U.S. Army Corps
of Engineers
Baltimore District

CENAB-EN-HN

Focused Feasibility Study
NIKE Battery Launch Area (W-44)
Formerly Used Defense Site
Waldorf, Maryland

FINAL

Contract Number DACA31-00-D-0023
Delivery Order 0034

December 2011

Prepared for:

U.S. ARMY CORPS OF ENGINEERS
10 South Howard Street
Baltimore, Maryland 21201

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Prepared by:

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West Chester,
Pennsylvania 19380-1499

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FOCUSED FEASIBILITY STUDY
NIKE BATTERY LAUNCH AREA (W-44)
FORMERLY USED DEFENSE SITE (FUDS)
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TABLE OF CONTENTS

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

LIST OF APPENDICES

LIST OF FIGURES

Title **Page**

LIST OF TABLES

Title **Page**

LIST OF ACRONYMS

μg/L	micrograms per liter
AHPA	Archaeological and Historic Preservation Act
AS/SVE	Air Sparging with Soil Vapor Extraction
ATEC	ATEC Associates, Inc.
bgs	below ground surface
CAA	Clean Air Act
CCl_4	carbon tetrachloride
CENAB	USACE Baltimore District
CFR	Code of Federal Regulations
COC	constituent of concern
COMAR	Code of Maryland Regulations
CPT	cone penetrometer test
CR	cancer risk
CWA	Clean Water Act
DERP-FUDS	Defense Environmental Restoration Program for Formerly Used Defense Sites
DNAPL	dense non-aqueous phase liquid
DOD	Department of Defense
EC	exposure concentration
EOS	emulsified oil substrate
EPA	U.S. Environmental Protection Agency
ERT	Earth Resources Technology, Inc.
ESA	Endangered Species Act
ETI	EnviroMetal Technologies, Inc.
FUDS	Formerly Used Defense Site
FS	Feasibility Study
GAC	granular-activated carbon
gpm	gallons per minute
HI	hazard index
HRC	hydrogen release compound

LIST OF ACRONYMS (CONTINUED)

INPR	Inventory Project Report
ISB	In Situ Bioremediation
ISCR	In Situ Chemical Reduction
K	conductivity
LDR	Land Disposal Restriction
LRP	Land Restoration Program
MCL	maximum contaminant level
MDE	Maryland Department of the Environment
MNA	Monitored Natural Attenuation
MSL	mean sea level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
PCB	polychlorinated biphenyl
ppb	parts per billion
PRB	Permeable Reactive Barrier
RA	Risk Assessment
RAO	remedial action objective
RG	remedial goal
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TCE	trichloroethene
TMV	toxicity, mobility, or volume
TPH	total petroleum hydrocarbon
UECA	Uniform Environmental Covenants Act

LIST OF ACRONYMS (CONTINUED)

UIC	Underground Injection Control
USACE	U.S. Army Corps of Engineers
USC	United States Code
UST	underground storage tank
v	velocity
WESTON	Weston Solutions, Inc.
WSSC	Washington Suburban Sanitary Commission
WWS	Waldorf Water System
ZVI	zero-valent iron

EXECUTIVE SUMMARY

This focused Feasibility Study (FFS) re-evaluates the technologies presented in the 2004 Draft FFS for the former Nike Battery W-44 Launch Area (Nike Launch Area) Formerly Used Defense Site (FUDS) in Waldorf, Maryland [FUDS Project Number C03MD0241; Project Number: DACA31-00-D-0023; Delivery Order: 0034; Type of Project: Hazardous, Toxic and Radioactive Waste (HTRW)]. The technologies presented in the 2004 F FS were evaluated for treating volatile organic compounds (VOCs) in groundwater located west of the Nike Launch Area under three potential home construction lots.

More recent analytical results from groundwater sampling west of the Nike Launch Area in 2008 and indoor air sampling in a new house built on one of the three home construction lots in 2010 have led the U.S. Army Corps of Engineers (USACE) to re-evaluate the remedial alternatives. The primary contaminants of concern, carbon tetrachloride (CCl_4) and trichloroethylene (TCE) were not detected in groundwater collected in 2008 from monitoring well MW-18, which is located west of the Nike Launch Area next to the home construction lots. However, additional sampling will be required during remedy implementation to fully delineate the nature and extent of groundwater contamination west of the Nike Launch Area.

Additionally, USACE collected indoor air samples from the first floor and basement of the newly constructed home on Lot No. 9 on Cedar Tree Lane. This house was constructed above the existing site contaminant plume in the area where vapor intrusion of contaminants is a concern. The indoor air samples were collected on 1 December 2010, and the contaminants of concern, CCl_4 and TCE, were not detected. These results confirmed that there is no current risk to human health via the vapor intrusion pathway in the house built on Lot No. 9.

This FFS focuses on evaluating remedial alternatives to address the CCl_4 source area identified in the vicinity of groundwater monitoring well MW-4 rather than the downgradient groundwater contaminant plume under the residential lots.

The Nike Launch Area is a FUDS located in the southern portion of Prince George's County and the northern portion of Charles County, approximately 15 miles southeast of the center of

Washington, DC. The site was formerly part of the Nike surface-to-air missile system deployed by the U.S. Army during the 1950s to protect major cities and government installations from the threat of bomber attack. The Nike Launch Area was established in 1955 and remained operational until 1971.

CCl_4 and TCE were detected in groundwater samples collected from monitoring wells MW-4 (1987 through 2008), MW-7 (1995 through 2008), and MW-12 (1999 through 2008) at the Nike Launch Area, at concentrations exceeding the EPA drinking water MCL of 5 µg/L for each constituent. Both CCl_4 and TCE are considered constituents of concern (COC). The sources of these COCs are assumed to be historical spills and/or releases of chlorinated solvents utilized for maintaining equipment during missile maintenance practices at Building 31, east of MW-4. This assumption has been verified through previous records reviews and past sampling results.

The highest contaminant concentrations were observed in well MW-4 at levels ranging from 97 µg/L to 450 µg/L for CCl_4 and 3 µg/L to 19 µg/L for TCE. CCl_4 was detected during 1996 in soil gas samples collected to the west of the Nike Launch Area at Cedar Creek Tree Properties (Lots 8, 9, and 10). TCE was not detected in the same soil gas samples. CCl_4 concentrations detected in soil gas in 1996 ranged from 0.02 µg/L to 6 µg/L, exceeding the soil gas remedial goal (RG) of 0.33 µg/L; however, CCl_4 concentrations in passive soil gas samples obtained by Earth Resources Technology, Inc. (ERT) in 2008 were below the soil gas RG and ranged from non-detect to 0.08 µg/L. Passive soil gas sampling is a screening level tool, and the results are not considered sufficient for risk assessment purposes. Also, CCl_4 was not detected in groundwater samples collected from MW-18 at the southern edge of Lot 10, which is directly downgradient of the contaminant source area, during the 2008 sampling activities. These passive soil gas screening results were confirmed by the USACE indoor air sampling results (non-detects) conducted in the new home constructed on Lot No. 9; however, additional groundwater sampling will be required to confirm the drop in downgradient CCl_4 concentrations in the groundwater contaminant plume.

Based on a re-evaluation of remedial technologies, a new remedial alternative for addressing the localized contaminant source area around MW-4, Alternative F - In Situ Chemical Reduction and In Situ Bioremediation (ISCR/ISB), was added to the FFS.

For Alternative F, ISCR/ISB amendments would be injected into the contaminant source area groundwater using Geoprobe's pressure-activated injection tools. Based on t he low VOC concentrations, groundwater and soil geochemistry, and the longevity of the ISCR/ISB amendments, only one injection of reactive medium is anticipated at the Nike Launch Area site.

Due to the low contaminant concentrations present in the Nike Launch Area groundwater, the combined effects of the ISCR/ISB technology and natural attenuation processes are expected to reduce the contaminant concentration to below the risk-based vapor intrusion RGs within approximately 1 to 2 years.

1. BACKGROUND

1.1 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), Baltimore District (CENAB), contracted with Weston Solutions, Inc. (WESTON®) to perform a focused Feasibility Study (FS) at the former Nike Battery W-44 Launch Area (Nike Launch Area) Formerly Used Defense Site (FUDS) in Waldorf, Maryland [FUDS Project Number C03MD0241; Project Number: DACA31-00-D-0023; Delivery Order: 0034; Type of Project: Hazardous, Toxic and Radioactive Waste (HTRW)]. The FS is focused on the organic contaminants present in groundwater at the former Nike Launch Area. The constituents of concern (COCs) in the Nike Launch Area groundwater are carbon tetrachloride (CCl_4) and trichloroethene (TCE). This revised FS was prepared under Delivery Order 034 of Contract DACA31-00-D-0023 in response to discussions between USACE and the Maryland Department of the Environment (MDE) concerning new data obtained in 2008 and 2010, and their impact upon the proposed remedial alternative.

In 2008, USACE contracted with Earth Resources Technology, Inc. (ERT) to conduct additional groundwater sampling and soil gas survey activities at the Nike Launch Area, and prepare an Addendum to the 2004 Remedial Investigation (RI) Report (WESTON, 2004a). The results of this follow-up investigation conducted in 2008 are presented in the *Draft Remedial Investigation Addendum, Waldorf Nike (W-44) Site, Launch Area*, ERT, 23 February 2009 (ERT, 2009).

The results of the 2008 RI activities showed that the CCl_4 and TCE concentrations had decreased significantly within the groundwater contaminant plume. However, this decrease is based on passive soil gas sampling and only one round of groundwater quality data; therefore, additional sampling will be required to confirm these results. Because of these developments, CENAB decided to shift the focus of the project remedial goals from the groundwater plume under Lots 8, 9, and 10 to the contaminant source area. The preferred alternative in 2004 was a permeable reactive barrier (PRB), which was focused on the off-site groundwater plume [PRBs are installed across the flow path of a contaminated groundwater plume, allowing the water portion of the plume to flow through the wall. Reactive materials in the wall trap harmful chemicals and/or change them into harmless products. Remediated groundwater flows out the other side of the wall (WESTON, 2004b)].

In 2010, CENAB collected indoor air samples from the first floor and basement of the newly constructed home on Lot No. 9 along Cedar Tree Lane. This house was constructed above the existing Nike Launch Area contaminant plume in the area where vapor intrusion of contaminants has been a concern. Indoor air samples were collected on 1 December 2010, and the contaminants of concern, CCl_4 and TCE, were not detected (USACE, 2010; ALSI, 2010). These results confirmed that in the house built on Lot No. 9, above the downgradient groundwater contaminant plume, there is no current risk to human health via the vapor intrusion pathway.

In response to these recent investigation results and discussions between CENAB and MDE, WESTON was tasked with reevaluating the technologies presented in the 2004 FS to focus on the contaminant source area rather than the groundwater contaminant plume downgradient of the Launch Area.

1.1.1 Previous Investigations

An environmental investigation of the Nike Launch Area was initiated in 1986. The findings of this initial investigation are presented in the *Final Report for Confirmation Study at Former NIKE Missile Battery (W-44), Waldorf, Maryland*, December 1987, Donohue & Associates, Inc. (Donohue, 1987). The results of a follow-up investigation conducted in 1991 are presented in the *Final Screening Site Inspection, Waldorf Launch*, Halliburton NUS Environmental Corporation, 28 May 1992 (Halliburton NUS, 1992).

Following these investigations, the Nike Launch Area was the subject of a limited Remedial Investigation (RI) conducted by WESTON. The limited RI was issued in September 1995 (WESTON, 1995). The limited RI recommended that an FS be conducted for the Nike Launch Area based on the presence of organic contaminants in groundwater at the site boundary. Subsequent to issuance of the RI, USACE received off-site groundwater monitoring data collected by ATEC Associates, Inc. (ATEC), which was contracted by an adjacent property owner (Cedar Tree Property). A limited Risk Assessment (RA) of the Nike Launch Area was conducted by WESTON and the RA Report was issued in September 1996 (WESTON, 1996).

Based on the results of the limited RI and RA of 1995 and 1996, respectively, an FS was developed to include remedial measures for groundwater at the Nike Launch Area. The original FS was issued in April 1997 (WESTON, 1997). No environmental concerns were identified in other media at the site.

The 1997 FS was submitted to MDE and to the County Commissioners of Charles County, La Plata, Maryland. Several issues were raised, including the need for additional testing to support natural attenuation, the potential for off-site impact due to CCl_4 and TCE in groundwater, and the need to further investigate the presence of dense non-aqueous phase liquid (DNAPL).

Additional RI activities conducted by WESTON during 1999, 2001, and 2003 were performed in response to concerns raised by MDE and the County Commissioners' office.

The results of the additional RI activities were presented along with the previous site investigation data in an updated RI report, issued in April 2004 (WESTON, 2004a). The 2004 RI report also included an update to the 1996 RA.

Based on the results of the 2004 RI Report, a revised FS Report was developed in 2004 (WESTON, 2004b) to include remedial measures for groundwater at the Nike Launch Area. The original FS was issued in April 1997 (WESTON, 1997). No environmental concerns were identified in other media at the site.

In summary, the following investigations and studies have been conducted at the Nike Launch Area:

- 1987 Confirmation Study, Donohue & Associates.
- 1992 Final Screening Site Inspection, Halliburton NUS.
- 1994 Groundwater Investigation – Cedar Tree Property, ATEC.
- 1995 Limited Remedial Investigation, WESTON.
- 1996 Limited Risk Assessment, WESTON.
- 1997 Feasibility Study, WESTON – Monitored Natural Attenuation was selected as the preferred remedial alternative.

- 2004 Updated Remedial Investigation, WESTON.
- 2004 Focused Feasibility Study, WESTON – Permeable Reactive Barrier was selected as the preferred remedial alternative.
- 2009 Remedial Investigation Addendum, ERT.
- 2010 Work Management Plan for Data Gap Investigation, ERT.
- 2010 Indoor Air Survey at House on Lot #9 – Cedar Tree Lane, USACE.
- 2011 Revised Feasibility Study, WESTON.

1.2 SITE HISTORY AND DESCRIPTION

The site is located on the boundary between the southern portion of Prince Georges County and the northern portion of Charles County, approximately 15 miles southeast of the center of Washington, DC. A site location map is presented in Figure 1-1. Nike Battery W-44 was established in the 1950s as part of the Nike missile system and remained operational until the mid-1970s. The W-44 site included both Missile Launch and Control Areas. The Launch Area is the subject of this FS.

The site was developed as Nike Battery W-44 and included easements for access roads, utilities, and a Launch Area buffer zone. Facilities constructed at the Nike Launch Area include the Acid Fueling Building (demolished), barracks, the Generator Building (Building 23), a kennel, the Missile Assembly and Test Building (Building 31), the Vehicle Maintenance Shop (Building 22), a sand filter, three underground storage tanks (USTs), two missile silos, and an electrical utility system (USACE, undated). The former USTs, located at the barracks, Building 22, and Building 23 were removed in the 1990s. Figure 1-2 presents the site map of the Nike Battery W-44 Launch Area.

Between June 1965 and February 1986, a total of 27.72 acquired acres, a 35.98-acre easement, and a 0.89-acre lease were declared as excess by the U.S. Department of Defense (DOD) and subsequently conveyed to other owners (USACE, 1990). All structures, USTs, and electrical distribution system equipment constructed by DOD remained on the property at the time of conveyance.

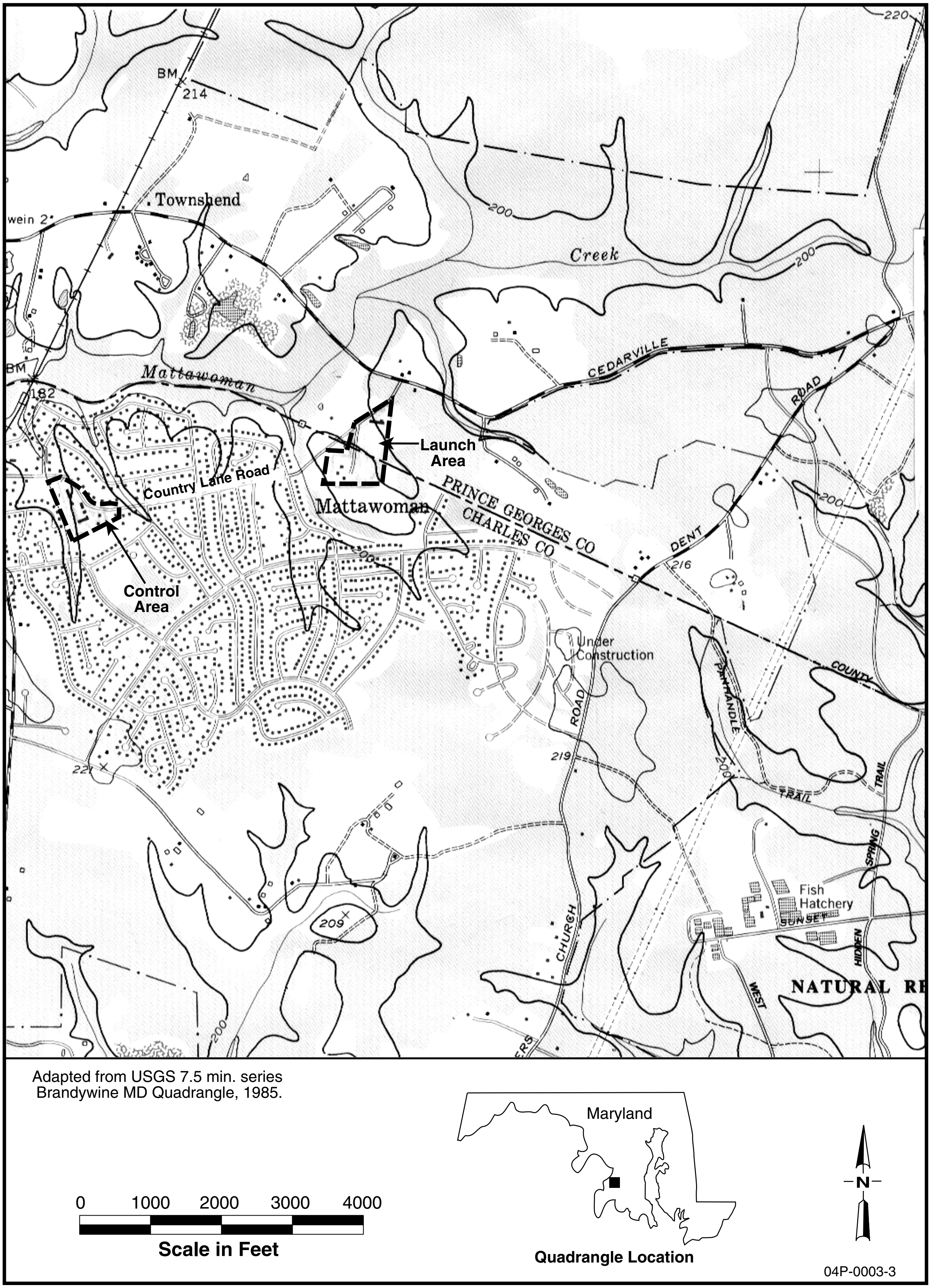

FIGURE 1-1 SITE LOCATION MAP

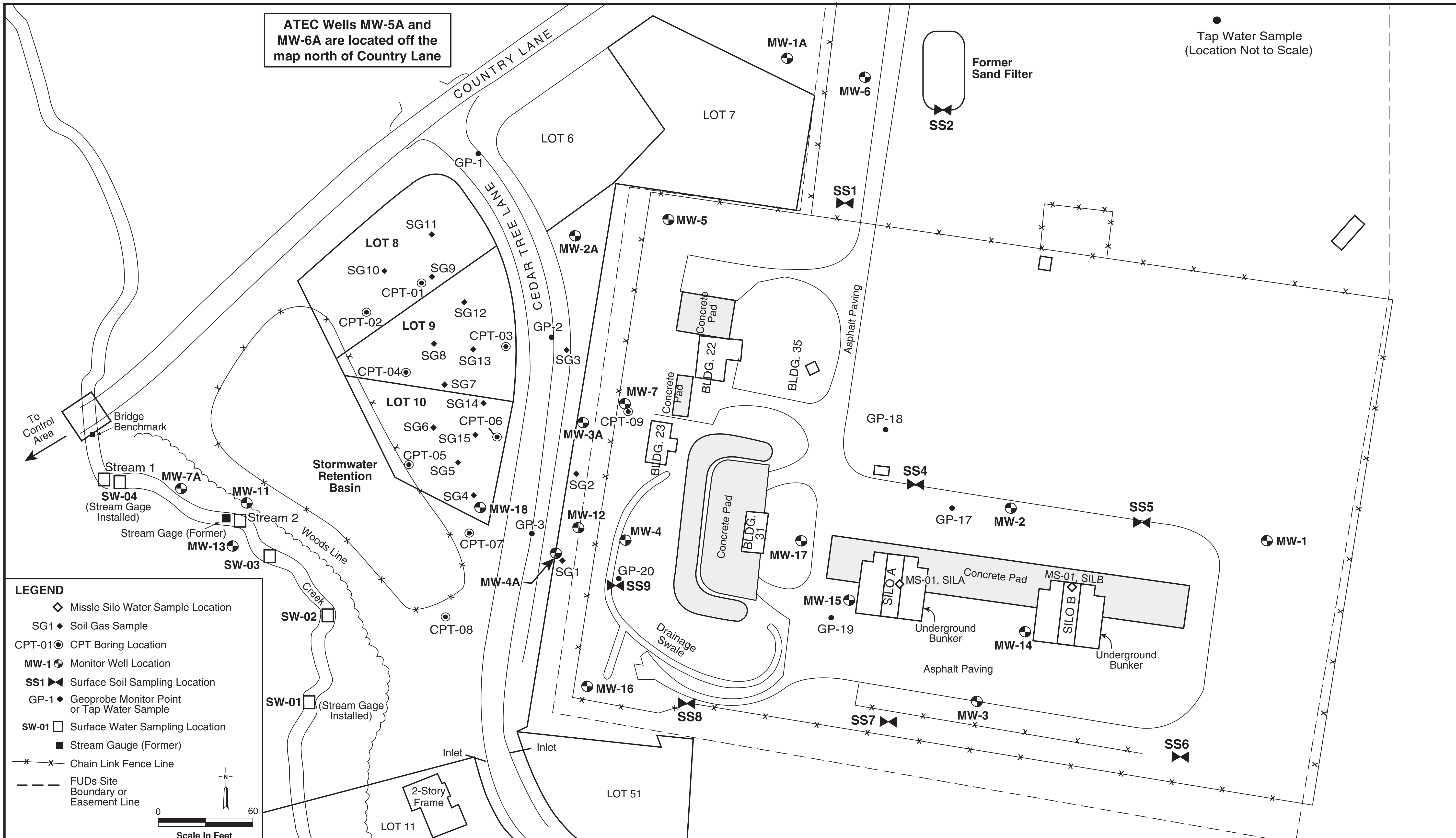

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FIGURE 1-2 SITE MAP
NIKE LAUNCH AREA

The Nike Launch Area is currently being leased by Charles County to the Maryland Indian Heritage Society for use as a cu ltural center; however, no identified cultural or historical resources are located at the site. Barracks are located adjacent to the missile silos at the Nike Launch Area and are also being used by the Maryland Indian Heritage Society. The Maryland Indian Heritage Society uses all former Nike Launch Area facilities except the missile silos. The two subsurface silos are partially filled with water. The drains in the vehicle maintenance shop and the barracks discharged to an on-site sand filter (leach field). Sanitary wastes from the Indian Heritage Society continue to be discharged to the sand filter.

1.3 ENVIRONMENTAL SETTING

The following environmental setting summary is based on information contained in the report, *Final Screening Site Inspection, Waldorf Launch* (Halliburton NUS, 1992) and updated with additional information collected during the RI.

1.3.1 Water Supply

Water supply to the area surrounding the Nike Launch Area comes from both deep groundwater aquifers and surface water sources such as the Potomac River.

1.3.1.1 Groundwater Supply

The communities of Mattawoman and Waldorf are serviced by Waldorf Water System (WWS). Currently, 14 deep wells (500 to 600-ft-deep) supply the system with groundwater. Eight of these wells tap the Magothy Formation; six wells draw from the Patapsco Formation. Four of the WWS wells, all drawing from the Magothy Formation, are located within the 4-mile radius: one is 0.17 mile east-southeast of the site; one is 0.97 mile west; one is 2.70 miles southwest; and one is 3.88 miles south-southwest.

Three deep private wells within the 4-mile radius of the site supply individual developments with potable water. The Idlewood Mobile Home Park, located approximately 1.86 miles southwest of the site, is supplied by a 550-ft-deep well that draws from the Magothy Formation. The Bellewood Water Association supplies drinking water to 128 residents from a 550-ft-deep well that draws from the Magothy Formation. This well is located approximately 3.05 miles south of the site. A single 605-ft-deep well, located approximately 2.92 miles south of the site that taps the Magothy Formation, supplies the Beantown Park Water Association.

Groundwater at the site typically flows west-northwest; therefore, downgradient wells located west-northwest from the site could be affected by potential discharges from the site. Of those wells identified within a 4-mile radius of the site (as discussed earlier), the WWS well located 0.97 mile west of the site and those assumed private domestic wells supplying persons within the 4-mile radius not supplied by water supply systems may be downgradient of the site. The homes along Country Lane Road between Nike Drive to the west of the site and Cedarville Road to the east of the site are supplied by WWS. This includes the newest housing development located to the west of the site on Country Lane Road.

1.3.1.2 Surface Water Supply

Washington Suburban Sanitary Commission (WSSC) provides potable water to some residents to the north and northwest of the site. Two surface water intakes located on the Patuxent and Potomac rivers are water sources for the WSSC. Neither of these intakes can be impacted by drainage from the site since they are located up river from the site and Mattawoman Creek (Halliburton NUS, 1992).

1.3.2 Regional Geology and Hydrogeology

The site is located in the Atlantic Coastal Plain Physiographic Province, and the area is underlain by sedimentary and metamorphic rocks. The sedimentary deposits consist of gravels, sands, silts, and clays up to 2,000 ft thick. The metamorphic rock formations consist of granite, gabbro, quartz diorite, schist, rhyolite, greenstone, and quartzite.

The shallow deposits in the area surrounding the site consist of Quarternary age Upland and Lowland Deposits consisting of sand and gravel with some silt and clay. In the region, these two units have a maximum combined total thickness of 200 ft. Underlying these deposits are the Calvert, Nanjemoy, Marlboro Clay, and the upper portion of the Aquia formation. All of these formations are confining units with a total thickness of 150 to 300 ft. The average vertical hydraulic conductivity in this interval is 1×10^{-5} ft/day. Underlying these deposits are the

Monmouth, Magothy, and Patapsco formations. These formations are all productive aquifers in the region.

1.3.3 Local Geology and Hydrogeology

Based on the soil boring and cone penetrometer data collected at the Nike Launch Area, the generalized statigraphy of the shallow Upland Deposits at the site consist predominantly of the following geologic units below ground surface (depths are approximate and vary slightly for each location):

- 0 to 5 ft: Medium to dark brown sandy silt and clay (approximately 70% silt and clay and 30% fine to medium sand).
- 5 to 20 f t: Alternating bands of brownish gray medium to fine grained sand (approximately 85% sand and 15% silt) and fine to coarse sandy gravel (approximately 60% gravel, 35% sand, and 5% silt).
- 20 to 35+ ft: Medium brown clayey silt with very fine sand (approximately 80% clayey silt and 20% very fine sand).

These shallow geologic units are found underneath most of the site. Geologic cross-sections have been developed based on the soil boring and cone penetrometer test (CPT) data collected at the site. Figure 1-3 shows the locations of the cross-sections, and Figure 1-4 presents three geologic cross-sections across the site. As shown on Figure 1-4, the primary water bearing geologic unit consists of interbedded sands and gravels. A clayey silt confining unit has been observed below the sand and gravel water bearing zone. This clayey silt unit was greater than 16 ft thick at GP-20 and, based on the cone penetrometer dynamic pore pressure data, the hydraulic conductivity of the clayey silt unit is low (approximately 5.0×10^{-5} centimeters/second [cm/sec]).

Groundwater within the northern Charles County Area is found in shallow unconfined Quaternary-age, surficial deposits and in deep Tertiary- and Cretaceous-age confined aquifers. Water storage and movement in these unconsolidated deposits occur within the interstices or voids of the unconsolidated overburden. The surficial aquifer is recharged through direct precipitation infiltration. The deeper aquifers are recharged through slow percolation of local precipitation and infiltration of precipitation through outcrops located west of the Potomac River in Virginia.

