ESTIMATED UNIT COSTS
FORMER DUPONT WORKS SITE

Remedial Action Process Or Technology	High Cost Estimate	Low Cost Estimate	Unit Type
COVER (>3 FT. OF SOIL)	$2.50	$1.50	($/SF)
CAPPING	$4.50	$2.75	($/SF)
CAP/COVER	$1.25	$0.75	($/SF)
EXCAVATION	$5.00	$2.25	($/CY)
DRY SCREENING	$15.00	$7.50	($/TON)
WET SCREENING	$40.00	$22.00	($/TON)
SOIL CLASSIFICATION	$125.00	$50.00	($/TON)
ACID EXTRACTION	$150.00	$110.00	($/TON)
CHELANT EXTRACTION	$150.00	$100.00	($/TON)
IN-PLACE STABILIZATION	$250.00	$150.00	($/CY)
STABILIZATION USING RCC	$80.00	$40.00	($/CY)
EXCAVATED STABLIZATION AND PLACEMENT	$100.00	$40.00	($/CY)
EXCAVATED STABILIZATION ONLY	$75.00	$20.00	($/CY)
BACKFILL EXCAVATION	$5.00	$5.00	($/CY)
BACKFILL CLEAN FRACTION	$5.00	$5.00	($/CY)
GOLF COURSE COSTS	$0.70	$0.51	($/SF)
TRANSPORT OFF-SITE	$6.00	$6.00	($/TON)
OFF-SITE DISPOSAL AS PROBLEM	$80.00	$55.50	($/TON)
OFF-SITE DISPOSAL AS DANGEROUS	$136.00	$99.00	($/TON)
RECYCLING AT ASPHALT PLANT OR CEMENT KILN	$42.00	$35.00	($/TON)
PRECIPITATION OF METAL SOLUTION	$5.00	$5.00	($/GALLON)
RECYCLING AT SMELTER	$600.00	$400.00	($/TON)

TABLE F-2 - ESTIMATED LOW AND HIGH RANGE DIRECT COSTS
FORMER DUPONT WORKS SITE
DUPONT, WASHINGTON

LOW RANGE UNIT COSTS	APPROX.	COVER	CAPPING	CAP/COVER	EXCAVATE	WET	SOIL	ACID	CHELANT	STABILIZE	Added Cost	TRANSPORT	OFF-SITE	PRECIP.
ALTERNATIVE	TOTAL					SCREENING	CLASS.	EXTRACT.	EXTRACT.	USING RCC	SOIL	OFF-SITE	DISP/HAZ	OF METAL
	COST										COVER		W/ STAB	SOLUTION
		$1.50	$2.75	$0.75	$2.25	$22.00	$50.00	$110.00	$100.00	$40.00	$0.51	$6.00	$108.90	$5.00
	($)	($/SF)	($/SF)	($/SF)	($/CY)	($/TON)	($/TON)	($/TON)	($/TON)	($/CY)	($/SF)	($/TON)	($/TON)	($/GALLON)
No Action	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cover	$30,000,000	$30,004,128	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capping	$55,000,000	$0	$55,007,568		$0	$0	$0	$0	$0		$0	$0	$0	$0
Cap/Cover	$15,000,000	$0		$15,002,064	$0	$0	$0	$0	$0		$0	$0	$0	$0
On-site Deposition with Cap/Cover	$9,200,000	$0		$2,940,300	$1,723,925	$0	$0	$0	$0		$4,000,000	$0	$584,066	$0
Off-site Disposal at Landfill	$125,900,000	$0	$0	$0	$2,643,577	$0	$0	$0	$0	$0	$0	$6,435,988	$116,813,175	$0
Soil Washing with chelants and offsite disposal	$52,300,000	$0	$0	$0	$1,723,925	$23,598,621	$0	$0	$10,726,646		$0	$643,599	$11,681,317	$3,930,945
Soil Washing with acid and offsite disposal	$53,400,000	$0			$1,723,925	$23,598,621	$0	$11,799,311	$0		$0	$643,599	$11,681,317	$3,930,945
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	$32,400,000	$0	$0	$0	$1,723,925	$23,598,621	$0	$0	$0	$3,064,756	$4,000,000			$0
Wet Screening, Classification and Disposal at Landfill	$43,000,000	$0	$0	$0	$1,723,925	$23,598,621	$5,363,323	$0	$0	$0	$0	$643,599	$11,681,317	$0
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$41,600,000	$0	$0	$0	$1,723,925	$23,598,621	$0	$0	$0		$4,000,000	$643,599	$11,681,317	$0

HIGH RANGE UNIT COSTS	APPROX.	COVER	CAPPING	CAP/COVER	EXCAVATE	WET	SOIL	ACID	CHELANT	STABILIZE	Added Cost	TRANSPORT	OFF-SITE	PRECIP.
ALTERNATIVE	TOTAL					SCREENING	CLASS.	EXTRACT.	EXTRACT.	USING RCC	SOIL	OFF-SITE	DISP/HAZ	OF METAL
	COST										COVER		W/ STAB	SOLUTION
		$2.50	$4.50	$1.25	$5.00	$40.00	$125.00	$150.00	$150.00	$80.00	$0.70	$6.00	$149.60	$5.00
	($)	($/SF)	($/SF)	($/SF)	($/CY)	($/TON)	($/TON)	($/TON)	($/TON)	($/CY)	($/SF)	($/TON)	($/TON)	($/GALLON)
No Action	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cover	$50,000,000	$50,006,880	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capping	$90,000,000	$0	$90,012,384		$0	$0	$0	$0	$0		$0	$0	$0	$0
Cap/Cover	$28,800,000	$0		$25,003,440	$3,830,945	$0	$0	$0	$0		$0	$0	$0	$0
On-site Deposition with Cap/Cover	$15,000,000	$0		$4,900,500	$3,830,945	$0	$0	$0	$0		$5,500,000	$0	$802,353	$0
Off-site Disposal at Landfill	$172,800,000	$0	$0	$0	$5,874,615	$0	$0	$0	$0	$0	$0	$6,435,988	$160,470,624	$0
Soil Washing with chelants and offsite disposal	$83,400,000	$0			$3,830,945	$42,906,584	$0	$0	$16,089,969		$0	$643,599	$16,047,062	$3,930,945
Soil Washing with acid and offsite disposal	$83,400,000	$0			$3,830,945	$42,906,584	$0	$16,089,969	$0		$0	$643,599	$16,047,062	$3,930,945
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	$58,400,000	$0	$0	$0	$3,830,945	$42,906,584	$0	$0	$0	$6,129,512	$5,500,000			$0
Wet Screening, Classification and Disposal at Landfill	$76,800,000	$0	$0	$0	$3,830,945	$42,906,584	$13,408,308	$0	$0	$0	$0	$643,599	$16,047,062	$0
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$68,900,000	$0	$0	$0	$3,830,945	$42,906,584	$0	$0	$0		$5,500,000	$643,599	$16,047,062	$0

