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FINAL

REMEDIAL INVESTIGATION REPORT AND BASELINE RISK ASSESSMENT

VOLUME II OF IV - TEXT

BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA

CONTRACT TASK ORDER 0269

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LIST OF ACRONYMS

ARARs	Applicable or Relevant and Appropriate Requirements
AST	Aboveground Storage Tank
ATc	Averaging Time (carcinogenic)
ATnc	Averaging Time (noncarcinogenic)
ATEC	ATEC Environmental Consultants
Baker	Baker Environmental, Inc.
BCF	Bioconcentration Factor
bgs	Below Ground Surface
BOA	Basic Ordering Agreement
BRA	Baseline Risk Assessment
BRAC	Base Realignment and Closure
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
BW	Body Weight
C	Centigrade
CAP	Corrective Action Plan
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
COC	Chain-of-Custody
COMNAVBASE	Commander, Naval Base
COPC	Chemical of Potential Concern
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
CS	Confirmation Study
CSF	Carcinogen Slope Factor
cu.yd.	cubic yard
DCE	Dichloroethene
DNAPL	Dense Non-Aqueous Phase Liquid
DoD	Department of Defense
E	Endangered
ED	Exposure Duration
EF	Exposure Frequency
Eh	Oxidation Reduction Potential
ESE	Environmental Science and Engineering, Inc.
FISC	Fleet Industrial Supply Center
FS	Feasibility Study
ft/day	feet/day
ft/year	feet/year
FWE	Foster Wheeler Enviresponse, Inc.

LIST OF ACRONYMS (Continued)

g	gram
GC	Gas chromatograph
gpd	Gallons Per Day
gpm	Gallons Per Minute
HCl	Hydrochloric Acid
HEAST	Health Effects Assessment Summary Tables
HHAG	Human Health Assessment Group
HI	Hazard Indices
HLA	Harding Lawson Associates
HQ	Hazard Quotient
HRS	Hazard Ranking System
IAS	Initial Assessment Study
ICR	Incremental (Lifetime) Cancer Risk
ILCR	Incremental Lifetime Cancer Risk
ID	Inside Diameter
IDW	Investigation Derived Waste
IR	Ingestion/Inhalation Rate
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
IW	Industrial Waste
IWS	Industrial Waste Sewer
IWTP	Industrial Waste Treatment Plant
Kg	Kilogram
Koc	Octanol-Carbon Partioning Coefficient
Kow	Octanol-Water Partioning Coefficient
Land-Tech	Land-Tech Remedial, Inc.
LOAEL	Lowest Observed Adverse Effect Level
LTA	Lighter-Than-Air
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MF	Milligram Modifying Factor
mg	Milligram
MI	Mobility Index
ml	Milliliter
MS	Matrix spike
MSD	Matrix spike duplicate
MSDS	Material Safety Data Sheet
MSL	Mean Sea Level
MTBE	Methyl Tertiary Butyl Ether

LIST OF ACRONYMS (Continued)

NADEP	Naval Aviation Depot
NAS	Naval Air Station
Navy CLEAN	Comprehensive Long-Term Environmental Action Navy Program
ND	Not Detected
NDI	Non-Destructive Inspection
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observable Adverse Effect Level
NOB	Naval Operating Base
NOEL	No-Observed Effect Level
NWS	National Weather Service
NyTest	Nytest Environmental, Inc.
O&G	O'Brien and Gere
OD	Outside Diameter
OWS	Oil/Water Separator
PA	Preliminary Assessment
PAH	Polynuclear Aromatic Hydrocarbons
PC	Permeability Constant
PCB	Poly Chlorinated Biphenyl
PCE	Tetrachloroethene
PID	Photoionization Detector
ppb	Part Per Billion
ppm	Part Per Million
PRAP	Proposed Remedial Action Plan
PVC	Polyvinyl Chloride
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QEC	Quality Environment Company, Inc.
QC	Quality Control
RA	Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk Based Concentration
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
Rfc	Reference Concentration
Rfd	Standard Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RPD	Relative Percent Difference

LIST OF ACRONYMS (Continued)

s	Standard Deviation
S	Water Solubility
SAP	Sampling and Analysis Plan
SARA	Superfund Amendment and Reauthorization Act
SDB	Small Disadvantaged Business
SDG	Sample Delivery Group
SI	Site Inspection
SPNC	Sewells Point Naval Complex
SPT	Standard Penetration Test
sq.ft.	Square Feet
SVOC	Semivolatile Organic Compound
T	Threatened
TAL	Target Analyte List
TCA	Trichloroethane
TCE	Trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TIC	Tentatively Identified Compound
TOC	Total Organic Carbon
TOX	Total Organic Halogens
TPH	Total Petroleum Hydrocarbon
Tracer	Tracer Research Corporation
TSS	Total Suspended Solids
TVH	Total Volatile Hydrocarbons
TVO	Total Volatile Organics
UCL	Upper Confidence Limit
UF	Uncertainty Factor
µg/kg	Microgram per Kilogram
µg/L	Microgram per Liter
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VDEQ	Virginia Department of Environmental Quality
VP	Vapor Pressure
VOC	Volatile Organic Compound
WQS	Water Quality Standard

7.0 NATURE AND EXTENT OF CONSTITUENT MIGRATION

The primary objectives of this study are to: 1) determine the source area(s) of contamination; 2) adequately define the nature and extent of environmental impact to the subsurface soils and groundwater in the vicinity of Building LP-20; 3) provide the necessary information to perform a public health risk assessment; and, 4) provide necessary information to screen alternatives to determine the most feasible methods for remediation, if necessary, of potential sources of risk to public health and safety and the environment. This section characterizes, based upon available data, surface and subsurface soils and groundwater quality with respect to specific constituents of concern. The characterization includes the following significant elements:

- Identification and quantification of constituents of interest in surface soils, subsurface soils, and groundwater.
- Definition of the horizontal and vertical extent of constituent migration in soils.
- Definition of the horizontal and vertical extent of constituent migration in groundwater.
- Information generated as part of the previous site investigations, as well as data generated from the RI field activities, serves as the basis for this evaluation.

As discussed in Section 2.0, ten separate investigations were performed in the Building LP-20 area prior to the RI activities. Information from these studies, such as groundwater flow rates, areas of contamination, and geologic conditions, was evaluated and compared to findings gathered during the preparation of this RI. This information is included in the appropriate appendices as discussed in Section 2.0.

7.1 Overview of Results

VOCs, SVOCs, and metals have been confirmed in soils (surface and subsurface) and groundwater (shallow and deep) in the Building LP-20 area. A number of contaminants in both media exceed

applicable Federal and/or State standards and guidelines. This contamination is attributed to several sources:

- Past storage and distribution systems for a variety of petroleum products, such as gasoline, waste oils, and aviation fuels (JP-5), are known to have leaked at various locations.

- Past storage and disposal areas for chemical solvents used in cleaning, painting, and metal plating operations performed in the Building LP-20 area where poor practices or accidents resulted in leaks or spills.

- Accidental releases of waste fluids via breaks in the IWS caused during construction activities in the area.

Data generated during the RI indicate that VOCs are the primary contaminants detected in the area. Two types of organic contaminants were detected in the Building LP-20 area: chlorinated solvents occur in the vicinity of Building LP-20 and LP-26, and petroleum products occur east of Building LP-22 and south of Building LP-179. The extent of free petroleum product measured in the study area is shown on Figure 5-9.

The extent of chlorinated solvent contamination in the shallow water table aquifer has been defined in the Building LP-20 area, but is not clearly defined near Building LP-14. The highest levels of organic contamination are found north of Buildings LP-20 and LP-26. The extent of the VOC contamination appears to be limited to the area south of Aircraft Tow Way.

Several of the chlorinated solvents detected during the investigation are classified as DNAPLs. DNAPLs are separate-phase hydrocarbon liquids that are denser than water. When released at the surface, free-phase DNAPL moves downward through the soil matrix under the force of gravity or laterally along the surface of sloping fine-grained stratigraphic units. DNAPLs will continue to migrate vertically through the saturated zone following preferential pathways through small-scale fractures and heterogeneities in the soil. Most DNAPLs undergo only limited degradation in the subsurface, and persist for long periods of time while slowly releasing soluble organic constituents to the ground water through dissolution. Even with a moderate DNAPL release, dissolution may

continue for hundreds of years or longer under natural conditions before all the DNAPL is dissipated and concentrations of soluble organics in groundwater return to background levels (USEPA 1992).

Petroleum contamination in the shallow aquifer occurs primarily east of Building LP-22 and is attributed to the past release of JP-5 from the LP Fuel Farm pipeline. The extent of this petroleum contamination was well defined in past UST Program investigations in the area. The RI field program, which primarily focused on solvent contamination, confirmed the existence of petroleum contaminants in this area.

Previous investigations have also identified petroleum contamination in the area of the LP Fuel Farm. However, this contamination does not appear to have influenced groundwater quality in the vicinity of the Building LP-20 site.

Two areas of potential concern, possibly unrelated to Building LP-20, were identified west of Building LP-20 (near Building U-132) and south of Building LP-13 where elevated levels of VOCs and BTEX, respectively, were found in groundwater.

In addition to these findings, high concentrations of metals were found to be prevalent in shallow and deep groundwater in a wide zone which extends from the LP-20 area to north of Aircraft Tow Way.

7.2 Data Comparisons to Standards and Criteria

As part of the RI/RA evaluation process, analytical results have been compared to chemical-specific, Applicable or Relevant and Appropriate Requirements (ARARs) or generally accepted criteria. Criteria used for the comparisons differ from ARARs in that ARARs are enforceable, while criteria are not mandatory requirements. Comprehensive ARAR comparisons, including chemical-specific, location-specific, and action-specific ARARs, will be included in the FS based upon COPCs identified in the RA portion of this report (Section 8.0).

Chemical-specific ARARs and criteria used for comparison varied with each sampled media, as follows:

- Risk-Based Calculations (RBCs) for Industrial and Residential Soils for surface and subsurface soils.

- Federal Maximum Contaminant Level (MCL) and Water Quality Standards (WQS) for the Commonwealth of Virginia for groundwater samples.