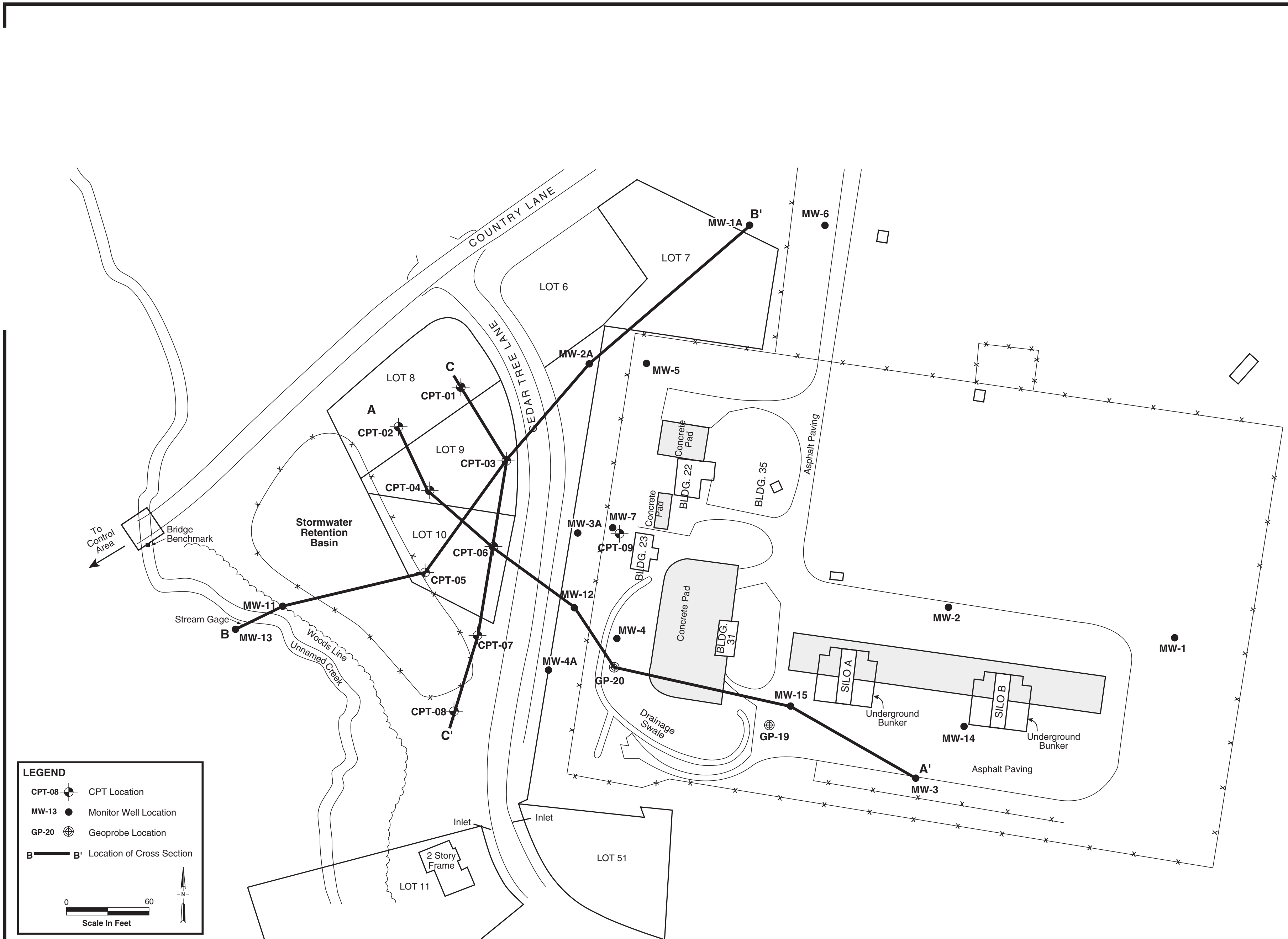

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FIGURE 1-3 INDEX TO SITE CROSS-SECTIONS

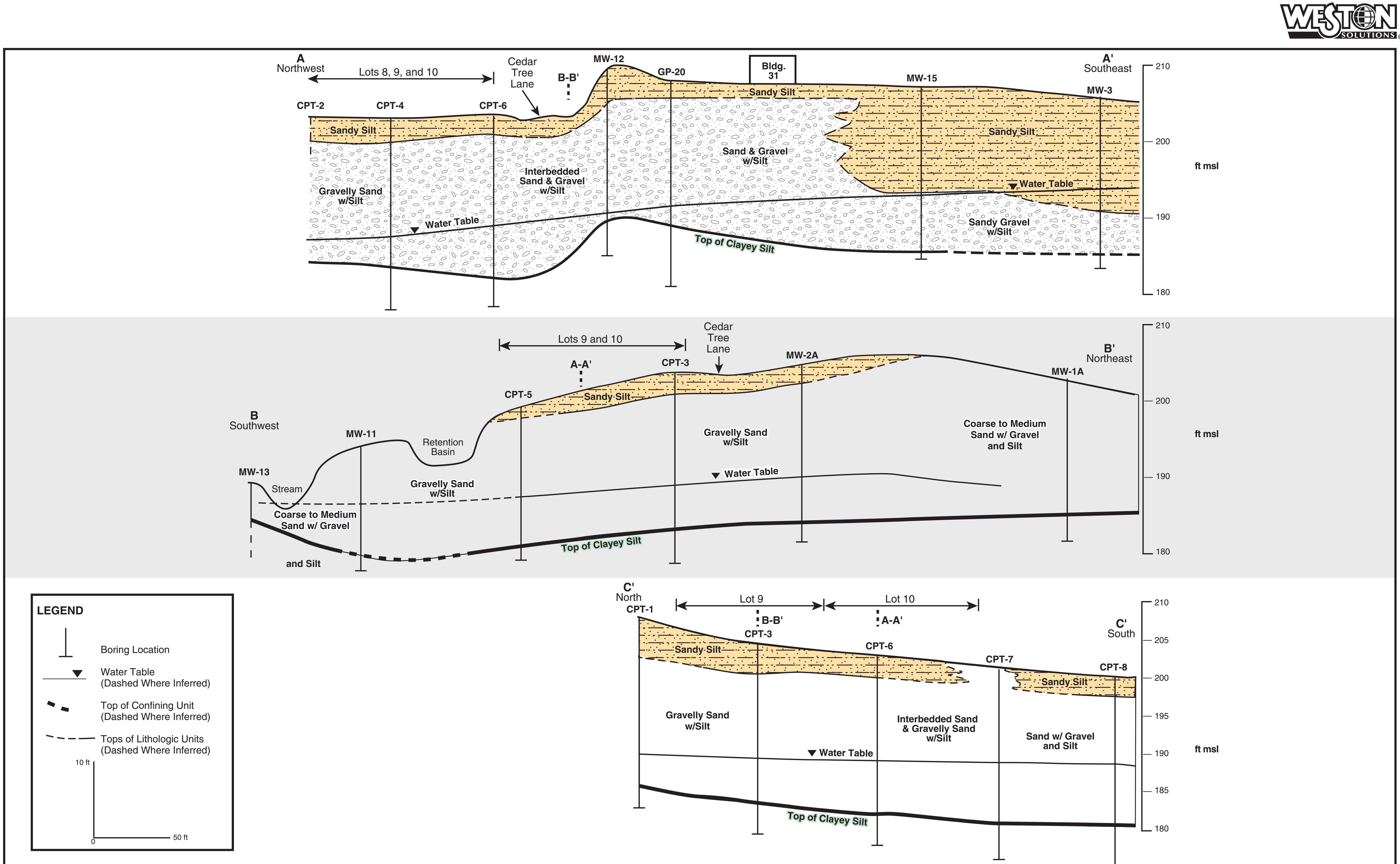

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FIGURE 1-4 SITE GEOLOGIC CROSS-SECTIONS

In general, streams dissect the Quaternary-age Upland and Lowland Deposits; their hydrologic function as conduits is largely limited to transmitting groundwater to maintain stream flow and to recharge underlying deposits through downward vertical leakage; however, these units will locally yield limited quantities of groundwater to large-diameter dug or bored wells. Wells tapping the Upland Deposits in the general vicinity of the site have yields ranging from 1.5 to 15 gallons per minute (gpm).

The shallow unconfined water bearing zone beneath the Nike Launch Area occurs within a sand and gravel unit with a saturated thickness of only 5 to 10 ft, due to the clayey silt confining unit identified beneath the site. The depth to water ranges from approximately 3 ft along the banks of the unnamed stream to between 15 and 22 ft beneath the Nike Launch Area. Groundwater yields at the site monitoring wells averaged less than 1 gpm during well development and purging. Groundwater beneath the site flows predominantly westward and discharges approximately 400 ft downgradient into the unnamed tributary to the Mattawoman Creek.

To estimate the groundwater travel time across the Site, the average groundwater seepage velocity (v) was calculated using the average surficial aquifer hydraulic conductivity (9.3 feet/day; K) and porosity (0.35; θ), the horizontal groundwater gradient (-0.012 feet/feet; i) and the following seepage velocity equation: $(v) = -K\ i\ /\ \theta$. The resulting groundwater seepage velocity for the surficial water bearing zone at the Launch Area was calculated as 0.32 feet/day.

1.3.4 Surface Water

The site is essentially flat terrain, and there appears to be little potential for significant runoff to leave the site. Surface drainage on the west side of the site flows approximately 300 ft overland to the southwest to an unnamed tributary of Mattawoman Creek. Surface water runoff that reaches Cedar Tree Lane is collected in storm drains and discharged into the storm water retention basin west of the site, between Lots 8, 9, and 10 (Figure 1-2) and the unnamed tributary, where it infiltrates down to the shallow groundwater.

The unnamed tributary flows northward approximately 600 ft to its confluence with Mattawoman Creek. Mattawoman Creek flows to the west and southwest, and eventually discharges into the

Potomac River. Another unnamed perennial stream passes approximately 700 ft northeast of the site, flowing northward into Mattawoman Creek about 1,500 ft north of the site.

Mattawoman Creek and the unnamed tributary are designated as Class I water bodies by the State of Maryland (the State) and are protected for the basic uses of water contact recreation; the growth and propagation of fish, other aquatic life, and wildlife; and water supply.

1.3.5 Land Use

The Nike Launch Area is on t he boundary of Prince Georges County and Charles County, Maryland. Land use around the site is primarily low-density residential. The nearest residences are adjacent to the west (including the Cedar Tree Property) and to the south property boundaries of the Nike Launch Area. Three lots designated for proposed residential housing are located approximately 50 to 100 ft to the west of the Nike Launch Area. Figure 1-5 presents an aerial view of land use around the site.

1.4 NATURE AND EXTENT OF CONTAMINATION

1.4.1 Groundwater Investigation

The groundwater was investigated at the Nike Launch Area by Donohue, Halliburton NUS, and WESTON. Five monitoring wells (MW-1 through MW-5) were installed in May 1987 by Donohue (Donohue, 1987). In May 1995, WESTON installed two monitoring wells (MW-6 and MW-7) at the Launch Area and three wells (MW-8, MW-9 and MW-10) at the Control Area. WESTON installed three wells at the Launch Area in 1999 (MW-11 through MW-13) and four more wells during 2003 (MW-14 through MW-17). Groundwater samples were collected in June 1987 by Donohue; in November 1991 by Halliburton NUS; in June 1995, June 1999, July 2001, October 2001, July 2003, October 2003, November 2004, December 2006 by WESTON; and in April 2008 by ERT.

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FIGURE 1-5 LAND USE – AERIAL PHOTOGRAPH

ATEC completed a groundwater investigation of the adjacent Cedar Tree property in November 1993 (ATEC, 1994b). The groundwater investigation consisted of the installation and sampling of six groundwater monitoring wells (MW-1A through MW-6A). In August 1994, A TEC conducted an Additional Phase II Subsurface Investigation at the Cedar Tree property (ATEC, 1994a). During this investigation, groundwater samples were collected from four new monitoring wells (MW-7A through MW-10A) (ATEC, 1994a). Only ATEC wells MW-2A, MW-3A, MW-4A, MW-5A and MW-7A fall within the investigation area, downgradient of the CCl_4 source area. The other ATEC wells are north, east and southeast of the Launch Area.

1.4.2 Groundwater Hydrology

Groundwater occurs under water-table conditions in the unconsolidated overburden deposits beneath the Nike Launch Area. Water-level measurements were recorded for all monitoring wells and the two stream gages prior to sampling during each sampling round conducted in 2003. The depths to water ranged from approximately 4 ft below ground surface (bgs) near the stream to 22 ft bgs at MW-7. Groundwater elevations ranged from 185.75 ft above mean sea level (MSL) in MW-13 in October 2003 to 196.25 ft above MSL in MW-2 in June 2003. Water level measurements indicated that the groundwater flows westward from the site toward the tributary to Mattawoman Creek at an average horizontal gradient of 0.012 ft/ft. Figure 1-6 shows the groundwater elevation contour map for the Nike Launch Area during June 2003.

The small unnamed creek downgradient of the site intercepts groundwater flow, preventing contaminated groundwater from migrating beyond the creek. This is supported by the clean water sample collected in ATEC well MW-7A, located downgradient of the site immediately across the tributary (Figure 1-6).

Slug tests were performed on MW-2, MW-4, and MW-7. The groundwater elevation data were collected with a transducer during the tests. These data were then analyzed with Aqtesolv™ for Windows using the Bouwer-Rice method.

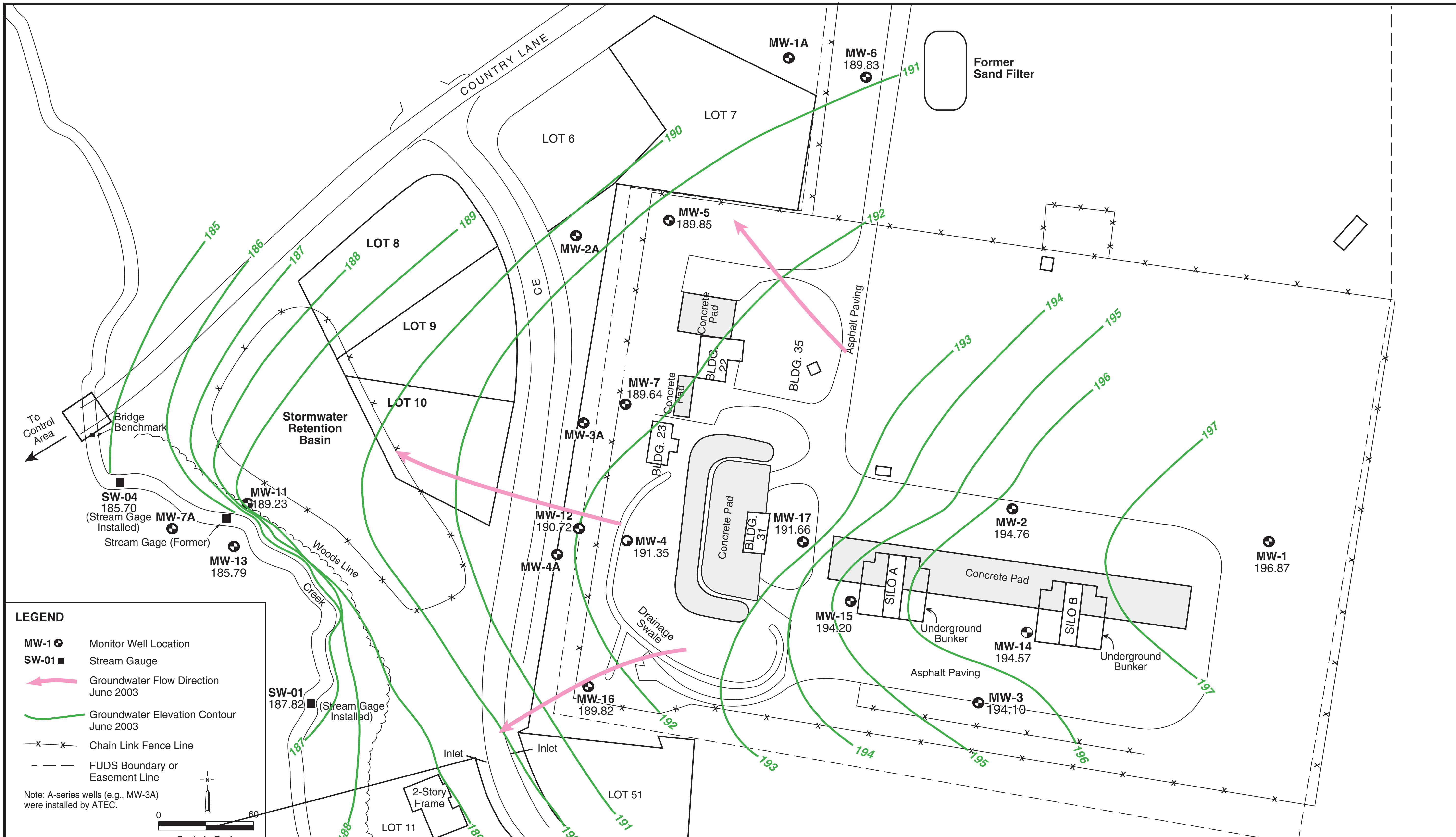

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FIGURE 1-6 GROUNDWATER ELEVATION MAP
JUNE 2003

The results of the hydraulic conductivity (K) calculations are as follows:

- MW-2: K = 2.61 to 3.05 ft/day (WESTON, 2000).
- MW-4: K = 1.04 to 1.38 ft/day (WESTON, 2000).
- MW-4: K = 2.43 to 3.68 ft/day. (WESTON, 2001).
- MW-7: K = 0.33 to 0.56 ft/day (WESTON, 2001).

Therefore, the average K calculated for all slug test results was 1.9 ft/day. However, results from the dissipation tests on the cone penetrometer (CPT) borings conducted in July 2001 are considered more accurate because no sandpack was used and discrete intervals were tested. The dissipation test results were as follows:

- CPT-03 (17-18 ft bgs): K = 1.7 ft/day.
- CPT-03 (18-19 ft bgs): K = 1.3 ft/day.
- CPT-06 (16.2-17 ft bgs): K = 27.1 ft/day.
- CPT-06 (17.2-18 ft bgs): K = 6.9 ft/day.

The dissipation test results ranged from 1.3 to 27.1 ft/day, with an average of 9.3 ft/day. These results indicate fairly uniform low flow conditions. The top of the confining unit slopes generally to the west-southwest below the three undeveloped lots (Lots 8, 9, and 10). The saturated thickness of the surficial sand unit is relatively thin (generally less than 8 ft).

1.4.2.1 On-Site Groundwater Sampling Results

Between 1987 and 2008, the groundwater was investigated and sampled at the Nike Launch Area by Donohue & Associates, Inc. (Donohue), Halliburton NUS, WESTON, and ERT. Fifteen monitoring wells (MW-1 through MW-7 and MW-11 through MW-18) were installed during this period. Groundwater samples were collected in June 1987 by Donohue; in November 1991 by Halliburton NUS; in June 1995, June 1999, July 2001, October 2001, July 2003, October 2003, and December 2006 by WESTON; and in April 2008 by ERT. The groundwater concentrations presented in this document are expressed in micrograms/liter (µg/L), which is equivalent to parts per billion (ppb).

Groundwater at the site has been analyzed for VOCs during the past 13 sampling rounds. The groundwater sampling locations are presented in Figure 1-2. Analytical results from between 1987 and 2008 are summarized in Table 1-1. VOCs (CCl_4 and TCE) were detected at concentrations exceeding drinking water maximum contaminant levels (MCLs) of 5 micrograms per liter (µg/L) during all of the sampling rounds. The concentrations of VOCs within the groundwater of MW-4 have consistently been the highest concentrations observed at the Nike Launch Area. In 2008, CCl_4 was detected above the MCL in MW-4, MW-7, and MW-12 at 340 µg/L, 11 µg/L, and 98 µg/L, respectively. The concentration of TCE was detected above the MCL only in MW-4 (19 µg/L), and below the MCL in MW-12 (3.2 µg/L). Figure 1-7 presents the groundwater concentration map for CCl_4 based on the 2008 groundwater sampling results.

The concentration of CCl_4 in MW-4 varied during the different sampling events—450 µg/L (1987), 34 µg/L (2003), and 340 µg/L (2008). Concentrations within MW-7, 90 ft north of MW-4, and MW-12, 30 ft west of MW-4, also fluctuated during the course of sampling. The concentration of TCE has also varied during sampling—9 µg/L (1987), 3 µg/L (2003), and 19 µg/L (2008).

Groundwater sampling at the Nike Launch Area has also been performed for semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, metals, perchlorate, total petroleum hydrocarbons (TPH), and radioactivity analyses. Based on the findings presented in the RI, none of these parameters was detected at concentrations exceeding MCLs, with the exception of gross alpha radiation in a sample from one upgradient monitoring well and unfiltered metals in the wells (Halliburton NUS, 1992). The metals results of the corresponding filtered samples were all below MCLs, indicating that these constituents do not present an environmental concern.

Table 1-1 Summary of Groundwater Sampling Results Between 1987 and 2008

MCL[a]	**Sample Results for CCl_4 reported in µg/L.**												
5 µg/L	**May-87**	**Nov-91**	**Dec-93**	**Jun-95**	**Jun-99**	**Jul-01**	**Oct-01**	**Jun-03**	**Oct-03**	**Nov-04**	**May-05**	**Dec-06**	**Apr-08**
MW-4	**450**	**400**	NS	**180**	**314**	**180**	**240**	**34**	**110**	**97**	**190**	NS	**340**
Qualifier													
MW-7	---	---	---	**6**	**20**	**10**	**19**	**9**	**17**	**24**	**19**	NS	**11**
Qualifier													
MW-11	---	---	---	---	1.0	2.0	0.2	0.7	1.0	0.9	3.0	NS	ND
Qualifier					U		U	J		J			U
MW-12	---	---	---	---	**131**	**110**	**190**	**43**	**98**	**130**	**130**	NS	**98**
Qualifier													
MW-16	---	---	---	---	---	---	---	1.0	0.2	0.9	0.1	NS	ND
Qualifier								U	J	J	J		U
MW-17	---	---	---	---	---	---	---	1.0	1.0	1.0	1.0	NS	ND
Qualifier								U	U	U	U		U
MW-18	---	---	---	---	---	---	---	---	---	---	---	**37**	ND
Qualifier													U
MW-4-A[b]	---	---	**210**	NS	NS	**200**	**260**	NS	NS	NS	NS	NS	NS
Qualifier													
MCL[a]	**Sample Results for TCE reported in µg/L.**												
5 µg/L	**May-87**	**Nov-91**	**Dec-93**	**Jun-95**	**Jun-99**	**Jul-01**	**Oct-01**	**Jun-03**	**Oct-03**	**Nov-04**	**May-05**	**Dec-06**	**Apr-08**
MW-4	**9**	**10**	NS	**9**	**13**	**9**	**14**	3	**6**	**7**	**11**	NS	**19**
Qualifier		B			J								
MW-7	---	---	---	5.0	1.0	0.4	0.5	0.3	0.4	0.6	0.6	NS	ND
Qualifier				U	U	J		J	J				U
MW-11	---	---	---	---	1.0	0.6	0.5	0.3	0.6	0.3	0.8	NS	ND
Qualifier					U			J	J	J	J		U
MW-12	---	---	---	---	1.0	4.0	**12.0**	2.0	3.0	4.0	4.0	NS	3.2
Qualifier					U					J	J		J
MW-16	---	---	---	---	---	---	---	1.2	1.0	2.0	1.0	NS	ND
Qualifier													U
MW-17	---	---	---	---	---	---	---	1.0	0.1	0.2	1.0	NS	ND
Qualifier								U	J	J	U		U
MW-18	---	---	---	---	---	---	---	---	---	---	---	0.4	ND
Qualifier												J	U
MW-4-A[b]	---	---	**11**	NS	NS	**8**	**10**	NS	NS	NS	NS	NS	NS
Qualifier													

Table 1-1 Summary of Groundwater Sampling Results Between 1987 and 2008 (Continued)

[a]Federal and State MCLs - most stringent level provided.

[b]A series of wells installed off-site by ATEC.

Notes:
U - Not detected above limit indicated.
J – Estimated, calculated value below method detection limit.
B - Compound detected in laboratory method blank.
Bold values indicate exceedance of standard.
ND - non-detect
NS - not sampled

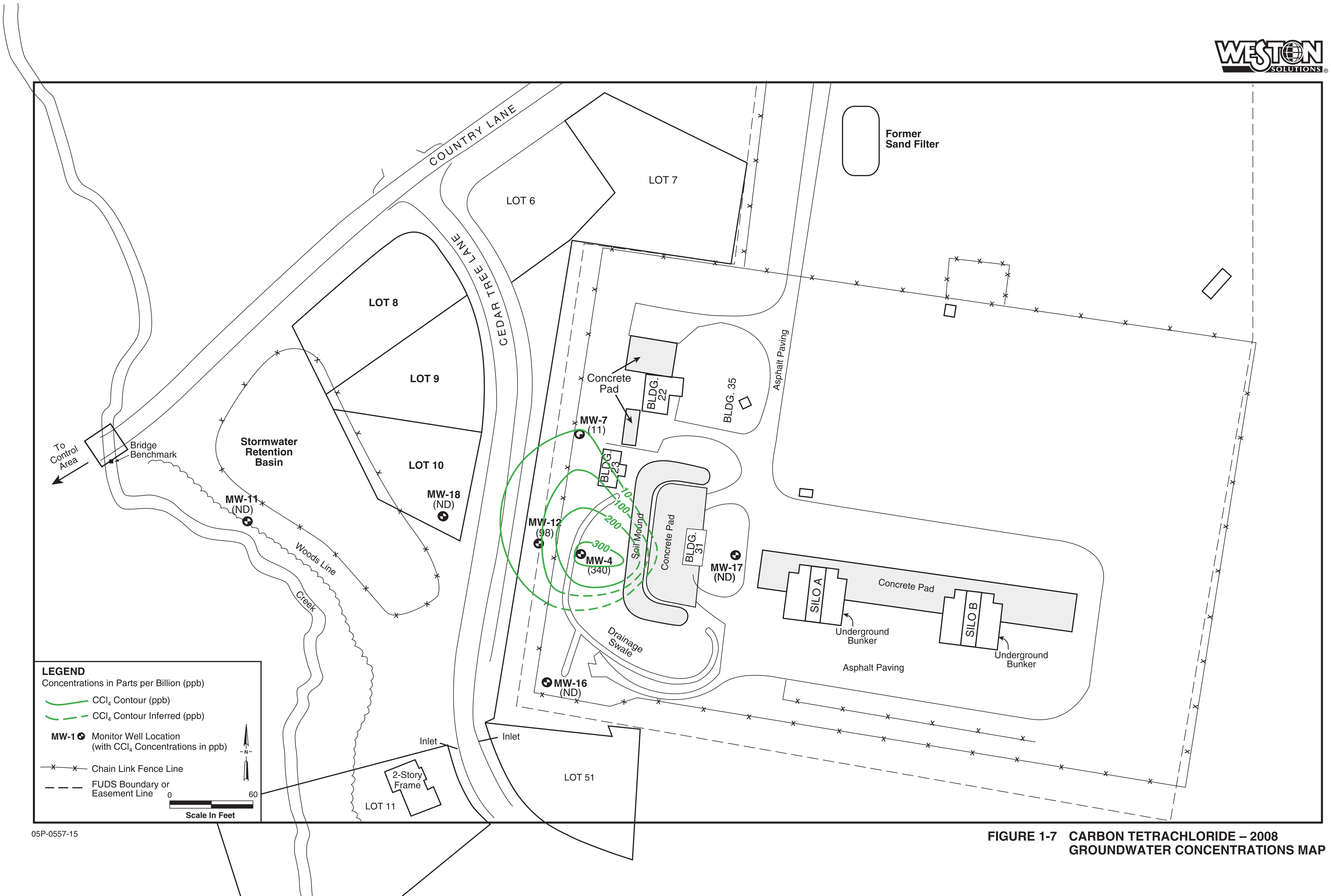

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FIGURE 1-7 CARBON TETRACHLORIDE – 2008 GROUNDWATER CONCENTRATIONS MAP

1.4.2.2 Off-Site Groundwater Sampling Results

Groundwater sampling was performed by ATEC at the Cedar Tree Property in November 1993 and August 1994. Groundwater samples were collected from seven ATEC monitoring wells at the site (MW-1A through MW-7A) and analyzed for priority pollutants, which include pesticides, PCBs, 13 metals, cyanide, phenols, VOCs, and SVOCs. The locations of the ATEC monitoring wells (identified with an 'A' suffix) and Geoprobe® sampling points are presented in Figure 1-2.

CCl_4 was detected in MW-3A and MW-4A at concentrations of 44 and 210 µg/L, respectively. TCE was detected at concentrations above the 5 µg/L MCL in samples collected from MW-4A (11 µg/L). CCl_4 and TCE were not detected in the groundwater collected from ATEC wells MW-1A, MW-2A, MW-5A, MW-6A or MW-7A (WESTON, 2004a).

To determine the groundwater concentration of CCl_4 within the vacant Lots 8, 9, and 10, an additional groundwater sampling well (MW-18) was installed downgradient of MW-4 and MW-12. MW-18 was placed in the southern corner of the Lot 10 boundary line. The December 2006 groundwater sampling results for MW-18 showed a CCl_4 concentration of 37 µg/L, which is below the calculated groundwater remediation goal for vapor intrusion (see Subsection 3.2.1.3), but not the groundwater MCL. CCl_4 was not detected at MW-18 in 2008.

No VOCs were detected in monitoring well MW-7A located across the creek downgradient of the site. Off-site sampling results indicate the VOC contamination has not migrated beyond the unnamed creek.

1.4.3 Surface Water Investigation

Surface water samples were collected in June 1999, June 2003, and October 2003. Sampling locations are shown in Figure 1-2. Surface water samples were submitted to certified environmental laboratories for the following analytical parameters:

- VOCs– not detected.
- PCBs– not detected.

- Perchlorate–not detected.
- Metals–detected at concentrations below MCLs.
- SVOCs–Di-2-butylphthalate was detected at concentrations below MCLs.
- Pesticides–Endrin aldehyde was detected at concentrations below MCLs.