TABLE F-3 - ESTIMATED LOW AND HIGH RANGE INDIRECT COSTS
FORMER DUPONT WORKS SITE
DUPONT, WASHINGTON

LOW RANGE COSTS BY ALTERNATIVE	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.
			PUBLIC	CONSTRUCTION	ADMIN. &	TOTAL	TOTAL	TOTAL
	DIRECT COSTS	DESIGN COSTS	RELATIONS	OVERSIGHT	REPORTING	CONTINGENCY	INDIRECT COSTS	COSTS
	($)	5%	1%	10%	3%	25%		
No Action	$0	$0	$0	$0	$0	$0	$0	$0
Cover	$14,600,000	$730,000	$146,000	$1,460,000	$438,000	$3,650,000	$6,424,000	$21,024,000
Capping	$55,000,000	$2,750,000	$550,000	$5,500,000	$1,650,000	$13,750,000	$24,200,000	$79,200,000
Cap/Cover	$17,500,000	$875,000	$175,000	$1,750,000	$525,000	$4,375,000	$7,700,000	$25,200,000
On-site Deposition with Cap/Cover	$8,400,000	$420,000	$84,000	$840,000	$252,000	$2,100,000	$3,696,000	$12,096,000
Off-site Disposal at Landfill	$126,900,000	$6,345,000	$1,269,000	$12,690,000	$3,807,000	$31,725,000	$55,836,000	$182,736,000
Soil Washing with chelants and offsite disposal	$53,000,000	$2,650,000	$530,000	$5,300,000	$1,590,000	$13,250,000	$23,320,000	$76,320,000
Soil Washing with acid and offsite disposal	$54,000,000	$2,700,000	$540,000	$5,400,000	$1,620,000	$13,500,000	$23,760,000	$77,760,000
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	$33,000,000	$1,650,000	$330,000	$3,300,000	$990,000	$8,250,000	$14,520,000	$47,520,000
Wet Screening, Classification and Disposal at Landfill	$43,700,000	$2,185,000	$437,000	$4,370,000	$1,311,000	$10,925,000	$19,228,000	$62,928,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$42,300,000	$2,115,000	$423,000	$4,230,000	$1,269,000	$10,575,000	$18,612,000	$60,912,000

HIGH RANGE COSTS BY ALTERNATIVE	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.	APPROX.
	TOTAL		PUBLIC	CONSTRUCTION	ADMIN.	TOTAL	TOTAL	TOTAL
	DIRECT COSTS	DESIGN COSTS	RELATIONS	OVERSIGHT	COSTS	CONTINGENCY	INDIRECT COSTS	COSTS
	($)	5%	1%	10%	3%	25%		
No Action	$0	$0	$0	$0	$0	$0	$0	$0
Cover	$18,600,000	$930,000	$186,000	$1,860,000	$558,000	$4,650,000	$8,184,000	$26,784,000
Capping	$90,000,000	$4,500,000	$900,000	$9,000,000	$2,700,000	$22,500,000	$39,600,000	$129,600,000
Cap/Cover	$14,100,000	$705,000	$141,000	$1,410,000	$423,000	$3,525,000	$6,204,000	$20,304,000
On-site Deposition with Cap/Cover	$12,900,000	$645,000	$129,000	$1,290,000	$387,000	$3,225,000	$5,676,000	$18,576,000
Off-site Disposal at Landfill	$174,200,000	$8,710,000	$1,742,000	$17,420,000	$5,226,000	$43,550,000	$76,648,000	$250,848,000
Soil Washing with chelants and offsite disposal	$84,400,000	$4,220,000	$844,000	$8,440,000	$2,532,000	$21,100,000	$37,136,000	$121,536,000
Soil Washing with acid and offsite disposal	$84,400,000	$4,220,000	$844,000	$8,440,000	$2,532,000	$21,100,000	$37,136,000	$121,536,000
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	$59,300,000	$2,965,000	$593,000	$5,930,000	$1,779,000	$14,825,000	$26,092,000	$85,392,000
Wet Screening, Classification and Disposal at Landfill	$77,800,000	$3,890,000	$778,000	$7,780,000	$2,334,000	$19,450,000	$34,232,000	$112,032,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$69,900,000	$3,495,000	$699,000	$6,990,000	$2,097,000	$17,475,000	$30,756,000	$100,656,000

TABLE F-4 - ESTIMATED LOW AND HIGH RANGE TOTAL COSTS
FORMER DUPONT WORKS SITE
DUPONT, WASHINGTON

	LOW RANGE BY ALTERNATIVE	HIGH RANGE BY ALTERNATIVE	"BEST ESTIMATE" BY ALTERNATIVE
	TOTAL COST	TOTAL COST	TOTAL COST
	($)	($)	($)
No Action	$0	$0	$0
Cover	$43,200,000	$72,000,000	$57,600,000
Capping	$79,200,000	$129,600,000	$104,400,000
Cap/Cover	$21,600,000	$41,472,000	$31,536,000
On-site Deposition with Cap/Cover	$13,248,000	$21,600,000	$17,424,000
Off-site Disposal at Landfill	$181,296,000	$248,832,000	$215,064,000
Soil Washing with chelants and offsite disposal	$75,312,000	$120,096,000	$97,704,000
Soil Washing with acid and offsite disposal	$76,896,000	$120,096,000	$98,496,000
Wet Screening with Stabilization, On Site Deposition, Cap/Cover	$46,656,000	$84,096,000	$65,376,000
Wet Screening, Classification and Disposal at Landfill	$61,920,000	$110,592,000	$86,256,000
Wet Screening, On-site Deposition, Cap/Cover and Off-Site Disposal	$59,904,000	$99,216,000	$79,560,000

Table F-5 – Estimated Low and High Remediation Costs for Miscellaneous Small Remediation Units

Type	Low Cost	High Cost	"Best" Cost
Similar Mixtures	$ 63,370	$ 63,926	$ 68,833
Similar Deposition	$ 63,370	$ 63,926	$ 68,833
Single Contaminant	$ 63,370	$ 63,926	$ 68,833
"Hot Spots"	$ 636,965	$ 642,550	$ 691,876
Debris	$ 759,684	$ 766,344	$ 825,174
Sequalitchew Creek NGRR	$ 633,704	$ 639,259	$ 688,333
Total	$ 2,220,635	$ 2,240,103	$ 2,411,884

Table F-6 – Summary of Site Remediation Costs

Item	Best Estimate of Cost in $
Proposed Remediation in this FS(1)	17,424,000
Miscellaneous Small Units	$ 2,411,884
Source Removal Costs Accrued(2)	$46,000,000
Costs for Studies, Sampling, Legal, Communications, etc. Accrued(2)	$7,300,000
Total Cost of Site Remediation	$73,135,884

(1)Based on the preferred alternatives for remediation presented in Section 8.0 and costs in Appendix F.
(2)Actual cost through December 31, 2001.

APPENDIX G – *ESTIMATION OF MINIMUM SOIL VOLUME REQUIRED FOR COST-EFFECTIVE ON-SITE TREATMENT*

To estimate the minimum soil volume required for treatment on Site, the remediation cost per unit volume (CY) was plotted as a function of soil volume for high, low, and average cleanup action cost options as presented on Figure G-1.

G.1 Assumptions

- The high cost option is based on a high treatment cost of \$200/CY and disposal as hazardous waste at \$180/ton. The low cost option is based on a low treatment cost \$90/CY and disposal as problem waste at \$61.50/ton.

- Mobilization and demobilization costs were assumed to be \$50,000 for the low cost option and \$100,000 for the high cost option. These costs are based on ranges provided by vendors for stabilization and soil washing.

- All options include engineering design (12%) and contingency (25%) (10% engineering design and contingency are included in the off-Site disposal costs to account for costs of stockpile management and uncertainty in volume of impacted soil to be disposed of). Long-term maintenance and monitoring cost are not included.

- The average cost treatment is simply the arithmetic average of the high and low cost treatments.

G.2 Conclusion

- If a soil can be characterized as problem waste, direct disposal at an industrial landfill is the best option.

- If the soil is hazardous, it becomes cost-effective to treat the soil with an average cost treatment when the volume is greater than approximately 5,000 CY.

- If the equipment has already been mobilized on Site for other impacted soils, and the mobilization cost does not need to be included in the cost per CY, then average cost treatment is always more cost-effective than disposal as hazardous waste.