7.3 Soil Characterization

VOCs, SVOCs, and metals detected in the surface and subsurface soils collected during the RI indicate the soils have been impacted by organic and inorganic contaminants. However, all VOCs in shallow and deep soils were below RBCs. SVOCs primarily were present in shallow and deep samples obtained from borings LP-20MW-10 and LP-20MW-11, and may not be related to past activities at the LP-20 site. Arsenic, beryllium, and iron exceeded RBCs in shallow soil and deep soils.

7.4 Shallow Groundwater Characterization

The shallow groundwater in the vicinity of Building LP-20 has been impacted by past activities performed in the area. Primary VOCs found in the vicinity of Buildings LP-20 and LP-26 include: vinyl chloride (15,000 µg/L), 1,2-DCE (total) (28,000 µg/L), and TCE (44,000 µg/L). In the area near Buildings LP-13 and LP-14, benzene was detected at a maximum concentration of 860 µg/L. Vinyl chloride, 1,2-DCE (total), and TCE were also detected in this area at maximum concentrations of 3,700 µg/L, 15,000 µg/L, and 2,700 µg/L, respectively. VOCs were present in shallow groundwater across the site in concentrations well above the Federal MCLs.

The maximum SVOC detected was bis(2-Ethylhexyl)phthalate (100 µg/L) in HLA well MW-22. Bis (2-Ethylhexyl) phthalate is a common laboratory contaminant. Because it was not used in any industrial process in the area, and it is not a degradation by product of other compounds, its presence may be the result of laboratory contamination. Several other SVOCs such as naphthalene and phenol were also detected. However, the various SVOCs were present at concentrations less than 5.0 µg/L and do not indicate a potential source area.

Elevated concentrations of metals such as aluminum, calcium, iron, magnesium, manganese, potassium, and sodium appear to occur naturally in the area. The total arsenic concentration in two wells located east of Building LP-22 indicates a possible metals problem in this area of the site. Dissolved metals exceeding MCLs or Virginia WQSs are present in shallow groundwater over the entire site. As stated earlier, these metal concentrations appear to be typical of the Tidewater area.

Chloride, sulfate, and alkalinity results indicate possible brackish conditions; chloride exceeds Virginia Standards in all samples and Federal values in six samples.

7.5 Yorktown Aquifer Groundwater Characterization

Although the level of contamination is significantly lower than detected in the shallow water table aquifer, it appears that the Yorktown Aquifer has been impacted by VOC and SVOC contaminants. VOCs and the associated high concentrations noted in the most recent (October 1995) groundwater sampling exercise, include vinyl chloride (50 µg/L); 1,2-DCE (total) (960 µg/L); TCE (110 µg/L); and benzene (19 mg/L). Two SVOCs, 2-methylnaphthalene (1J µg/L) and acenapthene (2J µg/L), were also identified. In addition, seven total metals were detected in the recent October 1995 sampling activities and are present at levels above standards and criteria: aluminum, arsenic, iron, lead, manganese, nickel, and sodium. In addition, three dissolved metals (iron, manganese, and sodium) were found at levels above standards and criteria. The metal concentrations appear to occur naturally in the area.

7.6 Extent of Constituent Migration

The field program for this RI primarily focused on the area west of the Bousch Creek Culvert, in the areas from Building LP-20 to Aircraft Tow Way. As described earlier, the RI activities detected other areas of concern, potentially not related to activities involving Building LP-20. To evaluate the extent of contaminant migration in the Building LP-20 area, information from previous investigations were evaluated with the findings from this RI including hydrogeologic information and analytical results.

Due to the age of the majority of the investigations and the variety of analytical methods used, compilation for presentation of much of the analytical data was not feasible. This is particularly true for soil samples collected during previous investigations. For a majority of the investigations either soil sampling was not performed or the analytical parameters are not comparable to those of the RI.

However, previous groundwater investigations have been performed more recently and yield more usable information. The most extensive groundwater sampling program was recently completed in March and April 1994 which addressed the extent of petroleum contamination in the vicinity of the Bousch Creek Culvert and the LP Fuel Farm. Nearly 50 monitoring wells were sampled during this study.

Baker has incorporated the information generated from the 1994 sampling activities with results of the RI to evaluate the horizontal extent of groundwater contamination in the areas east of the Bousch Creek culvert and in the vicinity of the LP Fuel Farm. With the inclusion of this information, further evaluation of potential contaminant sources is also possible.

7.6.1 Horizontal and Vertical Contaminant Distribution - Soils

VOCs were not detected in concentrations greater than associated RBC values. Low levels of VOC contamination, limited to acetone, TCE and 1,2-DCE (total), are present in shallow soils in the vicinity of the site. Acetone is found in higher concentration in the deeper sample at location LP-20MW-8, but is present in greater concentration in shallow soils in the sample from LP-20MW-6; thereby indicating two separate source areas for this constituent. As depicted on Figures 7-1 and 7-2, TCE is primarily found between Buildings LP-20 and LP-26 in shallow and deep soils, respectively.

Only four soil boring locations (LP-20MW-2, LP-20MW-8, LP-20MW-10, and LP-20MW-11) exhibited shallow soil SVOCs in concentrations which exceeded residential or industrial RBCs. As Figures 7-1 and 7-2 indicate, SVOCs do not appear to have migrated vertically in the vicinity of the site.

Elevated metal concentrations were detected in the shallow soils over the entire study area; however, horizontal extent was not defined beyond the LP-20 site. A majority of these metals are typical of

a marine environment. The vertical extent of the VOC, SVOC, and metal contaminants in the soils appears to have reached the shallow water table. Beryllium is present in shallow soils in an isolated area just north of Building LP-26 and antimony is found in a small zone between Buildings V-52 and V-117 north of Aircraft Tow Way.

The VOCs in deep subsurface soils were detected in four areas of the site, the alley between Buildings LP-20 and LP-26, north of Building LP-26 near Bellinger Boulevard, the vicinity of Building LP-147, and west of the intersection of Bellinger Boulevard and Aircraft Tow Way. VOCs were not detected above RBC values in the deep soil samples and only one soil boring (LP-20MW-11) exhibited a SVOC (benzo(a)pyrene) which exceeded RBCs.

SVOCs are present in the deep soil sample from LP-20MW-11, located north of Aircraft Tow Way which is assumed to be unrelated to past activities conducted at Building LP-20.

As with the shallow soil samples, the deeper soils have several metals that exceed RBCs. These metals are dispersed throughout the site and are typical of those found in marine environments. It is also likely that fill (dredge materials), brought on site during the development of the Bousch Creek area, may have contributed to the elevated concentrations of metals such as sodium, potassium, manganese, and iron. In general, high concentrations of arsenic were detected in the three soil borings in the vicinity of Building LP-20 (LP-20MW-2, LP-20MW-8, and LP-20MW-9) and the soil boring north of Building V-147 (LP-20MW-11). An elevated concentration (13.3 mg/kg) of arsenic was detected in the deep soil sample from boring LP-20MW-2 which shows a downward migration of this element.

Aluminum, antimony, arsenic, beryllium, and manganese were identified as COPCs in the shallow soils in the risk assessment (Section 8.0). Horizontal distribution of these elements are presented on Figure 7-3. As indicated on the figure, aluminum, arsenic, and manganese are present in a wide distribution over the entire area extending to just north of Aircraft Tow Way. These compounds are likely dispersed naturally over the site and are not associated with man-made activities.

Aluminum, antimony, arsenic, and beryllium were identified as COPCs in the subsurface soils in the risk assessment (Section 8.0). Horizontal distribution of these elements are presented on Figure 7-4. Deep soil samples show a wide dispersion of aluminum and arsenic over the entire study area,

whereas antimony is only present in the northeast corner of Building LP-20. This finding indicates that the presence of antimony in shallow and deep soils appears to be the result of isolated sources. Beryllium was not present in deep soil.

In summary, VOC, SVOC, and metal contaminants in soils are dispersed across the entire site. However, the level of the contamination is relatively low with few compounds exceeding RBCs. The affected area includes: 1) the vicinity of Building LP-20; 2) north of Building LP-26 near Bellinger Boulevard; 3) the vicinity of Building V-147 north of Aircraft Tow Way; and, 4) near the intersection of Bellinger Boulevard and Aircraft Tow Way. However, the primary contaminants generally are wide-spread and do not appear to be related to the same contaminant source. It is likely that a majority of these elements are naturally occurring and are not associated with man-made activities.

7.6.2 Horizontal and Vertical Contaminant Distribution - Groundwater

Both the shallow (water table) aquifer and the upper portion of the Yorktown Aquifer were assessed during the RI. The horizontal and vertical extent of contamination for each aquifer is discussed in the following sections. Table 7-1 provides a comparison of selected organic constituents in the shallow aquifer using results from previous studies. In general, a trend has developed whereby concentrations of vinyl chloride, TCE and 1,2- DCE (total) have been reduced over time.

7.6.2.1 Shallow Aquifer

As described in Section 2.0, the shallow groundwater in the vicinity of Building LP-20 has been studied on numerous occasions. Overall, ten previous investigations (nine investigations involving monitoring well installation and one consisting of sampling the existing monitoring wells) have been performed in the area. The primary focus of these investigations has been the area east of Building LP-22 and the LP Fuel Farm. All but one of the investigations focused on petroleum contamination in the areas surrounding Building LP-20. The 1991 investigation is the only study that focused on Building LP-20 prior to the current remedial investigation.

Organic Compound Distribution in the Shallow Aquifer

The in-situ groundwater survey included analyses of groundwater collected near the water table surface, as well as from a depth just above the confining clay unit at the base of the water table aquifer. Results of the on-site and confirmatory analyses indicate four primary areas of groundwater contamination, including: near the northwest corner of Building LP-20; north of Building LP-26; east of Building LP-26; and, near Building LP-13.

Chlorinated solvent contamination was identified in the vicinity of Building LP-20 with the greatest concentrations extending north of Building LP-26 and Bellinger Boulevard. TCE was the primary contaminant detected in the vicinity of Buildings LP-20 and LP-26 in both the shallow and deep groundwater samples. Results of the in-situ groundwater survey supported the groundwater monitoring program which indicate that VOC contamination (primarily TCE) may have originated from former activities of Buildings LP-20 and LP-26.

Three VOCs frequently detected in the monitoring wells and in-situ sampling locations are vinyl chloride, 1,2-DCE (total), and TCE. These three compounds are evaluated separately to further study the migration patterns of the organic contaminant plume and to determine potential source area(s).