The detection of phthalates and pesticides in the samples was determined by OnSite Labs to be due to lab contamination, as they were also detected in the associated method blanks (WESTON, 2000).

1.4.4 Soil Gas Investigation

In July 1996, WESTON completed soil gas collection and analysis from three lots (8, 9, and 10) located in the Cedar Tree property development. These soil gas sample locations are shown in Figure 1-2. CCl_4 and TCE were detected in the soil gas samples collected from the three lots at concentrations less than 10 µg/L. Sample results are summarized in Table 1-2.

During 2008, soil gas collection and analysis were conducted for 10 sampling locations at Lots 8, 9, and 10, and 5 sampling locations along the western boarder of Nike Launch Area using passive soil gas sampling methods (i.e., GORE-SORBER). Figure 1-8 shows the soil gas sampling locations used by ERT. CCl_4 and TCE were detected at SG-1E, and CCl_4 was detected at SG-2E (Table 1-2). CCl_4 and TCE were not detected in soil gas beneath Lots 8, 9, and 10 in 2008.

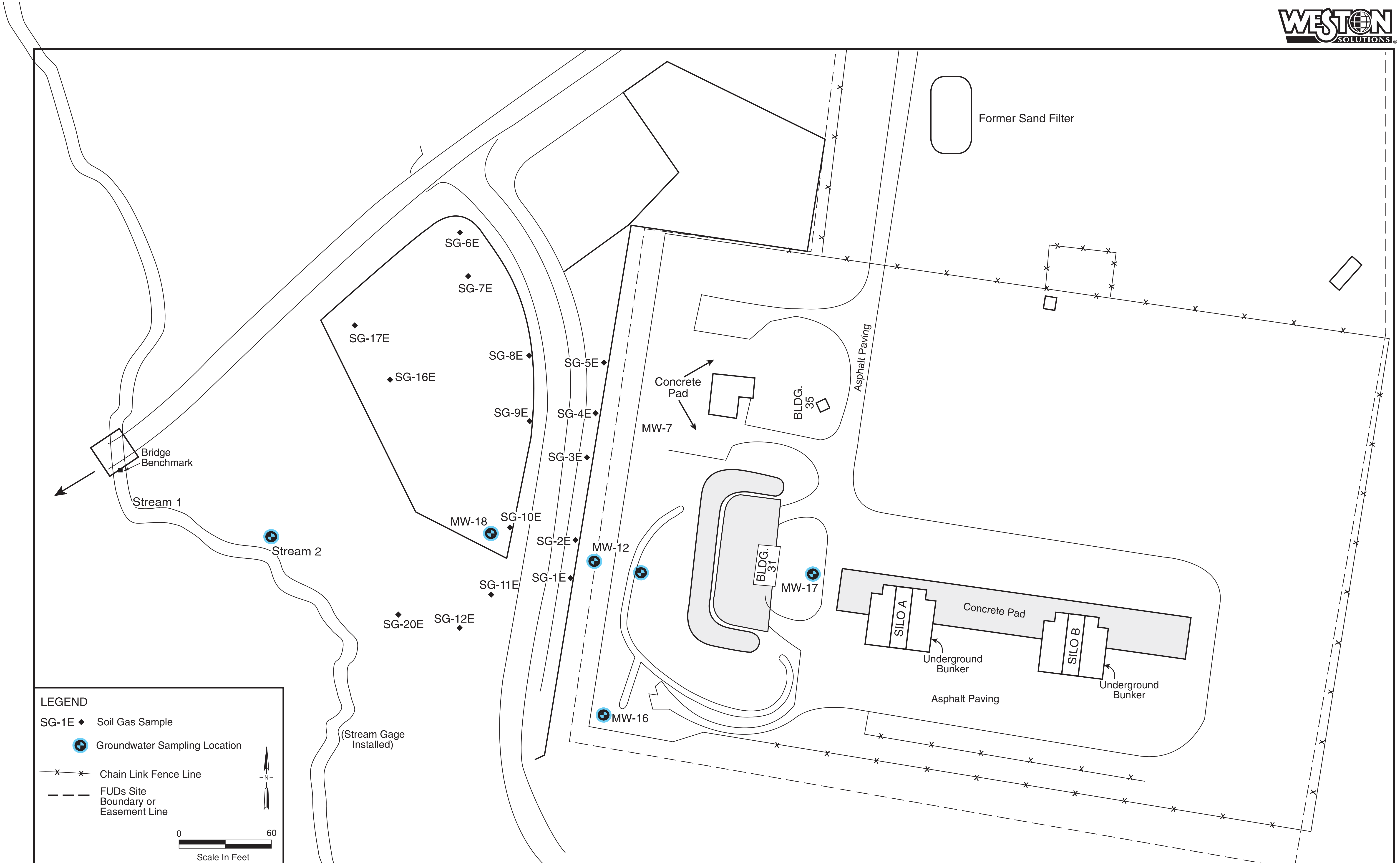
1.4.5 Baseline Risk Assessment Results

WESTON submitted a Baseline RA for the Nike Launch Area in September 1996 (WESTON, 1996) that examined the potential risk to future residents on Lots 8, 9, and 10 of the Cedar Tree property due to the migration of CCl_4 and TCE from groundwater to the basements of the residential dwellings, if built. The scope of this RA was limited to the current groundwater contamination near the southwestern border of the Nike Launch Area and the neighboring off-site area of the Cedar Tree property. The RA was based on the results of the soil gas survey and groundwater sampling events. The findings of the 1996 RA were updated in the 2004 RI Report and are summarized in the following paragraphs (WESTON, 2004a).

Table 1-2 1996 and 2008 Soil Gas Sample Depths and Results

1996 Results – WESTON					2008 Results* – ERT			
Sample ID	**Depth (ft bgs)**	**Analytical Results**			**Sample ID**	**Depth (ft bgs)**	**Analytical Results**	
		CCl_4	**TCE**				**CCl_4**	**TCE**
Upgradient		**units: (µg/L)**			*Upgradient*		**units: (µg/L)**	
SG-1W	15	14	23		SG-1E	3–4	0.022	0.001
SG-2W	15	16	ND		SG-2E	3–4	0.005	ND
SG-3W	15	8	ND		SG-3E	3–4	ND	ND
Downgradient					SG-4E	3–4	ND	ND
SG-4W	8	6	ND		SG-5E	3–4	ND	ND
SG-5W	8	4	ND		*Downgradient*			
SG-6W	8	1	ND		SG-6E	3–4	ND	ND
SG-7W	15	0.02	0.05		SG-7E	3–4	ND	ND
SG-8W	8	3	0.07		SG-8E	3–4	ND	ND
SG-9W	15	3	ND		SG-9E	3–4	ND	ND
SG-10W	10	3	ND		SG-10E	3–4	ND	ND
SG-11W	8	2	0.08		SG-11E	3–4	ND	ND
SG-12W	8	4	ND		SG-12E	3–4	ND	ND
SG-13W	13	4	ND		SG-16E	3–4	ND	ND
SG-14W	8	3	ND		SG-17E	3–4	ND	ND
SG-15W	8	4	ND		SG-20E	3–4	ND	ND

Notes:
* Soil gas samples were obtained using GORE-SORBER® modules (ERT, 2009). GORE-SORBER® results were reported from the laboratory in mass values of µg per sample. By using the Millington Quirk model and soil data (e.g., type, porosity), the laboratory converted the values to concentration in µg/L.
ND = Not detected.



09P-1080-2

FIGURE 1-8 2008 SOIL GAS SAMPLING ERT

Risks were calculated using the maximum contaminant concentration in the groundwater and soil gas samples. The carcinogenic risks to the future resident as a result of childhood exposure to CCl_4 based on modeling results from 2003 groundwater and 1996 soil gas data were 2.4E-06 and 1.2E-05, respectively. The carcinogenic risks to the future resident as a result of childhood exposure to TCE based on modeling results from groundwater and soil gas data were substantially lower, 6.2E-09 and 1.9E-08, respectively.

Under the childhood exposure scenario, the total calculated carcinogenic risks were 2.4E-06, based on 2003 groundwater data, and 1.2E-05, based on 1996 soil gas data. These risk estimates represent upperbound, incremental probability of an individual developing cancer over a lifetime as a result of exposure as a child to CCl_4 and TCE in the basement air. For example, the carcinogenic risk of 2.4E-06 indicates that there is a chance for approximately two excess cancer cases to develop in a population of 1 million individuals as a result of exposure during childhood to CCl_4 and TCE concentrations in the basement air, based on a model using groundwater data. CCl_4 was the major contributor (more than 99% of the above risks) to the carcinogenic risks. The carcinogenic risks to the future resident as a result of adult exposure to CCl_4 based on modeling results from groundwater and soil gas data were 2.6E-06 and 1.3E-05, respectively. The carcinogenic risks to the future resident as a result of adult exposure to TCE, based on modeling results from groundwater and soil gas data, were substantially lower, 6.6E-09 and 2.0E-08, respectively.

Under the adult exposure scenario, the total calculated carcinogenic risks were 2.6E-06, based on groundwater data, and 1.3E-05, based on soil gas data. This indicates the chance for approximately three excess cancer cases to develop in a population of 1 million individuals from exposure during adulthood to CCl_4 and TCE concentrations based on groundwater data. The total calculated risk values are the same as the risk values for CCl_4, indicating that CCl_4 was the major contributor (more than 99% of the above risks) to the carcinogenic risks.

The U.S. Environmental Protection Agency (EPA) has determined that when the carcinogenic risk resulting from reasonable maximum exposures for both current and future land use is less than 1E-06 (one case in 1 million individuals), action is generally not warranted unless there are adverse environmental impacts (EPA, 1991). In general, risks that fall within the range of 1E-06 to 1E-04 (1 in 10,000) are considered acceptable (USACE, 1995); however, the risk manager may decide that a risk within this range is unacceptable based on site-specific issues. Based on the above results, the carcinogenic risks to the future residents resulting from inhalation of indoor air in the basements of the planned houses in Lots 8, 9, and 10 are within the risk range of 1E-06 to 1E-04.

Noncancer health effects were evaluated by calculating hazard indices (HIs). The total HIs for the future child resident based on modeling results from groundwater and soil gas data were 0.9 and 4.8, respectively. The total HIs for the future adult resident based on modeling results from groundwater and soil gas data were 0.2 and 1.0, respectively. The total HIs were based on the noncancer health effects of CCl_4. Based on the above results, the noncancer hazard index (HI), calculated using soil gas data, for the child resident exceeds the regulatory threshold value of unity (1). The HI is not a mathematical prediction of the incidence or severity of effects. When a value of unity (1) is exceeded, it merely indicates that there is a potential for noncarcinogenic health effects under the defined exposure conditions; however, conservative assumptions that lead to upperbound estimates of risk were used in this RA. The actual risk under the selected scenarios is likely to be lower. The HI for the adult resident based on modeling results from groundwater and soil gas data is at or below the threshold value of 1. Therefore, the inhalation exposure to indoor air is unlikely to result in any adverse noncancer health effects in the case of the adult resident.

Because of the effects of natural attenuation, the risks associated with vapor intrusion at Lots 8, 9, and 10 have diminished since 2004. To confirm these results, USACE collected indoor air samples from the first floor and basement of the newly constructed home on Lot No. 9 on Cedar Tree Lane. This house was constructed above the existing Nike Launch Area contaminant plume in the area where vapor intrusion of contaminants has been a concern. The indoor air samples were collected on 1 December 2010 and the contaminants of concern, CCl_4 and TCE, were not detected. These results confirmed that in the house built on Lot No. 9, above the downgradient groundwater contaminant plume, there is no current risk to human health via the vapor intrusion pathway.

1.4.6 Groundwater Model

A one-layer, homogeneous groundwater flow and transport model (WinTran®) was used to predict migration of the CCl_4 plume downgradient and off-site of the Nike Launch Area. WinTran® is a two-dimensional groundwater flow and contaminant transport model developed by Environmental Simulations, Inc. (Rumbaugh, 1995). This model was selected because it is a thoroughly documented and verified numerical model capable of simulating the effects of wells, ponds, line sources, and groundwater sinks.

Steady-state groundwater flow conditions were simulated to represent the long-term and average conditions that dictate groundwater flow. Steady-state heads were determined by generating the statistical average of the last two rounds of water levels collected at the site. The model incorporated the June and October 2003 water-level elevation data. These data reflect some seasonal variation, thereby making the model more representative of long-term site conditions.

Three groundwater flow/contaminant transport prediction scenarios were simulated in 2004 using the model to determine the following:

- When the concentrations of CCl_4 would decrease below 48 µg/L in the groundwater beneath Lots 8, 9, and 10 (Prediction Scenario A).
- When the concentrations of CCl_4 would decrease below 48 µg/L in the entire groundwater plume (Prediction Scenario B).
- When the concentrations of CCl_4 would decrease below the MCL of 5 µg/L in groundwater beneath Lots 8, 9, and 10 (Prediction Scenario C).

Results of Prediction Scenario A in 2004 indicated that concentrations of CCl_4 would decrease below 48 µg/L in the groundwater beneath Lots 8, 9, and 10 in 1,500 days (4.1 years). Results of Prediction Scenario B indicate that concentrations of CCl_4 would decrease below 48 µg/L in the groundwater plume in 2,240 days (6.1 years). Results of Prediction Scenario C indicate that concentrations of CCl_4 would decrease below 5 µg/L in the groundwater beneath Lots 8, 9, and 10 in 4,300 days (11.8 years). The results from the 2008 groundwater sampling analyses supported these predictions.

1.5 REPORT ORGANIZATION

The remainder of the FS report has been organized as follows:

- **Section 2, Applicable or Relevant and Appropriate Requirements**— Identifies and evaluates federal and State regulations as they may apply to the Nike Launch Area.
- **Section 3, Development of Remedial Action Objectives and Technology Screening**—Develops remedial action objectives and evaluates technologies that may be effective in meeting the objectives.
- **Section 4, Development of Remedial Action Alternatives**—Technologies that were retained in Section 3 are grouped into remedial alternatives that cover a r ange of remediation strategies.
- **Section 5, Detailed Analysis of Remedial Action Alternatives**—Remedial action alternatives that were retained in Section 4 are analyzed in detail.
- **Section 6, Comparative Analysis of Alternatives**—The remedial alternatives that were analyzed in detail in Section 5 are compared among each other.
- **Section 7, References**—Lists the references cited in the report.

2. APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Applicable or relevant and appropriate requirements (ARARs) have been defined by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) as the following:

Applicable requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a Comprehensive Environmental Response, Compensation, and Liability (CERCLA) site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable (NCP, 1994).

Relevant and appropriate requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate (NCP, 1994).

Furthermore; EPA has stated the following in its quick reference fact sheet dated August 1991:

> "Section 1221(d) of the CERCLA, as amended by the 1986 Superfund Amendments and Reauthorization Act (SARA), requires that on-site remedial actions must attain or waive Federal or more stringent State ARARs upon completion of the remedial action. The 1990 NCP requires compliance with ARARs during remedial actions as well as at their completion, and compels attainment of ARARs during removal actions to the extent practicable, considering the exigencies of the situation."

2.1 INTRODUCTION

Identification of potential ARARs is performed on a site-specific basis. CERCLA, SARA, and the NCP do not provide across-the-board standards for determining whether a particular remedy will produce an adequate cleanup at a particular site. Rather, the process recognizes that each site will have unique characteristics that must be evaluated and compared to those requirements that apply under the given circumstances. Under SARA, permits for compliance with the Resource Conservation and Recovery Act (RCRA), National Pollutant Discharge Elimination System (NPDES), and Clean Air Act (CAA) regulations for on-site remedial actions are not required. CERCLA and SARA, however, do require that the selected remedial alternative meet applicable or relevant and appropriate regulations where possible. The remedial action selected must meet all enforceable and applicable requirements unless a waiver from specific requirements has been granted. A waiver from compliance with a specific potential ARAR can be granted for an alternative under the following circumstances:

- The alternative is an interim measure and will become part of a total remedial action that will meet ARARs.
- Compliance with the ARAR is technically impractical from an engineering perspective.
- Compliance with the ARAR will result in a greater risk to human health and the environment than other alternatives.
- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.
- With respect to a state ARAR, the State of Maryland (the State) has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the State.
- Compliance with the ARAR would be costly relative to the degree of protection or risk reduction likely to be attained, and the expenditure would jeopardize remedial actions at other sites.

ARARs may be divided into the following categories:

- Chemical-specific requirements are health- or risk-based concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants. These limits may take the form of action levels or discharge levels.
- Location-specific requirements are restrictions on activities that are based on the characteristics of a site or its immediate environment. An example would be restrictions on wetlands development.
- Action-specific requirements are controls or restrictions on particular types of activities in related areas such as hazardous waste management or wastewater treatment. An example would be RCRA incineration standards.

USACE has reviewed the ARARs in the 2004 FFS and has instructed WESTON to check for updates or new ARARs applicable to the site. The following ARARs and requirements to-be-considered (TBC) have been updated, or added, with the most current dates applicable to federal, state, or local requirements.

2.2 CHEMICAL-SPECIFIC ARARS

Chemical-specific ARARs set health- or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants. These requirements generally set protective cleanup levels for the COCs in the designated media or indicate a safe level of discharge that may be incorporated in a remedial activity.

2.2.1 Resource Conservation and Recovery Act

The State has been delegated the authority to administer the regulations that govern the identification and listing of hazardous waste. The two basic classifications of hazardous waste are as follows:

- Listed hazardous wastes.
- Characteristic hazardous wastes:
  - Ignitability (D001 waste).
  - Corrosivity (D002 waste).
  - Reactivity (D003 waste).
  - Toxicity (D004 to D043 wastes).

Requirements for treatment, storage, or disposal of hazardous wastes apply to a site if the site contains listed or characteristic hazardous waste that was treated or disposed of after the effective date of these regulations.

The COCs found at the Nike Launch Area do not meet the criteria for listed wastes under RCRA (40 Code of Federal Regulations [CFR].261 Subpart D). Furthermore, they do not exhibit the characteristics of ignitability, corrosivity, reactivity, or toxicity under 40 CFR 261 Subpart C. Therefore, the COCs at the Nike Launch Area are not classified as hazardous wastes under RCRA.

2.2.2 Federal Drinking Water Standards

EPA has developed drinking water standards, referred to as primary standards, to protect human health. Primary Drinking Water Standards consist of contaminant-specific standards, known as MCLs. For water that is to be used for drinking, the MCLs established under the Safe Drinking Water Act (SDWA) are generally the comparison standard. Drinking water standards apply to public water systems, which provide water for human consumption through at least 15 service connections, or regularly serve at least 25 individuals. Public water systems include municipal water companies, homeowner associations, schools, businesses, campgrounds, and shopping malls. In other cases, MCLs may be used as cleanup standards where either surface water or groundwater is or may be used for drinking water. The National Primary Drinking Water Standards for the Nike Launch Area COCs are as follows:

- CCl_4: 5 µg/L.
- TCE: 5 µg/L.

At the Nike Launch Area, groundwater and surface water are not currently used for drinking purposes. However, MCLs are relevant and appropriate for the Nike Launch Area because the State considers all groundwater as potential drinking water and requires that all groundwater meet MCLs.

2.2.3 Maryland Groundwater Quality Standards

The State mandates groundwater quality standards based on MCLs. These regulations are promulgated under Title 26 of the Code of Maryland Regulations (COMAR), Subtitle 08. These standards apply to a variety of drinking water supplier classifications. The State MCLs are based on potential adverse health effects resulting from long-term exposure to the contaminants in drinking water. The State MCLs may be used as cleanup standards where either surface water or groundwater is or may be used for drinking water. Groundwater at the Nike Launch Area, or in the vicinity, is not used for drinking water purposes because the area is supplied with public water from the local municipality. Therefore, the State MCLs are not applicable for the site, but are relevant and appropriate due to the potential for groundwater usage. MCLs for the primary COCs at the Nike Launch Area are summarized below:

- CCl_4: 5 µg/L.
- TCE: 5 µg/L.

The State does not provide groundwater quality standards related to groundwater migration to indoor air. Depending on the site-specific conditions, MDE may require additional evaluation, including modeling to evaluate potential risks from vapor migration to indoor air.

2.3 LOCATION-SPECIFIC ARARS

Location-specific requirements set restrictions on activities depending on the characteristics of a site or its immediate environs. In determining the use of these location-specific ARARs for selection of remedial actions at CERCLA sites, one must investigate the jurisdictional prerequisites of each regulation. Basic definitions, exemptions, etc., should be analyzed on a site-specific basis to confirm the correct application of the requirements.

2.3.1 Resource Conservation and Recovery Act

Floodplain Consideration—40 CFR 264.18(b) requires that a facility located in a 100-year floodplain be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood. Nike Launch Area is not located within the 100-year floodplain.

Seismic Consideration—40 CFR 264.18(a) requires that portions of new facilities where treatment, storage, or disposal of hazardous wastes are conducted must not be located within 200 ft of a fault that has had displacement in Holocene time. No fault meeting this definition exists at the Nike Launch Area.

Therefore, RCRA location-specific regulations are not applicable to the Nike Launch Area.

2.3.2 Endangered Species Act of 1973

The Endangered Species Act (ESA) of 1973, 16 United States Code (USC) 1531 et seq., is applicable if endangered or threatened species are present. It requires that action be taken to conserve endangered or threatened species. Remedial activities must not destroy or adversely modify the critical habitat upon which endangered or threatened species depend. No endangered or threatened species exist at the Nike Launch Area (Halliburton NUS, 1992).

The ESA of 1973 is not applicable to the Nike Launch Area.

2.3.3 Archaeological and Historic Preservation Act

The Archaeological and Historic Preservation Act (AHPA) (16 USC 469) provides for the preservation of historical and archaeological data that might otherwise be lost as a result of remedial actions. The AHPA requires that action be taken to preserve the data and differs from the National Historic Preservation Act (NHPA) in that it encompasses a broader range of resources than those listed on the National Register and mandates only the preservation of the data. There are no historical or archeological sites located within the Nike Launch Area.

The AHPA is not applicable to the Nike Launch Area.

2.3.4 Other Location-Specific Regulations

The following regulations were also considered for the Nike Launch Area, and were found to be not applicable:

- Floodplain Management—Executive Order 11988.
- Protection of Wetlands—Executive Order 11990.
- Bald and Golden Eagle Protection Act (16 USC 668 et seq.).

2.4 ACTION-SPECIFIC ARARS

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to site remediation. These requirements are triggered by the particular remedial activities that are selected to accomplish an alternative. Because there are usually several alternative actions for any remedial site, various requirements may be applicable or relevant and appropriate. These action-specific requirements do not in themselves determine which remedial alternative is selected; rather, they indicate how a selected alternative must be implemented.

2.4.1 Resource Conservation and Recovery Act

Under the provisions of RCRA, EPA has promulgated regulations governing the handling of hazardous waste. EPA has delegated responsibility for administering portions of the hazardous waste regulations to the State. The State has promulgated hazardous waste regulations under Title 26 of COMAR, Subtitle 13: Disposal of Controlled Hazardous Substances. The following are areas where potentially applicable action-specific ARARs exist for management of hazardous waste:

- Identification and listing of hazardous waste (COMAR 26.13.02).
- Standards applicable to generators of hazardous wastes (COMAR 26.13.03).

2.4.1.1 Standards Applicable to Generators of Hazardous Wastes

This regulation (COMAR 26.13.03) establishes the standards for generators of hazardous wastes. This regulation will be applicable if hazardous waste is generated during remedial actions. The regulations primarily include procedures for manifesting the waste off-site, pre-transport requirements (packaging, labeling, marking, and placarding), recordkeeping, and reporting. The accumulation time standard is under the pre-transport requirement subpart. A generator can accumulate hazardous waste on-site up to 90 days without a permit, or interim status (this is commonly referred to as the 90-day rule).

2.4.1.2 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) regulates the subsurface emplacement of liquids through the Underground Injection Control (UIC) program (40 CFR Parts 144-148), which governs the design and operation of five classes of injection wells in order to prevent contamination of underground sources of drinking water.

For any class of injection well used at a CERCLA site, the substantive provisions of the UIC program may be applicable. The UIC program regulates well construction, including the design of the well casing; well operation, including maintenance of injection pressure; and monitoring, including analysis of injected fluids and periodic demonstrations of well integrity. UIC administrative requirements may include permits, inventory records, and other reporting requirements.

2.4.1.3 Land Disposal Restrictions

Regulation 40 CFR 268 establishes concentration- or treatment technology-based restrictions on land disposal of RCRA hazardous wastes. Land disposal is defined to include, but not be limited to, any placement of a RCRA hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome or salt bed formation, or underground mine or cave. Any land disposal activities that involve placement of soils/sludges contaminated with listed or characteristics waste may be subject to the RCRA Land Disposal Restrictions (LDRs). EPA has determined that disposal and placement are synonymous for purposes of determining the applicability of the LDRs under RCRA.

As a result, RCRA LDRs could apply to any wastes generated during remedial activities that are determined to be hazardous waste. Established treatment standards are presented under Subpart D of 40 CFR 268. Wastes that meet these treatment standards may be directly land disposed. Wastes that do not meet these standards must be treated to meet the corresponding standard before they are placed in a landfill.

2.4.2 Air Quality

Air emissions regulations for the State are codified in COMAR 26.11. These regulations are potentially applicable to the Nike Launch Area for remedial actions that would result in air emissions. Potential air emissions sources would be evaluated against General Emission Standards, Prohibitions, and Restrictions, regulated under COMAR 26.11.06. Under the General Emissions Standards, Prohibitions, and Restrictions provisions, VOC emissions from any new source cannot exceed 20 pounds per day without treatment.

EPA has issued draft guidance to assist in evaluating the vapor intrusion exposure pathway and to determine if the pathway poses a significant risk to human health (EPA, 2002). MDE's Land Restoration Program (LRP) has incorporated this guidance as a screening criterion for the protection of human health.

The LRP is charged with assessing and cleaning up uncontrolled hazardous waste sites throughout Maryland to protect public health and the environment at sites contaminated by hazardous substances. Cleanups must abate immediate uncontrolled discharges, ensure that contaminated soil does not pose a risk to public health and the environment, address groundwater contamination that may affect drinking water supplies or otherwise pose a risk to public health and the environment, and address surface water discharges (MDE, 2006).

2.4.3 Maryland Uniform Environmental Covenants Act

The Uniform Environmental Covenants Act (UECA) (HB 679), dated October 1, 2005, enforces restrictions on the use of environmentally remediated real estate. The UECA establishes requirements for a new valid real estate document – an "environmental covenant" – to control the future use of Brownfields (i.e., real property that has sustained damage due to the presence or potential presence of a hazardous substance, pollutant, or contaminant, and has the potential for expansion, redevelopment, or reuse) when real estate is transferred from one person to another. The Nike Launch Area is currently owned by Charles County, and leased to the Maryland Indian Heritage Society for use as a cultural center; however, no identified cultural or historical resources are located at the site. Land use controls for Buildings 23 and 31 will be discussed with the USACE PM (see Subsection 6.2), but these controls are not governed by UECA; therefore, the UECA is not applicable to the Nike Launch Area.

2.4.4 Maryland Discharge Limitations

The State has promulgated regulations (COMAR 26.08) to protect the waters of the State. The State has adopted water quality criteria (COMAR 26.08.02) and discharge limitations (COMAR 26.08.03) for both surface water and groundwater (COMAR 26.08.03). These requirements will be applicable if a remedial action that involves a discharge to surface water or groundwater is selected. In either case, it would be necessary to obtain an NPDES permit for the discharge. The State would establish discharge limitations within the structure of the permit.

Groundwater criteria are based on State MCLs, as discussed in Subsection 2.2.3. EPA has established Ambient Water Quality Criteria as part of the Clean Water Act (CWA). These criteria are often used by states to establish discharge limitations. The State has promulgated specific water quality criteria based on the designated use of the water body (COMAR 26.08.02.03). The State has classified the Mattawoman Creek and the tributary that flows behind Lots 8, 9, and 10 of the Cedar Creek Property as Class I water bodies, protected for the basic uses of water contact recreation; the growth and propagation of fish, other aquatic life, and wildlife; and water supply.

3. DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES AND TECHNOLOGY SCREENING

3.1 INTRODUCTION

This section presents the development of remedial action objectives (RAOs), the results of the evaluation of remedial technologies, and the elimination of unsuitable remedial technologies. The four steps of this assessment are:

- Step 1—Development of RAOs.
- Step 2—Identification of general response actions for each RAO.
- Step 3—Identification and initial screening of appropriate feasible technologies and process options applicable to each general response action.
- Step 4—Evaluation of technology process options based on the criteria of effectiveness, implementability, and cost.

Appropriate RAOs, consisting of environmental media-specific goals for the protection of human health and the environment, are identified in the first step. RAOs specify the COCs, potential exposure routes and receptors, and acceptable chemical concentrations or ranges of concentrations for each potential exposure route.

In the second step, appropriate general response actions that involve either the identification of measures that could provide a remedy or the incorporation of measures into a coordinated remedy are determined. General response actions identify those actions that, by themselves or in conjunction with other general response actions, can satisfy the RAOs.

The third step addresses the identification of feasible remedial technologies and technology process options existing within each general response action. Technology types are general categories of technologies (e.g., thermal treatment), while technology process options are specified processes within a technology (e.g., rotary kiln incineration). During this step, technology types and technology process options are screened on the basis of site and waste characteristics and technical implementability.

In the fourth step, technology process options considered implementable are further assessed based on the screening criteria of effectiveness, implementability, and cost.