Sensitivity of Remediation Costs to Volume of Soil Treated

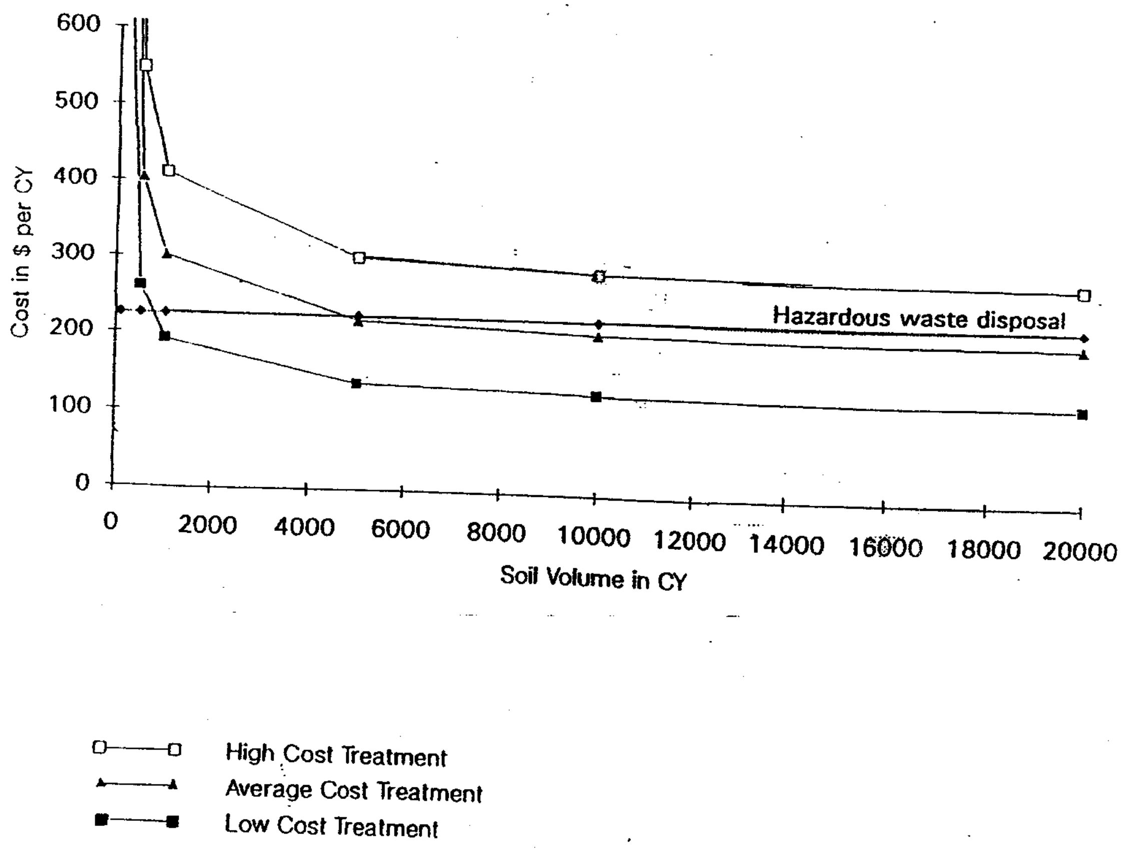


Figure G-1

APPENDIX H – *Development of Soil Remediation Levels for the Golf Course Groundskeeper*

H.1 Introduction

This appendix presents a summary of the approach used to calculate soil remediation levels for areas included in the golf course land use areas, assuming that an engineered cap is placed over the contaminated soil. The approach used to calculate these levels is the same as that used to calculate Site-specific cleanup standards presented in Chapter 3 of the Human Health and Ecological Risk Assessment for the Former DuPont Works Site (PIONEER, 2002).

The equations used to calculate soil remediation levels for the golf course evaluation units were obtained from the Model Toxics Control Act (MTCA) – Washington Administrative Code (WAC) 173-340-745. Soil remediation levels were calculated using these equations considering the potential reasonable maximum exposure for golf course groundskeepers who may occasionally contact contaminated soil beneath the cap during intrusive maintenance activities, such as repairing sprinkler lines.

The Environmental Protection Agency (EPA) has chosen to evaluate the potential health effects of lead using a physiologically based model. Therefore, lead has not been assigned the toxicity values required to calculate Site-specific remediation levels using the equations presented in WAC 173-340-745. The model developed by EPA for establishing lead remediation levels in non-residential areas is the Adult Lead Model (EPA, 1996).

H.2 Development of Soil Remediation Levels for Golf Course Groundskeepers

The equations and input values used to develop soil remediation levels for golf course groundskeepers potentially exposed to constituents of concern (COCs) identified in the RA (other than lead) based on incidental soil ingestion are presented below.

<u>Equation for Noncarcinogens:</u>

WAC 173-340-745-1 – Soil Remediation Level (mg/kg) = $\dfrac{RfD\ x\ ABW\ x\ UCF\ x\ HQG\ x\ AT_n}{SIR\ x\ AB1\ x\ EF\ x\ ED}$

<u>Equation for Carcinogens:</u>

WAC 173-340-745-2 – Soil Remediation Level (mg/kg) = $\dfrac{CRG\ x\ ABW\ x\ AT_c\ x\ UCF}{CPF\ x\ SIR\ x\ AB1\ x\ EF\ x\ ED}$

Where;

Parameter	**Description**
EF	= Exposure Frequency (days/year)
ED	= Exposure Duration (years)
SIR	= Soil Ingestion Rate (mg/day)
AB1	= Gastrointestinal Absorption Fraction (AB1) (unitless)
ABW	= Body Weight (kg)
ATn & ATc	= Averaging Time (days)
RfD	= Noncarcinogenic reference dose (mg/kg-day).

CPF = Cancer potency factor $(mg/kg\text{-}day)^{-1}$.
UCF = Unit conversion factor (mg/kg).
HQG = Hazard quotient goal (i.e., 1)
CRG = Cancer risk goal (i.e., 1E-05).

H.2.1 Equation Input Values

The input values for these equations consist of exposure factors, which describe the exposure patterns of the receptors (i.e., exposure frequency, exposure duration, ingestion rate, gastrointestinal absorption fraction, body weight, and averaging time); toxicity values (i.e., reference doses and carcinogenic potency factors), and benchmark values (i.e., target hazard quotients and target cancer risks). These input values are discussed below.

H.2.2 Exposure Factors

Exposure factors are used to estimate the likely intake level of a constituent. The exposure factors used to calculate remediation levels were approved by Ecology (Ecology, 1998) and are described below:

- *Exposure Frequency (EF)* – The number of days per year that a person is exposed. For the golf course groundskeeper exposure is assumed to occur 12 days/year (i.e., once per month).

- *Exposure Duration (ED)* – The number of years over which exposure is assumed to occur. For the golf course groundskeeper the exposure duration was assumed to be 20 years, which is the MTCA default value for worker exposure duration.

- *Soil Ingestion Rate (SIR)* – The amount of soil ingested per day of exposure. For the golf course groundskeeper the soil ingestion rate was assumed to be 100 mg/day.

- *Gastrointestinal Absorption Fraction (AB1)* – This is the percentage of a constituent that is available for absorption by the gastrointestinal tract once ingested. This is typically a constituent-specific value, but based on direction given by Ecology this value was conservatively chosen to be 100% for all constituents.

- *Body Weight (ABW)* – The average body weight, in kilograms, of the receptor being evaluated. For the golf course groundskeeper this value was assumed to be the MTCA default of 70 kg, the average weight of an adult (average of both females and males).

- *Averaging Time (Atn and Atc)* – The number of days over which exposure is averaged. Exposure levels for carcinogens are averaged over the lifetime of the exposed individual (i.e., 75 years) while exposure levels for noncarcinogens are averaged over the duration of exposure. Therefore, for carcinogens, the averaging time is calculated as the exposure frequency (days/year) X 75 year life expectancy. The averaging time for noncarcinogens is calculated as the exposure frequency (days/year) X exposure duration (years).

The exposure factors used to calculate soil remediation levels are presented in Table H-1.

H.2.3 Toxicity Values

The toxicity values used to develop soil remediation levels include noncarcinogenic reference doses (RfDs) and carcinogenic potency factors (CPFs) are presented in Table H-1. The following sources of toxicity information were consulted to identify the toxicity values used to develop the soil remediation levels:

- The Integrated Risk Information System (IRIS) (EPA, 2001).

- The Health Effects Assessment Summary Tables–Annual Update (HEAST) (EPA, 1997).