- Vinyl chloride is distributed within a wide shallow groundwater zone which extends in a northerly direction beneath Building LP-20 and LP-26 to north of Bellinger Boulevard as shown on Figure 7-5. A smaller plume exists to the east of Building LP-20 beneath Engine Test Avenue and extends to the east beyond the Bousch Creek Culvert. Figure 7-5 suggest three potential source areas in the vicinity of Building LP-20. One area, located on the western side of Building LP-20; the other potential source area, located at Building LP-22. The vinyl chloride may be related to former metal plating or painting activities performed in the western portion of Building LP-20 or past usage and storage activities in the vicinity of Building LP-22. It should be noted that vinyl chloride is a product of the degradation of TCE. Therefore, elevated concentrations of vinyl chloride in these areas may also be an indication of prior TCE contamination.

The extent of vinyl chloride contamination appears to have been defined north of Bellinger Boulevard and in the areas south and southeast of Building LP-20. It appears that another area of vinyl chloride contamination is present in the vicinity of Building LP-13. This contamination is not associated with the contaminant plume identified in the vicinity of Building LP-20.

- Figure 7-6 depicts TCE dispersion over a large portion of the study area. A lesser plume exists between Buildings LP-24 and LP-20 which may indicate another source area. Results indicate that TCE is present in greater concentration at the base of the shallow aquifer. Because TCE has a specific gravity (1.46 grams per cubic centimeter), which is greater than water, the chemical would have a tendency to migrate vertically within the saturated soils to impact the shallow aquifer. With limited concentrations of VOCs detected north of Bellinger Boulevard, it appears that contamination originated in the vicinity of Buildings LP-20 and LP-26, has migrated vertically through the shallow aquifer to the coarse sand unit just above the top of clay, and has moved in a northerly direction towards Building V-147. Several sources exist in the study area: former metal plating activities; painting operations; IWS lines; and, previous storage and disposal of waste liquids. Several of these potential sources were discussed previously in Section 2.0.

The area south of Building LP-20 has likely been impacted with TCE either through accidental releases from the IWS or previous activities/occurrences in the area. As discussed in Section 2.0, the IWS in this area of the site has been damaged on numerous occasions. Historical information also indicates that former Building LP-21 (the Propeller Shop) was originally situated within the present northeast section of Building LP-24. Solvents were used in metal plating operations which were conducted at Building LP-21.

A second source area is located north of Building LP-26. North of Bellinger Boulevard, at location GP-22, TCE contamination was only detected at the base of the water table aquifer. This suggests that TCE has migrated horizontally and vertically from north of Building LP-26 to the Building V-147 area. Although

chemicals are not used within Building LP-26, past storage and transportation activities in the area may have caused releases to the environment.

The clay layer between Building LP-20 and Aircraft Tow Way appears to have influenced the migration patterns of the TCE. Because the clay surface has been scoured in the vicinity of LP-20 and north to Building V-147, this condition has resulted in TCE accumulating in this area and inhibits the contaminant from migrating north of Aircraft Tow Way.

The third significant area of elevated TCE contamination is in the vicinity of Building LP-14. It is believed that the TCE present in this area originated near Buildings LP-20 and LP-22 and is the result of migration eastward along the clay surface. It is expected that the lower elevation of the clay at LP-20MW-4 has provided the TCE with a preferential pathway which has directed the plume eastward.

Analytical results indicate that the TCE contamination in the shallow water table aquifer is defined south and southeast of Building LP-20. A separate area of TCE contamination is present south of Building LP-13.

- Elevated concentrations of 1,2-DCE (total) are present in shallow groundwater (see Figure 7-7) in three discrete areas, including: an elongated plume extending from Building LP-20 to Building V-147 located north of Bellinger Boulevard which indicates a possible release at LP-20; a lesser plume in the vicinity just east of Building LP-26; and, a small, isolated area between Buildings LP-24 and LP-20.

1,2-DCE (total) contamination extends from south of Building LP-20 northward to Building V-147 and from west of Building LP-20 to Building LP-14. As with the TCE contamination, an area of elevated 1,2-DCE (total) concentration is present from the northwest corner of Building LP-20 to south of Building V-147. Analyses indicate that the 1,2-DCE (total) plume is following the surface of the underlying clay layer. This results in areas of preferential migration as observed near

Buildings LP-20 and LP-26. The higher elevation of the clay in the vicinity of Building V-147 appears to have inhibited the northward migration of contaminants.

An area of 1,2-DCE (total) contamination also is present south of Building LP-13. However, the 1,2-DCE (total) concentrations detected in this area do not exceed the MCL of 70 µg/L.

In addition, an area of petroleum contamination was identified east of Building LP-22, near Hangar Buildings LP-13 and LP-14, which is likely the remnants of the petroleum release associated with the JP-5 pipeline. Figure 7-8 depicts benzene concentrations in the shallow groundwater. Results indicate that the benzene plume extends north from Building LP-176 to Bellinger Boulevard and east from Building LP-22 to Building LP-14. It is expected that the petroleum contamination is associated with the past release of JP-5 which has occurred in the area as discussed in Section 2.0.

Previous investigations detected areas of petroleum contamination in the vicinity of the LP Fuel Farm. As shown on Figure 7-8, wells sampled between the LP Fuel Farm and the Building LP-20 site during a previous study indicate that the fuel farm contamination has not migrated onto the Building LP-20 site. As stated earlier, a remediation system will be installed at the fuel farm under the supervision of the LANTDIV UST Program.

The distribution of SVOCs in groundwater was irregular over the central portion of the site. Generally, SVOCs were either detected in low concentrations or not detected in the wells sampled along the periphery of the site.

As stated earlier, several of the VOCs detected are classified as DNAPLs. An understanding of DNAPL migration patterns has been developed from evaluations made at other sites with similar contaminants and reference materials supplied by the USEPA. After being released, DNAPL moves vertically downward under the force of gravity and soil capillarity and, if a sufficient amount was released, eventually reaches the groundwater. The DNAPL will continue vertical migration through the aquifer until it is trapped as a residual hydrocarbon or until low-permeability stratigraphic units are encountered which create DNAPL "pools" in the soil/aquifer matrix (USEPA 1992).

In respect to the Building LP-20 site, the clay layer at the base of the shallow aquifer, the physical characteristics of the contaminants, and the groundwater flow direction appear to be the major factors which influence the contaminant distribution. Monitoring wells and in-situ groundwater sampling activities located in the vicinity of Aircraft Tow Way and Bellinger Boulevard have indicated that the organic contaminant plume does not extend northward beyond Aircraft Tow Way. The extent of VOCs detected near Building V-147 is restricted by an increase in the elevation of the clay layer beneath Aircraft Tow Way. Meanwhile, the migration of VOCs to the east is aided by the decline in the elevation of the clay layer in the area near Building LP-14. The slope of the clay layer beneath Building LP-14 creates a preferential migration pathway for DNAPLs. This condition is supported by the elevated VOC concentrations detected in monitoring well LP-20MW-4 while the in-situ sampling locations in the shallow portion of the aquifer in the area show significantly lower concentrations.

Although it is likely that the Bousch Creek Culvert influences the groundwater flow patterns of the area and that groundwater does enter the culvert, the impact of the solvent contaminants on the culvert appears to be limited. This is supported by the in-situ groundwater survey which observed elevated levels of organic compounds in the shallow aquifer in the vicinity of Buildings LP-20 and LP-26. However, as the contaminants migrate eastward, toward the culvert, The VOCs move downward in the aquifer and are not detected in the shallow portion of the aquifer near the culvert. By following the clay layer at the base of the culvert, the majority of the VOCs appear to pass beneath the culvert, thereby, providing a limited impact.

The culvert likely has an influence on the migration of petroleum contaminants in the southern area of the site, near Building LP-177. Because petroleum contaminants have a specific gravity less than one and float on the groundwater surface, disruptions to the groundwater flow pattern associated with the culvert would also have an impact on the migration of the petroleum contaminants. This situation is why the LANTDIV UST Program is installing petroleum recovery systems in the southern portion of the study area.

Inorganic Compounds in the Shallow Aquifer

Figures 7-9, 7-10, 7-11, 7-12, and 7-13 present the estimated extent of total antimony, arsenic, cadmium, chromium, and lead respectively, in shallow groundwater, or areas where extent of

contamination has not been completely defined. Aluminum, manganese and vanadium contamination, found to be widely dispersed within the shallow aquifer, have not been visually presented.

As shown on Table 6-24, these inorganic compounds are dispersed over the entire study area at concentrations which exceed Federal and Virginia standards. The elevated concentrations in the background well locations suggests that several of these compounds occur naturally in the site area.

As Figure 7-9 shows, antimony is present in a large area in the vicinity of Building LP-20; however, horizontal extent has not be established for this element west of Building LP-24 or east of the Bousch Creek Culvert.

Arsenic is distributed over the entire study area (Figure 7-10). However, horizontal dispersion has not been completely defined.

Cadmium contamination appears to be clearly established in Figure 7-11. An elongated plume (most likely the result of a break in IWS lines) extends from between Buildings LP-24 and LP-20 and trends north across Bellinger Boulevard to just south of Aircraft Tow Way. However, the extent of cadmium contamination has not been defined in a small zone near Building LP-14.

Chromium has been found in two separate plumes as shown on Figure 7-12. The larger plume extends from just northeast of Building LP-20 northward to beyond Aircraft Tow Way. However, the extent of chromium contamination has not been clearly defined east toward the intersection of Bellinger Boulevard and Aircraft Tow Way or west of Building V-147. A smaller plume is present in an area between Buildings LP-24 and LP-20. Because chromium was detected in well OGMW-7, a possible source could be located farther west of this location.

Lead appears to be defined in the vicinity of Building LP-20; however, distribution of lead east of the Bousch Creek Culvert, southwest of Building V-147, and north of Aircraft Tow Way has not been established. The western extent of lead contamination in the vicinity of Building U-117 also has not been established. The presence of lead in shallow groundwater may be the result of leaking underground storage tanks which may have contained leaded gasoline. The estimated extent of total lead in the shallow aquifer is shown on Figure 7-13.

7.6.2.2 Yorktown Aquifer

Deep monitoring wells were installed into the Yorktown Aquifer in two phases. Initially, three deep wells were installed; however, since the horizontal extent of VOC contamination could not be established, six additional deep wells were installed. One of the six, LP-20MW-19, was advanced to a depth of 114 feet to evaluate the vertical extent of organic contaminant migration within the Yorktown Aquifer.