Feasible technology process options not eliminated in the prior step are assembled into remedial alternatives for subsequent evaluation in the FS.

3.2 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

3.2.1 Risk-Based Remediation Goals

3.2.1.1 Introduction

Remedial goals (RGs) are chemical-specific, health-based cleanup goals (i.e., risk-based concentrations protective of human health) calculated using carcinogenic and noncarcinogenic toxicity values under site-specific exposure conditions. The RGs for the Nike Launch Area were calculated based on the exposure assumptions presented in the Risk Assessment Exposure Assessment, Subsection 6.2 of the RI submitted in 2004 (WESTON, 2004a). The calculated RGs are based on inhalation exposure of potential future residents at Lots 8, 9 and 10 to vapor-phase chemicals enclosed in the basement resulting from migration of volatile chemicals from groundwater and subsurface soils.

3.2.1.2 Approach

Vapor intrusion RGs were developed for the COCs that posed a cancer risk greater than 1E-06 or a Hazard Index (HI) of greater than 1. This approach is consistent with the *Risk Assessment Handbook, Volume I: Human Health Evaluation* (USACE, 1995). Revised Table 6-8 of the 2004 RI (included as Table A-1 in Appendix A) was used to select the chemicals for which RGs were calculated using the above-mentioned criteria. CCl_4 is the only COC that exceeds the above criteria. The carcinogenic risk calculated for TCE was well below 1E-06. Therefore, RGs for the FS were calculated only for CCl_4.

The vapor intrusion RGs calculated for CCl_4 in groundwater reflect exposure to residents through inhalation of volatile chemicals in the basement resulting from migration from groundwater to enclosed-space air inside the basement, based on the conservative assumptions developed in the

RA report and discussed in Subsection 1.4.5. The RGs calculated for CCl_4 in soil gas reflect exposure to residents through inhalation of volatile chemicals in the basement resulting from migration from subsurface soil to enclosed-space air inside the basement. The exposure assumptions and models developed in the RA for the Nike Launch Area were used to develop the RGs. Because the cancer risk (CR), or HI, for a chemical is directly proportional to the exposure concentration (EC), a simplified equation was developed to estimate RGs. RGs were calculated based on target cancer risks of 1E-06 and chemical-specific HI of 1.

The following equation was used to calculate the Vapor Intrusion RGs:

Vapor Intrusion Remedial Goal (RG) = (TL*EC)/(CR or HI)

Where:

TL	=	Target Level (HI = 1 for noncarcinogenic effects and cancer risk = 1E-06 for carcinogenic effects)
EC	=	Medium-Specific Exposure Concentration (Table A-1 in Appendix A)
CR or HI	=	Cancer Risk or Hazard Index calculated based on the EC (Tables A-2 and A-3 in Appendix A)

<u>Calculation for CCl_4 Based on Groundwater Data - Carcinogenic Risk (Adult Resident)</u>:

RG	=	TL * EC/CR
	=	1E-06 * 1.10E + 02 µg/L[a]/2.3 E-06[b]
	=	48 µg/L

[a]Data from Table A-1, Appendix A.

[b]Data from Table A-2, Appendix A.

3.2.1.3 Results

The vapor intrusion RGs for groundwater and soil gas, respectively, for the residential scenario evaluated in the risk assessment for the Nike Launch Area site are presented below:

Chemical	Media	RG Based on Carcinogenic Risk - Adult Resident	RG Based on Carcinogenic Risk - Child Resident	RG Based on Noncancer Hazard Index – Adult Resident	RG Based on Noncancer Hazard Index - Child Resident
CCl_4	Groundwater (µg/L)	48	85	611	212
CCl_4	Soil Gas (µg/L)	0.33	0.56	4.3	1.4

The vapor intrusion RGs for CCl_4 in groundwater (48 µg/L) and soil gas (0.33 µg/L) were chosen based on the lowest calculated values. As shown, the vapor intrusion RGs for carcinogenic risk were based on the risk results for the adult resident, while the RGs based on noncarcinogenic effects were based on the HI calculated for the child resident (Tables A-1 through A-3, Appendix A).

3.2.2 Comparison with Chemical-Specific ARARs

Federal and State MCLs are ARARs for the Nike Launch Area, and may be used as cleanup standards where groundwater is or may be used as drinking water. Federal and State MCLs for the primary COCs are as follows:

- CCl_4: 5 µg/L.
- TCE: 5 µg/L.

3.2.3 Remedial Action Objectives

As part of this FS, groundwater-specific RAOs were established to facilitate development of remedial alternatives that are protective of human health and the environment. These RAOs were developed based on the RGs established in Subsection 3.2.1 of this report and the chemical-specific ARARs identified in Subsection 3.2.2 and are presented as follows:

- Prevent direct human exposure to site-related contaminants above risk-based concentrations calculated based on inhalation of vapor-phase CCl_4 in residential basements.
- Prevent the use of groundwater until the groundwater quality meets Federal and State MCLs.

3.3 IDENTIFICATION OF APPROPRIATE GENERAL RESPONSE ACTIONS

General response actions are those remedial actions that attempt to satisfy the RAOs. The environmental media of concern will be groundwater and the vadose zone both on-site and in the properties downgradient of the site. The following general response actions are considered for the remediation of the Nike Launch Area:

- No Action—The No Action response provides no remedial actions for contaminated media. Therefore, no technologies or process options are associated with this response. No active efforts would be made to reduce the potential risk to human health. In accordance with EPA CERCLA guidance (EPA, 1988), the No Action response must be considered as a potential remedy so as to serve as a baseline for comparison with other general response actions, and to evaluate the effects of responses that directly address the RAOs.
- Institutional Actions—Under this response action, institutional actions that restrict site access and inhibit future land and groundwater use would be recommended as the primary means for mitigating the potential risk to human health. Long-term groundwater monitoring would be required.
- Containment—Under this response action, remedial actions take the form of reducing or eliminating transfer or migration of contaminants by installing subsurface barriers. These barriers are effective in controlling the horizontal distribution of contaminants, thereby protecting human health.
- Recovery—Under this response action, remedial actions that remove contaminated media are used.
- Treatment—Treatment response actions include both in situ and ex situ applications that use biological, chemical, physical, or thermal measures to reduce the toxicity, mobility, or volume of the contaminants. The physical or chemical properties of the contaminant and/or the media are modified, thereby altering the chemical structure, bonding with, isolating, or completely destroying the contaminants. In situ applications involve the in-place (e.g., below ground) treatment of contaminated media. Ex situ treatment occurs at an aboveground location, either on-site or off-site, where treatment is completed. The treatment technology is selected based on the waste characteristics, contaminant types, contaminant concentrations, location,

potential for site reuse, and cost. Treatment technologies considered herein include the physical, chemical, and biological treatment of groundwater and/or soil gas.

3.4 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND TECHNOLOGY PROCESS OPTIONS

The objective of this subsection is to identify and screen technologies and process options for the general response actions identified in Subsection 3.3 that are best suited for further consideration in developing remedial alternatives for the Nike Launch Area. The methodology used in this section includes identification and screening of potential technologies, and retaining technologies and associated process options that are viable for the site, and eliminating those that are not feasible or do not achieve the RAOs.

Characteristics used to screen technologies included:

- Site characteristics—Site data gathered during the RI that identified conditions that could limit or promote the use of specific technologies.
- Affected media characteristics—Identification of affected media characteristics that limit the effectiveness, feasibility, or viability of technologies.
- Technology limitations—These include level of technology development, performance capabilities, capital and operating costs, and maintenance.

Those technologies that are precluded by site characteristics, affected media characteristics, poor reliability, or performance, or those that are substantially more expensive than equally effective technologies are eliminated in the screening process. During the screening process, the effectiveness, implementability, and cost for each technology are evaluated.

The specific remedial technologies are presented in the following subsections.

3.4.1 No Action

Under the No Action option, no remedial actions would be implemented at the site. Contaminants would continue to remain at the site. Under this option, the screening criteria would be met as follows:

Effectiveness—This option does not achieve the RAOs.

Implementability—This option is readily implementable.

Cost—No costs are incurred in implementing this option.

Recommendation—Although this option does not achieve the RAOs, it will be retained for further consideration as required by EPA guidance.

3.4.2 Institutional Actions

3.4.2.1 Groundwater Monitoring

Groundwater monitoring would involve long-term periodic sampling, analysis, and water level measurement of selected monitoring wells. If necessary, the option may include the installation of additional monitoring wells. Monitoring would establish a measure of protection of human health by monitoring contaminant concentrations and contaminant migration. Under this option, the screening criteria would be met as follows:

Effectiveness—This technology is useful in monitoring variations and migration of site contaminants. If used in conjunction with groundwater treatment, groundwater monitoring can be used to evaluate the effectiveness of the treatment.

Implementability—Installation and sampling of monitoring wells are conventional methods, and can be easily implemented.

Cost—Cost of implementation of additional monitoring wells is low to moderate. Cost of sampling and analysis is low.

Recommendation—This option will be retained for further consideration.

3.4.2.2 Ambient Air Monitoring and Soil Gas Monitoring

Ambient air monitoring would involve sampling and analysis of residences to ensure that COCs do not pose health risks. Monitoring would be recommended for any residence for which groundwater monitoring results indicate that groundwater concentrations exceed the established RGs. Under this option, the screening criteria would be met as follows:

Effectiveness—These technologies are useful for documenting and/or confirming safe conditions at residences and would provide a level of protectiveness by alerting residents to potential health risks.

Implementability—Ambient air monitoring and soil gas monitoring are readily implementable.

Cost—Costs for ambient air monitoring and soil gas monitoring would be low.

Recommendation—This option will be retained for further consideration.

3.4.2.3 Well Permit Restrictions

This option involves developing a restricted groundwater management zone. Well permit restrictions on installation of new groundwater production wells would be implemented to control future use of groundwater for drinking purposes until the Federal and State MCLs are met. Under this option, the screening criteria would be met as follows:

Effectiveness—This option would be effective in preventing the use of contaminated groundwater.

Implementability—This option would require cooperation of State and local authorities in implementing well installation restrictions.

Cost—Costs for implementing this technology are expected to be low.

Recommendation—This option will be retained for further consideration.

3.4.3 Containment Technologies

3.4.3.1 Vapor-Proof Construction

Vapor-proof construction is a series of construction techniques that can be used in new home construction or to retrofit existing homes to prevent toxic gases from accumulating in areas such as basements. These techniques are most commonly used to address radon gas in homes. New home construction would include the following features:

- A layer of gas-permeable material under the building foundation.
- Plastic sheeting over the gas-permeable material.
- Sealing and caulking of all openings in the foundation floor.
- Installation of a gas-tight vent pipe that runs from the layer of gas-permeable material under the foundation through the house to the roof.

Vapor that collects within the gas-permeable layer is dispersed to the atmosphere through the vent pipe. The venting system can either be operated passively, relying on convective flow to draw air from beneath the slab, or actively, using a fan to draw the air. Under this option, the screening criteria would be met as follows:

Effectiveness—These techniques have been shown to be very effective at preventing the accumulation of dangerous levels of radon within buildings.

Implementability—These construction techniques are readily implementable for new home construction.

Cost—The cost of this option would be low.

Recommendation—This option will not be retained for further consideration because it is unlikely that the land developer would accept this option.

3.4.4 Recovery Technologies

3.4.4.1 Groundwater Extraction

Groundwater extraction is used to remove contaminants and prevent off-site migration of contaminants by controlling the groundwater flow system. This is accomplished by the construction of a series of pumping recovery wells that draw water from the affected water-bearing zones. The groundwater can then be treated and returned through injection wells or discharged to surface waters or to a publicly owned treatment works.

In general, there are two basic approaches for groundwater recovery. Recovery wells can be placed near the source of any contamination. This approach accelerates groundwater remediation by extracting the most contaminated groundwater. The second major approach is to use recovery wells that are located downgradient of source areas and are spaced so that their cones of depression overlap. As a result, these wells form a hydraulic barrier to lateral groundwater flow. Under this option, the screening criteria would be met as follows:

Effectiveness—Groundwater recovery wells can be effective at many sites in containing contaminated groundwater. Effectiveness of a lateral barrier at the Nike Launch Area is somewhat limited due to low pumping yields and small capture zones. The capture zone around each recovery well has been estimated to be less than 10 ft.

Implementability—A recovery system design would be prepared, based on the existing groundwater model, specifying the number and placement of recovery wells and the pumping rate. Prior to installation of a recovery system, regulatory acceptance through permitting will be necessary.

Cost—Costs for this option are expected to be higher relative to in situ treatment technologies because of the large number of recovery wells that would be necessary to intercept the contaminant plume.

Recommendation—This option has not been retained for further consideration because there are in situ treatment technologies available that would be more effective at reducing the concentration of CCl_4 in groundwater. In addition, current information indicates that air sparging or groundwater circulation cell with in-well air stripping can remediate sites with groundwater contamination more rapidly than groundwater recovery and treatment.

3.4.4.2 Groundwater Interceptor Trenches

Interceptor trenches are used to prevent the migration of contaminants by intercepting and collecting groundwater for removal and treatment. The interceptor trench is typically located downgradient of the source areas or contaminant plume to intercept the flow of contaminated groundwater. Groundwater collection trenches use highly permeable materials in the water bearing-zone to convey groundwater flow to a collection sump. By using such materials, groundwater will preferentially flow to the collection area.

Interceptor trenches are constructed using common engineering and construction practices. A trench is excavated and filled with a highly permeable material and/or perforated piping. The contaminated water then flows through the highly permeable material to collection sumps where it can be pumped to the surface for treatment. Under this option, the screening criteria would be met as follows:

Effectiveness— Interceptor trench materials would have a permeability substantially higher than that of the surrounding soil; therefore, groundwater would preferentially flow into the trench for collection. Installation of an interceptor trench along the property boundary would effectively eliminate future off-site migration of VOCs. An interceptor trench would not address any upgradient groundwater contamination until it had migrated to the interceptor trench; therefore, such a system would likely need to be operated for a substantially longer period than an approach that would address the source area.

Implementability—This technology uses materials and construction techniques that are readily available.

Cost—The cost of this option would be high.

Recommendation—It is anticipated that this option would require more time to remediate groundwater and would be significantly more expensive than some of the other treatment technologies discussed and, therefore, will not be retained for further consideration.

3.4.5 Treatment Technologies

3.4.5.1 Air Sparging with Soil Vapor Extraction

Air sparging is a technology in which air is injected into groundwater, creating an underground air stripper that removes VOCs through volatilization. This is accomplished by installing a series of air injection wells within the groundwater that are connected to an air compressor. Air sparging systems are commonly operated in conjunction with a soil vapor extraction (SVE) system that would capture VOCs stripped from the groundwater. SVE removes VOCs from the vadose (unsaturated) zone by drawing air through the soil pore spaces. With SVE, a series of vents are installed in the vadose zone that are connected to a vacuum blower. The VOC-laden stream is then collected and either discharged or treated, depending on the concentration, flow rate, and types of VOCs present.

Air sparging can be implemented both for source remediation and for downgradient interception and treatment of VOCs in groundwater. Under this option, the screening criteria would be met as follows:

Effectiveness—Air sparging with vapor extraction has been successfully used to remediate sites with VOCs in groundwater and generally in a shorter period of time compared to groundwater recovery.

Implementability—Air sparging with vapor extraction can be readily implemented using conventional construction techniques. Pilot-scale testing, which would consist of a limited number of injection wells, extraction vents, and monitoring points, is recommended to determine the operating and design parameters for full implementation at the site. Prior to installation of the system, it would be necessary to obtain permits to construct and to operate from MDE.

Cost—The cost of this option is expected to be moderate.

Recommendation—This option will be retained for further consideration.

3.4.5.2 In-Well Air Stripping

In-well air-stripping, in combination with groundwater circulation wells, has been extensively used to remove VOCs from groundwater. With groundwater circulation, groundwater is drawn into the well either at the top or the bottom and is discharged at the opposite end. This vertical flow creates a cell within the groundwater that draws contaminated water to the well for treatment. The vapor-phase VOCs that are removed from groundwater are treated aboveground, or released to the atmosphere without treatment, if the emissions meet applicable State and Federal standards. Groundwater circulation systems can be implemented both for source remediation and for downgradient interception and treatment of VOCs in groundwater. Under this option, the screening criteria would be met as follows:

Effectiveness—Groundwater circulation systems have been successfully used to remediate VOCs in groundwater and generally in a shorter period of time compared to groundwater recovery.

Implementability—Successful implementation of groundwater circulation technology would require additional hydrogeological evaluation of the contaminated groundwater unit to determine the specific design of the system. The necessary equipment to operate a groundwater circulation system is readily available. Prior to installation of the system, it would be necessary to obtain permits to construct and to operate from MDE.

Cost—The cost of this option is expected to be moderate.

Recommendation—This option will be retained for further consideration.

3.4.5.3 Activated Carbon Adsorption

Activated carbon adsorption is a common technology for removing VOCs from aqueous and gaseous streams. In this process, VOCs are adsorbed to the carbon as the air or water stream passes through the treatment bed. Adsorption is a result of physical and chemical forces that act upon the organic molecules and bond them to the surface of the carbon. Vapor-phase granular-activated carbon (GAC) is an effective adsorbent because of its large surface area to volume ratio. Exhausted GAC, which contains the concentrated contaminants, requires disposal or regeneration. Under this option, the screening criteria would be met as follows:

Effectiveness—Vapor-phase GAC is an effective adsorbent for many organic compounds including CCl_4 and TCE.

Implementability—Vapor-phase GAC is a commonly used technology for the removal of organics from air streams. Many types of GAC are readily available. Off-site regeneration or disposal facilities readily handle spent GAC. Prior to installation of the system, it would be necessary to obtain State permits to construct and to operate.

Cost—The cost of vapor-phase GAC is expected to be moderate.

Recommendation—This option will be retained for further consideration. It would be utilized in combination with vapor extraction technologies.

3.4.5.4 In Situ Chemical Oxidation

Chemical oxidation uses chemicals called oxidants to destroy pollution in soil and groundwater. Oxidants help change harmful chemicals into harmless products, such as water and carbon dioxide. Chemical oxidation can destroy many types of chemicals, such as fuels, solvents, and pesticides.

Chemical oxidation does not involve excavation of soil or groundwater recovery. Instead, wells are drilled at different depths in the contaminated area. Oxidants are pumped into the ground. The oxidant mixes with the harmful chemicals and causes them to break down into harmless compounds. When the process is complete, only water and other harmless chemicals are left behind. To increase the rate of the process, oxidants can be pumped in one well and pumped out from another well. This approach helps mix the oxidant with the harmful chemicals in the groundwater and soil. As pumping and mixing continues, more contaminated soil and/or groundwater are remediated.

The most common oxidant used for in situ chemical oxidation is potassium permanganate. Another is hydrogen peroxide, which is more expensive. Both oxidants are pumped as liquids, and both have advantages depending on the site and COCs. Under this option, the screening criteria would be met as follows:

Effectiveness—Chemical oxidation is a very effective technology for the remediation of a wide range of organic compounds. This technology has been used extensively for the remediation of sites containing dichloroethene and TCE. However, chlorinated organic compounds derived from saturated aliphatic hydrocarbons (alkanes) (e.g., chloroform and CCl_4) are extremely difficult to treat using chemical oxidation.

Implementability—A number of vendors specialize in the design and installation of chemical oxidation systems. State and local permits may be required to install and operate chemical oxidation systems. Pilot studies will be required to design and optimize the selected oxidation system prior to implementation.

Cost—Cost of chemical oxidation system varies widely depending on the groundwater and soil characteristics, contaminant concentrations, and the type of the chemical oxidation system selected.

Recommendation—In situ chemical oxidation will not be retained for further consideration because the technology will be ineffective in treating CCl_4.

3.4.5.5 In Situ Chemical Reduction (ISCR)

In situ chemical reduction (ISCR) refers to the use of chemical amendments such as zero valent iron to promote direct chemical reduction of contaminants, or indirect chemical reduction of contaminants via the formation of hydrogen, which is used by bacteria as the electron donor. ISCR technology creates low redox conditions within an aquifer which promotes abiotic, non-sequential dechlorination of recalcitrant compounds such as CCl_4 and TCE (the primary site groundwater contaminants), and minimizes the formation of toxic daughter products. The chemical amendments are generally introduced as injected liquid solutions or by emplacement of a solid media into the source area of a contaminant plume. The use of a combined zero-valent iron/complex organic carbon amendment can also stimulate the biological reduction/consumption of oxygen and other electron acceptors like nitrate and sulfate, which can produce strong reducing conditions. The resulting synergistic physical, chemical, and microbiological reactions have been shown to effectively degrade otherwise persistent compounds such as CCl_4 at many solvent sites.

Effectiveness—This option would be effective in remediating saturated soil and groundwater contamination in the VOC source area at the site. The remaining contaminant plume would decline in size and concentration as a result of the source zone treatment, which would reduce the mass flux of VOCs migrating downgradient.

Implementability—The maximum injection depth at the Nike Launch Area would be less than 25 ft, and techniques are readily available to accomplish this task. The precise mix of reactive materials is proprietary; however, the injected ISCR amendments would be designed based on microcosm tests and/or bench-scale test results (chemical and physical characteristics) from site samples. Several vendors are available to perform the microcosm/bench-scale tests and to design and supply the reactive ISCR materials.

Cost—The cost of this option is expected to be low to moderate.

Recommendation—In situ chemical reduction will be retained for further consideration.

3.4.5.6 In Situ Bioremediation (ISB)

Microbial populations involved in bioremediation require a source of carbon, an electron donor, an electron acceptor, appropriate nutrients, a suitable temperature range, pH, and other environmental conditions. Very often the carbon source serves as the electron donor. Enhanced in situ bioremediation (ISB) systems stimulate the biodegradation of chlorinated solvents by manipulating these requirements in the subsurface. Some systems further stimulate biodegradation by adding naturally-occurring or engineered microorganisms that are particularly suited to biodegradation of chlorinated solvents. This process is known as bioaugmentation. Most VOCs, including the primary site COCs, CCl_4 and TCE, undergo biodegradation via anaerobic, reductive dechlorination (Mueller and Brown, 2008). The challenge at the Nike Launch Site, which is naturally aerobic (Oxidation-Reduction Potential [ORP] values range from +100 to +200), will be to convert the site geochemistry to anaerobic, reducing conditions. Addition of food grade carbon and electron donor amendments, which produce high molecular hydrogen concentrations through biologically mediated processes, have been shown to promote strongly reducing conditions in otherwise aerobic systems (ITRC, 2002). In addition, sites with generally low microbial populations have been successfully augmented or stimulated to produce robust bacterial populations capable of rapidly dechlorinating CCl_4 (Biteman et al., 2007). Microcosm and/or bench-scale testing of several electron donor/carbon amendments would be performed on site source area samples to determine the optimal bioremediation amendment for the site.

Effectiveness—This option would be effective in remediating saturated soil and groundwater contamination within the source zone at the site. The remaining contaminant plume would decline in size and concentration as a result of the source area treatment, which would reduce the mass flux of VOC migrating downgradient.

Implementability—The maximum injection depth at the Nike Launch Area would be less than 25 ft, and amendment injection techniques are readily available to accomplish this task. The actual bioremediation amendment or bioaugmentation approach would be determined based on microcosm/bench-scale testing of site source area samples. There are several vendors available to perform the microcosm/bench-scale testing and to both design and supply the ISB amendments or bioaugmentation cultures.

Cost— The cost of this option is expected to be low to moderate.

Recommendation—In situ bioremediation of the source zone will be retained for further consideration.

3.4.5.7 Permeable Reactive Barrier

Permeable reactive barriers (PRBs) are installed across the flow path of a contaminated groundwater plume, allowing the water portion of the plume to flow through the wall. Reactive materials in the wall trap harmful chemicals and/or change them into harmless products. Clean groundwater flows out the other side of the wall. A PRB is built by excavating a long, narrow trench in the path of the contaminated groundwater. The trench is filled with a reactive material that can clean up the harmful chemicals. Iron, limestone, and carbon are common types of reactive materials that can be used. Other specially designed proprietary materials may also be added to enhance the process. Reactive materials may be mixed with sand to make it easier for water to flow through the wall, rather than around it. PRBs are typically installed downgradient of the contaminant source area. Under this option, the screening criteria would be met as follows:

Effectiveness—This option would be effective in remediating groundwater contamination before it leaves the site. However, because the PRB is installed downgradient of the source area, the source area contaminant problem would not be addressed.

Implementability—The maximum excavation depth at the Nike Launch Area would be less than 25 ft, and excavation equipment and construction techniques are readily available to accomplish this task. The reactive materials used in the wall are proprietary material designed specifically for a given site based on chemical and physical characteristics. There are several vendors who are available to perform the design and supply the reactive materials. Permits would be required for the installation of the PRB.

Cost**—**The cost of this option is expected to be moderate.

Recommendation**—**PRB will be retained for further consideration. However, although this technology would effectively address the downgradient plume, the source area would not be directly addressed.

4. DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

In this section, remedial alternatives are developed by using technologies that were retained during technology screening in Section 3.

Groundwater at the Nike Launch Area and immediately downgradient is impacted by VOCs at concentrations that exceed MCLs. The Federal and State MCL for drinking water for both CCl_4 and TCE is 5 μg/L. Currently, CCl_4 concentrations in the source area well MW-4 (340 μg/L) exceed the MCL. TCE concentrations in the source area (19 μg/L in MW-4) also exceeded the MCL during the 2008 sampling round. The CCl_4 and TCE RGs for groundwater (used for drinking water) at the site are their associated Federal and State MCLs of 5 µg/L.

The primary health-risk concern at the site has been exposure to VOCs that could potentially volatilize from the groundwater plume and migrate into residential basements of future homes on Lots 8, 9, and 10 of the Cedar Tree Development (Figure 1-2). A risk-based analysis that was performed to evaluate the effects of potential exposure to residents through inhalation indicated that the only chemical that exceeded the risk-based concentration was CCl_4. The calculated risk-based vapor intrusion RG for CCl_4 in groundwater is 48 µg/L.

To determine the groundwater concentration of CCl_4 within the vacant Lots 8, 9, and 10, an additional groundwater sampling well (MW-18) was installed downgradient of MW-4. MW-18 was placed in the southern corner of the Lot 10 boundary line. The 2006 groundwater sampling results for MW-18 showed a CCl_4 concentration of 37 µg/L, which was below the groundwater risk-based RG for vapor intrusion. CCl_4 and TCE were not detected at MW-18 in 2008.

As a result of the 2006 and 2008 groundwater results at Lots 8, 9, and 10, CENAB has shifted the focus of the remedial technologies and alternatives to groundwater in the contaminant source area and meeting the downgradient (off-site) groundwater MCLs for CCl_4 and TCE at the site.

The following technologies were retained during the technology screening:

- No action.
- Groundwater monitoring.

- Ambient air monitoring and soil gas monitoring.
- Well restrictions.
- Air sparging with soil vapor extraction (AS/SVE).
- In-well air stripping.
- Activated carbon adsorption.
- In situ chemical reduction (ISCR)
- In situ bioremediation (ISB)
- Permeable reactive barrier (PRB).

The following remedial alternatives were developed by combining the previously listed technologies (except the No Action alternative, which is used by itself), based on site-specific conditions and RGs:

Alternative 1: No Action

Under the No Action alternative, no active remedial action will be implemented. The No Action alternative was evaluated to provide a baseline against which other alternatives may be compared.

Alternative 2: Monitored Natural Attenuation (MNA)

EPA defines MNA as "the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to those offered by other more active remediation methods" (EPA, 1999). The processes that contribute to natural attenuation include biodegradation, dilution, dispersion, absorption, adsorption, volatilization, and chemical transformation. MNA is generally considered a cost-effective alternative to active remedial technologies, provided there is no longer a source of contamination contributing to the site plume. Under favorable site geochemical conditions, MNA can be relied on to achieve final cleanup of a range of organic compounds from groundwater. MNA is often initiated at sites where contaminant levels have reached asymptotic levels (i.e., above state or federal MCLs), where continued operation of active remedies is determined to be providing diminishing returns.

In addition to groundwater monitoring, institutional controls (by state and/or local governments) are also included in this alternative to restrict installation of drinking water wells within the contaminated groundwater plume until the CCl_4 and TCE concentrations in groundwater have decreased to levels below their MCL of 5 μg/L.

Alternative 3: Air Sparging with Soil Vapor Extraction (AS/SVE)

Air sparging is a technology that mechanically injects air under pressure below the water table, using an air compressor to feed a series of injection wells. Volatile and semivolatile organic compounds that are dissolved in the groundwater volatilize into the vapor-phase as the air bubbles move up through the groundwater to the unsaturated soil above. This vapor is captured by an SVE system, where a vacuum is applied to the soil through a series of vapor extraction vents to induce the controlled flow of air and remove the vapor from the soil. The gas leaving the soil may be treated to recover or destroy the contaminants, depending on local and state air discharge regulations.

In addition to groundwater remediation occurring through air sparging/SVE, natural attenuation processes also contribute to the reduction in contaminant concentrations in groundwater. Therefore, MNA, groundwater monitoring, and institutional controls are included as part of this alternative.