- Ecology's Cleanup Levels and Risk Calculation (CLARC) Table Updates (Ecology, 2001a).
- EPA Region IX Preliminary Remediation Goal (PRG) Tables (EPA, 2000).

Since multiple toxicity values were available for some chemicals, the sources of toxicity information were prioritized as follows to select the toxicity values used in the development of soil remediation levels:

1. IRIS values.
2. HEAST values.
3. CLARC table values.
4. PRG table values.

H.2.4 Benchmark Values

The last category of equation input values are the risk benchmark values, used to define the "acceptable" risk level for a person exposed to Site contamination. The benchmark values used are the hazard quotient goal (HQG), which is the benchmark for noncarcinogenic effects, and the cancer risk goal (CRG), which is the benchmark for carcinogenic risk. A description of these values is presented in Chapter 3 of the RA. In calculating soil remediation levels for the golf course groundskeeper, the benchmark values used were a HQG of 1.0 and a CRG of 1 in 100,000 (i.e., 1E-05) for individual constituents. These are the benchmark values for industrial exposures stipulated in MTCA (WAC 173-340-745).

H.3 Development of Soil Remediation Levels for Lead

EPA's Adult Lead Model used to calculate soil remediation levels for lead is described in Chapter 3 of the RA (PIONEER, 2002) and (EPA, 1996). The model input values used for the golf course groundskeeper are presented in Table H-2; the lead remediation level obtained from this calculation is presented in Table H-3 along with the other Site-specific remediation levels calculated for golf course development.

Table H-1 – Soil Golf Course Groundskeeper Soil Remediation Levels

Constituent	RfD$^{(1)}$	CPF$^{(1)}$	ABW$^{(2)}$	Atn$^{(2)}$	Atc$^{(2)}$	UCF$^{(2)}$	SIR$^{(2)}$	AB1$^{(2)}$	EF$^{(2)}$	ED$^{(2)}$	HQG$^{(3)}$	CRG$^{(3)}$	Soil Remediation Level (Noncarcingen) (mg/kg)	Soil Remediation Level (Carcinogen) (mg/kg)
Monomethylamine Nitrate	0.0081		70	7,300		1.0E+06	100	100%	12	20	1		172,463	
Nitroglycerine		0.014	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		57,031
2,4,6-Trinitrotoluene	0.0005	0.03	70	7,300	27,375	1.0E+06	100	100%	12	20	1	1.0E-05	10,646	26,615
Aluminum	1		70	7,300		1.0E+06	100	100%	12	20	1		21,291,667	
Arsenic (inorganic)	0.0003	1.5	70	7,300	27,375	1.0E+06	100	100%	12	20	1	1.0E-05	6,388	532
Copper	0.037		70	7,300		1.0E+06	100	100%	12	20	1		787,792	
Mercury	0.0003		70	7,300		1.0E+06	100	100%	12	20	1		6,388	
Benzo(a)anthracene		0.73	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		1,094
Benzo(a)pyrene		7.3	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		109
Benzo(b)fluoranthene		0.73	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		1,094
Benzo(k)fluoranthene		0.073	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		10,938
Chrysene		0.0073	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		109,375
Dibenz(a,h)anthracene		7.3	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		109
Indeno(1,2,3-cd)pyrene		0.73	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		1,094
Aldrin	0.00003	17	70	7,300	27,375	1.0E+06	100	100%	12	20	1	1.0E-05	639	47

Equation Input Values:

Input	Definition	Units
RfD	Noncancer Reference Dose	mg/kg-day
CPF	Cancer Potency Factor	(mg/kg-day)$^{-1}$
ABW	Average Body Weight	kg
At$_n$	Averaging Time for Noncarcinogenic Effects	days
At$_c$	Averaging Time for Carcinogenic Effects	days
UCF	Unit Conversion Factor	mg/kg
SIR	Soil Ingestion Rate	mg/day
AB1	Gastrointestinal Absorption Rate	unitless
EF	Exposure Frequency	days/year
ED	Exposure Duration	years
HQG	Hazard Quotient Goal for Noncarcinogenic Health Effects	unitless
CRG	Cancer Risk Goal for Carcinogenic Health Effects	unitless

Equations:

Noncarcinogenic Soil Remediation Level (mg/kg):
WAC 173-340-745-1

$$\boxed{\frac{RfD \times ABW \times UCF \times HQ \times AT_n}{SIR \times AB1 \times EF \times ED}}$$

Carcinogenic Soil Remediation Level (mg/kg):
WAC 173-340-745-2

$$\boxed{\frac{Risk \times ABW \times UCF \times AT_c}{CPF \times ASIR \times B1 \times EF \times ED}}$$

Notes:
$^{(1)}$RfDs and CPFs were obtained from (IRIS, 2001), (HEAST, 1997), (Ecology, 2001a), or (EPA, 2000).
$^{(2)}$All exposure parameters were obtained from WAC 173-340-745 except the soil ingestion rate (SIR) and exposure frequency (EF). These are Site-Specific values.
$^{(3)}$Risk goals were obtained from WAC 173-340-745.

Table H-2 – Input Parameters and Results of the Adult Lead Model

Input Parameter	Units	Golf Course Groundskeeper Parameter Value(1)
$PbB_{fetal,0.95}$	ug/dl	10
$R_{fetal/maternal}$	(unitless)	0.9
BKSF	ug/dl per ug/day	0.4
$GSD_{i,adult}$	(unitless)	1.81
$PbB_{adult,0}$	ug/dl	1.36
IR_S	g/day	0.100
AF_S	(unitless)	0.12
EF	days/year	52
AT	days/year	365
Results		
RBRG(3)	ug/g	4,134(2)

Notes:

(1)These Site-specific values were specified for use by Ecology (Ecology, 1997).

(2)This value was rounded down to 4,100 ug/g (note: 4,100 ug/g = 4,100 mg/kg).

(3)Risk-based remediation goal.

Table H-3 – Golf Course Groundskeeper Soil Remediation Levels(1)

Constituent	Golf Course Groundskeeper Soil Remediation Level (mg/kg)
Explosives	
2,4,6-Trinitrotoluene(2)	10,600
Inorganics	
Arsenic	530
Lead(3)	4,100
Mercury(4)	6,390
PAHs	
Benzo(a)Pyrene	109
Pesticides	
Aldrin	47

Notes:

(1)Where remediation levels were calculated for both carcinogenic and noncarcinogenic effects, the value presented in the table is the lower of the two values. The soil remediation levels presented in Table 3 have been rounded down from the values shown in Table 1.

(2)Based on agreement with Ecology, the Site-specific cleanup level for 2,4,6-Trinitrotoluene is 1.75 mg/kg (Ecology, 2001b)

(3)Value was derived using EPA's Adult Lead Model (EPA, 1996).

(4)Based on agreement with Ecology, the Site-specific cleanup level for mercury is 24 mg/kg (Ecology, 1993).

H.4 References for Appendix H

Ecology (Washington State Department of Ecology). 1993. Mercury Cleanup Levels Summary and Mercury/Lead Leaching Study. Letter from Mike Blum to Vern Moore, Linda Rudisel, and Jack Frazier. August 12, 1993.

Ecology (Washington State Department of Ecology). 1997. Residential Soil-Lead Cleanup Standard for Former DuPont Works Site. Memo from Mike Blum to Vern Moore and Jack Frazier. October 1, 1997.

Ecology (Washington State Department of Ecology). 1998. EPA's Adult Lead Model and Its Use in Washington State to Evaluate Risk. Memo from Mike Blum to the MTCA Science Advisory Board Members. October 27, 1998.

Ecology (Washington State Department of Ecology). 2001. Cleanup Levels and Risk Calculation (CLARC) Table Updates, Version 3.1, November, 2001.

Ecology (Washington State Department of Ecology). 2001b. Hot spot Interim Action Report. Letter from Mike Blum to Jim Odendahl and Ron Buchanan. January 11, 2001.