Analytical results of deep groundwater investigated during this RI indicate that the Yorktown Aquifer has been impacted by VOCs and SVOCs. Several total and dissolved inorganics also exceeded groundwater criteria in deep aquifer samples.

Organic Compound Distribution in the Deep Aquifer

Chlorinated solvent contamination was identified in the Yorktown Aquifer during both the Phase 3 (February 1995) and Phase 5 (October 1995) field programs. Based upon the limited number of wells (three) installed during the earlier investigation activities, the source and extent of the contamination within the Yorktown Aquifer was not defined. With the installation of additional monitoring wells during Phase 5, the horizontal and vertical extent of contamination within the Yorktown Aquifer was further defined.

Three VOCs, vinyl chloride, 1,2-DCE (total), and TCE were the contaminants detected in the greatest concentrations. Based upon the results of the Phase 5 analytical results, these three compounds are evaluated separately to further study the migration patterns of the organic plume within the Yorktown Aquifer and to determine potential source area(s).

- Vinyl chloride was detected within four (LP-20MW-7, LP-20MW-8, LP-20MW-14, and LP-20MW-15) of the nine monitoring wells as shown on Figure 7-14. The downgradient extent of the contamination is defined by the absence of vinyl chloride in monitoring wells LP-20MW-16 and LP-20MW-17. The vertical extent of the contamination is also defined by the absence of vinyl chloride in monitoring well LP-20MW-19.

As shown on Table 6-22, the highest levels of vinyl chloride were detected at monitoring well LP-20MW-7 (50 μg/L). Overall, each of the four wells with detected vinyl chloride concentrations exceeded the Federal MCL of 2 μg/L).

Table 7-2 provides a comparison of organic concentrations of the analytical results of Phase 3 and Phase 5 within the three deep monitoring wells sampled in each event. As shown on Table 7-2, the vinyl chloride levels detected in wells LP-20MW-8 and LP-20MW-9 were relatively consistent between Phase 3 and Phase 5. However, the vinyl chloride concentrations in monitoring well LP-20MW-7 increased from 4J μg/L to 50 μg/L. It should be noted that vinyl chloride is a product of the degradation of TCE. Therefore, elevated concentrations of vinyl chloride may also be an indication of prior TCE contamination.

- Elevated concentrations of 1,2-DCE(total) are present in the deep groundwater in the vicinity of Buildings LP-20, LP-26, and V-147. The estimated extent of the contamination is depicted on Figure 7-15.

Three of the nine monitoring wells (LP-20MW-7, LP-20MW-8, and LP-20MW-14) had detectable concentrations of 1,2-DCE(total). The highest concentration (960 μg/L) was detected within monitoring well LP-20MW-8. The downgradient extent of the contamination is defined by the absence of 1,2-DCE (total) in monitoring wells LP-20MW-15, LP-20MW-16, and LP-20MW-17. The vertical extent of the contamination is also defined by the absence of 1,2-DCE (total) in monitoring well LP-20MW-19.

As shown on Table 7-2, the 1,2-DCE (total) levels detected in wells LP-20MW-8 and LP-20MW-9 were relatively consistent between Phase 3 and Phase 5. However, between these sampling periods the 1,2-DCE (total) concentrations in monitoring well LP-20MW-7 increased from 6J μg/L to 28 μg/L. This may be an indication of deteriorating groundwater conditions in this area of the Yorktown Aquifer. Further monitoring of the Yorktown Aquifer is required to accurately establish contaminant concentration trends.

- Elevated concentrations of TCE are present in the deep groundwater in the vicinity of Buildings LP-20, LP-26, and V-147. The estimated extent of the contamination is depicted on Figure 7-16.

  Three of the nine monitoring wells (LP-20MW-7, LP-20MW-8, and LP-20MW-14) had detectable concentrations of TCE. The highest concentration (110 μg/L) was detected within monitoring well LP-20MW-8. The downgradient extent of the contamination is defined by the absence of TCE in monitoring wells LP-20MW-15, LP-20MW-16, and LP-20MW-17. The vertical extent of the contamination is also defined by the absence of TCE in monitoring well LP-20MW-19.

  As shown on Table 7-2, the TCE levels detected in wells LP-20MW-8 and LP-20MW-9 were relatively consistent between Phase 3 and Phase 5. However, between these sampling periods the TCE concentrations in monitoring well LP-20MW-7 increased from 6J μg/L to 28 μg/L. This may be an indication of deteriorating groundwater conditions in this area of the Yorktown Aquifer. Further monitoring of the Yorktown Aquifer is required to accurately establish contaminant concentration trends.

Results of the Phase 5 sampling activities indicate that the VOC contamination originated in the vicinity of Buildings LP-20 and LP-26. Analytical results from monitoring well LP-20MW-18 indicate that an off-site, upgradient source does not exist. The horizontal and vertical extent of the chlorinated solvent contamination is relatively defined.

One VOC (4J μg/L, toluene) was detected in the deepest (114 feet bgs) monitoring well installed within the Yorktown Aquifer. This well was located downgradient of the suspected source area. The absence of other detectable concentrations of VOCs and SVOCs suggest that the compounds with high specific gravity values have not migrated into the lower portion of the Yorktown Aquifer.

In general, the concentrations of the SVOCs detected in the Yorktown Aquifer were lower than the VOC concentrations. Six SVOCs were detected in the Phase 3 sampling event. Monitoring well LP-20MW-9 had the highest SVOC concentrations 10 μg/L of bis (2-ethylhexyl) phthalate, detected during the Phase 3 sampling event. Only two SVOCs were detected in the Phase 5 sampling event.

No SVOCs above criteria were detected during the Phase 5 event. Table 7-2 provides a comparison of SVOC concentration of the analytical results of Phase 3 and Phase 5 within the three deep monitoring wells sampled in each event.

Based upon the analytical results of the Phase 3 and Phase 5 sampling activities, the following observations of organic contaminant distribution were developed:

- Organic levels detected in monitoring wells LP-20MW-8 and LP-20MW-9, were relatively consistent between the Phase 3 (February 1995) and Phase 5 (October 1995) sampling events. However, monitoring well LP-20-MW-7 exhibited increases in the concentrations of vinyl chloride, 1,2-DCE (total), and TCE. Overall, these analytical results indicate a migration of contaminants into the portion of the Yorktown Aquifer in the vicinity of LP-20MW-7.

- The absence of acetone and SVOCs in the Phase 5 results suggest that these constituents were either laboratory contaminants or present in negligible concentrations.

- The source of the upper Yorktown Aquifer contamination is apparently from activities associated with Building LP-20. Several possible explanations exist as to how these contaminants reached the lower aquifer. With several of the contaminants having a specific gravity greater than water, and areas of the site displaying a downward vertical flow, it is possible that the contaminants from the shallow aquifer migrated downward through the clay layer and into the Yorktown Aquifer. At boring locations LP-20MW-7 and LP-20MW-8, the clay layer ranges in thickness from 8 to 12 feet, respectively. Considering the age of the facility and the elevated contaminant concentrations detected in the vicinity of Buildings LP-20 and LP-26, the contaminants may have penetrated the clay layer over a period of several decades.

  Another scenario is that the vertical migration of contaminants may have been initiated by the intrusion of the Building LP-20 support piles through the clay layer during facility expansion. This would create a preferential pathway for contaminant

migration from the shallow aquifer. Efforts were made to locate drawings or other information which would identify the location and construction details of these pilings. However, due to the age of the facility and inadequate record keeping during the 1940's construction period, this information is unavailable at this time.

- There are no indications that the contaminants migrated to the site from an off-site area. Monitoring well LP-20MW-18 located southeast (upgradient) of the site, did not have detectable levels of VOCs or SVOCs present.

As stated earlier, DNAPLs follows the path of least resistance. Low permeability zones may stop or divert the migration route of the contaminant. If a clay layer is encountered, the DNAPL will pool on the surface of the clay until a pathway is eventually encountered through or around the clay zone. This scenario explains how VOCs were able to reach the Yorktown Aquifer beneath the Building LP-20 site. Over the nearly 50 years since the area has been developed, the VOCs penetrated the clay layer beneath the site. This penetration may have been through cracks in the clay or by vertical migration along the support pilings constructed to support the building. Once the VOCs reached the Yorktown Aquifer, they were further dispersed by the groundwater flow pattern.

Such a situation may explain the detection of VOCs such as TCE in the Yorktown Aquifer. TCE has a specific gravity greater than 1.0 (1.46) and has a history of extensive use in the area. The high concentrations of the compound present in the shallow aquifer, combined with the physical characteristics of the compound and the vertical gradient observed in areas of the site was sufficient to eventually penetrate the underlying clay layer. The vinyl chloride detected in the deeper aquifer is likely the by product of the natural degradation of the TCE.

DNAPLs such as TCE also have a cosolvency effect on other chemicals. This suggests that other immobile chemicals may migrate or be "dragged" with the DNAPL. This may provide an explanation for the detection of petroleum hydrocarbon contaminants such as benzene and toluene in the Yorktown Aquifer. Each of these VOCs are common constituents of petroleum hydrocarbons and have specific gravity values less than 1.0. Separate phase petroleum hydrocarbons have been detected in various areas of the site, particularly in the southern area near Building LP-177. However, given the age and past history of Building LP-20, the use of petroleum hydrocarbons in areas which also used chlorinated solvents is not unexpected. A likely scenario is that chlorinated

solvents and petroleum hydrocarbons were released to the subsurface in the vicinity of Building LP-20 as a result of leaking USTs, surface spills, and poor storage practices. The petroleum hydrocarbons then migrated with the solvents to the base of the water table aquifer and eventually into the Yorktown Aquifer.

Inorganic Compound Distribution in the Deep Aquifer

Several total and dissolved inorganic compounds were detected during both the Phase 3 (February 1995) and Phase 5 (October 1995) sampling activities. In general, during both sampling periods, aluminum, calcium, iron, magnesium, manganese, potassium, and sodium were frequently detected over the entire site. The widespread detection of these compounds is likely due to the natural presence of these metals within the Yorktown Aquifer.