Alternative 4: Groundwater Circulation Wells with In-Well Air Stripping

In-well air stripping is a technology where air is injected into a vertical groundwater circulation well that has been screened at two depths. The lower screen is set below the groundwater table (saturated zone), and the upper screen is placed above the groundwater table in the unsaturated zone. Pressurized air is injected into the well below the water table, aerating the water. The aerated water rises in the well and flows out of the system at the upper screen. Contaminated water is drawn into the system at the lower screen. Volatile compounds vaporize within the well at the top of the water table, as the air bubbles out of the water. Partially treated groundwater is never brought to the surface. After it is released in the unsaturated zone, the water percolates back down to the groundwater table. Contaminant concentrations are gradually reduced as the process is repeated. Vapors released in the wells are captured by a vapor extraction system and are treated aboveground to recover or destroy the contaminants, depending on local and state air discharge regulations.

In addition to groundwater remediation occurring through in-well air stripping, natural attenuation processes also contribute to the reduction in contaminant concentrations in groundwater. Therefore, MNA, groundwater monitoring, and institutional controls are included as part of this alternative.

Alternative 5: Permeable Reactive Barrier (PRB)

PRBs are installed across the flow path of a contaminated groundwater plume, allowing the water portion of the plume to flow through the wall. Reactive materials in the wall trap harmful chemicals or change them into harmless products. Clean groundwater flows out the other side of the wall. A PRB is built by digging a long, narrow trench in the path of the contaminated groundwater. The trench is filled with a reactive material that can clean up the harmful chemicals. Iron, limestone, and carbon are common types of reactive materials that can be used. The reactive materials may be mixed with sand to make it easier for water to flow through the wall, rather than around it. PRBs are typically installed downgradient of the contaminant source area.

In addition to groundwater remediation occurring at the PRB, natural attenuation processes also contribute to the reduction in contaminant concentrations in groundwater. Therefore, MNA, groundwater monitoring, and institutional controls are included as part of this alternative

Alternative 6: In Situ Chemical Reduction (ISCR) and In Situ Bioremediation (ISB)

In situ chemical reduction (ISCR) refers to the use of micro- or nano-scale, reactive iron amendments to promote reducing conditions in an aquifer and to achieve direct chemical reduction of oxidized organics via abiotic, non-sequential dechlorination reactions. In situ bioremediation (ISB) involves the use of simple organic carbon compounds to stimulate the naturally occurring microorganisms in the subsurface to degrade chlorinated compounds to environmentally acceptable end products such as ethene, CO_2, water and chloride (Major et al., 1992). The dominant biodegradation reaction in groundwater environments is reductive dechlorination, which involves the sequential replacement of chlorine atoms with hydrogen atoms. Under reducing conditions, the chlorinated compounds serve as the electron acceptor, while hydrogen, typically produced during the bacterial metabolism (fermentation) of the simple organic carbon, serves as the electron donor in the dechlorination reactions.

Carbon tetrachloride (CCl_4), the primary site contaminant, has been shown to degrade under anaerobic conditions via both chemical reduction (abiotic) and enhanced biologic, reductive dechlorination (Mueller and Brown, 2008). As a result, Alternative F would involve the use of ISCR and/or ISB amendments to degrade the source zone contaminants. Typical ISCR amendments include zero-valent iron (ZVI), or emulsified EZVI, which contains both reactive iron and a vegetable oil carbon source to promote both biological dechlorination as well as abiotic dechlorination via chemical reduction. Typical ISB amendments include emulsified oil substrates (EOS) or hydrogen release compound (HRC) which provide a carbon source to stimulate the growth of dechlorinating bacteria (*Dehalococcoides* spp. or *Pseudomonas* sp. KC). Microcosm and bench-scale testing of site groundwater and sediment samples would be performed to determine the optimal ISCR/ISB amendments for the site. Pilot testing/injection of the optimal amendment mixture directly into the site source zone would be performed prior to full-scale implementation to verify the relative rates of degradation indicated from the microcosm/bench scale testing results.

The ISCR/ISB treatment program will consist of direct injection of amendments via temporary Geoprobe borings using EHC® reagents (Adventus, 2010) at multiple locations on a grid pattern within the targeted source zone. The ISCR/ISB amendments will be injected within an area assumed to be approximately 50 ft long x 50 ft wide and 10 ft deep, focusing on the saturated interval between 15 and 25 ft below grade. Amendments would be introduced using Geoprobe's pressure-activated injection tools.

In addition to the remediation of the source zone via ISCR and ISB technology, natural attenuation processes will also contribute to the reduction in contaminant concentrations in the downgradient groundwater. Therefore, MNA groundwater monitoring and institutional controls on groundwater use at the site are included as part of this alternative.

5. DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

5.1 INTRODUCTION

This section provides a detailed analysis of each of the following remedial alternatives that were retained following the initial screening of alternatives in Section 4:

- Alternative A—No Action.
- Alternative B—Monitored Natural Attenuation.
- Alternative C—Air Sparging with Soil Vapor Extraction.
- Alternative D—Groundwater Circulation Wells with In-Well Air Stripping.
- Alternative E—Permeable Reactive Barrier.
- Alternative F—In Situ Chemical Reduction and Bioremediation.

For remedial actions of longer duration than 5 years, in accordance with CERCLA Section 121, a Five-Year Review would be required when remedial actions leave hazardous substances on the site at levels that do not allow for unlimited use and unrestricted exposure (UU/UE) (EPA, 2003). A Five-Year Review would be conducted by the federal agency in charge of the Nike Launch Area.

5.2 OVERVIEW OF EVALUATION CRITERIA

Nine criteria have been developed by the EPA in its CERCLA Remedial Investigation/Feasibility Study (RI/FS) Guidance Document (EPA, 1988) to address SARA requirements. A detailed analysis was performed on each alternative using the nine criteria in order to select the preferred alternative to achieve the RAOs. The nine criteria are further divided into three categories, as presented below:

Threshold Criteria: Assessments against two of the criteria relate directly to statutory findings that must ultimately be made in the ROD. Therefore, these are categorized as threshold criteria in that each alternative must meet them. These two criteria are:

- Overall protection of human health and the environment.
- Compliance with ARARs.

Primary Balancing Criteria: The five criteria listed below are grouped together because they represent the primary criteria upon which the analysis is based:

- Long-term effectiveness.
- Reduction of TMV.
- Short-term effectiveness.
- Implementability.
- Cost.

Modifying Criteria: The final two criteria, state or support agency acceptance and community acceptance, will be evaluated following comment on the RI/FS report and the proposed plan, and will be addressed once a final decision is being made and the ROD is being prepared. The criteria are as follows:

- State acceptance.
- Community acceptance.

A description of each criterion is provided in the following subsections.

5.2.1 Overall Protection of Human Health and the Environment

This criterion provides a final check to assess whether the alternatives are protective of human health and the environment. The overall assessment of protectiveness is based on a composite of factors assessed under the evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

5.2.2 Compliance with ARARs

This criterion will evaluate the compliance of each alternative with the pertinent ARARs identified in Section 2.

5.2.3 Long-Term Effectiveness and Permanence

This criterion involves the evaluation of the long-term effectiveness of alternatives for protecting human health and the environment after the response actions have been completed. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the potential risks posed by treatment residuals and/or untreated wastes. The following components will be addressed under this criterion:

- Magnitude of Remaining Risk—Evaluates the residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities.
- Adequacy and Reliability of Controls—Considers the adequacy and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site. It also determines if these controls are sufficient to ensure that any possible exposure to human and environmental receptors is within protective limits. In addition, it evaluates the long-term reliability of controls for providing continued protection from residual contamination.

5.2.4 Reduction of Toxicity, Mobility, or Volume

The assessment of reduction of toxicity, mobility, or volume (TMV) evaluates the anticipated performance of specific treatment technologies. This evaluation criterion addresses the statutory preference for selecting remedial actions that use treatment technologies to permanently and significantly reduce TMV of wastes.

This criterion focuses on the following factors:

- The amount of hazardous materials that will be destroyed or treated, including how principal threats will be addressed.
- Irreversibility of treatment.
- The type and quantity of residuals that will remain following treatment.
- The treatment processes the remedy will use and the materials they will treat.
- The degree of expected reduction in TMV measured as a percentage of reduction (or order of magnitude).
- Whether or not the alternative would satisfy the statutory preference for treatment as a principal element.

5.2.5 Short-Term Effectiveness

This criterion examines the effectiveness of alternatives for protecting human health and the environment during the construction and implementation period until the response objectives have been met. The following factors will be addressed under this criterion:

- Protection of the Community during Remedial Actions—Addresses the potential risks to human health from implementation of the proposed remedial action (e.g., VOC emissions for treatment system operation).

- Protection of On-Site Workers during Remedial Actions—Assesses potential risks to on-site workers as well as the effectiveness and reliability of protective measures to reduce worker exposure.

- Environmental Impacts—Addresses the potential adverse environmental impacts that may result from implementation of an alternative and evaluates the effectiveness of available mitigative measures to prevent or reduce impacts.

- Time until Remedial Action Objectives (RAOs) Are Achieved—Estimates the time required to achieve protection for either the entire site or for individual elements associated with specific threats.

5.2.6 Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during implementation. This criterion involves analyses of the following factors:

5.2.6.1 Technical Feasibility

Technical feasibility includes the following:

- Construction and Operation—Relates to the technical difficulties and unknowns associated with a technology.

- Reliability of Technology—Focuses on t he likelihood that technical problems associated with implementation will lead to scheduling delays.

- Ease of Undertaking Additional Remedial Actions—Discusses the types, if any, of future remedial actions that may be undertaken and the difficulty of implementing such additional actions.

- Monitoring Considerations—Addresses the ability to monitor the effectiveness of a remedy, and includes an evaluation of the potential risks from exposure should monitoring be insufficient to detect a system failure.

5.2.6.2 Administrative Feasibility

Administrative feasibility includes the following:

- Administrative feasibility relates to the activities that need coordination with other offices and agencies (e.g., obtaining permits for off-site activities).

5.2.6.3 Availability of Services and Materials

Availability of services and materials includes the following:

- Availability of adequate off-site treatment, storage capacity, and disposal services.
- Availability of necessary equipment and specialists to ensure any necessary additional resources.
- Availability of prospective technologies.
- Availability of services and materials, including the potential for obtaining competitive bids.

5.2.7 Cost

Cost evaluation of each alternative includes consideration of capital costs and annual costs. A contingency of 20% is included in the costs to provide funds to cover unanticipated expenses. A present-worth analysis is also conducted, allowing all remedial action alternatives to be compared on the basis of a single cost. The definitions of cost terns are presented below:

- Capital Costs—Consist of direct (i.e., construction) and indirect (i.e., overhead) costs. Direct costs include expenditures for the equipment, labor, and materials necessary to install the necessary remedial actions. Indirect costs include expenditures for engineering, financial, and other services that are required to support the remedial actions.
- Operation and Maintenance (O&M) Costs—Include post-construction costs necessary to ensure the continued effectiveness of a remedial action.
- Present-Worth Analysis—After completion of the cost estimate, an economic analysis considering the time value of money is conducted to allow comparison of alternatives through a present-worth analysis. Expenditures that occur over different time periods are evaluated by discounting future costs to the current year. This figure represents the

amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life, minus inflation. A discount rate of 3% was assumed when calculating present-worth costs.

5.2.8 State Acceptance

This criterion evaluates the technical and administrative issues and concerns that the State may have regarding each alternative. It is anticipated that the formal comments from the State on USACE's preferred alternative will be provided during the public comment period. These comments will then be addressed in the Final FS Report or in the Responsiveness Summary of the Decision Document.

5.2.9 Community Acceptance

This criterion incorporates public comments into the evaluation of the remedial alternatives. It is anticipated that the formal comments from the community on USACE's preferred alternative will be provided during the public comment period. These comments will then be addressed in the Final FS Report or in the Decision Document.

5.3 DESCRIPTION AND DETAILED ANALYSIS OF ALTERNATIVES

5.3.1 Alternative A: No Action

Under the No Action alternative, no active remedial action or monitoring will be implemented. The No Action alternative was evaluated as required by the NCP, to provide a baseline against which other alternatives may be compared.

5.3.1.1 Overall Protection of Human Health and the Environment

The No Action alternative would not be protective of human health or the environment. Potential risks to human health from contaminated groundwater will not be actively addressed.

The potential risk from the inhalation of VOCs in residential basements would continue to exist on Lots 8, 9, and 10, if houses are built on these lots. Although it is anticipated that natural attenuation processes (predominantly dilution and dispersion rather than biodegradation) would continue to reduce VOC concentrations in groundwater, the extent of reduction or the timeframe to achieve the RAOs will not be known without a groundwater monitoring program.

5.3.1.2 Compliance with ARARs

Without a monitoring program, compliance with Chemical-Specific ARARs cannot be determined. There are no location-specific ARARs associated with this alternative. Action-Specific ARARs are not applicable because there are no remedial actions associated with this alternative.

5.3.1.3 Long-Term Effectiveness and Permanence

The No Action alternative could be effective in the long-term as a result of contaminant reduction due to natural attenuation processes, but its effectiveness cannot be determined without groundwater monitoring. The potential risk of inhalation of CCl_4 vapors in a future residential basement on Lots 8, 9, and 10 would continue to exist. Without the implementation of institutional controls, the potential risk of using contaminated groundwater for drinking purposes would continue to exist.

5.3.1.4 Reduction of Toxicity, Mobility, or Volume

In the No Action alternative, there would be no active treatment process for the contaminated groundwater. Therefore, TMV may only be reduced through natural attenuation processes. The extent or the rate of reduction may not be known without a groundwater monitoring program. This alternative would not satisfy the statutory preference for treatment as a principal element of a remedial action.

5.3.1.5 Short-Term Effectiveness

There would be no additional risks to the community or the workers because there would be no remedial work at the site in this alternative.

5.3.1.6 Implementability

The No Action alternative can be easily implemented. No technical or administrative issues are associated with the No Action alternative.

5.3.1.7 Cost

There are no costs associated with this alternative.

5.3.2 Alternative B: Monitored Natural Attenuation

EPA defines MNA as "the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remedial objectives within a timeframe that is reasonable compared to those offered by other more active methods" (EPA, 1999). The processes that contribute to natural attenuation include biodegradation, dilution, dispersion, absorption, adsorption, volatilization, and chemical transformation. MNA is a cost-effective technology. Under favorable site conditions, MNA can be used effectively to remediate a range of organic compounds from groundwater.

Primary components of the MNA alternative at the Nike Launch Area site are as follows:

- Semi-annual sampling and analysis of groundwater from five shallow water monitoring wells.
- Implementation of institutional controls to prevent the use of groundwater for drinking purposes from the site and the impacted area downgradient of the site. Institutional controls will be imposed through deed restrictions.

At the Nike Launch Area site, monitoring will be conducted at three existing wells (MW-4, MW-11, and at MW-12), and at two new wells to be installed along the eastern borders of Lots 9 and 10. All the wells are located downgradient of the source area (Figure 1-2). Periodic monitoring at these wells would provide the data needed to evaluate the variation in contaminant concentrations over time, and eventually, to determine when risk-based concentrations and MCLs are achieved in groundwater.

After the risk-based CCl_4 concentration of 48 μg/L has been achieved (for inhalation at residential basements) in groundwater, monitoring will continue to confirm the contaminant concentrations in groundwater until the groundwater concentrations are below the MCLs. The length of the confirmation period will be determined in consultation with the State. Once the CCl_4 concentrations are stabilized below the risk-based concentration, a soil-gas survey will be performed in or just upgradient from Lots 8, 9, a nd 10 to confirm the groundwater results. Alternatively, if houses are built on Lot Nos. 8 and/or 10, indoor air sampling will be conducted in the houses to determine whether there is an inhalation risk.

Under the MNA alternative, institutional controls will be implemented to prevent the use of groundwater for drinking purposes. The MCL for both CCl_4 and TCE is 5 µg/L, which is less than the risk-based concentration of 48 µg/L. Consequently, the drinking water standards will be achieved at a l ater time, after the risk-based standard for CCl_4 has been achieved. The groundwater monitoring program will continue until the MCLs are achieved. Therefore, institutional controls will remain in place until the MCLs are achieved.

5.3.2.1 Overall Protection of Human Health and the Environment

Based on t he evidence of declining VOC concentrations in groundwater since 1987 a nd predictions derived from the WinTran® groundwater transport model, it is anticipated that natural attenuation processes (predominantly dilution and dispersion rather than biodegradation) would reduce VOC concentrations to acceptable levels and provide adequate protection to human health and the environment within a reasonable timeframe. Natural attenuation processes are predicted by the groundwater transport model to reduce CCl_4 concentrations to below the MCL of 5 µg/L downgradient of the source area within approximately 18 y ears (WinTran® model results, WESTON, 2004a).

Institutional controls would be required to restrict installation of drinking water wells until the CCl_4 concentrations have been reduced to levels below the MCL of 5 µg/L. The groundwater model predicts that by 2022 (18 years) natural attenuation processes will reduce downgradient CCl_4 concentrations to levels below the MCL of 5 µg/L.

5.3.2.2 Compliance with ARARs

This alternative would achieve chemical-specific risk-based RGs and MCLs through natural attenuation.

There are no location-specific ARARs associated with the site.

Well installation and sampling activities would be performed in compliance with applicable SSHP regulations.

5.3.2.3 Long-Term Effectiveness and Permanence

The MNA alternative would be effective in the long-term. The magnitude of residual risk is expected to decline over the long-term to acceptable levels. The rate of reduction of contaminant levels and mass is expected to be slower than for the active remedial alternatives and would be determined through the results of the groundwater monitoring program.

Based on the historical data and the groundwater transport model predictions, MNA would be an adequate and reliable response action to address the groundwater contamination at the site. To the extent that the contaminants are transformed into harmless compounds through natural attenuation processes, the process is irreversible.

5.3.2.4 Reduction of Toxicity, Mobility, or Volume

With this alternative, there would be no active treatment process to treat contaminated groundwater. Reduction in the TMV of contaminants is expected to occur through natural attenuation processes. The degree of reduction in TMV would be evaluated through the monitoring program. This alternative would not satisfy the statutory preference for treatment as a principal element of a remedial action.

5.3.2.5 Short-Term Effectiveness

There would be minimal additional risk to the community in the short-term since there is only limited activity associated with the MNA alternative, such as groundwater sampling, drilling, and installation of new groundwater monitoring wells (if required). All activities will be performed in accordance with an SSHP and should present no danger to the surrounding community, workers, or the environment. Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements.

5.3.2.6 Implementability

The MNA alternative can be easily implemented. Standard construction techniques may be used to install additional groundwater monitoring wells, if required.

Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. Sample analyses can be performed using an environmental laboratory.

Implementation of groundwater well installation, deed restrictions, and off-site groundwater monitoring well permits will not require approval and cooperation of state and local authorities. However, USACE will work closely with Maryland and local authorities to meet the substantive requirements of any state and local permits or regulations pertaining to the proposed work.

5.3.2.7 Cost

Capital costs for this alternative include the implementation of groundwater use restrictions and performance of a soil-gas survey once the contaminant concentrations in groundwater decline to levels below the risk-based RGs. O&M costs for this alternative include the costs associated with annual groundwater sampling and analysis. For costing purposes, 5 and 20-year timeframes were assumed for comparison purposes. The 5-year timeframe represents the estimated length of time required to meet the vapor intrusion RG of 48 µg/L at the Lots 8, 9, and 10, while the 20-year timeframe represents the estimated length of time required to reach the MCL of 5 µg/L. A discount rate of 3% was assumed when calculating O&M present worth costs. The costs associated with this alternative are presented in Table B-1, and the total present worth costs are summarized as follows:

- Total Present-Worth Cost $171,000 (assumed 5 years)
- Total Present-Worth Cost $440,000 (assumed 20 years)

5.3.3 Alternative C: Air Sparging with Soil Vapor Extraction

Air sparging is a technology that mechanically injects air under pressure below the water table, using an air compressor to feed a series of injection wells. Volatile and semivolatile organic compounds that are dissolved in the groundwater volatilize into the vapor-phase as the air bubbles move up through the groundwater to the unsaturated soil above. This vapor is captured by an SVE system, in which a vacuum is applied to the soil through a series of vapor extraction vents to induce the controlled flow of air and remove the vapor from the soil. The gas leaving the soil may be treated to recover or destroy the contaminants or released to the atmosphere, depending on local and State air discharge regulations. Figure 5-1 presents a schematic diagram of an air sparging and SVE system.

At the Nike Launch Area, air sparging pipes and vapor extraction vents will be installed around the source area, which would result in reduction of contaminant concentrations at the source. As a result, the contaminant concentrations of the downgradient plume originating from the source area will gradually decline. The already decreased contaminant levels will be further reduced by the natural attenuation processes, resulting in overall reduction in contaminant concentrations throughout the entire plume.

Primary components of air sparging/SVE alternative include:

- Predesign investigation of air sparging/SVE system, including pilot testing.
- Installation of air sparging/SVE system.
- Operation and maintenance of air sparging/SVE system and aboveground gaseous treatment system (if required).
- Semi-annual sampling and analysis of groundwater from five shallow water monitoring wells.
- Implementation of institutional controls to prevent the use of groundwater for drinking purposes from the site and the impacted area downgradient of the site. Institutional controls will be imposed through deed restrictions.

Based on the horizontal and vertical permeability of the soil at the Nike Launch Area and the groundwater flow rate, it is expected that the full-scale system would require a relatively large number of air injection wells and a similar number of vapor extraction vents. This system would rely on a line of barrier vents to intercept and treat contaminated groundwater before it flows off-site. Additional vents would be placed upgradient of the barrier vents to enhance the source area remediation. The actual spacing would be determined using the data collected during the pilot study.

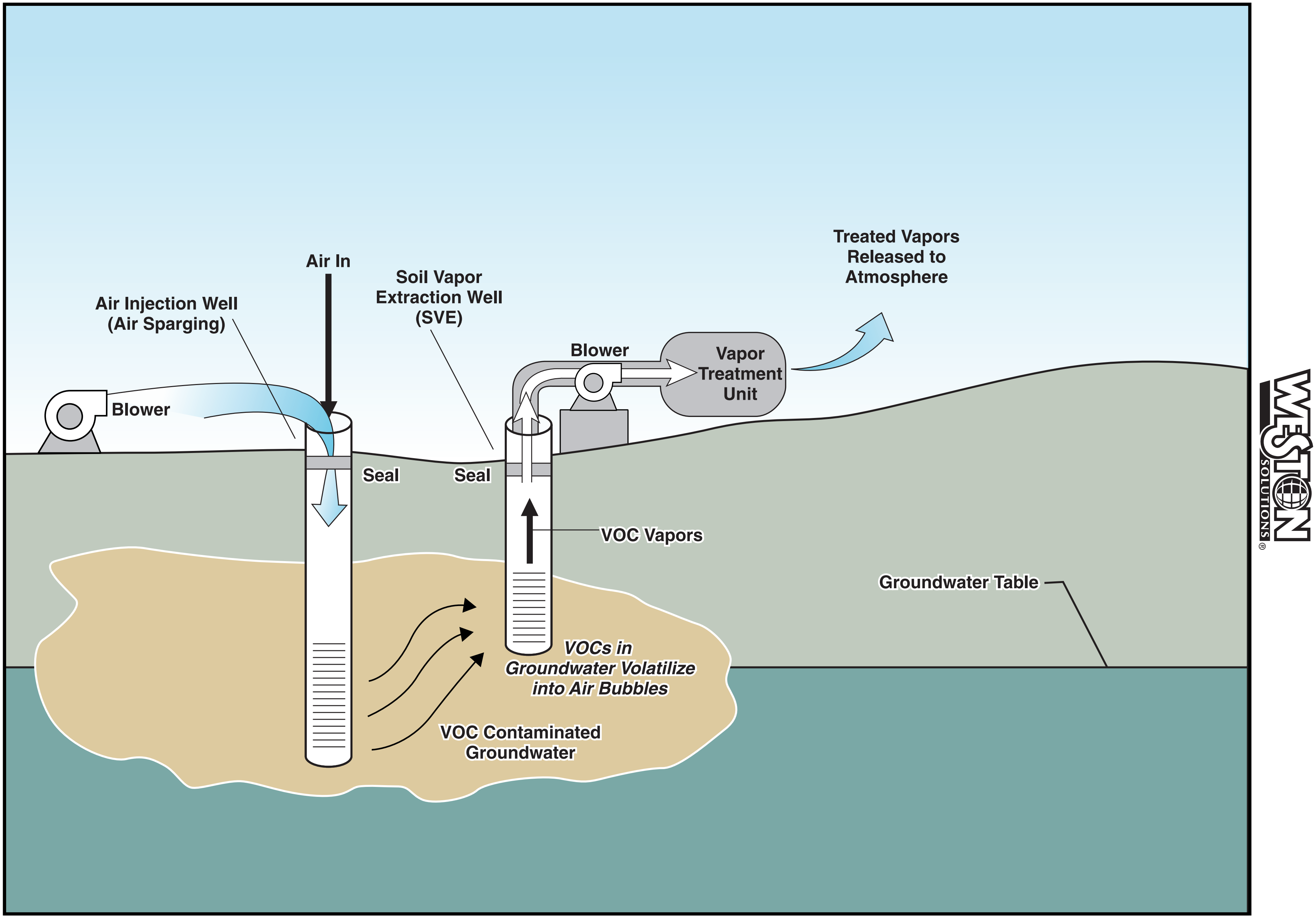


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FIGURE 5-1 SCHEMATIC DIAGRAM OF AIR SPARGING AND SOIL VAPOR EXTRACTION

It is difficult to accurately estimate the exact timeframe for achieving RGs under the air sparging/SVE alternative due to factors such as low vertical permeability, the ultimate system design and the effect of natural attenuation processes. However, conservatively, it is anticipated that the air sparging/SVE, in combination with natural attenuation processes, would achieve the risk-based CCl_4 concentration of 48 µg/L within a period of 3 to 4 years, and the CCl_4 MCL of 5 µg/L within 6 to 8 years.

WESTON estimates that it will take approximately one year of active remediation to lower the source area concentrations below the vapor intrusion goal and approximately another two years to lower the source area concentrations below the MCL goal. The distance from the source area to the ends of the lots ranges from approximately 200 to 300 feet. The distance from the contaminant source area to the stream ranges from approximately 300 to 440 feet. The estimated timeframe for achieving the RGs was determined using the active remediation times, the average groundwater seepage velocity of 0.32 ft/day, a CCl_4 retardation factor of 1.2, the measured distances and the following formula:.

$$\mathbf{T_{total}} = \mathbf{T_A} + [(d / v) / 365]\, \mathbf{R}$$

where $\mathbf{T_{total}}$ is the total time to achieve RGs in years, $\mathbf{T_A}$ is the active remediation time in years, **d** is the distance in feet, **v** is the average groundwater seepage velocity in feet/day and **R** is the retardation factor.

5.3.3.1 Overall Protection of Human Health and the Environment

This alternative would provide protection to human life and the environment. Air sparging and SVE are well-proven technologies for removing a range of organic compounds from groundwater, including the COCs found at the Nike Launch Area. Through treatment, CCl_4 levels would be reduced to risk-based concentration of 48 µg/L at Lots 8, 9, and 10, and eventually to below the MCL of 5 µg/L.

5.3.3.2 Compliance with ARARs

This alternative would achieve chemical-specific risk-based RGs and State MCLs.

There are no location-specific ARARs associated with the site.

The vapors collected from the air stripping process will meet all applicable federal and state (if state requirements are more stringent than federal requirements) emission requirements.

5.3.3.3 Long-Term Effectiveness and Permanence

The air sparging/SVE alternative would be effective in the long-term. The magnitude of residual risk is expected to decline over the long-term to acceptable levels. The rate of reduction of contaminant levels and mass would be determined through periodic groundwater sampling.

Treatment processes associated with this alternative, and natural attenuation processes that transform site contaminants into harmless compounds are permanent and irreversible.

5.3.3.4 Reduction of Toxicity, Mobility, or Volume

Toxicity of the contaminants would not change during the air sparging/SVE process, since the process involves only removal of organic contaminants. However, if activated carbon is used to treat extracted gas (as opposed to direct release to the atmosphere), regeneration of activated carbon will transform contaminants to harmless compounds, thereby reducing the toxicity.

Mobility and volume of contaminants would be reduced because they are permanently removed from the site groundwater. The degree of reduction would be evaluated through the implementation of the groundwater monitoring program. This alternative would satisfy the statutory preference for treatment as a principal element of a remedial action.

5.3.3.5 Short-Term Effectiveness

Short-term risks to the community from this alternative would be due to activities associated with drilling and installation of air-sparging wells, vapor extraction vents, vapor treatment system, installation of groundwater monitoring wells (if required), and groundwater sampling. All activities will be performed in accordance with an SSHP and should present no danger to the surrounding community, workers, or the environment. Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements.

5.3.3.6 Implementability

The air-sparging/SVE alternative can be easily implemented. Materials, equipment, and qualified personnel for installation are readily available. Standard construction techniques may be used to install additional groundwater monitoring wells, if required.

Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. Sample analyses can be performed using an environmental laboratory. Spent carbon from a vapor treatment system would be transported off-site for disposal or regeneration in an approved off-site facility. A pilot study would be conducted to optimize the effectiveness of the system and to determine optimal air-sparging well and vent spacing.

Implementation of groundwater well installation, deed restrictions, and off-site groundwater monitoring well permits will not require approval and cooperation of state and local authorities. However, USACE will work to meet the substantive requirements of any state and local permits or regulations pertaining to the proposed work.