EPA (United States Environmental Protection Agency) 1996. Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Exposures to Lead in Soil. Technical Review Workgroup for Lead. Adult Risk Assessment Committee.

EPA (United States Environmental Protection Agency) 1997. The Health Effects Assessment Summary Tables- Annual Update (HEAST): FY 1997 Update. EPA/540-R-97-036. PB97-921199. July. OSWER, Washington, D.C.

EPA (United States Environmental Protection Agency) 2000. EPA Region IX Preliminary Remediation Goal (PRG) Tables. 2000 Update. http://www.epa.gov/region09/waste/sfund/prg/.

EPA (United States Environmental Protection Agency) 2001. The Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Cincinnati, Ohio. 4rd Quarter Update.

PIONEER (PIONEER Technologies Corporation) 2002. Human Health and Ecological Risk Assessment for the Former DuPont Works Site, Dupont, Washington.

APPENDIX I – *Impractability of Groundwater Remediation at the Former DuPont Works Site, DuPont, WA*

I.1 Introduction

The cost for pumping and treating groundwater at the Former DuPont Works Site (Site) to meet the DNT drinking water screening level would be substantial and disproportionate to the degree of risk reduction which could be achieved. Therefore, in accordance with MTCA (WAC 173-340-360, it is impractical to consider active groundwater remediation at the Site for an end use (drinking water) that is not planned. This conclusion is based on the following:

- Site groundwater poses no risk to human health or the environment.
- Because off-Site drinking water supplies will supply more than double the full projected population of DuPont through the year 2020, Site groundwater is not currently and will not in the future be used as a drinking water source (due to a deed restriction).
- Future Site development plans will include deed restrictions as necessary to prevent drilling of drinking water supply wells;
- Even assuming a hypothetical drinking water exposure that does not and will not exist at the Site, the highest DNT concentrations currently in Site aquifers (less than 0.5 µg/L) represent a worst-case risk of less than 4×10^{-6}, which meets a risk threshold of $1 \times l0^{-5}$;
- Current DNT concentrations pose no risk to golfers, other visitors, or golf course maintenance workers who would be most likely to encounter Site groundwater on a regular basis when it is used for golf course irrigation; and
- Site groundwater poses no risk to any Site ecological environment (including Sequalitchew Creek and Old Fort Lake) or off-Site ecological environment (e.g. Puget Sound).
- Natural groundwater recovery will occur following the completed interim DNT source removal. Removal of more than 40,000 cubic yards of DNT-impacted Site soils has been completed, thus the source of DNT to Site groundwater has been removed;
- Already low DNT concentrations in Site groundwater will decline further because Site aquifers are highly permeable and DNT is mobile. This allows for natural flushing of DNT from the groundwater system and further reductions over time in the already low risk under a hypothetical drinking water scenario; and
- The current Site groundwater monitoring program will continue to document the DNT concentrations over time.

Acknowledging groundwater pump and treat systems poor historical performance in achieving drinking water standards, the existing DNT concentrations in Site groundwater would represent a reasonable remediation endpoint at sites where active remediation is under consideration or underway.

The cost to implement active groundwater remediation would be excessive, with preliminary estimates ranging between 33 and 58 million dollars. Consistent with the intent of MTCA and CERCLA, resources should be directed toward making substantive reductions in overall Site risk, which will be best accomplished at this Site by addressing other contaminants remaining in soils.

I.2 Site Groundwater Poses No Risk to Human Health or the Environment

DNT is the only constituent present in Site groundwater at concentrations above drinking water screening levels. The concentrations of DNT in Site aquifers are very low (maximum 95% UCL is less than 0.5 µg/L) and do not represent a risk as explained below.

I.2.1 Site Groundwater Poses No Risk to Human Health

Based on data collected, the highest average DNT concentration in an aquifer beneath the Site is 0.47 µg/L (95% UCL for MW-22). The MTCA drinking water screening level of 0.13 µg/L is based on a 1×10^{-6} risk level. The worst-case risk based on a hypothetical Site drinking water exposure scenario (drinking current DNT concentration in MW-22 for 30 years) is less than 4×10^{-6} which is below the MTCA risk threshold of 1×10^{-5}.

Site groundwater is not being used for drinking water under current Site conditions, and it will not be used in the foreseeable future because adequate off-Site drinking water supply exists to meet future demand. For a projected full build-out population of 10,000 people at the year 2020 (McCamett, June 1995) and an average water consumption of 150 gallons per capita day (Clark et a1, 1977; Metcalf and Eddy, 1979; Linsley and Franzini, 1979), the City of DuPont will have an estimated maximum water demand of approximately 1.5 million gallons per day (MGD). The City of DuPont's existing water system will supply this demand while maintaining excess reserve capacity. The two existing Bell Hill wells have permitted water rights of 2.0 MGD; additions to the system may include an additional well(s) at Hoffman Hill which could potentially double the supply capacity. The Bell Hill wells are located hydraulically up-gradient of the Site and are incapable of drawing water from beneath the Site. As part of the Bell Hill water rights permitting process Ecology reviewed and concurred with technical evaluations (Hart Crowser, 1991) supporting the long-term safety of the Bell Hill water supply even under continuous maximum production. Similarly, Hoffman Hill is located cross-gradient of the Site and wells drilled there would be developed to prevent drawing any groundwater from beneath the Site. Off-Site water supply from the Bell Hill and Hoffman Hill well alone will support more than double the projected population of the City of DuPont, without additional water supply development.

There is no need for drinking water wells to be drilled within the Site under any foreseeable development scenario. As a final measure of protection, Site development plans will include institutional controls, as necessary, in the form of deed restrictions to prevent drilling of wells within the Site for the purpose of water supply.

In addition, Site groundwater poses little to no risk to golfers, visitors, or golf course maintenance workers from dermal contact with irrigation water or from drinking of irrigation water. Attachment A provides a screening evaluation of potential risk to a golf course worker, the person most likely to come in contact with irrigation water.

I.2.2 Site Groundwater Poses No Risk to the Environment

DNT concentrations discharging in seeps to Puget Sound are an order of magnitude below the surface water screening level (an ARAR) of 9.1 µg/L, which is protective of marine aquatic life. DNT was not detected in Sequalitchew Creek or springs discharging to it, or in Old Fort Lake, indicating no potential risk to freshwater aquatic life.

DNT was not detected in samples of marine sediments collected at locations where Site groundwater discharges to Puget Sound or in samples of freshwater sediments from Sequalitchew Creek or Old Fort Lake.

DNT is not detectable in surface water or sediments within or adjacent to the Site, and concentrations in Site groundwater discharging to Puget Sound are below the surface water quality standards.

I.3 Groundwater Recovery Will Occur Naturally

The extensive interim DNT source removal has been successful in removing the vast majority of DNT-impacted soils from the Site. Groundwater flow rates at the Site are very high leading to rapid flushing of the aquifers. As a result, natural recovery of Site groundwater should occur relatively rapidly.

I.4 The DNT Source Has Been Removed

Been 1992 and 1995, more than 40,000 cubic yards of Site soils with DNT concentrations above 3 mg/kg were removed in the five areas where DNT was detected above 1 mg/kg (RI Areas 5, 10, 18, 25, and 31). Data from hundreds of designation samples collected from excavated soils and hundreds of verification samples collected from the excavations suggest that the vast majority of DNT mass (nearly 5,300 kg. or more than 5 tons) has been removed from these two areas. These data, and verification data from the other smaller areas, indicate that the DNT source has been effectively removed from the Site. The most important step in facilitating natural groundwater restoration is removal of the source to prevent further DNT leaching to groundwater. This has been accomplished at the Site.