Table 7-3 provides a comparison of total metals detected during the Phase 3 and Phase 5 sampling events. In general, the total metal concentrations from the Phase 5 sampling event were greater than those detected in the Phase 3 event, except for mercury in wells LP-20MW-8 and LP-20MW-9 and antimony in well LP-20MW-9. The compound with greatest increase in concentrations between sampling periods was aluminum. Detected aluminum concentrations in the three deep monitoring wells increased between three and 36 times the initial concentrations. Other increases in concentrations between Phase 3 and Phase 5 sampling events were not as significant. An explanation for the higher metal concentrations detected in Phase 5 compared to Phase 3 is not readily available. However, the total metal concentrations do not indicate a degradation of the Yorktown Aquifer due to inorganic contaminants.

Based on the recent Phase 5 analytical results, the total inorganics aluminum, arsenic, barium, chromium, lead, and vanadium were identified as COPCs in Section 8.0 of this report. Aluminum, arsenic, and chromium were generally detected over the entire site. The distribution of these metals are depicted on Figures 7-17, 7-18, and 7-19, respectively. The other metals were not detected as frequently and, therefore, not depicted in figures.

Figure 7-17 shows total aluminum is present in a large area in the vicinity of Building LP-20 investigation area. However, horizontal extent has not been established for this element west and south of Building LP-20 or north of Building V-147.

Arsenic is distributed over the entire area, except for well LP-20MW-16 (Figure 7-18). However, horizontal dispersion has not been completely defined.

Chromium was found across the entire site, except for well LP-20MW-8, LP-20MW-16, and LP-20MW-17. As shown on Figure 7-19, the extent of chromium contamination east or south of Building LP-20 or north of Building V-147 has not been established.

As with the total metals, calcium, magnesium, potassium, and sodium were the dissolved metals detected in the highest concentrations. Overall, the analytical results for the dissolved metals are similar to the total metals.

Table 7-4 provides a comparison of dissolved inorganic concentrations from the three deep monitoring wells (LP-20MW-7, LP-20MW-8, and LP-20MW-9) sampled during both groundwater sampling events. Typically, the Phase 5 dissolved metal concentrations are greater than those detected in Phase 3. However, the difference in concentrations is not as substantial as those observed for the total metals.

SECTION 7.0
TABLES

TABLE 7-1

COMPARISON OF ORGANICS IN THE SHALLOW AQUIFER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Well Number / Consultant / Date Sampled / Units	PUBLISHED STANDARD		SW-1			OGMW-44			OGMW-36		
	µg/L	µg/L	ESE 3/91 µg/L	ESE 6/91 µg/L	Baker 2/95 µg/L	ESE 3/91 µg/L	ESE 2/94 µg/L	Baker 2/95 µg/L	ESE 3/91 µg/L	ESE 2/94 µg/L	Baker 2/95 µg/L
VOLATILE ORGANICS:	FWQC	VWQS									
Vinyl Chloride	2	---	**730**	**820 J**	**590**	ND	**12**	**10**	ND	**170**	**96**
1,2-Dichloroethene (total)	70	---	**3300**	**5500**	**3500**	170	11	6 J	**380**	**190**	**180**
Trichloroethene	5	---	**6100**	**13000**	**3300**	**380**	ND	1 J	**200**	**120**	**68**

Well Number / Consultant / Date Sampled / Units	PUBLISHED STANDARD		HLMW-18		HLMW-22		OGMW-40		OGMW-45		OGMW-46	
	µg/L	µg/L	ESE 2/94 µg/L	Baker 2/95 µg/L	ESE 2/94 µg/L	Baker 2/95 µg/L	ESE 2/94 µg/L	Baker 2/95 µg/L	ESE 2/94 µg/L	Baker 2/95 µg/L	ESE 2/94 µg/L	Baker 2/95 µg/L
VOLATILE ORGANICS:	FWQC	VWQS										
Vinyl Chloride	2	---	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	70	---	ND	ND	ND	ND	ND	31	**160**	**150**	ND	2 J
Trichloroethene	5	---	ND	ND	ND	ND	ND	**29**	990	**810**	ND	1 J

Notes:

Bolded concentrations meet or exceed published standards.
FWQC = Federal Water Quality Criteria
VWQS = Virginia Water Quality Standard
µg/L = Micrograms per liter
ND = Below method detection limit
J = Value is estimated.
Source: Environmental Science Engineering, August 1991. "Draft Interim Remedial Investigation Report, LP-20 Aircraft Engine Maintenance Facility." Contract No. N62470-90-R-7661.
Environmental Science Engineering, May 1994. "Draft Monitoring Well Sampling Report - Bousch Creek Culvert." Contract No. N62470-93-D-4019.

TABLE 7-2
COMPARISON OF ORGANICS IN THE DEEP AQUIFER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Well Number	PUBLISHED STANDARD		LP-20MW-7		LP-20MW-8		LP-20MW-9	
Date Sampled			02/12/95	10/03/95	02/12/95	10/03/95	02/12/95	10/03/95
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANICS	FWQC	VWQS						
Acetone	---	---	60	ND	ND	ND	8 J	ND
Benzene	5	---	ND	ND	2 J	3 J	**14**	**19**
Xylene (Total)	10000	---	ND	ND	ND	ND	3 J	4 J
Vinyl Chloride	2	---	**4 J**	**50**	**32**	**28**	ND	ND
1,2-Dichloroethene (Total)	70	---	6 J	28	**900**	**960**	ND	ND
Trichloroethene	5	---	**6 J**	**28**	**130**	**110**	ND	ND
1,1-Dichloroethene	7	---	ND	ND	4 J	4 J	ND	ND
SEMIVOLATILE								
Phenol	---	---	2 J	ND	ND	ND	7 J	ND
Naphthalene	---	---	3 J	ND	ND	ND	13	ND
Phenanthrene	---	---	2 J	ND	ND	ND	ND	ND
Fluoranthene	---	---	1 J	ND	ND	ND	ND	ND
Bis(2-Ethylhexyl)phthalate	6	---	1 J	ND	ND	ND	**10**	ND
2-Methylnaphthalene	---	---	ND	ND	ND	ND	2 J	ND
Acenaphthene	---	---	ND	ND	ND	ND	ND	ND

Notes:

Bolded concentrations meet or exceed published standards
FWQC = Federal Water Quality Criteria
VWQS = Virginia Water Quality Standard
µg/L = Micrograms per liter
ND = Below method detection limit
J = Value is estimated

TABLE 7-3

COMPARISON OF TOTAL INORGANICS IN THE DEEP AQUIFER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Well Number	PUBLISHED STANDARD		LP-20MW-7		LP-20MW-8		LP-20MW-9	
Date Sampled			02/12/95	10/03/95	02/12/95	10/03/95	02/12/95	10/03/95
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
INORGANICS	FWQC	VWQS						
Aluminum	---	---	750	6450	466J	1320	66	2400
Antimony	6	---	38U	36U	38U	36U	**95**	36U
Arsenic	50	50	13.7	31.4	5UL	8.2	5U	9.8
Barium	2,000	1,000	31.6	99.7B	148	143B	419	572
Cadmium	5	0.4	2U	3.5B	2U	0.8U	2U	0.8U
Calcium	---	---	97,800	147,000	148,000	153,000	291,000	319,000
Chromium	100	50	5.4K	25.6	8.6B	4.6U	5U	6.2
Cobalt	---	---	7U	7.7	7U	4.4U	7U	4.4U
Copper	---	---	4U	12.4	4U	4.6U	4U	4.6U
Iron	300	300	**1,560L**	**22,000**	**2,110**	**5,620**	**3,340L**	**11,300**
Lead	15	50	3U	10.9	3U	3U	3U	3U
Magnesium	---	---	2,920	11,000B	25,500	32,100	67,600	90,000
Manganese	50	50	15.7	**209**	**113J**	**215**	**255**	**459**
Mercury	2	0.05	0.2U	0.2U	**0.21**	0.2U	**0.91**	0.2U
Nickel	100	---	27U	17.3	27UL	4.5	27U	5
Potassium	---	---	10,200	1,4700B	7,660	10,100B	50,500	102,000
Sodium	---	100,000	**210,000**	**234,000**	**177,000**	**179,000**	**1,270,000**	**1,310,000**
Vanadium	---	---	15U	36.3	15U	7.8	15U	6.8

Notes:

Bolded concentrations meet or exceed published standards
FWQC = Federal Water Quality Criteria
VWQS = Virginia Water Quality Standard
µg/L = Micrograms per liter
J = Value is estimated
L = Reported value may be biased low.
K = Reported value may be biased high.