5.3.3.7 Cost

Capital costs for this alternative include activities associated with air-sparging/SVE (groundwater evaluation, pilot study, installation of the system, and system startup), implementation of groundwater use restrictions, and performance of a soil-gas survey once the contaminant concentrations in groundwater decline to levels below the risk-based RGs. O&M costs for this alternative include annual O&M of the air-sparging/SVE system and the costs associated with annual groundwater sampling and analysis for MNA. For costing purposes, two scenarios were considered. For Option A, a 5-year air-sparging/SVE operation was assumed. For Option B, a 10-year air-sparging/SVE operation was assumed. For both options, MNA costs for 10 years were assumed. A discount rate of 3% was assumed when calculating O&M present worth costs. The costs associated with this alternative are presented in Table B-2, and the total present worth costs are summarized as follows:

- Option A Total Present-Worth Cost $ 831,000
- Option B Total Present-Worth Cost $1,064,000

5.3.4 Alternative D: Groundwater Circulation Wells with In-Well Air Stripping

The groundwater circulation well with in-well air stripping alternative involves two physical processes: groundwater circulation and in-well air stripping. The groundwater circulation well is used to mobilize contaminated groundwater to the circulation cell around the well. Groundwater is drawn into the circulation well at either the top or the bottom of the aquifer and discharged back into the aquifer at the opposite end (bottom or top) of the well. This vertical flow of groundwater through the circulation well creates a vertical circulation cell in the aquifer that is superimposed on top of the natural groundwater flow patterns. After it is released in the unsaturated zone, the water percolates back down to the groundwater table. Volatile compounds vaporize within the well at the top of the water table as the air bubbles out of the water. Contaminant concentrations are gradually reduced as the process is repeated. Vapors released in the wells are captured by a vapor extraction system and treated to recover or destroy the contaminants or released to the atmosphere without treatment, depending on local and State air discharge regulations. Figure 5-2 presents a schematic diagram of a groundwater circulation well with in-well air stripping system.

At the Nike Launch Area, groundwater circulation wells will be installed around the source area to capture the most contaminated groundwater, which would effectively reduce the contaminant concentrations at the source. As a result, the contaminant concentrations of the downgradient plume originating from the source area will gradually decline. The already decreased contaminant levels will be further reduced by the natural attenuation processes, resulting in overall reduction in contaminant concentrations throughout the entire plume.

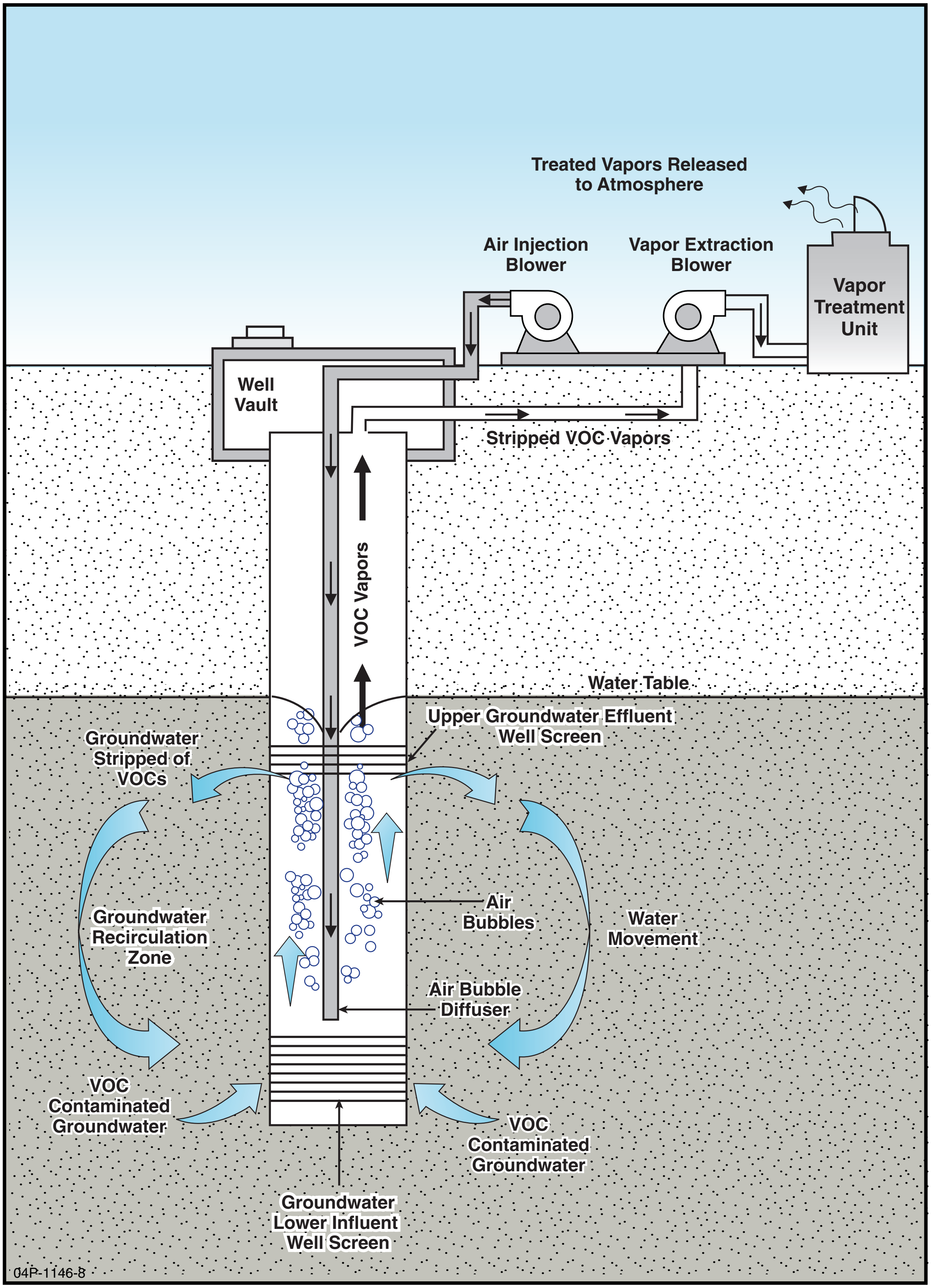

FIGURE 5-2 SCHEMATIC DIAGRAM OF GROUNDWATER CIRCULATION WELL WITH IN-WELL AIR STRIPPING

Primary components of groundwater circulation wells with in-well air stripping alternative would include:

- Predesign investigation of groundwater circulation well/in-well air stripping system, including pilot testing.
- Installation of groundwater circulation well/air-stripping system and aboveground gaseous treatment system (if required).
- O&M of the groundwater circulation well/in-well air stripping system.
- Semi-annual sampling and analysis of groundwater from five shallow water monitoring wells.
- Implementation of institutional controls to prevent the use of groundwater for drinking purposes from the site and the impacted area downgradient of the site. Institutional controls will be imposed through deed restrictions.

Major considerations in applying the technology are contaminant volatility, the thickness of the contaminated zone, horizontal conductivity, and vertical conductivity. These considerations affect the time required for cleanup, the number of circulation wells needed, and the air flow rate. The ratio of the horizontal conductivity to the vertical conductivity determines the size of the circulation cell.

It is difficult to accurately estimate the exact timeframe for achieving RGs under this alternative due to factors such as variable site geology, the ultimate system design and low groundwater flow rate. However, conservatively, it is anticipated that groundwater circulation well/in-well air stripping, in conjunction with natural attenuation processes would achieve the risk-based CCl_4 concentration of 48 µg/L within a period of 3 to 4 years, and the CCl_4 MCL of 5 µg/L within 6 to 8 years.

WESTON estimates that it will take approximately one year of active remediation to lower the source area concentrations below the vapor intrusion goal and approximately another two years to lower the source area concentrations below the MCL goal. The distance from the source area to the ends of the lots ranges from approximately 200 to 300 feet. The distance from the contaminant source area to the stream ranges from approximately 300 to 440 feet. The estimated timeframe for achieving the RGs was determined using the active remediation times, the average groundwater seepage velocity of 0.32 ft/day, a CCl_4 retardation factor of 1.2 and the measured distances.

5.3.4.1 Overall Protection of Human Health and the Environment

This alternative would provide protection to human life and the environment. Groundwater circulation wells and in-well air stripping are well-proven technologies for removing a range of organic compounds from groundwater, including the COCs found at the Nike Launch Area. CCl_4 levels would be reduced to the risk-based concentration of 48 µg/L at Lots 8, 9, and 10, and eventually to State MCL of 5 µg/L.

5.3.4.2 Compliance with ARARs

This alternative would achieve chemical-specific risk-based RGs and State MCLs through treatment.

There are no location-specific ARARs associated with the site.

The vapors collected from the air stripping process will meet all applicable federal and state (if state requirements are more stringent than federal requirements) emission requirements.

5.3.4.3 Long-Term Effectiveness and Permanence

Groundwater circulation wells and in-well air stripping alternative would be effective in the long-term. The magnitude of residual risk is expected to decline over the long-term to acceptable levels. The rate of reduction of contaminant levels and mass would be determined through periodic groundwater sampling.

Treatment processes associated with this alternative, and natural attenuation processes that transform site contaminants into harmless compounds are permanent and irreversible.

5.3.4.4 Reduction of Toxicity, Mobility, or Volume

Toxicity of the contaminants would not change during the air stripping process since the process involves only removal of organic contaminants. However, if activated carbon is used to treat collected gas from the circulation wells, regeneration of activated carbon may transform contaminants to harmless compounds, thereby reducing the toxicity.

Mobility and volume of contaminants would be reduced because they are permanently removed from groundwater. The degree of reduction can be evaluated through the groundwater monitoring program. This alternative would satisfy the statutory preference for treatment as a p rincipal element of a remedial action.

5.3.4.5 Short-Term Effectiveness

Short-term risks to the community from this alternative would be due to activities associated with drilling and installation of groundwater circulation wells, vapor extraction vents, vapor treatment system, installation of groundwater monitoring wells (if required), and groundwater sampling. All activities will be performed in accordance with an SSHP and should present no danger to the surrounding community, workers, or the environment. Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements.

5.3.4.6 Implementability

This alternative can be easily implemented. Materials, equipment, and qualified personnel for installation of the groundwater circulation well/in-well air stripping system are readily available. Standard construction techniques may be used to install additional groundwater monitoring wells, if required.

Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. Sample analyses can be performed using an environmental laboratory. Spent carbon from a vapor treatment system would be transported off-site for disposal or regeneration in an approved off-site facility. A pilot study would be conducted to optimize the effectiveness of the system and to determine the exact number of circulation wells and well spacing.

Implementation of groundwater well installation, deed restrictions, and groundwater monitoring well permits will not require approval and cooperation of the state and local authorities. However, USACE will work to meet the substantive requirements of any state and local permits or regulations pertaining to the proposed work.

5.3.4.7 Cost

Capital costs for this alternative include activities associated with groundwater circulation well/in-well air stripping system (groundwater evaluation, pilot study, installation of the system, and system startup), implementation of groundwater use restrictions, and performance of a soil-gas survey once the contaminant concentrations in groundwater decline to levels below the risk-based RGs. O&M costs for this alternative include annual O&M of the groundwater circulation well with in-well air stripping system and the costs associated with annual groundwater sampling and analysis for MNA. For costing purposes, two scenarios were considered. For Option A, a 5-year groundwater circulation well/in-well air stripping system operation was assumed. For Option B, a 10-year groundwater circulation well/in-well air stripping system operation was assumed. For both options, MNA costs for 10 years were assumed. A discount rate of 3% was assumed when calculating O&M present worth costs. The costs associated with this alternative are presented in Table B-3, and the total present worth costs are summarized as follows:

- Option A Total Present-Worth Cost $ 897,000
- Option B Total Present-Worth Cost $ 1,176,000

5.3.5 Alternative E: Permeable Reactive Barrier

PRBs are installed across the flow path of a contaminated groundwater plume, allowing the water portion of the plume to flow through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. The reactive materials may be mixed with sand to make it easier for water to flow through the wall, rather than around it. A number of firms specialize in design and construction of PRBs. Most of them have developed their proprietary reactive materials for specific chemicals, or will develop site-specific reactive materials during the design stage based on site contaminants and concentrations. Figure 5-3 presents a schematic diagram of a permeable reactive barrier system.

In addition to groundwater treatment using PRB, naturally occurring processes also contribute to the reduction of contaminant concentrations.

Primary components of the PRB alternative include:

- Investigation (including groundwater sampling, Geoprobe® soil sampling, and bench-scale testing), design, and installation of PRB.
- Semi-annual sampling and analysis of groundwater from five shallow water monitoring wells.
- Implementation of institutional controls to prevent the use of groundwater for drinking purposes at the site and the impacted area downgradient of the site. Institutional controls will be imposed through deed restrictions.

PRBs are typically installed downgradient of the contaminant source area to control downgradient migration of contaminants. At the Nike Launch Area, the barrier wall will be installed between the source area and Lots 8, 9, and 10. Passive treatment walls may lose their reactive capacity and permeability over time due to chemical precipitation or biological activity, requiring replacement of the reactive medium. Due to the very low contaminant concentrations present in the Nike Launch Area groundwater, the combined effect of PRB and MNA are expected to reduce the contaminant concentration to below the risk-based RGs within a few years at Lots 8, 9, and 10. Since the effectiveness of the PRB is limited to the groundwater downgradient of the PRB, the source area concentrations will not be decreased due to the presence of the PRB. However, there are no identified risks within the source area. Contaminant concentrations on both sides of the PRB (upgradient and downgradient) will continue to decline over time due to natural attenuation processes.

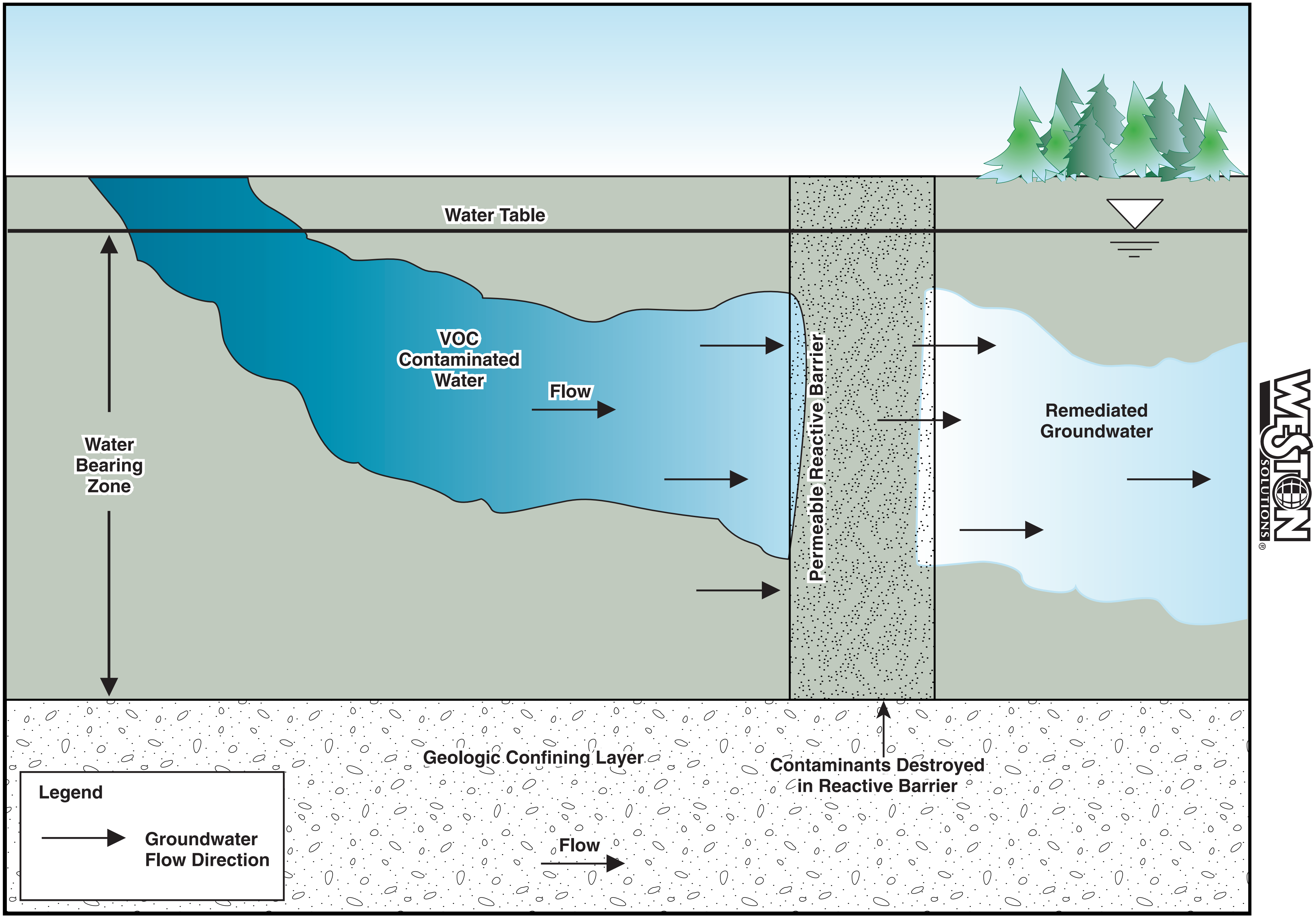

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FIGURE 5-3 SCHEMATIC DIAGRAM OF PERMEABLE REACTIVE BARRIER

The PRB at the Nike Launch Area will be designed to reduce the CCl_4 and TCE concentrations in groundwater leaving the wall to less than 5 µg/L. Therefore, immediately after the installation of the PRB, both the risk-based concentration of 48 µg/L and the MCL of 5 µg/L (for CCl_4 and TCE) will be achieved just downgradient of the wall. Initially, the contamination will remain downgradient of the PRB, but it will decrease over time due to natural attenuation processes. It is anticipated that the PRB, in conjunction with natural attenuation processes, will decrease CCl_4 levels in groundwater at Lots 8, 9, and 10 to below the risk-based concentration of 48 µg/L within a period of 1 to 2 years, and the MCL of 5 µg/L within 2 to 4 years.

The proposed PRB location is downgradient of the contaminant source area near MW-12, parallel to the FUDS boundary. The distance from the PRB to the ends of the lots will range from approximately 130 to 230 feet. Once the PRB is installed CCl_4 concentrations will drop below 5 µg/L immediately downgradient of the wall, so the time required to meet the RGs will be determined by the time it will take for the groundwater downgradient of the PRB to travel to the ends of the lots and to the stream (210 to 340 feet). The estimated timeframe for achieving the RGs was determined using the average groundwater seepage velocity of 0.32 ft/day, a CCl_4 retardation factor of 1.2 and the measured distances to the ends of the lots and stream.

The reaction of CCl_4 with the PRB materials will potentially produce low concentrations of CCl_4 breakdown products, such as chloroform and methylene chloride (dichloromethane). Preliminary PRB design calculations (ETI, 2004) predict that chloroform will be released from the PRB at concentrations below its MCL; however, methylene chloride concentrations leaving the PRB (calculated to be 12 µg/L) may slightly exceed its MCL of 5 µg/L at the center of the CCl_4 groundwater plume where CCl_4 concentrations exceed 100 µg/L. Elsewhere along the barrier, methylene chloride concentrations leaving the PRB will be less than its MCL. According to published groundwater degradation rates (Howard, 1991), methylene chloride (half-life of 8 weeks) degrades much faster than its parent products, CCl_4 (half-life of 1 year) and chloroform (half-life of 5 years). Using a more recent conservative degradation rate of 15 weeks (Fiorenza, 1994) the Win Tran® contaminant transport model predicts that the methylene chloride concentrations will quickly decrease below 5 µg/L as the groundwater moves away from the

PRB. Before groundwater leaving the PRB reaches Lots 8, 9, and 10, the methylene chloride concentrations will have decreased to levels below its MCL.

5.3.5.1 Overall Protection of Human Health and the Environment

The PRB would provide protection to human health and the environment by controlling contaminant migration to Lots 8, 9, and 10, and reducing the CCl_4 concentrations to below the risk-based concentration of 48 µg/L, and eventually below the State MCL of 5 µg/L. Although this alternative does not address the source area located upgradient of the wall, there are no identified impacts to human health from site-related contaminants upgradient of the PRB.

5.3.5.2 Compliance with ARARs

This alternative would achieve chemical-specific risk-based RGs and State MCLs.

There are no location-specific ARARs associated with the site.

5.3.5.3 Long-Term Effectiveness and Permanence

The PRB alternative would be effective in the long-term at maintaining reduced groundwater contaminant concentrations downgradient of the site. The magnitude of residual risk upgradient of the PRB is expected to reduce over the long-term to acceptable levels. The rate of reduction of contaminant levels and mass would be documented through periodic groundwater sampling until ARARs are achieved.

The treatment process that takes place in the reactive medium of the PRB and natural attenuation processes that transform site contaminants into harmless compounds are permanent and irreversible.

5.3.5.4 Reduction of Toxicity, Mobility, or Volume

TMV of contaminants will be reduced gradually over time due to chemical reactions that occur between contaminants and the reactive material of the PRB.

5.3.5.5 Short-Term Effectiveness

The short-term risks to the community from this alternative would be due to activities associated with excavation and installation of the PRB, installation of groundwater monitoring wells (if required), and groundwater sampling. All activities will be performed in accordance with an SSHP and should present no danger to the surrounding community, workers, or the environment. Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements.

5.3.5.6 Implementability

This alternative can be easily implemented. Excavation of the PRB and installation of additional groundwater wells can be performed using standard excavation and construction techniques. Firms that specialize in design and construction of PRBs perform design, and provide expertise and reactive medium for PRB construction.

Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. Sample analyses can be performed using an environmental laboratory.

Implementation of groundwater well installation, deed restrictions, and groundwater monitoring well permits will not require approval and cooperation of the state and local authorities. However, USACE will work to meet the substantive requirements of any state and local permits or regulations pertaining to the proposed work.

5.3.5.7 Cost

The primary capital costs for this alternative include design and installation of the PRB (including reactive material and construction costs), implementation of groundwater use restrictions, and the performance of a soil-gas survey once the contaminant concentrations in groundwater decline to levels below the risk-based RGs. O&M costs for this alternative include costs associated with annual groundwater sampling and analysis for MNA. For costing purposes, it was assumed that MNA will be conducted for 10 years. A discount rate of 3% was assumed when calculating O&M present worth costs. The costs associated with this alternative are presented in Table B-4.

The total present worth cost for this alternative is $ 668,000.

5.3.6 Alternative F: In Situ Chemical Reduction and Bioremediation (ISCR/ISB)

ISCR/ISB amendments, typically consisting of fibrous organic carbon and micro-scale zero-valent iron (ZVI), are injected into the saturated portion of the CCl_4 source zone where a number of physical, chemical and microbiological processes combine to create strongly reducing conditions that stimulate the rapid and complete dechlorination of the contaminants. The organic component is nutrient rich and has high surface area, which is ideal for supporting growth of indigenous bacteria in the groundwater system. As the bacteria grow, they consume dissolved oxygen, thereby reducing the redox potential in the groundwater. In addition, as the bacteria grow, they ferment carbon and release a variety of volatile fatty acids that provide hydrogen as an electron donor for other indigenous dechlorinating bacteria species. Finally, the small ZVI particles provide substantial reactive surface area that stimulates direct, abiotic chemical dechlorination of the CCl_4, which also results in additional drop in the redox potential of the groundwater via chemical oxygen scavenging. The extremely low redox potentials (i.e., ORP levels <-500 mV) yield thermodynamic conditions that will physically degrade most persistent organic constituents, thereby avoiding the accumulation of dead end catabolites such as chloroform from CCl_4 . The ISCR/ISB amendments will remain reactive in the subsurface for 1-3 years, which reduces the potential for contaminant rebound. Further, based on the site contaminant levels and historical case studies on ISCR/ISB technology, CCl_4 levels in the site source zone are expected to be reduced by over 80% with the first 9-12 months (Adventus, 2010). Downgradient contaminant levels would be expected to decline commensurate with the reduction in mass flux that should occur following source zone CCl_4 destruction.

The ISCR/ISB treatment program will consist of direct injection of amendments via Geoprobe® methods using EHC® reagents (Adventus, 2010). In addition to the source zone groundwater treatment using ISCR/ISB technology, the low redox conditions will extend beyond the immediate injection area, thereby promoting naturally occurring attenuation processes to further contribute to the reduction of contaminant concentrations downgradient.

Primary components of the ISCR/ISB alternative include:

- Investigation and delineation of the source zone via GoreSorber® screening, followed by a focused soil boring sampling program.
- Microcosm testing of the site groundwater for the presence of dechlorinating bacteria and the effects of various ISCR/ISB amendments on site contaminants and geochemistry.
- Pilot testing through full-scale implementation of ISCR/ISB injection program at the site CCl_4 source area.
- Quarterly sampling of 7 to 9 monitoring wells for the first year following amendment injections, followed by 2 years of semi-annual sampling and analysis of groundwater.
- An additional round of soil gas sampling would be performed in the three vacant parcels (Lots 8, 9 , and 10) at the Cedar Tree Properties located immediately downgradient of the site to verify that there is no remaining VIP risk present.
- Implementation of institutional controls to prevent the use of groundwater for drinking purposes at the site and the impacted area downgradient of the site until groundwater COCs are compliant with State and Federal MCLs.

5.3.6.1 Overall Protection of Human Health and the Environment

ISCR/ISB technology would provide protection to human health and the environment by destroying the source zone contaminant mass and reducing the CCl_4 concentrations to below the risk-based concentration of 48 μg/L, and eventually below the State MCL of 5 μg/L. By destroying the source zone contaminants in situ, the mass flux of contaminants migrating downgradient would also be reduced.

5.3.6.2 Compliance with ARARs

This alternative would achieve chemical-specific, risk-based RGs and State MCLs.

There are no location-specific ARARs associated with the site.

5.3.6.3 Long-Term Effectiveness and Permanence

The ISCR/ISB alternative would be effective in the long-term at maintaining reduced groundwater contaminant concentrations in both the on-site source zone and in the downgradient, off-site portions of the site. The rate of reduction of contaminant levels and mass would be documented through periodic groundwater sampling until ARARs are achieved.

The abiotic and biotic destruction/degradation processes that takes place in situ within the injection treatment zone would are permanent and irreversible, and would transform site contaminants into harmless compounds.

5.3.6.4 Reduction of Toxicity, Mobility, or Volume

TMV of contaminants will be reduced fairly rapidly (9-12 months) due to abiotic and biotic degradation processes that are stimulated by the injection of the reactive materials of the ISCR/ISB technology.

5.3.6.5 Short-Term Effectiveness

The short-term risks to the community from this alternative would be due to activities associated with the mixing and injection of reactive ISCR/ISB amendments. All mixing, injection and follow-up sampling activities will be performed in accordance with an SSHP and should present no danger to the surrounding community, workers, or the environment. Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements.

5.3.6.6 Implementability

This alternative can be easily implemented. Mixing and injection of ISCR/ISB amendments, along with the installation of additional groundwater monitoring wells can be performed using standard grout mixers, Geoprobe and auger rig drilling, and well construction techniques. Firms that specialize in the design, mixing and injection of ISCR/ISB amendments are readily available and trained in the health and safety protocols for conducting site remediation work.

Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. Sample analyses can be performed using an environmental laboratory.

Implementation of groundwater well installation, deed restrictions, and groundwater monitoring well permits will not require approval and cooperation of the state and local authorities. However, USACE will work to meet the substantive requirements of any state and local permits or regulations pertaining to the proposed work.

5.3.6.7 Cost

The primary capital costs for this alternative include a final delineation of the CCl_4 source zone, a limited bench scale/microcosm testing of source area groundwater/sediment materials, and pilot testing of the ISCR/ISB amendments within the focused source zone at the site, followed by expansion to full-scale design and application of the technology. A soil gas survey of the downgradient, off-site property would also be performed following reductions in CCl_4 concentrations to verify that the vapor intrusion pathway no longer presents a risk to future residents. O&M costs for this alternative include costs associated with quarterly and semi-annual groundwater sampling and analysis for VOCs and MNA parameters. For costing purposes, it was assumed that groundwater sampling would be conducted quarterly for 1 year and semi-annually for 2 years following full-scale ISCR/ISB application. A discount rate of 3% was assumed when calculating O&M present worth costs. The costs associated with this alternative are presented in Table B-5.

The total present worth cost for this alternative is $ 425,000.

6. COMPARATIVE ANALYSIS OF ALTERNATIVES

6.1 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section provides a comparative analysis of the following alternatives that were subject to detailed analysis in Section 5:

- Alternative A—No Action.
- Alternative B—Monitored Natural Attenuation (MNA).
- Alternative C—Air Sparging with Soil Vapor Extraction (AS/SVE).
- Alternative D—Groundwater Circulation Wells with In-Well Air Stripping.
- Alternative E—Permeable Reactive Barrier (PRB).
- Alternative F—In Situ Chemical Reduction and In Situ Bioremediation (ISCR/ISB).

For comparison, the analysis results from Section 5 are summarized in Table 6-1. During the comparative analysis, the performance of the alternatives is compared relative to each of the following evaluation criteria to identify key differences:

- Overall protection of human health and the environment.
- Compliance with ARARs.
- Long-term effectiveness.
- Reduction of TMV.
- Short-term effectiveness.
- Implementability.
- Cost.

The comparative analysis of the alternatives is presented in the following subsections.