I.5 Rapid Natural Groundwater Flushing in Site Aquifers

Aquifers beneath the Site are highly permeable (including the exceptionally permeable Steilacoom Gravels), resulting in estimated groundwater flow rates likely on the order of 5,000 to 8,000 feet per year (median values for the Water Table and Unconfined Sea Level Aquifers from ranges presented in Hart Crowser, 1994). The large quantities of groundwater flushing naturally through the aquifers each year will be effective in further reducing the already low residual DNT concentrations in Site aquifers. There is sufficient water moving through the groundwater system under ambient conditions to achieve natural recovery (reducing DNT to below the drinking water screening level) without attempting to supplement the process with active groundwater treatment.

A pump and treat system would involve the same mechanism for aquifer restoration as is occurring naturally via groundwater discharge from the Site (that is removal of water containing DNT from the aquifer system). In a hypothetical pump and treat system, pumpage from the Sea Level Aquifer (SLA) would be approximately equal to the quantity of water discharging naturally from the Site via the SLA. A Site pump and treat system would also include pumping from a portion of the Water Table Aquifer (WTA). Preliminary pumping rate estimates indicate that pumpage from the WTA would comprise about 20 percent and pumpage from the SLA about 80 percent, of the total water pumped in a hypothetical Site pump and treat system (pumping rate estimates discussed below). Aggressive pump and treat of both Site aquifers would provide a 25 percent increase in water removed from the aquifer system relative to natural discharge, which, in time, could decrease the aquifer restoration time by only 20 percent relative to natural flushing. [A 20 percent decrease in time is based on a simple “batch flush” model ($t = \ln[Ct/Co] * PV * R / Q$; EPA, 1988). Increasing flow rare, Q, by 0.25 decreases restoration time, t, by 0.20 in this model. Other values in the equation would be constants for this demonstration.]

I.6 Technical Infeasibility Considerations

Groundwater pump and treat is the only groundwater remediation technology which could be applied at the Site for the following reasons:

- Groundwater which would be targeted for remediation is deep (100 to 200 feet below surface) and laterally extensive, preventing use of impermeable barriers, gates, or other groundwater isolation techniques;

- DNT has low volatility, preventing use of sparging or other venting technologies;

- Although DNT can be degraded through natural in situ processes, only biological degradation could potentially occur in Site aquifers and attempting to enhance this process as part of a remediation program would likely be infeasible;

- DNT readily degrades by photolysis (half-life on the order of days; Etnier, 1987), but this process will not occur in aquifers;
- DNT can be transformed to formic and acetic acids, but only at temperatures at which water would not persist (520°F; Etnier, 1987); and
- DNT in water degrades through biological processes under some aerobic and anaerobic conditions (Spanggord. 1980; Etniert 1987), but the metabolism of DNT is strongly dependent on environmental conditions and the presence of viable microorganisms (ATSDR, 1989). Biodegradation of DNT may be occurring naturally in Site aquifers, yet attempting to establish or enhance appropriate natural microorganism populations (e.g., by introducing nutrients) in Site aquifers would likely be infeasible because of the size of the Site and the substantial depth of the aquifers.

The National Research Council (NRC) Committee on Ground Water Cleanup Alternatives' published report lists "conventional pump and treat" as the only effective technology (out of 12 technology categories) for dissolved constituents, which are non-reactive or non-volatile (NRC, 1994). DNT in Site groundwater falls into this category.

In a pump and treat scenario, groundwater extracted from Site aquifers would be treated most cost-effectively using granular activated carbon (GAC). Recent studies at another site have demonstrated that GAC is considerably more cost-effective to use than advanced oxidation technologies (e.g. UV/Ozone) at low influent concentrations (Hart Crowser, 1993).

The historical performance of groundwater pump and treat systems in restoring aquifers to drinking water standards has been poor suggesting that groundwater pump and treat to achieve drinking water standards everywhere in an aquifer may be technically infeasible. This fact is widely acknowledged within the environmental industry, including the EPA (Travis and Doty, 1990; Doty and Travis, 1991; EPA, 1992; Makdisi, 1994). Of 77 pump and treat sites evaluated in the NRC (1994) report, eight small sites (pumping rates between 1 and 37 gpm; 5 were service stations) with volatile organic compounds (VOCs) had apparently achieved cleanup goals, some of which had the benefit of using venting/sparging to enhance VOC removal. In contrast, the Former DuPont Works Site is very large and hydro-geologically complex and DNT would need to be extracted solely through conventional groundwater pumping. Therefore, the time required for pump and treat to achieve the DNT drinking water standard throughout the Site could be approximately 10 to 20 years or longer, if it were to be implemented. One-half of the sites evaluated by the NRC have already been pumping and treating for at least 10 years without achievement of drinking water standards (NRC, 1994).

At other sites where groundwater concentrations are orders of magnitude higher than at this Site, pump and treat may make sense for reducing concentrations (thus reducing risk) to the extent practical. General evaluations of pump and treat performance suggest it would not be unreasonable to expend 50 percent of available resources (time and money) initially reducing groundwater concentrations by 90 percent, and then expend the remaining 50 percent attempting to remove the residual 10 percent (i.e., below some low asymptotic level). Maximum DNT concentrations at the Site would likely fall within the final one percent at sites where active groundwater remediation is undertaken.

I.7 Cost of Active Groundwater Remediation

The cost to implement active groundwater remediation (pump and treat) at the Site would be excessive, primarily because of the high groundwater flow rates and resulting large volume of water which would need to be extracted, treated, and reintroduced to Site aquifers.

I.7.1 Groundwater Pumping Rate Estimates.

The following analytical equation presented in Keely (1984) was used to estimate the pumping rate needed to capture all Site groundwater with DNT concentrations above 0.13 µg/L in the Water Table Aquifer and in the Sea Level Aquifer:

(1) Max width of capture zone (w) = Q / H v n (I)

where:

Q = pumping rate in ft^3/day;
H = initial saturated thickness in feet;
v = average linear groundwater velocity in ft/day; and n = effective porosity (dimensionless).

Because average linear velocity (v) is equal to Ki/n, effective porosity drops out of the equation. Rearranging the equation to solve for pumping rate (Q) then gives:

(2) Q = w H K i (2)

where:

Q, w, and H are defined above;
K = hydraulic conductivity in ft/day; and
i = hydraulic gradient in ft/foot.

Equation (2) was solved using Monte Carlo simulation to develop a probabilistic range of pumping rates which encompasses reasonable ranges of uncertainties in hydraulic parameters. The equation was solved independently for the Water Table Aquifer (assuming capture of groundwater in Area 18 with DNT above 0.13 µg/L) and the" Sea Level Aquifer (assuming capture of all groundwater in the Sea Level Aquifer with DNT above 0.13 µg/L) .The flow rates from the two aquifers were added to provide an estimated total system now rate for a hypothetical Site pump and treat system.

Hydraulic parameters were assigned assumed probability distributions based on information presented in the initial Draft RI (Hart Crowser, 1994). The assumptions follow, and are provided in Attachment B.
Water Table Aquifer (WTA) Assumptions:

- Hydraulic conductivity (K) was assigned a lognormal distribution with geometric mean of 5 x 10^{-2} cm/sec and a standard deviation of 10 percent of the mean. [This compares favorably with reliable pumping test results from Fort Lewis which provide a K estimate for the Water Table Aquifer (WTA) of 2 x 10^{-1} cm/sec, which is higher than the range presented in the initial RI. This value is consistent with the coarse-grained nature of the WTA. Based on this value and other WTA pumping test results presented in the initial Draft RI, we assumed 5 x 10^{-2} cm/sec as our best judgment estimate of an average K value. Because these flow rate estimates are most sensitive to uncertainty in K (which can vary by orders of magnitude) relatively small standard deviations (for both aquifers) were assumed about the mean values in an effort to provide a more tightly constrained, thus useful, range of resultant flow rates.]

- Horizontal hydraulic gradient (i) estimates for the WTA, ranging from 0.02 to 0.05 ft/ft are based on water table elevation contour maps. Hydraulic gradient for the WTA was assigned a triangular distribution with minimum, most likely, and maximum values of 0,02, 0.035 (midpoint of range), and 0.05 ft/ft, respectively,

- The thickness of the WTA was assigned a triangular distribution with minimum, most likely, and maximum values of 10, 30, and 50 feet, respectively, based on geologic information from drilling Site monitoring wells.