TABLE 7-4

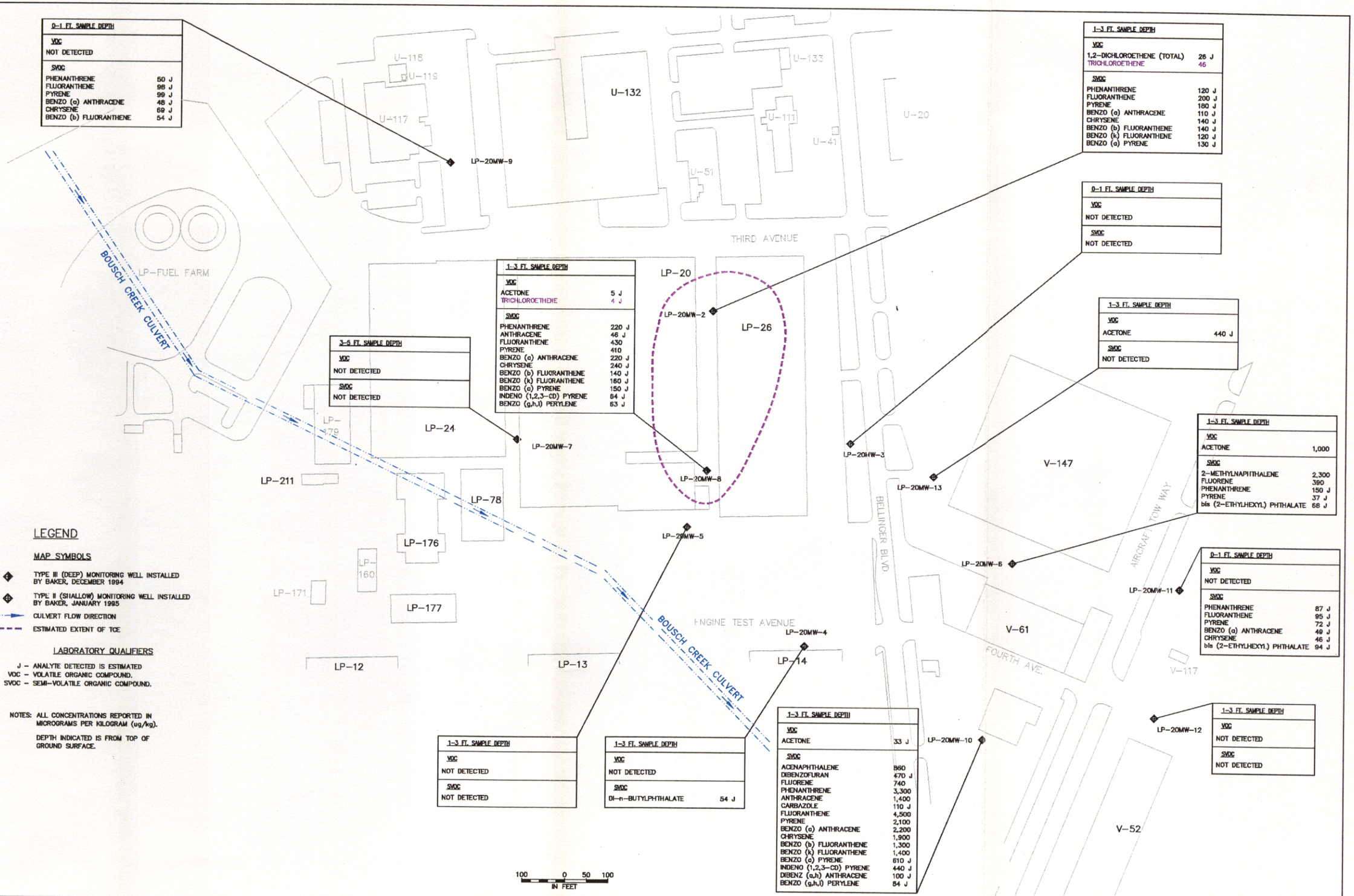
COMPARISON OF DISSOLVED INORGANICS IN THE DEEP AQUIFER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Well Number	PUBLISHED STANDARD		LP-20MW-7		LP-20MW-8		LP-20MW-9	
Date Sampled			02/12/95	10/03/95	02/12/95	10/03/95	02/12/95	10/03/95
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
INORGANICS	FWQC	VWQS						
Aluminum	---	---	203	191B	24U	125B	24U	79.9B
Antimony	6	---	**63.3K**	36U	38U	36U	111K	36U
Arsenic	50	50	12.5	14.8	5.2L	6.2B	5U	4.7B
Barium	2,000	1,000	29	37.5B	140	136B	400	492
Cadmium	5	0.4	2U	0.8U	**4.1**	0.8U	**4.2**	0.8U
Calcium	---	---	69,600	73,900	143,000	149,000	285,000	291,000
Cobalt	---	---	8.5	4.4U	7U	4.4U	7U	4.4U
Iron	300	300	13UL	75U	13UL	75U	**2,120L**	**1,550**
Magnesium	---	---	2,700	4,320	24,900	31,500	66,100	83,200
Manganese	50	50	1.8	3B	**95.6**	**177**	**249**	**380**
Potassium	---	---	10,000	14,700	8,040	10,800	50,300	102,000
Sodium	---	**100,000**	**214,000**	**222,000B**	**172,000**	**177,000B**	**1,260,000L**	**1,190,000**

Notes:

Bolded concentrations meet or exceed published standards
FWQC = Federal Water Quality Criteria
VWQS = Virginia Water Quality Standard
µg/L = Micrograms per liter
J = Value is estimated
L = Reported value may be biased low.
K = Reported value may be biased high.

SECTION 7.0
FIGURES



LEGEND

MAP SYMBOLS

- TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- CULVERT FLOW DIRECTION
- ESTIMATED EXTENT OF TCE

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
VOC – VOLATILE ORGANIC COMPOUND.
SVOC – SEMI-VOLATILE ORGANIC COMPOUND.

NOTES: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).

DEPTH INDICATED IS FROM TOP OF GROUND SURFACE.

REVISIONS			
	DRAWN WAC	NORTH	BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA
	REVIEWED DJM		BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania
	S.O.# 62470-269-0000-05100		
	CADD# 269041RI		

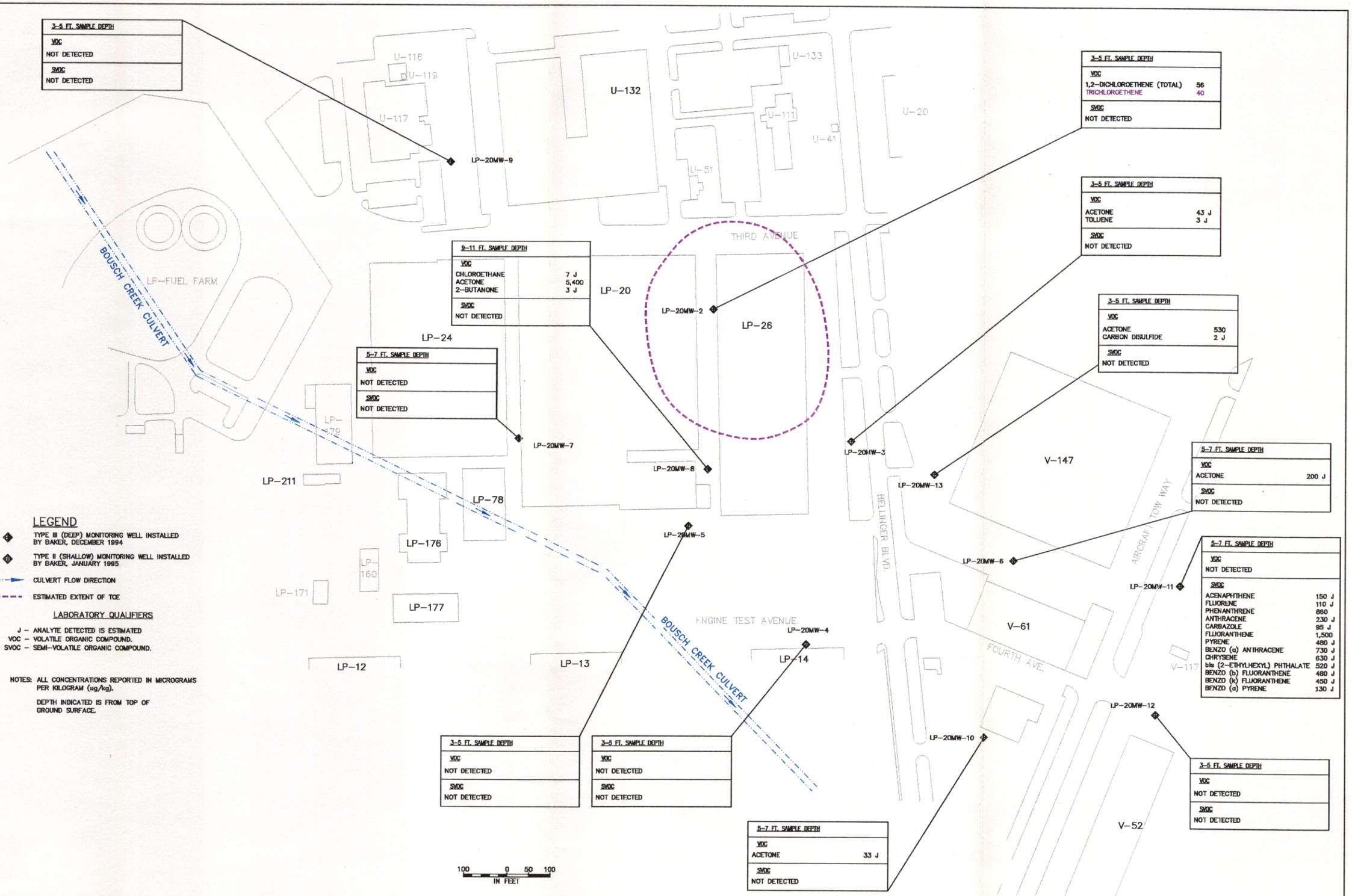
Baker
Baker Environmental, Inc.