Table 6-1 Comparison of Remedial Alternatives for the Nike Launch Area Site

Criterion	Alternative A No Action	Alternative B Monitored Natural Attenuation	Alternative C Air Sparging With Soil Vapor Extraction	Alternative D Groundwater Circulation Wells With In-Well Air Stripping	Alternative E Permeable Reactive Barrier	Alternative F In Situ Chemical Reduction/In Situ Bioremediation
Overall Protection of Human Health and the Environment	• The No Action alternative would not be protective of human health or the environment.	• Based on the declining VOC concentrations in groundwater since 1987 and the recent non-detect levels at MW-18 during the 2008 sampling activities, natural attenuation processes are slowly reducing VOC concentrations to acceptable levels, and have the potential to provide protection to human health and the environment over a reasonably long timeframe. • Institutional controls would be required to restrict installation of drinking water wells until the CCl_4 levels are reduced to below the MCL of 5 µg/L.	• Would provide protection to human health and the environment. Air sparging and SVE are well-proven technologies for removing a range of organic compounds from groundwater, including the COCs found at Nike Launch Area. • Institutional controls would be required to restrict installation of drinking water wells until the CCl_4 levels are reduced to below the MCL of 5 µg/L.	• Would provide protection to human health and the environment. Groundwater circulation wells and in-well air stripping are well-proven technologies for removing a range of VOCs from groundwater, including the COCs found at Nike Launch Area. • Institutional controls would be required to restrict installation of drinking water wells until the CCl_4 levels are reduced to below the MCL of 5 µg/L.	• Would provide protection to human health and the environment by controlling contaminant migration to Lots 8, 9, and 10, and reducing the CCl_4 concentrations to below the MCL of 5 µg/L. Although this alternative does not address the source area located upgradient of the wall, there are no identified impacts to human health from site-related contaminants upgradient of the proposed location of the PRB. • Institutional controls would be required to restrict installation of drinking water wells until the CCl_4 levels are reduced to below the MCL of 5 µg/L.	• Would provide protection to human health and the environment in a timely manner by abiotically and biotically degrading CCl_4 concentrations in place within the source zone on-site. By destroying the CCl_4 source zone on-site, the mass flux of VOCs migrating downgradient and off-site would also be significantly reduced in a timely manner. • Institutional controls would be required to restrict installation of drinking water wells until the CCl_4 levels are reduced to below the MCL of 5 µg/L.
Compliance with ARARs	• Without a monitoring program, compliance with chemical-specific ARARs cannot be determined. • There are no location-specific ARARs associated with this alternative. • Action-specific ARARs are not applicable because there is no remedial work associated with this alternative.	• Would achieve chemical-specific risk-based RGs and State MCLs through natural attenuation. • There are no location-specific ARARs associated with the site.	• Would achieve chemical-specific risk-based RGs and the State MCLs through treatment. • There are no location-specific ARARs associated with the site. • The vapors collected from the air stripping process will meet all applicable federal and state (if state requirements are more stringent than federal requirements) emission requirements.	• Would achieve chemical-specific risk-based RGs and the State MCLs through treatment. • There are no location-specific ARARs associated with the site. • The vapors collected from the air stripping process will meet all applicable federal and state (if state requirements are more stringent than federal requirements) emission requirements.	• Would achieve chemical-specific risk-based RGs and the State MCLs through treatment. • There are no location-specific ARARs associated with the site.	• Would achieve chemical-specific risk-based RGs and the State MCLs through treatment. • There are no location-specific ARARs associated with the site.

Table 6-1 Comparison of Remedial Alternatives for the Nike Launch Area Site (Continued)

Criterion	Alternative A No Action	Alternative B Monitored Natural Attenuation	Alternative C Air Sparging With Soil Vapor Extraction	Alternative D Groundwater Circulation Wells With In-Well Air Stripping	Alternative E Permeable Reactive Barrier	Alternative F In Situ Chemical Reduction/In Situ Bioremediation
Long-Term Effectiveness and Permanence	• The No Action alternative could be effective in the long-term as a result of contaminant reduction due to natural attenuation processes, but its effectiveness cannot be determined without groundwater monitoring. The potential risk of inhalation of CCl_4 vapors in a future residential basement on Lots 8, 9, and 10 would continue to exist. • Without the implementation of institutional controls, the potential risk of using contaminated groundwater for drinking purposes would continue to exist.	• The MNA alternative would be effective in the long-term. The magnitude of residual risk is expected to decline over the long-term to acceptable levels. • Based on the historical data and the groundwater transport model predictions, MNA would be an adequate and reliable response action to address the groundwater contamination at the site. To the extent that the contaminants are transformed into harmless compounds through natural attenuation processes, the process is irreversible.	• The air sparging/SVE alternative would be effective in the long-term. The magnitude of residual risk is expected to decline over the long-term to acceptable levels. The rate of reduction of contaminant levels and mass would be known through periodic groundwater sampling. • Treatment processes associated with this alternative and natural attenuation processes that transform site contaminants into harmless compounds are permanent and irreversible.	• The groundwater circulation wells and in-well air stripping alternative would be effective in the long-term. The magnitude of residual risk is expected to decline over the long-term to acceptable levels. The rate of reduction of contaminant levels and mass would be determined through periodic groundwater sampling. • Treatment processes associated with this alternative and natural attenuation processes that transform site contaminants into less harmful compounds are permanent and irreversible.	• The PRB alternative would be effective in the long-term. The magnitude of residual risk is expected to reduce over the long-term to acceptable levels. The rate of reduction of contaminant levels and mass would be known through periodic groundwater sampling. • The treatment process that takes place in the reactive medium of the PRB and natural attenuation processes that transform site contaminants into harmless compounds are permanent and irreversible.	• The in situ chemical and biological degradation of the VOC source zone would be effective in the long-term. The magnitude of residual risk is expected to decline quickly to acceptable levels relative to the non-source treatment alternatives. The rate of contaminant mass reduction will be determined through periodic groundwater monitoring. • The in situ treatment and destruction processes associated with this Alternative transform VOCs into harmless end products which are irreversible.
Reduction of Toxicity, Mobility or Volume (TMV) Through Treatment	• In the No Action alternative, there would be no active treatment process for the contaminated groundwater. Therefore, TMV may only be reduced through natural attenuation processes. The extent or the rate of reduction would not be known without a groundwater monitoring program. • This alternative would not satisfy the statutory preference for treatment as a principal element of a remedial action.	• In the MNA alternative, there would be no active treatment process to treat contaminated groundwater. Reduction in the TMV of contaminants is expected to occur through natural attenuation processes based on historical data and groundwater model predictions. • This alternative would not satisfy the statutory preference for active treatment as a principal element of a remedial action.	• Toxicity of the contaminants would not change during the air sparging /SVE process, since the process involves only removal of organic contaminants. However, regeneration of GAC (if used) would transform contaminants to harmless compounds, thereby reducing the toxicity. • Mobility and volume of contaminants would be reduced because they are permanently removed from the site groundwater. • This alternative would satisfy the statutory preference for active treatment as a principal element of a remedial action.	• Toxicity of the contaminants would not change during the air stripping process since the process involves only removal of organic contaminants. However, regeneration of GAC (if used) would transform contaminants to harmless compounds, thereby reducing the toxicity. • Mobility and volume of contaminants would be reduced because they are permanently removed from the site groundwater. • This alternative would satisfy the statutory preference for active treatment as a principal element of a remedial action.	• Toxicity, mobility, and volume of contaminants will be reduced gradually over time due to chemical reactions that occur between contaminants and the reactive material of the PRB. • Mobility and volume of contaminants would be reduced because they are permanently removed from the site groundwater. • This alternative would satisfy the statutory preference for active treatment as a principal element of a remedial action, but it would not address source area contamination.	• Toxicity, mobility and volume of contaminants will be reduced quickly through abiotic chemical reduction reactions that occur between the VOCs and the reactive iron amendments. Additional reductions in TMV of contaminants will occur more gradually via biological transformation processes stimulated by the carbon portion of the in situ amendments. • This alternative would satisfy the statutory preference for active treatment as a principal element of a remedial action.

Table 6-1 Comparison of Remedial Alternatives for the Nike Launch Area Site (Continued)

Criterion	Alternative A No Action	Alternative B Monitored Natural Attenuation	Alternative C Air Sparging With Soil Vapor Extraction	Alternative D Groundwater Circulation Wells With In-Well Air Stripping	Alternative E Permeable Reactive Barrier	Alternative F In Situ Chemical Reduction/In Situ Bioremediation
Short-Term Effectiveness	• There would be no additional risks to the community or the workers because there would be no remedial work at the site.	• There would be minimal additional risk to the community in the short-term since there is only limited activity associated with the MNA alternative. • Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements. • Workers will be protected during site activities by taking standard safety measures and complying with the SSHP.	• Short-term risks to the community from this alternative would be due to activities associated with drilling and installation of air-sparging wells, SVE vents, vapor treatment system, installation of groundwater monitoring wells (if required), and groundwater sampling. All activities will be performed in accordance with an SSHP. • Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements. • Workers will be protected during site activities by taking standard safety measures and complying with the SSHP. • This source treatment alternative would achieve remedial action objectives (RAOs) in a timeframe commensurate with Alternatives D and F.	• Short-term risks to the community from this alternative would be due to activities associated with drilling and installation of groundwater circulation wells, vapor extraction vents, vapor treatment system, installation of groundwater monitoring wells (if required), and groundwater sampling. All activities will be performed in accordance with a site-specific health and safety plan. • Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements. • Workers will be protected during site activities by taking standard safety measures and complying with the SSHP. • This source treatment alternative would achieve remedial action objectives (RAOs) in a timeframe commensurate with Alternatives C and F.	• Short-term risks to the community from this alternative would be due to activities associated with excavation and installation of the PRB, installation of groundwater monitoring wells (if required), and groundwater sampling. All activities will be performed in accordance with a site-specific health and safety plan. • Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements. • Workers will be protected during site activities by taking standard safety measures and complying with the SSHP.	• Short-term risks to the community from this alternative would be due to activities associated with the installation and sampling of groundwater monitoring wells, drilling of injection borings, and the handling/mixing of in situ treatment amendments. In general, the treatment amendments are naturally occurring compounds such as zero-valent iron and food-grade, fibrous organic carbon which present little or no human health risk. • Potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements. • Workers will be protected during site activities by taking standard safety measures and complying with the SSHP. • This source treatment alternative would achieve remedial action objectives (RAOs) in a timeframe commensurate with Alternatives C and D.

Table 6-1 Comparison of Remedial Alternatives for the Nike Launch Area Site (Continued)

Criterion	Alternative A No Action	Alternative B Monitored Natural Attenuation	Alternative C Air Sparging With Soil Vapor Extraction	Alternative D Groundwater Circulation Wells With In-Well Air Stripping	Alternative E Permeable Reactive Barrier	Alternative F In Situ Chemical Reduction/In Situ Bioremediation
Implementability	• No technical or administrative issues are associated with the No Action Alternative.	• The MNA alternative can be easily implemented. Standard construction techniques may be used to install additional groundwater monitoring wells, if required. • Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. Sample analyses can be performed using an environmental laboratory. • Implementation of groundwater well installation and deed restrictions will be coordinated with state and local authorities.	• Air-sparging/SVE alternative can be easily implemented. Materials, equipment, and qualified personnel for installation of air-sparging wells and SVE vents are readily available. Standard construction techniques may be used to install additional groundwater monitoring wells, if required. • Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. • A pilot study would be conducted to optimize the effectiveness of the system.	• Groundwater circulation wells/in-well air stripping alternative can be easily implemented. Materials, equipment, and qualified personnel for installation of the groundwater circulation well/in-well air stripping system are readily available. Standard construction techniques may be used to install additional groundwater monitoring wells, if required. • Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. • A pilot study would be conducted to optimize the effectiveness of the system.	• Excavation of the PRB and installation of additional groundwater wells can be performed using standard excavation and construction techniques. There are firms specialized in design and construction of PRBs who perform design and provide expertise and reactive medium for PRB construction. • Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. • A bench-scale test would be conducted to determine the optimal PRB design parameters.	• Installation of additional groundwater monitoring wells or drilling of injection borings can be performed using standard construction and Geoprobe drilling techniques. There are firms readily available who specialize in the design, handling and injection of in situ ISCR/ISB amendments. • Periodic groundwater sampling and analysis can be conducted by employing trained personnel using standard sampling techniques. • Pilot-scale testing of this alternative would likely be conducted in the focused source area to optimize effectiveness of the system.
Cost	Total Present Worth Cost $0	Total Present Worth Cost Option A* $171,000 Option B*** $440,000	Total Present Worth Cost Option A* $ 831,000 Option B** $1,064,000	Total Present Worth Cost Option A* $ 897,000 Option B** $1,176,000	Total Present Worth Cost $668,000**	Total Present Worth Cost* $425,000 Includes 1 year of in situ treatment and 2 years of MNA.
		* Based on 5-yr system operation ** Based on 10-yr system operation *** Based on 20-yr system operation				

6.1.1 Overall Protection of Human Health and the Environment

The No Action Alternative (Alternative A) would not be protective of human health or the environment. The potential risk from the inhalation of VOCs in residential basements would continue to exist on Lots 8 and 10, if houses are built on these lots. In the absence of a groundwater monitoring program, the extent of any contaminant reduction would not be known.

Alternatives B, C, D, E, and F would ultimately provide protection to human health and the environment, although Alternatives C, D, and F would achieve protection in a more timely manner.

Based on the historical groundwater data and the predictions derived from the groundwater transport model, it is anticipated that non-biological natural attenuation processes (MNA, Alternative B), would reduce CCl_4 concentrations in groundwater to below the VIP risk-based concentration of 48 µg/L within a reasonable timeframe (approximately 4 to 5 years), and subsequently, to below the MCL of 5 µg/L downgradient of the source area within approximately 18 years (WinTran® model results, WESTON, 2004a).

Alternatives C, D, and F are more aggressive than Alternative B because of the active, focused remediation processes being targeted directly within the source zone. By directly addressing the source area contamination, the mass flux of contaminants migrating downgradient would be significantly reduced, thereby gradually reducing the contaminant concentrations in the entire plume. Active remediation, in conjunction with the naturally occurring processes, would result in achieving the RAOs within a shorter timeframe than in Alternative B.

Alternative E addresses the groundwater downgradient of the PRB by abruptly reducing the COC concentrations in groundwater passing through the PRB to the MCLs. As a result, Alternative E focuses on reducing plume strength downgradient (i.e., in off-site Lots 8, 9, and 10), but does not address the on-site source area contamination. COC concentrations in the site source area would be gradually decreased through natural attenuation processes.

6.1.2 Compliance with ARARs

The alternatives would be in compliance with the ARARs as follows:

Chemical-Specific ARARs—Chemical-specific ARARs would not be achieved in a reasonable timeframe with Alternatives A and B, because each would rely only on natural attenuation processes to reduce CCl_4, concentrations. Due to the aerobic nature of the site groundwater, natural attenuation processes are not favorable for achieving chemical-specific ARARs in a timely manner. In addition, without a monitoring program, compliance with chemical-specific ARARs could not be determined with Alternative A. Alternative E would achieve chemical-specific ARARs in a timely manner downgradient of the PRB; however, in the upgradient, on-site portion of the site, compliance with ARARs would again be limited only to natural attenuation processes. Alternatives C, D, and F would all achieve chemical-specific risk-based RGs and MCLs in a timely manner.

Location-Specific ARARs—There are no location-specific ARARs associated with the Nike Launch Area site.

Action-specific ARARs—There are no action-specific ARARs associated with Alternative A because there are no remedial actions under this alternative.

All action-specific ARARs would be met in Alternatives B, C, D, E, and F.

6.1.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternative A cannot be determined in the absence of a monitoring program. The potential risks to the future residents through inhalation of VOCs in the basements of houses built on Lots 8 and 10 would continue to exist.

Alternatives B, C, D, E, and F would be effective in the long-term. In Alternative B, the magnitude of residual risk is expected to reduce to acceptable levels through reduction in VOC concentrations as predicted by the historical data and groundwater modeling; however, this alternative would require a significantly longer timeframe to reach acceptable levels throughout the plume than alternatives C, D, and F. In Alternatives C, D, and F, the effectiveness is further enhanced by the active remediation processes associated with these alternatives. Although the remediation process is passive in Alternative E, the chemical agents in the PRB would actively contribute to the remediation process downgradient; however, the upgradient portion of the plume would reduce in VOC concentrations over a longer timeframe comparable to Alternative B.

In Alternatives B, C, D, E, and F, the VOCs are transformed into harmless compounds, or the VOC concentrations would be reduced to levels that are protective of human health and the environment. The transformation processes associated with these alternatives are irreversible.

6.1.4 Reduction of Toxicity, Mobility, and Volume

In Alternative A, there would be no active treatment process to address the contaminated groundwater. Any reduction in VOC concentrations would not be known without a groundwater monitoring program.

Although Alternative B also does not actively address groundwater contamination, historical groundwater data and groundwater model predictions indicate that the VOC concentrations will decline over time via natural attenuation processes, thereby reducing the TMV.

In Alternatives C and D, toxicity of the contaminants would not change during the VOC removal from groundwater; however, if activated carbon is used to treat extracted gas (as opposed to direct release to the atmosphere), regeneration of activated carbon will transform contaminants to harmless compounds, thereby, reducing the TMV of contaminants removed from the site groundwater.

In Alternative E, TMV of contaminants will be reduced gradually over time due to chemical reactions that occur between the VOC contaminants and the reactive material of the PRB.

In Alternative F, TMV of contaminants will be reduced quickly at first due to the abiotic chemical reactions that occur between the VOC contaminants and the reactive material in the amendment, then more gradually due to the slower biological transformations processes stimulated by the carbon amendments.

Alternatives C, D, E, and F all meet the statutory preference for treatment as a principal element of the remedy.

6.1.5 Short-Term Effectiveness

In Alternative A, there would be no additional risks to the community or the workers because there would be no remedial work at the site.

In Alternative B, there would be minimal additional risk to the community in the short-term because only limited activity is associated with the MNA alternative, such as, groundwater sampling, drilling, and installation of new groundwater monitoring wells (if required).

In Alternatives C and D, minimal short-term risks to the community would be due to activities associated with drilling and installation of wells, vapor extraction treatment system, installation of groundwater monitoring wells (if required), and groundwater sampling. Due to the relatively low VOC concentrations requiring treatment, VOC emissions from treatment system operations would be negligible.

In Alternative E, the short-term risks to the community would be due to activities associated with excavation and installation of the PRB, installation of groundwater monitoring wells (if required), and groundwater sampling.

In Alternative F, the short-term risks to the community would be due to activities associated with the installation of groundwater monitoring wells and injection points; the handling and injection of chemical and biological amendments and groundwater sampling. However, the chemical and biological amendments are naturally occurring compounds, such as zero-valent iron and food-grade, fibrous organic carbon, which would pose little if any exposure/handling risk to on-site workers or the community.

In Alternatives B, C, D, E, and F, potential risks to the community will be minimized by taking appropriate measures prior to the execution of any work and by complying with applicable state emission requirements. Workers will be protected during the site activities by following standard safety measures and complying with the SSHP. Therefore, site activities would not present any danger to the surrounding community, workers, or the environment.

Remedial action objectives (RAOs) would be most quickly achieved with Alternatives C, D, and F, whereas Alternative E would achieve RAOs downgradient of the PRB comparable to

Alternatives C, D, and F. Alternative E would achieve RAOs upgradient of the PRB comparable to Alternative B for the entire plume. Alternative A would not achieve RAOs in a timely manner because there are no institutional controls preventing human exposure to contaminated site groundwater or monitoring of site cleanup progress to determine when acceptable VOC reductions have occurred.

6.1.6 Implementability

Alternative A can be easily implemented. No technical or administrative issues are associated with the No Action Alternative.

Alternatives B, C, and D can be easily implemented. Standard sampling and construction techniques would be used for the activities associated with these alternatives. Remediation technologies associated with Alternatives C and D are well established, and materials and qualified personnel for installation and operation are readily available.

Technical expertise and reactive materials for implementation of Alternative E are available from vendors who specialize in the design and installation of PRBs. The PRB trench excavation can be performed using standard excavation equipment.

Technical expertise and reactive materials for implementation of Alternative F are available from vendors who specialize in the design and injection of chemical and biological amendments. The injection points will be installed using standard Geoprobe drilling/injection equipment.

Implementation of groundwater well installation and deed restrictions will be coordinated with the state and local authorities.

6.1.7 Cost

There are no costs associated with Alternative A.

An explanation of costs for Alternatives B, C, D, E, and F is presented in Section 5, and the costs are itemized in Appendix B. Total present worth costs for these alternatives are summarized below:

Alternative B: Monitored Natural Attenuation

- Total Present-Worth Cost (5 years) $171,000
- Total Present-Worth Cost (20 years) $440,000

Alternative C: Air Sparging with Soil Vapor Extraction

Total Present-Worth Cost Option A* $ 831,000

Total Present-Worth Cost Option B** $1,064,000

* 5 years of air sparging/SVE, 10 years of MNA.

** 10 years of air sparging/SVE, 10 years of MNA.

Alternative D: Groundwater Circulation Wells with In-Well Air Stripping.

Total Present-Worth Cost Option A* $ 897,000

Total Present-Worth Cost Option B** $1,176,000

* 5 years of GW circulation wells/air stripping, 10 years of MNA.

** 10 years of GW circulation wells/air stripping, 10 years of MNA.

Alternative E: Permeable Reactive Barrier

Total Present-Worth Cost* $668,000

* Includes 10 years of MNA.

Alternative F: In Situ Chemical Reduction and Bioremediation

Total Present-Worth Cost* $425,000

* Includes 1 year of in situ treatment and 2 years of MNA.

6.2 REMEDIAL ALTERNATIVE EVALUATION SUMMARY

Land Use Controls (LUCs) for Buildings 23 and 31 on-site would be required for all alternatives until such time that the CCl_4 concentrations within the groundwater are below the RG of 48 µg/L. LUCs for Buildings 23 and 31 would consist of restricting personnel from using these buildings to conduct indoor activities (i.e., working within a confined area without proper ventilation) that would place a person within an environment that could possibly be affected by vapor intrusion. LUCs would reduce the possibility for vapor intrusion within these buildings becoming a threat to human health.

Based on the comparative analysis, Alternative A would not be protective of human health or the environment. The potential risks from contaminated groundwater and vapor intrusion into residential basements in Lots 8 and 10 would continue to exist, and there would be no monitoring program in place to assess any change in VOC concentrations.

Alternatives B, C, D, E, and F would all eventually provide protection to human health and the environment, but within substantially different timeframes. Alternatives B and E would not achieve cleanup in the site source area groundwater as quickly as the source zone treatment technologies; however, Alternative E would achieve cleanup of the downgradient portion of the contaminant plume commensurate with Alternatives C, D, and F. Alternative B is a passive alternative and the reduction in VOC concentrations in groundwater is dependent entirely upon naturally occurring processes. Due to the aerobic nature of the site groundwater system, natural declines in CCl_4 concentrations would be slow and reliant primarily on non-destructive attenuation process (dilution, dispersion, and sorption).

Alternatives C, D, and F are more aggressive than Alternative B because of the active remediation processes associated with them. All three alternatives address the source area contamination directly, thereby gradually reducing the contaminant concentration in the entire plume. Active remediation, in conjunction with the natural attenuation processes, would result in achieving the RAOs within a much shorter timeframe than Alternatives B and E (within the source zone).

The approach in Alternative E is slightly different from Alternatives C, D, and F in that, although it employs active treatment technology, it relies on the passive migration of the contaminant plume through the reactive wall. Although it does not address the source area contamination directly, it abruptly reduces the CCl_4 and TCE concentrations in the groundwater that passes through the PRB to achieve the MCLs as per design requirements. Lots 8, 9, and 10 are located downgradient of the PRB. Because the groundwater entering these lots will not contain VOC concentrations exceeding MCLs, the concentrations of the VOCs that already existed prior to the installation of the PRB would be reduced at a faster rate than they could be achieved with the MNA alternative alone. Based on the existing contaminant plume characteristics and the average groundwater flow velocity, MNA could reduce the VOC concentrations in the groundwater downgradient of the PRB to below MCLs within approximately 2 to 4 years.

The primary focus of the groundwater remediation is achieving MCLs. Although Alternatives C, D, and F would each achieve the RAOs in similar timeframes, Alternative F is deemed the most cost-effective, sustainable alternative for the site source zone. Although Alternatives C and D involve active remediation of the source zone (similar to Alternative F), both technologies would require substantially higher energy output than Alternative F, and would require constant operation and maintenance (O&M). In contrast, Alternative F would achieve destruction of the site source zone entirely in situ, which would eliminate O&M and operational energy usage throughout the life of the cleanup. In addition, at the conclusion of the cleanup, unlike Alternatives C and D, there would be no above ground decommissioning of treatment and electrical equipment associated with Alternative F. As a result, in terms of total present worth costs, the cost of Alternative F is substantially less than the costs of Alternatives C or D.

6.2.1 Components of In Situ Chemical Reduction and Bioremediation

If Alternative F is selected for the groundwater remediation at the Nike Launch Area, the following information provides additional details for implementation of the alternative. ISCR/ISB amendments, typically consisting of fibrous organic carbon and micro-scale zero-valent iron (ZVI), are injected into the saturated portion of the CCl_4 source zone where a number of physical, chemical and microbiological processes combine to create strongly reducing conditions that stimulate the rapid and complete dechlorination of the contaminants. The organic component is nutrient rich and has high surface area, which is ideal for supporting growth of indigenous bacteria in the groundwater system. As the bacteria grow, they consume dissolved oxygen, thereby reducing the redox potential in the groundwater. In addition, as the bacteria grow, they ferment carbon and release a variety of volatile fatty acids that provide hydrogen as an electron donor for other indigenous dechlorinating bacteria species. Finally, the small ZVI particles provide substantial reactive surface area that stimulates direct, abiotic chemical dechlorination of the CCl_4, which also results in additional drop in the redox potential of the groundwater via chemical oxygen scavenging. The extremely low redox potentials (i.e., ORP levels <-500 mV) yield thermodynamic conditions that will physically degrade most persistent organic constituents, thereby avoiding the accumulation of dead end catabolites such as chloroform from CCl_4. The ISCR/ISB amendments will remain reactive in the subsurface for 1 to 3 years, which reduces the potential for contaminant rebound. Further, based on the site contaminant levels and historical case studies on ISCR/ISB technology, CCl_4 levels in the site source zone are expected to be reduced by over 80% with the first 9 to 12 months (Adventus, 2010). Downgradient contaminant levels would be expected to decline commensurate with the reduction in mass flux that should occur following source zone CCl_4 destruction.

This alternative assumes that the ISCR/ISB treatment program will consist of direct injection of amendments via Geoprobe methods using EHC® reagents (Adventus, 2010). Figure 6-1 is a schematic plan view map of the ISCR/ISB injection grid showing the assumed targeted source zone and the location and radius of influence of each Geoprobe injection location.

In addition to the source zone groundwater treatment using ISCR/ISB technology, the low redox conditions will extend beyond the immediate injection area, thereby promoting naturally occurring attenuation processes to contribute to the reduction of contaminant concentrations downgradient.

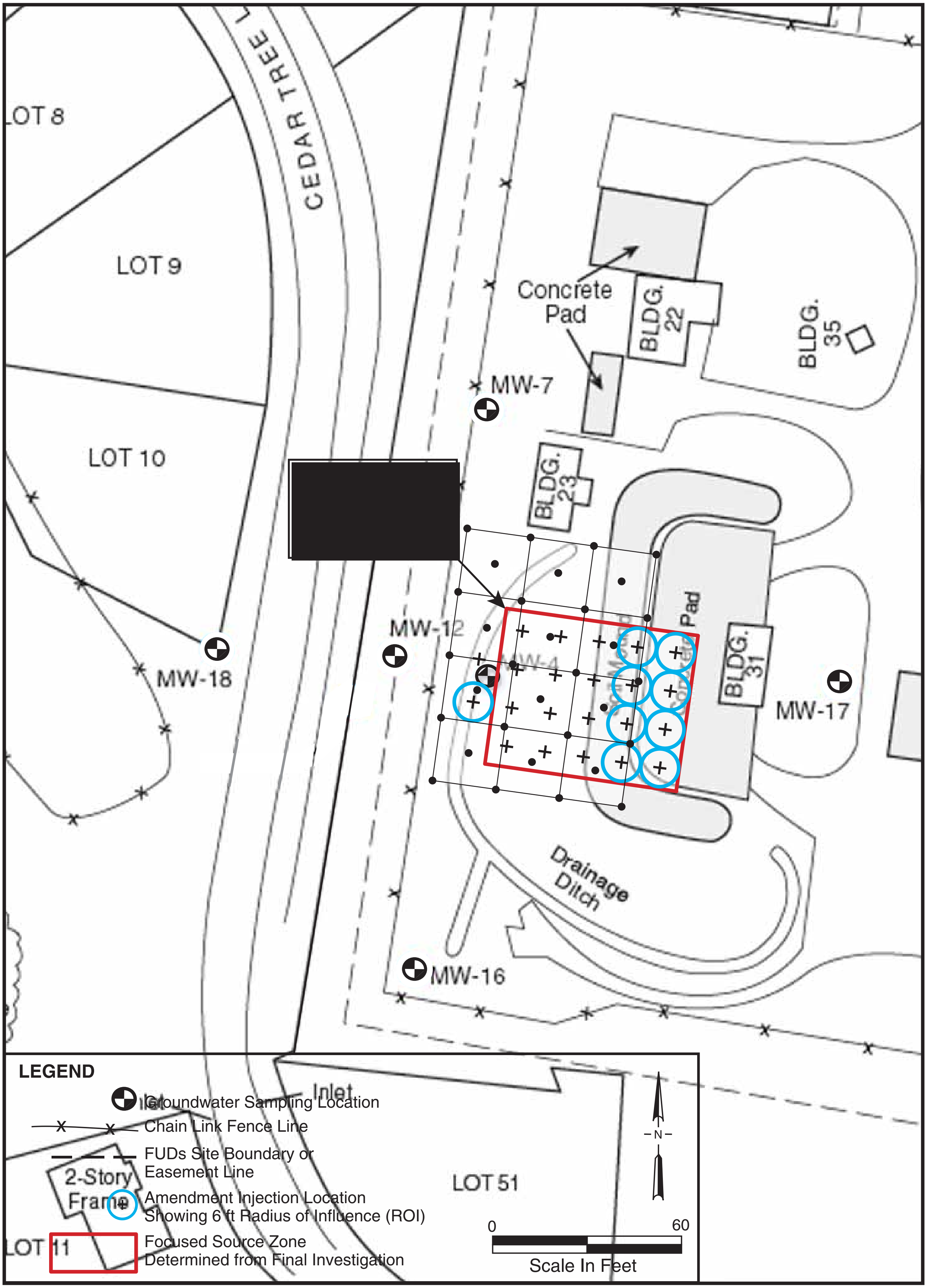

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FIGURE 6-1 SCHEMATIC OF ISCR/ISB ALTERNATIVE F

Primary components of the ISCR/ISB alternative include:

- Investigation and delineation of the source zone via GoreSorber screening, followed by a focused soil boring sampling program. This effort will delineate the size, location, and geometry of the CCl_4 source zone. Included in this investigation will be the installation of 2 to 3 additional monitoring wells located within the source zone.