The width of the WTA to be captured was assigned a triangular distribution with minimum, most likely, and maximum values of 1,200, 1.600, and 2,000 feet, respectively, based on the locations of interim DNT source removal excavations and groundwater flow directions presented in the Draft RI.

I.7.2 Sea Level Aquifer (SLA) Assumptions

- Hydraulic conductivity was assigned a lognormal distribution with geometric mean of 1 x 10^{-1} cm/sec (midpoint of the range presented in the Draft RI) and a standard deviation of 10 percent of the mean (as discussed above).

- Horizontal hydraulic gradient (i) estimates for the Unconfined SLA ranging from 0.005 to 0.02 ft/ft were based on water table elevation contour maps. Hydraulic gradient for the SLA was assigned a triangular distribution with minimum, most likely, and maximum values of 0.005, 0.013 (midpoint of range), and 0.02 ft/ft, respectively.

- The thickness of the SLA was assigned a triangular distribution with minimum, most likely, and maximum values of 80, 100, and 120 feet, respectively based on geologic information from drilling of a deep test well north of the Site which penetrated approximately 120 feet of saturated Steilacoom Gravels (Unconfined Sea Level Aquifer).

- The width of the SLA to be captured was assigned a triangular distribution with minimum, most likely, and maximum values of 2,000, 2,500, and 3.000 feet, respectively, based on the distribution of DNT within the Unconfined Sea Level Aquifer.

Using these parameter distributions as input, equation (2) was run as a Monte Carlo simulation using Crystal Ball software, a forecasting and risk analysis add-on to the Excel spreadsheet. The equation was solved for each aquifer 5,000 times by randomly selecting parameter values from the aquifer-specific probability distributions outlined above, and summing the flow rates from both aquifers into an estimated total system flow rate. The 5,000 estimates of the total system flow rate were automatically compiled into a probability distribution for which percentiles are provided. Attachment B provides the supporting information for the now rate estimates (including assumptions, forecasts, and statistical output).

Using the probability distribution for total system flow rate, we selected a range of system flow rates corresponding to 95 percent and 25 percent probabilities (i.e., a reasonable range of likely outcomes) for the purposes of developing a range of cost estimates. Based on the Monte Carlo simulation, the 5th percentile value was approximately 3,500 gpm (95 percent probability that the flow rate would be at least that high; refer to page B-2 in Attachment B) and the 75th percentile value was approximately 7,000 gpm (25 percent probability that it would be that high). This range of flow rates appears reasonable when compared with a relatively large-scale pump and treat system operating at Ponders Corner, approximately 5 miles from the Site, which had pumped 2,000 gpm from only the lower permeability portion (Advance Outwash) of the Water Table Aquifer (EPA, 1992).

I.7.3 Preliminary Cost Estimate for Groundwater Remediation

Using the estimates for pumping rates presented above, preliminary estimates of cost range from approximately $33 million (assuming pumping, treatment by granular activated carbon (GAC), and reintroduction to the aquifer of 3,500 gpm [5 MGD] for a 10-year duration) to approximately $58 million (assuming pumping, treatment, and reintroduction to the aquifer of 7,000 gpm [10 MGD] for a 20-year duration). A ten (10) year duration of operation was based on the findings of the NRC (1994) report, where one-half of all systems studied have already been operating 10 years or more (with a maximum of 21 years). As such, the twenty (20) year duration was used as the high-end estimate for the purposes of developing cost estimates.

The cost estimates were developed using EPA's Cost of Remedial Action (CORA) Model (CH2M Hill, 1990). The preliminary cost estimate included the following components;

- Installation of extraction wells;

- Installation of conveyance (piping) systems;
- Purchase and operation of granular activated carbon (GAC) treatment system (including carbon change out and off-Site thermal regeneration);
- Installation of re-introduction wells to return treated groundwater back to the aquifers (also used to help control saltwater intrusion in the Sea Level Aquifer);
- Performance monitoring for full period of operation; and
- Operation and maintenance of all systems for period of operation.

Table 1 provides a summary of CORA's estimated costs for constructing (capital costs) and operating and maintaining (O&M costs) a groundwater pump and treat system at the Site under four assumed scenarios (5 MGD for 10 or 20 years, and 10 MGD for 10 or 20 years). These cost estimates do not include pilot testing or engineering design.

I.8 Conclusions

For the Former DuPont Works Site, there is a clear case that the cost to implement active groundwater remediation would be substantial and disproportionate to any risk reduction it could achieve, as specified in MTCA.

- First, there is no risk to human health or the ecological environment posed by DNT in groundwater under any current or foreseeable future land use of the Sire; ample off-Site water supply exists to meet all future drinking water demand, and intuitional controls will be implemented, as necessary, during future Site development to prevent withdrawal of Site groundwater for drinking water use;
- Second, the DNT source at the Site has been removed so that natural recovery will be effective in further reducing the extremely low DNT concentrations currently detected in Site groundwater;
- Third, concentrations in Site groundwater are already low enough that active groundwater pump and treat would likely be little or no more effective than natural flushing in removing the last residual DNT from Site aquifers; and
- Finally, the cost to undertake groundwater pump and treat would be excessive, particularly since it would not provide a substantive reduction in Site risk.

The intent of MTCA and CERCLA is to focus cleanup resources to reduce overall Site risk under current and future land use. This will be accomplished at the Former DuPont Works Site by addressing Site soils, not Site groundwater.

Table I-1 – Summary of Cost(1) Estimates for Implementing Groundwater Pump and Treat for the Former DuPont Works Site

Scenario	Capital Cost	O & M Costs(2)	Total Cost
5 MGD for l0 years	$16.5	$16.7	$33
5 MGD for 20 years	$16.5	$23.0	$40
10 MGD for 10 years	$20.0	$27.0	$47
10 MGD for 20 years	$20.0	$38.0	$58

Notes:
(1)Cost estimates developed using CORA -EPA's Cost of Remedial Action Model (CH2M Hill, 1990). All costs in millions.
(2)Present worth based on 10% annual interest rate.

I.9 References for Appendix I

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ATTACHMENT A
GROUNDWATER RISK SCREENING EVALUATION

ATTACHMENT A
GROUNDWATER RISK SCREENING EVALUATION

The potential risks associated with groundwater at the Site are expected to be minimal because the future uses are limited and because the RI results indicate that low concentrations of DNT represent the only Site-related constituents present in the groundwater.

Irrigation of the golf course after the Site is developed represents the only potential future use of groundwater at the Site. No other future uses are planned because the City of Dupont will provide water for all residential and industrial uses. Golfers or occasional visitors are not expected to come in contact with the irrigation water on any significant basis. Thus, risks were quantified for exposure by a golf course worker responsible for operating the irrigation system. Risks were evaluated assuming dermal contact with irrigation water as well as drinking of the irrigation water. Because of the greater potential frequency and duration of contact with irrigation water, a golf course worker represents the most conservative exposure scenario. Highly conservative assumptions were used throughout this screening evaluation to provide a high level of confidence that use of Site groundwater for golf course irrigation will be protective of human health.