ESTIMATED EXTENT OF TRICHLOROETHENE IN SHALLOW SOIL

SCALE

DATE APRIL 1995

FIGURE NO. 7-1



LEGEND

- TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- CULVERT FLOW DIRECTION
- ESTIMATED EXTENT OF TCE

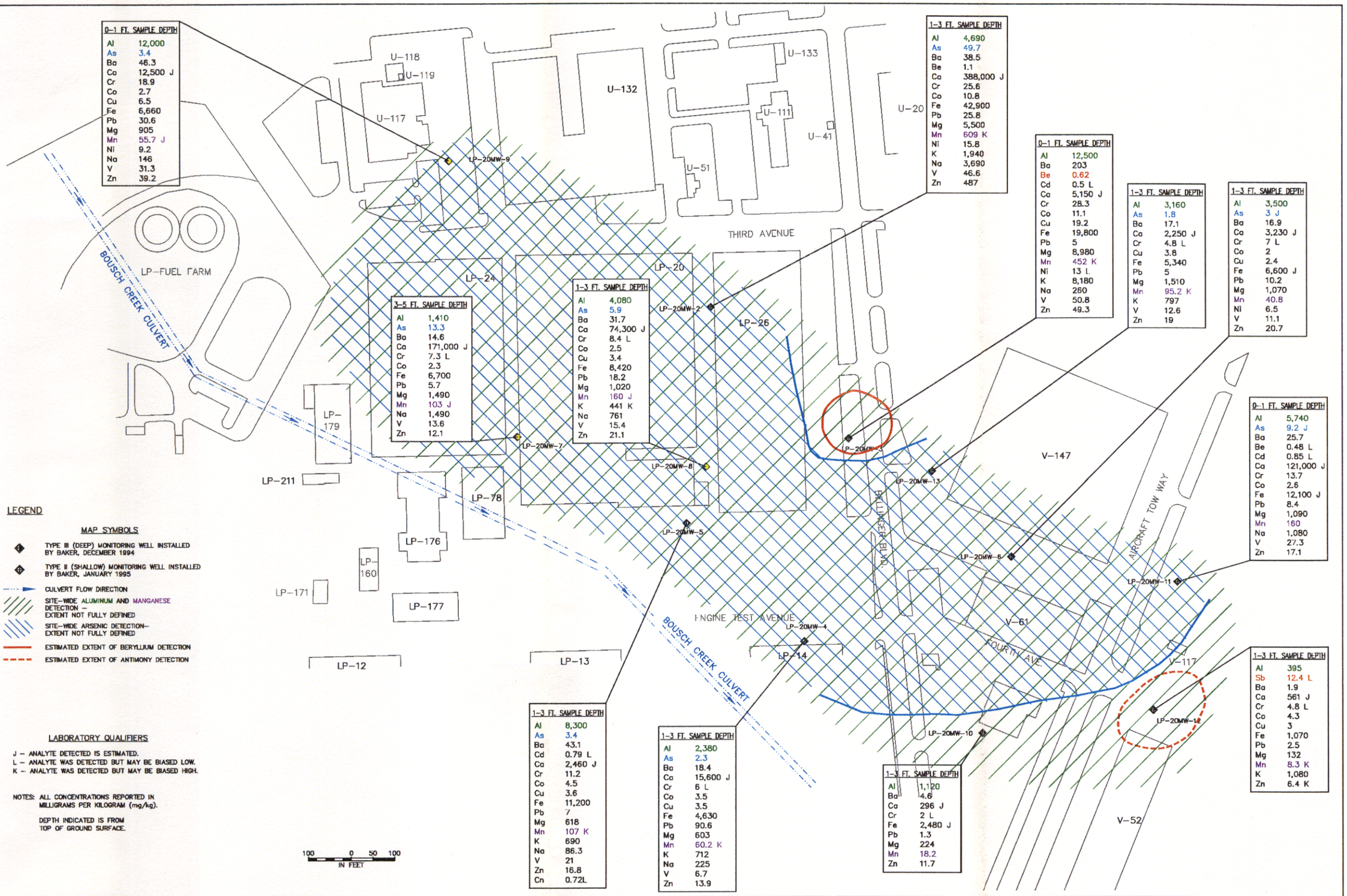
LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
VOC – VOLATILE ORGANIC COMPOUND.
SVOC – SEMI-VOLATILE ORGANIC COMPOUND.

NOTES: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).

DEPTH INDICATED IS FROM TOP OF GROUND SURFACE.

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TRICHLOROETHENE IN DEEP SOIL	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269042RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE APRIL 1995	7-2



0-1 FT. SAMPLE DEPTH

Al	12,000
As	3.4
Ba	46.3
Ca	12,500 J
Cr	18.9
Co	2.7
Cu	6.5
Fe	6,660
Pb	30.6
Mg	905
Mn	55.7 J
Ni	9.2
Na	146
V	31.3
Zn	39.2

1-3 FT. SAMPLE DEPTH

Al	4,690
As	49.7
Ba	38.5
Be	1.1
Ca	388,000 J
Cr	25.6
Co	10.8
Fe	42,900
Pb	25.8
Mg	5,500
Mn	609 K
Ni	15.8
K	1,940
Na	3,690
V	46.6
Zn	487

0-1 FT. SAMPLE DEPTH

Al	12,500
Ba	203
Be	0.62
Cd	0.5 L
Ca	5,150 J
Cr	28.3
Co	11.1
Cu	19.2
Fe	19,800
Pb	5
Mg	8,980
Mn	452 K
Ni	13 L
K	8,180
Na	260
V	50.8
Zn	49.3

1-3 FT. SAMPLE DEPTH

Al	3,160
As	1.8
Ba	17.1
Ca	2,250 J
Cr	4.8 L
Cu	3.8
Fe	5,340
Pb	5
Mg	1,510
Mn	95.2 K
K	797
V	12.6
Zn	19

1-3 FT. SAMPLE DEPTH

Al	3,500
As	3 J
Ba	16.9
Ca	3,230 J
Cr	7 L
Co	2
Cu	2.4
Fe	6,600 J
Pb	10.2
Mg	1,070
Mn	40.8
Ni	6.5
V	11.1
Zn	20.7

3-5 FT. SAMPLE DEPTH

Al	1,410
As	13.3
Ba	14.6
Ca	171,000 J
Cr	7.3 L
Co	2.3
Fe	6,700
Pb	5.7
Mg	1,490
Mn	103 J
Na	1,490
V	13.6
Zn	12.1

1-3 FT. SAMPLE DEPTH

Al	4,080
As	5.9
Ba	31.7
Ca	74,300 J
Cr	8.4 L
Co	2.5
Cu	3.4
Fe	8,420
Pb	18.2
Mg	1,020
Mn	160 J
K	441 K
Na	761
V	15.4
Zn	21.1

0-1 FT. SAMPLE DEPTH

Al	5,740
As	9.2 J
Ba	25.7
Be	0.48 L
Cd	0.85 L
Ca	121,000 J
Cr	13.7
Co	2.6
Fe	12,100 J
Pb	8.4
Mg	1,090
Mn	160
Na	1,080
V	27.3
Zn	17.1

1-3 FT. SAMPLE DEPTH

Al	395
Sb	12.4 L
Ba	1.9
Ca	561 J
Cr	4.8 L
Co	4.3
Cu	3
Fe	1,070
Pb	2.5
Mg	132
Mn	8.3 K
K	1,080
Zn	6.4 K

1-3 FT. SAMPLE DEPTH

Al	8,300
As	3.4
Ba	43.1
Cd	0.79 L
Ca	2,460 J
Cr	11.2
Co	4.5
Cu	3.6
Fe	11,200
Pb	7
Mg	618
Mn	107 K
K	690
Na	86.3
V	21
Zn	16.8
Cn	0.72L

1-3 FT. SAMPLE DEPTH

Al	2,380
As	2.3
Ba	18.4
Ca	15,600 J
Cr	6 L
Co	3.5
Cu	3.5
Fe	4,630
Pb	90.6
Mg	603
Mn	60.2 K
K	712
Na	225
V	6.7
Zn	13.9

1-3 FT. SAMPLE DEPTH

Al	1,120
Ba	4.6
Ca	296 J
Cr	2 L
Fe	2,480 J
Pb	1.3
Mg	224
Mn	18.2
Zn	11.7

LEGEND

METALS LIST

- Al – ALUMINUM
- Sb – ANTIMONY
- As – ARSENIC
- Ba – BARIUM
- Be – BERYLLIUM
- Cd – CADMIUM
- Ca – CALCIUM
- Cr – CHROMIUM
- Co – COBALT
- Cu – COPPER
- Cn – CYANIDE
- Fe – IRON
- Pb – LEAD
- Mg – MAGNESIUM
- Mn – MANGANESE
- Hg – MERCURY
- Ni – NICKEL
- K – POTASSIUM
- Se – SELENIUM
- Ag – SILVER
- Na – SODIUM
- Tl – THALLIUM
- V – VANADIUM
- Zn – ZINC

MAP SYMBOLS

- TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- CULVERT FLOW DIRECTION
- SITE-WIDE ALUMINUM AND MANGANESE DETECTION – EXTENT NOT FULLY DEFINED
- SITE-WIDE ARSENIC DETECTION– EXTENT NOT FULLY DEFINED
- ESTIMATED EXTENT OF BERYLLIUM DETECTION
- ESTIMATED EXTENT OF ANTIMONY DETECTION

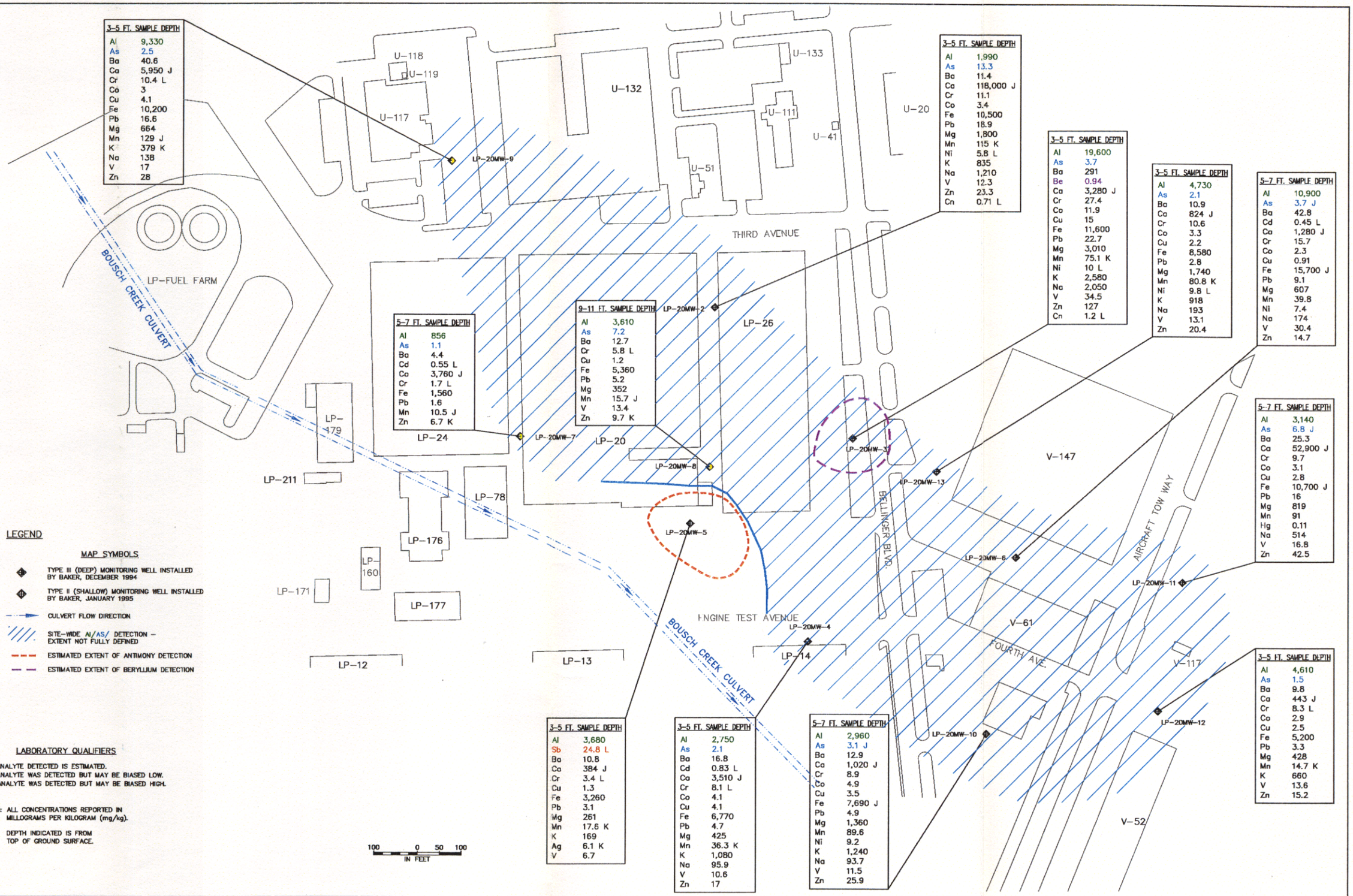
LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED.
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTES: ALL CONCENTRATIONS REPORTED IN MILLIGRAMS PER KILOGRAM (mg/kg).