- Microcosm testing of the site groundwater for the presence of dechlorinating bacteria and the effects of various ISCR/ISB amendments on-site contaminants and geochemistry (i.e., ORP, pH, sulfate, nitrates, DO). This effort may also include bench-scale testing of site groundwater and sediments for determining optimal ISCR/ISB amendment mixtures/concentrations.

- Pilot testing through full-scale implementation of ISCR/ISB injection program at the site CCl_4 source area.

- Quarterly sampling of 7 to 9 monitoring wells for the first year following amendment injections, followed by semi-annual sampling and analysis of groundwater for 2 additional years. Sampling would include analyses for VOCs (i.e., CCl_4 breakdown products chloroform, chloromethane and methylene chloride) and MNA geochemistry parameters (i.e., alkalinity, chloride, sulfate, nitrates, etc).

- Once groundwater sampling results indicate that groundwater VOC levels have been reduced to sub-MCLs in the off post monitoring wells, an additional round of soil gas sampling would be performed in the three vacant parcels (Lots 8, 9, and 10) at the Cedar Tree Properties located immediately downgradient of the site to verify that there is no remaining VIP risk present.

- Implementation of institutional controls to prevent the use of groundwater for drinking purposes at the site and the impacted area downgradient of the site until groundwater COCs are compliant with State and Federal MCLs. Institutional controls off-site will be imposed through deed restrictions.

The ISCR/ISB amendments will be injected within an area assumed to be approximately 50 ft long x 50 ft wide and 10 ft deep, focusing on the saturated interval between 15 and 25 ft below grade. With an assumed radius of influence of the injected amendment of 6 ft, approximately 22 direct injection points would be required spaced 12 ft apart. Amendments would be introduced using Geoprobe's pressure activated injection tools. Based on the low VOC concentrations, groundwater and soil geochemistry, and the longevity of the ISCR/ISB amendments, re-injection of reactive medium is not anticipated at the Nike Launch Area site.

Due to the low contaminant concentrations present in the Nike Launch Area groundwater, the combined effects of ISCR/ISB technology and natural attenuation processes are expected to reduce the contaminant concentration to below the risk-based RGs within approximately 1 to 2 years.

Initially, the VOC concentrations in the existing groundwater downgradient of the ISCR/ISB treatment zone will slightly exceed their respective MCLs. However, it is anticipated that these concentrations will rapidly decrease to sub-MCLs through natural attenuation processes and because the mass flux of CCl_4 impacted groundwater emanating from the treatment source zone will be greatly reduced within the first 9 to 12 months. At a groundwater flow rate of 0.32 ft/day (WESTON, 2004a), the groundwater just downgradient of the ISCR/ISB treatment zone will reach the unnamed stream in approximately 2 years. It is anticipated that the successful destruction of the CCl_4 source zone, in conjunction with natural attenuation processes, will reduce CCl_4 levels in groundwater at Lots 8, 9, and 10 to below the MCL of 5 μg/L within 1 to 2 years.

7. REFERENCES

Adventus (Adventus Americas, Inc.). 2010. *Proposal and Cost Estimate for the Treatment of CVOCs using ISCR Technology – Former Nike Missile Site – Maryland.* Proposal No AAI10-468. 17 June 2010.

ALSI (Analytical Laboratory Services, Inc.). 2010. Certificate of Analysis Letter – Indoor Air Sampling Results. 13 December 2010.

ATEC (ATEC Associates, Inc.). 1994a. *Additional Phase II Subsurface Investigation—Cedar Tree Development*, Pinefield, MD. ATEC Project No. 31-07-93-00440. 7 November 1994.

ATEC. 1994b. *Groundwater Investigation—Cedar Tree Property*, Pinefield, MD. ATEC Project No. 31-07-93-00440. 3 January 1994.

Biteman, S., G. Foote, S. MacFabe, J. Mueller, and J. Molin. 2007. *Pilot-Scale Reductive Dechlorination of Carbon Tetrachloride in Groundwater.* Proceedings of Battelle's 9th International In Situ & On-site Bioremediation Symposium. Baltimore, MD. May 2007.

Donohue (Donohue & Associates, Inc.). 1987. *Final Report for Confirmation Study at Former NIKE Missile Battery (W-44), Waldorf, Maryland.* Prepared for U.S. Army Corps of Engineers (USACE), Omaha District. Sheboygan, WI.

EnviroMetal Technologies, Inc. (ETI). 2004. *Potential PRB Application at the Nike Launch Area, Waldorf, MD*. Cost estimate and technical approach. 17 August 2004.

EPA (U.S. Environmental Protection Agency). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA.* October 1988.

EPA (U.S. Environmental Protection Agency). 1991. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions.* Memorandum from Don R. Clay, Assistant Administrator.

EPA (U.S. Environmental Protection Agency). 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* EPA Office of Solid Waste and Emergency Response, Directive 9200.4-17P. 21 April 1999.

EPA (U.S. Environmental Protection Agency). 2003. *Five-Year Review Process in the Superfund Program*. April. Accessed: 21 January 2010.
http://www.epa.gov/superfund/cleanup/postconstruction/fiveyearreviewfactsheet.pdf.

ERT (Earth Resources Technology, Inc.). 2009. *Draft Remedial Investigation Addendum, Waldorf Nike (W-44) Site, Launch Area*. 23 February 2009.

ERT (Earth Resources Technology, Inc.). 2010. *Draft Final Work Management Plan for Data Gap Investigation, Waldorf Nike (W-44) Site, Launch Area, Charles County, Maryland*. 23 March 2010.

Fiorenza, S., E.L. Hockman, Jr., S. Szojka, R.M. Woeller, and J.W. Wigger. 1994. "Natural anaerobic degradation of chlorinated solvents at a Canadian manufacturing plant." In: Hinchee et al. eds. *Bioremediation of chlorinated and polycyclic aromatic hydrocarbon compounds*. Lewis Publishers, Boca Raton, FL.

Halliburton NUS (Halliburton NUS Environmental Corporation). 1992. *Final Screening Site Inspection, Waldorf Launch.* Project No. 3263-03.

Howard, P. 1991. *Handbook of Environmental Degradation Rates*. Lewis Publishers, Inc., Chelsea, MI.

ITRC (Interstate Technology Regulatory Council). 2002. Technical/Regulatory Guidelines – A Systematic Approach to In Situ Bioremediation in Groundwater for Nitrates, Carbon Tetrachloride and Perchlorate. August 2002.

Major, D.W. and E.E. Cox. 1992. *Field and Laboratory Evidence of In Situ Biotransformation of Chlorinated Ethenes at Two Distinct Sites: Implications for Bioremediation.* In Situ Bioremediation Symposium, Niagara-on-the-Lake, Canada. pp. 48-56. 1992.

Mueller, J. and Brown, D. 2008. *Oxidation or Reduction, How to Decide.* Pollution Engineering Magazine – April 2008.

National Oil and Hazardous Substances Pollution Contingency Plan (NCP). 1994. NCP; Final Rule, Environmental Protection Agency, 40 Code of Federal Regulations (CFR) Parts 9 and 300. 1994. Accessed: 21 January 2010. http://www.epa.gov/emergencies/content/frps/09_94_fulltext.htm.

Rumbaugh, J. 1995. *Guide to Using WinTran: Two-Dimensional Groundwater Flow & Contaminant Transport Model*. Environmental Simulations, Inc., Herndon, VA.

USACE (U.S. Army Corps of Engineers). 1990. *Inventory Project Report (INPR), Nike Battery W-44, Waldorf, MD*. Defense Environmental Restoration Program for Formerly Used Defense Sites (DERP-FUDS).

USACE (U.S. Army Corps of Engineers). 1995. *Risk Assessment Handbook Human Health Evaluation, Volume I: Human Health Evaluation*. Engineer Manual No. EM 200-1-4. 30 June 1995.

USACE (U.S. Army Corps of Engineers). 2010. Final Sampling Plan, Former Nike Battery Launch Area (W-44) Formerly Used Defense Site—Indoor Air Survey at House on Lot #9—Cedar Tree Lane, Waldorf, Maryland. Prepared by Engineering Division, U.S. Army Engineer District, Baltimore. November 2010

USACE Baltimore District. n.d. *Defense Environmental Restoration Program for Formerly Used Defense Sites Inventory Project Report, NIKE Battery W-44, Waldorf, Maryland*. Project No. CO3MD024100.

WESTON (Roy F. Weston, Inc.). 1995. *Limited Remedial Investigation*. NIKE Battery W-44, Waldorf, Maryland, Final Report. Prepared for USACE, Baltimore District. September 1995.

WESTON (Roy F. Weston, Inc.). 1996. *Limited Risk Assessment for the NIKE Battery W-44 Launch Area, Waldorf, Maryland.* Prepared for USACE, Baltimore District. September 1996.

WESTON (Roy F. Weston, Inc.). 1997. *Revised Feasibility Study, NIKE Battery W-44 Waldorf, Maryland*. Prepared for USACE, Baltimore District. April 1997.

WESTON (Roy F. Weston, Inc.). 2000. *Remedial Investigation, NIKE-Battery W-44 Launch Area, Waldorf, Maryland, Pre-Final Report*. Prepared for USACE, Baltimore District. April 2000.

WESTON (Roy F. Weston, Inc.). 2001. *Final Work/Field Sampling Plan Addendum, NIKE Battery Launch Area (W-44), Waldorf, MD.*

WESTON (Weston Solutions, Inc.). 2004a. *Remedial Investigation, NIKE-Battery W-44 Launch Area, Waldorf, Maryland, Final Report*. Prepared for USACE, Baltimore District. April 2004.

WESTON (Weston Solutions, Inc.). 2004b. *Focused Feasibility Study, NIKE-Battery Launch Area (W-44), Waldorf, Maryland*. Prepared for USACE, Baltimore District. September 2004.

APPENDIX A

RISK ASSESSMENT DATA USED IN CALCULATION OF REMEDIATION GOALS

Table A-1

Exposure Point Concentrations
Nike Battery W-44 Site
Waldorf, Maryland

Chemical	Selected Input Groundwater Concentration[a] (µg/L)	Selected Input Soil Gas Concentration[b,c] (µg/L-vapor)	Indoor Air Concentration Based on Groundwater to Enclosed-Space Air Modeling ($\mu g/m^3$-air)	Indoor Air Concentration Based on Soil Gas to Enclosed-Space Air Modeling ($\mu g/m^3$-air)
Carbon tetrachloride	1.1E+02	3.9E+00	1.1E+00	5.7E+00
Trichloroethene	6.0E+00	8.0E-02	2.5E-02	7.6E-02

Notes:
Table A-1 is a revision of Table 6-8 in the Final RI Report.
[a]Represents the maximum detected groundwater concentration measured in on-site well MW-4A in 2003.
[b]Represents the 95% upper confidence limit (UCL) or the maximum detected soil gas concentration (if the UCL exceeded the maximum) in lots 8, 9, and 10 (see Table 3-1).
[c]Note: 1 ug/L = 1000 ug/m^3.

Table A-2

Summary of Cancer Risks and Hazard Indices - Modeling Based On Groundwater Data
NIKE Battery W-44 Site
Waldorf, Maryland

				Noncancer Effects			Cancer Risk		
Chemical	**VF_{WESP}[1] L/m^3**	**EPC[2] mg/L**	**Predicted Indoor Air Concentration[3] mg/m^3**	**Intake[4] mg/kg-day**	**Inhalation Reference Dose[5] mg/kg-day**	**HI**	**Intake[4] mg/kg-day**	**Inhalation Slope Factor[6] $mg/kg\text{-}day^{-1}$**	**Risk**
Future Child Resident									
Carbon Tetrachloride	1.0E-02	0.11	1.1E-03	3.0E-04	5.7E-04	5.2E-01	2.5E-05	5.3E-02	1.3E-06
Trichloroethene	4.2E-03	0.006	2.5E-05	6.7E-06	1.0E-02	6.7E-04	5.8E-07	6.0E-03	3.5E-09
Total	---	---	---	---	---	5.2E-01	---	---	1.3E-06
Future Adult Resident									
Carbon Tetrachloride	1.0E-02	0.11	1.1E-03	1.0E-04	5.7E-04	1.8E-01	4.3E-05	5.3E-02	2.3E-06
Trichloroethene	4.2E-03	0.006	2.5E-05	2.3E-06	1.0E-02	2.3E-04	9.8E-07	6.0E-03	5.9E-09
Total	---	---	---	---	---	1.8E-01	---	---	2.3E-06

Notes:

EPC = Exposure Point Concentration In Groundwater

HI = Noncancer Hazard Index

[1] Volatilization factors were determined based on methodologies presented in the Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. Designation: E 1739 – 95[e1.] e1 = Editorial changes were made throughout in December 1996.

[2] Refer to Table 6-8.

[3] Predicted Indoor Air Concentration = VF_{WESP} x EPC

[4] Intake equations for the future child and adult receptors are presented in the Final RI Report Tables 6-4 and 6-5, respectively.

[5] Noncancer toxicity data is presented in the Final RI Report Table 6-11.

[6] Cancer toxicity data is presented in the Final RI Report Table 6-10.

Table A-3

Summary of Cancer Risks and Hazard Indices - Modeling Based On Soil Gas Data
NIKE Battery W-44 Site
Waldorf, Maryland

Chemical	Predicted Indoor Air Concentration[1, 2] mg/m^3	Noncancer Effects			Cancer Risk		
		Intake[3] mg/kg-day	Inhalation Reference Dose[4] mg/kg-day	HI	Intake[3] mg/kg-day	Inhalation Slope Factor[5] mg/kg-day^{-1}	Risk
Future Child Resident							
Carbon Tetrachloride	5.7E-03	1.5E-03	5.7E-04	2.7E+00	1.3E-04	5.3E-02	7.0E-06
Trichloroethene	7.6E-05	2.1E-05	1.0E-02	2.1E-03	1.8E-06	6.0E-03	1.1E-08
Total	---	---	---	2.7E+00	---	---	7.0E-06
Future Adult Resident							
Carbon Tetrachloride	5.7E-03	5.2E-04	5.7E-04	9.1E-01	2.2E-04	5.3E-02	1.2E-05
Trichloroethene	7.6E-05	7.0E-06	1.0E-02	7.0E-04	3.0E-06	6.0E-03	1.8E-08
Total	---	---	---	9.1E-01	---	---	1.2E-05

Notes:

HI = Noncancer Hazard Index

[1] Predicted indoor air concentrations were determined based on soil gas data and methodologies presented in the Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. Designation: E 1739 – 95$^{e1.}$ e1 = Editorial changes were ma

[2] Refer to Table 6-8.

[3] Intake equations for the future child and adult receptors are presented in the Final RI Report Tables 6-6 and 6-7, respectively.

[4] Noncancer toxicity data is presented in the Final RI Report Table 6-11.

[5] Cancer toxicity data is presented in the Final RI Report Table 6-10.

APPENDIX B

COST ESTIMATES FOR REMEDIAL ALTERNATIVES

Table B-1 – Estimated Costs for Alternative B
Monitored Natural Attenuation

Item	Quantity	Unit Price	Subtotal	Total
CAPITAL COSTS				
Well Use Restrictions	Lump Sum	$13,911	$13,911	$13,911
Install 2 new wells	Lump Sum	$13,500	$13,500	$13,500
Soil Gas Survey	Lump Sum	$8,115	$8,115	$8,115
	Total Direct Construction Costs (TDCC)			$35,526
	Engineering, Legal, Health & Safety, and Construction Management @ 25% of TDCC			$8,882
	20% Contingency			$7,105
Total Estimated Installed Capital Cost				$51,513
OPERATION AND MAINTENANCE COSTS				
Annual Groundwater Sampling Costs				
Labor (Field Effort, Report Preparation)	Lump Sum		$13,227	
Expenses	Lump Sum		$4,985	
Subcontract (Analytical) (a)	18	$197	$3,547	
Subtotal			$21,760	
20% Contingency			$4,352	
Total Annual Groundwater Sampling Costs (b)				$26,110

Option A - Based on 5 years of monitoring

Estimated Total O&M Cost for 5 years based on an inflation rate of 3%	$119,576
TOTAL PRESENT-WORTH COST (rounded)	**$171,000**

Option B - Based on 20 years of monitoring

Estimated Total O&M Cost for 20 years based on an inflation rate of 3%	$388,451
TOTAL PRESENT-WORTH COST (rounded)	**$440,000**

(a) Semi-annual sampling (spring and fall) will be conducted at 5 monitoring wells. Four QC samples will also be collected at each round. i.e., Total number of samples per year = 2 x (5 + 4) = 18. Price includes $20 per sample for data validation.

(b) 5-year reviews are included in the annual groundwater sampling costs.

Table B-2 – Estimated Costs for Alternative C
Air Sparging With Soil Vapor Extraction

Item	Quantity	Unit Price	Subtotal	Total
CAPITAL COSTS				
Well Use Restrictions	Lump Sum	$13,911	$13,911	$13,911
Install 2 new wells	Lump Sum	$13,500	$13,500	$13,500
Soil Gas Survey	Lump Sum	$8,115	$8,115	$8,115
Groundwater Evaluation				
Labor (field effort, report preparation)	Lump Sum	$13,227	$13,227	
Expenses	Lump Sum	$4,985	$4,985	
Subcontract (Analytical)	18	$197	$3,547	
Groundwater Evaluation Total				$21,760
Pilot Study				
Labor (Field Effort, Report Preparation)	Lump Sum	$15,071	$15,071	
Expenses	Lump Sum	$7,651	$7,651	
Subcontract (Drilling)	Lump Sum	$5,217	$13,227	
Pilot Study Total				$35,949
Installation of Full-Scale Air Sparging System				
Labor	Lump Sum	$18,085	$18,085	
Expenses	Lump Sum	$7,651	$7,651	
Subcontract (Drilling)	1000	$46	$46,371	
Equipment (Sparge Blower Package, SVE Blower Package, Foundation)	Lump Sum	$31,300	$31,300	
Pipe Installation	Lump Sum	$11,593	$11,593	
Installation Total				$115,000
Startup of System				
Labor (field effort, report preparation)	Lump Sum	$17,783	$17,783	
Expenses	Lump Sum	$5,565	$5,565	
Subcontract (analytical)	4	$406	$1,623	
Startup Total				$24,971
Total Direct Construction Costs (TDCC)				$233,206
Engineering, Legal, Health & Safety, and Construction Management @ 25% of TDCC				$58,300
20% Contingency				$46,641
Total Estimated Installed Capital Cost				$338,150
OPERATION AND MAINTENANCE COSTS				
Annual Groundwater Sampling Costs for MNA				
Labor (Field Effort, Report Preparation)	Lump Sum		$13,227	
Expenses	Lump Sum		$4,985	
Subcontract (Analytical) (a)	18	$197	$3,547	
Subtotal			$21,760	
20% Contingency			$4,352	
Total Annual Groundwater Sampling Costs (b)				$26,111
Annual Operation and Maintenance of Air Sparging/Soil VaporExtraction System				
Labor	Lump Sum	$27,962	$27,962	
Expenses	Lump Sum	$4,973	$4,973	
Subcontract (Analytical)	24	$406	$9,738	
Electrical	70000	$0.09	$6,492	
Subtotal			$49,165	
Contingency @20%			$9,833	
Operation and Maintenance Total				$59,000

Table B-2 – Estimated Costs for Alternative C
Air Sparging With Soil Vapor Extraction

Option A - Based on 5-year system operation and 10-year MNA

Estimated Total O&M Cost based on an inflation rate of 3%	$492,939
TOTAL PRESENT-WORTH COST (rounded)	**$831,000**

Option B - Based on 10-year system operation and 10-year MNA

Estimated Total O&M Cost based on an inflation rate of 3%	$726,018
TOTAL PRESENT-WORTH COST (rounded)	**$1,064,000**

(a) Semi-annual sampling (spring and fall) will be conducted at 5 monitoring wells. Four QC samples will
(b) 5-year reviews are included in the annual groundwater sampling costs.

Table B-3 – Estimated Costs for Alternative D
Groundwater Circulation Wells and In-Well Air Stripping

Item	Quantity	Unit Price	Subtotal	Total
CAPITAL COSTS				
Well Use Restrictions	Lump Sum	$13,911	$13,911	$13,911
Install 2 new wells	Lump Sum	$13,500	$13,500	$13,500
Soil Gas Survey	Lump Sum	$8,115	$8,115	$8,115
Groundwater Assessment				
Labor (field effort, report preparation)	Lump Sum	$13,227	$13,227	
Expenses	Lump Sum	$4,985	$4,985	
Subcontract (Analytical)	18	$197	$3,547	
Groundwater Assessment Total				$21,760
Inst. of Groundwater Circulation Sys.				
Labor	Lump Sum		$25,272	
Recirculation Well	Lump Sum		$81,149	
Drilling/Installation of Recirculation Well	Lump Sum		$46,371	
Expenses	Lump Sum		$8,440	
Installation Total				$161,232
Startup of System				
Labor	Lump Sum		$15,186	
Expenses	Lump Sum		$5,912	
Subcontract (Analytical)	4	$406	$1,623	
Startup Total				$22,722
Total Direct Construction Costs (TDCC)				$241,239
Engineering, Legal, Health & Safety, and Construction Management @ 25% of TDCC				$60,310
20% Contingency				$48,250
Total Estimated Installed Capital Cost				$349,799
OPERATION AND MAINTENANCE COSTS				
Annual Groundwater Sampling				
Labor (Field Effort, Report Preparation)	Lump Sum		$13,227	
Expenses	Lump Sum		$4,985	
Subcontract (Analytical) (a)	18	$197	$3,547	
Subtotal			$21,760	
20% Contingency			$4,352	
Total Annual Groundwter Sampling Costs (b)				$26,110
Annual Operation and Maintenance of System				
Labor	Lump Sum	$36,100	$36,100	
Expenses	Lump Sum		$11,651	
Subcontract (Analytical)	24	$406	$9,738	
Electricity	16,000	$0.09	$1,484	
Subtotal			$58,972	
Contingency @20%			$11,794	
Total GW Circulation Well System Maintenance (annual)				$70,770

Table B-3 – Estimated Costs for Alternative D
Groundwater Circulation Wells and In-Well Air Stripping

Option A - Based on 5-year system operation and 10-year MNA

Estimated Total O&M Cost based on an inflation rate of 3%	$546,829
TOTAL PRESENT-WORTH COST (rounded)	**$897,000**

Option B - Based on 10-year system operation and 10-year MNA

Estimated Total O&M Cost based on an inflation rate of 3%	$826,406
TOTAL PRESENT-WORTH COST (rounded)	**$1,176,000**

(a) Semi-annual sampling (spring and fall) will be conducted at 5 monitoring wells. Four QC samples
(b) 5-year reviews are included in the annual groundwater sampling costs.

Table B-4 – Estimated Costs for Alternative E
Permeable Reactive Barrier

Item	Quantity	Unit Price	Subtotal	Total
CAPITAL COSTS				
Well Use Restrictions	Lump Sum	$13,911	$13,911	$13,911
Install 2 new wells	Lump Sum	$13,500	$13,500	$13,500
Soil Gas Survey	Lump Sum	$8,115	$8,115	$8,115
Geoprobe PRB Investigation	Lump Sum	$11,013	$11,013	$11,013
Groundwater Assessment				
Labor (field effort, report preparation)	Lump Sum	$13,227	$13,227	
Expenses	Lump Sum	$4,985	$4,985	
Subcontract (Analytical)	18	$197	$3,547	
Groundwater Assessment Total				$21,760
Design and Installation of Permeable	Lump Sum	$238,810	$238,810	$238,810
Total Direct Construction Costs (TDCC)				$307,109
Engineering, Legal, Health & Safety, and Construction Management @ 25% of TDCC				$76,780
20% Contingency				$61,420
Total Estimated Installed Capital Cost				$445,309
OPERATION AND MAINTENANCE COSTS				
Annual Groundwater Sampling				
Labor (Field Effort, Report Preparation)	Lump Sum		$13,227	
Expenses	Lump Sum		$4,985	
Subcontract (Analytical) (b)	18	$197	$3,547	
Subtotal			$21,760	
20% Contingency			$4,352	
Total Annual Groundwater Sampling Costs (c)				$26,110
Estimated Total O&M Cost for 10 years based on an inflation rate of 3%				$222,724
TOTAL PRESENT-WORTH COST (rounded)				**$668,000**

(a) Cost for installation of a granular iron PRB (180ft long x 3ft wide x 25ft deep) using standard

(b) Semi-annual sampling (spring and fall) will be conducted at 5 monitoring wells. Four QC samples

(c) 5-year reviews are included in the annual groundwater sampling costs.

Table B-5 – Estimated Costs for Alternative F
In Situ Chemical Reduction and Bioremediation

Item	Quantity	Unit Price	Subtotal	Total
CAPITAL COSTS				
Well Use Restrictions	Lump Sum	$12,000	$12,000	$12,000
Install 2 new wells	Lump Sum	$13,500	$13,500	$13,500
Soil Gas Survey	Lump Sum	$7,000	$7,000	$7,000
Bio Trap Sampling	Lump Sum	$7,400	$7,400	$7,400
Microcosm Testing	Lump Sum	$27,400	$27,400	$27,400
Design and Application of Amendment				
Labor (field effort, report preparation)	Lump Sum	$64,500	$64,500	
Expenses	Lump Sum	$2,300	$2,300	
Subcontract (Amendment)	Lump Sum	$32,400	$32,400	
Subcontract (Geoprobe)	Lump Sum	$9,200	$9,200	
Application Total				$108,400
20% Contingency				$21,680
Baseline Groundwater Assessment				
Labor (field effort)	Lump Sum	$7,400	$7,400	
Expenses	Lump Sum	$1,200	$1,200	
Subcontract (Analytical) (a)	14	$510	$7,140	
Groundwater Assessment Total				$15,740
20% Contingency				$3,150
Total Estimated Installed Capital Cost				$216,270
OPERATION AND MAINTENANCE COSTS				
Quarterly Groundwater Sampling (1 Year)				
Labor (Field Effort, Report Preparation)	Lump Sum	$54,000	$54,000	
Expenses	Lump Sum	$4,400	$4,400	
Subcontract (Analytical) (a)	56	$510	$28,560	
Subtotal			$86,960	
20% Contingency			$17,390	
OPERATION AND MAINTENANCE COSTS				
SemiAnnual Groundwater Sampling (2 Years)				
Labor (Field Effort, Report Preparation)	Lump Sum	$54,000	$54,000	
Expenses	Lump Sum	$4,400	$4,400	
Subcontract (Analytical) (a)	56	$510	$28,560	
Subtotal			$86,960	
20% Contingency			$17,390	
Total Groundwater Sampling Costs				$208,700
TOTAL PRESENT-WORTH COST (rounded)				**$425,000**

(a) Baseline, Quarterly, and SemiAnnual sampling will be conducted at 9 monitoring wells for 3 years - 9 events. Four QC samples will also be collected at each round. Price includes $20 per sample for data validation.

Updated Estimated Costs for Remedial Alternatives
Nike Battery W-44 - Waldorf, Maryland

Alternative	Estimated Present Worth Cost		
	5-yr System Operation	10-yr System Operation	20-yr System Operation
A. No Action	$0		
B. Natural Attenuation	$171,000		$440,000
C. Air Sparging with Soil Vapor Extraction (SVE)	$831,000	$1,064,000	
D. In-Well Air Stripping	$897,000	$1,176,000	
E. Permeable Reactive Barrier		$668,000	
F. In Situ Chemical Reduction and Bioremediation	$411,000		

Notes:

1. Estimated Present Worth Costs are for the year 2009.
2. For Alternatives B through E, Present Worth Costs were calculated by updating the costs in the 2004 focused Feasibility Study, assuming an inflation rate of 3% per year.
3. Alt F is less than 5 years.