The potential cancer risks associated with exposure to groundwater are below 1 x 10^{-6}, even with the highly conservative assumptions used in this screening evaluation. Therefore, groundwater does not represent a media of concern for impact to human health. The potential risks were quantified as presented below:

Dermal Contact with Groundwater

The dermally absorbed dose is calculated with the following equation:

$$DAD = \left(\frac{DA_{event} \times EV \times ED \times EF \times A}{BW \times AT} \right)$$

Where:

DAD = dermally absorbed dose in mg/kg-day
DA_{event} = absorbed dose per event in mg/cm^2-event
EV = event frequency in events/day
ED = exposure duration in years
EF = exposure frequency in days/year
A = skin surface area available for contact in cm^2

BW = body weight in kg
AT = averaging time in days

The following values were substituted into the above equation:

DA_{event} = 5.9×10^{-9} mg/cm^2-event; as calculated separately below
EV = 1 event/day; which assumes that a groundskeeper sets up and attends to watering systems once per day
ED = 9 years
EF = 180 days/year; a Site-specific value suitable for the Pacific Northwest climate
A = 2,000 cm^2; equal to the average surface area of an adult's hands and forearms
BW = 70 kg; MTCA and EPA default value
AT= 25,550 days; the averaging time for carcinogens (70 years) times 365 days/year

DA_{event} is calculated with the following equation:

$$DA_{event} = 2K_pC_v\sqrt{\frac{6\ \tau\ t_{event}}{\pi}}$$

Where:

K_p= chemical-specific permeability constant in cm/hour
C_v= chemical concentration in water in mg/cm^3
τ= lag time in hours; this term is used to account for chemicals entering the skin at a rapid rate during initial contact (a non-steady state phenomenon)
t_{event}= the duration of the exposure event in hours
π= pi; a constant equal to 3.14

Values of 3.8×10^{-3} cm/hour and 1.1 hour for K_p and τ , respectively, were taken from EPA (1992). The value of K_p for 2,4-DNT was used as the higher value for the two given DNT isomers. t_{event} was assumed to be equal to 0.5 hour, which is a conservative approximation of the amount of time a golf course worker might be in contact with irrigation water per exposure event. C_v was assumed to be 0.76 μg/L, the highest DNT concentration ever detected in Site aquifers (converted to 7.6×10^{-7} mg/cm^3) as an additional measure of conservatism.

Calculating DA_{event} with the above values results in $DA_{event} = 5.9 \times 10^{-9}$. Substituting this into the equation used to calculate DAD results in DAD = 1×10^{-8}. Multiplying DAD by the oral CSF of 0.68 gives an estimated risk by this pathway of 7×10^{-9}, or 7 in 1 billion. Therefore, potential incremental risks associated with this pathway are well below thresholds of risk management consideration, even with the highly conservative assumptions that a worker would have their arms immersed in water containing maximum Site DNT concentrations for a period of one-half hour every day for 180 days per year.

For EF, the upper-bound default for worker exposure is normally 250 days/year. However, the climate in the Pacific Northwest is such that golf course irrigation is not expected to exceed 6 months per year. Assuming the golf course is operating 7 days per week for 6 months, an EF of 180 days/year was assumed. This further assumes that the golf course will be watered on every one of those 180 days, which is a conservative assumption.

The event time and frequency of 0.5 hour/event, 1.0 event/day, respectively, may not capture the actual conditions by which a worker is exposed. Assuming that a worker makes contact with the irrigation equipment or with materials that have come into contact with the irrigated sections of the golf course, exposure may, in fact, occur with greater frequency for much shorter periods of time. To examine this, the above calculations were repeated with $\tau_{event} = 0.1$ hour (six minutes), and EV = 16 events/day. That is, an individual makes contact with irrigation water for 6 minutes out of every 15 minutes for four hours each working day, which are highly conservative assumptions. With these values substituted in the above equations, $DA_{event} = 2.6 \times 10^{-9}$, $DAD = 7.7 \times 10^{-8}$, and the risk is determined to be 5×10^{-8}, or 5 in 100 million. Therefore, exposures of greater frequency and shorter time still results in estimated potential incremental risks well below risk management thresholds.

Ingestion of Groundwater

The orally absorbed dose is calculated with the following equation:

$$Intake = (mg/kg\text{-}day) = \left(\frac{CW \times IR \times EF \times ED}{BW \times AT}\right)$$

Where:

CW = chemical concentration in water in mg/L
IR = ingestion rate in liters/day
EF = exposure frequency in days/year
ED = exposure duration in years
BW = body weight in kg

AT = averaging time (period over which exposure is averaged - days)

The following values were substituted into the above equation:

CW = 0.76 μg/L, the highest detected DNT concentration in groundwater at the Site
IR = 1 liter/day. This equals half of the EPA default IR of 2 liters/day
EF = 180 days/year; a site-specific value suitable for the Pacific Northwest climate
ED = 9 years
BW = 70 Kg; MTCA and EPA default value
AT = 25,550 days; the averaging time for carcinogens (70 years) times 365 days/year

The value of 1 liter per day for the IR is based on the assumption that a golf course worker consumes half their daily intake of 2 liters/day from irrigation water while at work. This represents a highly conservative assumption since it assumes a worker would preferentially drink water from the golf course irrigation system rather than the water specifically provided for drinking water at the golf course (from the City of Dupont water supply). Because water used for irrigation may not be suited for drinking water purposes, the assumption of any drinking water exposure to irrigation water, much less half of their intake, is highly conservative. Values for CW, EF, ED, BW, and AT are the same as used above for dermal exposure.

Potential risk was calculated for both carcinogenic and non-carcinogenic end points for exposure to DNT in drinking water using EPA guidance (1989). A cancer slope factor of 0.68 and an oral reference dose of 0.001 mg/kg-day were used. The cancer risk was calculated as 5×10^{-7}, considerably below 1 in 1 million (10^{-6}). The non-cancer risk was calculated as 7×10^{-4}, much less than a hazard quotient of 1.0. These calculated risks are well below risk management thresholds.

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ATTACHMENT B
SUPPORTING INFORMATION FOR PROBABILISTIC FLOW RATE ESTIMATES

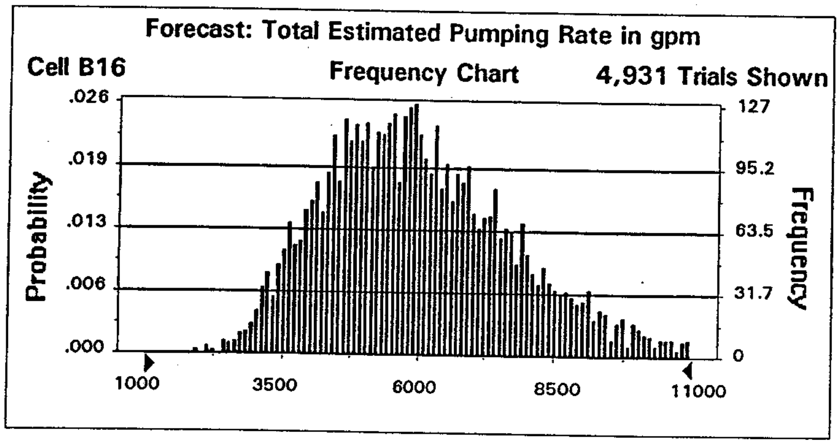
Crystal Ball Report

Forecast: Total Estimated Pumping Rate in gpm **Cell: B16**

Summary:

Display Range is from 1000 to 11000
Entire Range is from 1912 to 16401
After 5,000 Trials, the Std. Error of the Mean is 26

Statistics:	Value
Trials	5000
Mean	6101
Median (approx.)	5868
Mode (approx.)	5897
Standard Deviation	1847
Variance	3411761
Skewness	0.82
Kurtosis	4.23
Coeff. of Variability	0.30
Range Minimum	1912
Range Maximum	16401
Range Width	14488
Mean Std. Error	26.12



Forecast: Total Estimated Pumping Rate in gpm (cont'd) **Cell: B16**

Percentiles:

Percentile	Value (approx.)
0%	1912
5%	3529
25%	4754
50%	5868
75%	7202
95%	9406
100%	16401

End of Forecast

Forecast: WTA Pumping Rate in gpm (cont'd) **Cell: B14**

Percentiles:

Percentile	Value (approx.)
0%	187
5%	530
25%	866
50%	1186
75%	1611
95%	2474
100%	6654

End of Forecast

Forecast: SLA Pumping Rate in gpm (cont'd) **Cell: F14**

Percentiles:

Percentile	Value (approx.)
0%	1191
5%	2416
25%	3549
50%	4533
75%	5821
95%	8045
100%	15022

End of Forecast