DEPTH INDICATED IS FROM TOP OF GROUND SURFACE.

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF ALUMINUM, ANTIMONY, ARSENIC, BERYLLIUM AND MANGANESE IN SHALLOW SOIL	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269043RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE APRIL 1995	7-3



3-5 FT. SAMPLE DEPTH	
Al	9,330
As	2.5
Ba	40.6
Ca	5,950 J
Cr	10.4 L
Co	3
Cu	4.1
Fe	10,200
Pb	16.6
Mg	664
Mn	129 J
K	379 K
Na	138
V	17
Zn	28

3-5 FT. SAMPLE DEPTH	
Al	1,990
As	13.3
Ba	11.4
Ca	118,000 J
Cr	11.1
Co	3.4
Fe	10,500
Pb	18.9
Mg	1,800
Mn	115 K
Ni	5.8 L
K	835
Na	1,210
V	12.3
Zn	23.3
Cn	0.71 L

3-5 FT. SAMPLE DEPTH	
Al	19,600
As	3.7
Ba	291
Be	0.94
Ca	3,280 J
Cr	27.4
Co	11.9
Cu	15
Fe	11,600
Pb	22.7
Mg	3,010
Mn	75.1 K
Ni	10 L
K	2,580
Na	2,050
V	34.5
Zn	127
Cn	1.2 L

3-5 FT. SAMPLE DEPTH	
Al	4,730
As	2.1
Ba	10.9
Ca	824 J
Cr	10.6
Co	3.3
Cu	2.2
Fe	8,580
Pb	2.8
Mg	1,740
Mn	80.8 K
Ni	9.8 L
K	918
Na	193
V	13.1
Zn	20.4

5-7 FT. SAMPLE DEPTH	
Al	10,900
As	3.7 J
Ba	42.8
Cd	0.45 L
Ca	1,280 J
Cr	15.7
Co	2.3
Cu	0.91
Fe	15,700 J
Pb	9.1
Mg	607
Mn	39.8
Ni	7.4
Na	174
V	30.4
Zn	14.7

5-7 FT. SAMPLE DEPTH	
Al	856
As	1.1
Ba	4.4
Cd	0.55 L
Ca	3,760 J
Cr	1.7 L
Fe	1,560
Pb	1.6
Mn	10.5 J
Zn	6.7 K

9-11 FT. SAMPLE DEPTH	
Al	3,610
As	7.2
Ba	12.7
Cr	5.8 L
Cu	1.2
Fe	5,360
Pb	5.2
Mg	352
Mn	15.7 J
V	13.4
Zn	9.7 K

5-7 FT. SAMPLE DEPTH	
Al	3,140
As	6.8 J
Ba	25.3
Ca	52,900 J
Cr	9.7
Co	3.1
Cu	2.8
Fe	10,700 J
Pb	16
Mg	819
Mn	91
Hg	0.11
Na	514
V	16.8
Zn	42.5

3-5 FT. SAMPLE DEPTH	
Al	4,610
As	1.5
Ba	9.8
Ca	443 J
Cr	8.3 L
Co	2.9
Cu	2.5
Fe	5,200
Pb	3.3
Mg	428
Mn	14.7 K
K	660
V	13.6
Zn	15.2

3-5 FT. SAMPLE DEPTH	
Al	3,680
Sb	24.8 L
Ba	10.8
Ca	384 J
Cr	3.4 L
Cu	1.3
Fe	3,260
Pb	3.1
Mg	261
Mn	17.6 K
K	169
Ag	6.1 K
V	6.7

3-5 FT. SAMPLE DEPTH	
Al	2,750
As	2.1
Ba	16.8
Cd	0.83 L
Ca	3,510 J
Cr	8.1 L
Co	4.1
Cu	4.1
Fe	6,770
Pb	4.7
Mg	425
Mn	36.3 K
K	1,080
Na	95.9
V	10.6
Zn	17

5-7 FT. SAMPLE DEPTH	
Al	2,960
As	3.1 J
Ba	12.9
Ca	1,020 J
Cr	8.9
Co	4.9
Cu	3.5
Fe	7,690 J
Pb	4.9
Mg	1,360
Mn	89.6
Ni	9.2
K	1,240
Na	93.7
V	11.5
Zn	25.9

LEGEND

METALS LIST

Al – ALUMINUM
Sb – ANTIMONY
As – ARSENIC
Ba – BARIUM
Be – BERYLLIUM
Cd – CADMIUM
Ca – CALCIUM
Cr – CHROMIUM
Co – COBALT
Cu – COPPER
Cn – CYANIDE
Fe – IRON
Pb – LEAD
Mg – MAGNESIUM
Mn – MANGANESE
Hg – MERCURY
Ni – NICKEL
K – POTASSIUM
Se – SELENIUM
Ag – SILVER
Na – SODIUM
Tl – THALLIUM
V – VANADIUM
Zn – ZINC

MAP SYMBOLS

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994

TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995

CULVERT FLOW DIRECTION

SITE-WIDE Al/AS/ DETECTION – EXTENT NOT FULLY DEFINED

ESTIMATED EXTENT OF ANTIMONY DETECTION

ESTIMATED EXTENT OF BERYLLIUM DETECTION

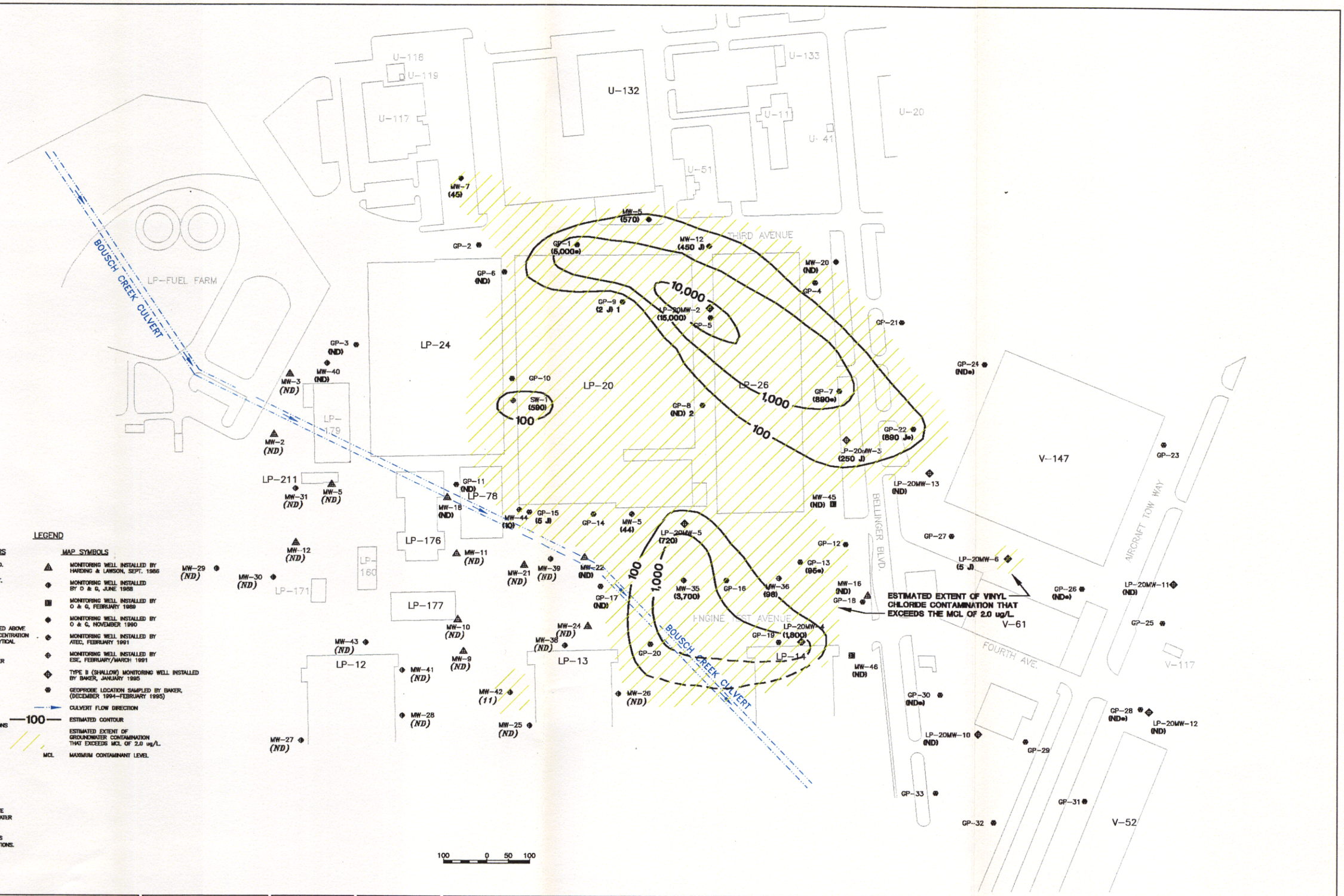
LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED.
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTES: ALL CONCENTRATIONS REPORTED IN MILLOGRAMS PER KILOGRAM (mg/kg).

DEPTH INDICATED IS FROM TOP OF GROUND SURFACE.

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF ALUMINUM, ANTIMONY, ARSENIC, AND BERYLLIUM IN DEEP SOIL	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269040RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE APRIL 1995	7-4



LEGEND

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED.

ND – BELOW METHOD DETECTION LIMIT.

NOTES:

● GEOPROBE SAMPLE COLLECTED ABOVE CLAY LAYER. CHEMICAL CONCENTRATION INDICATED IS THE CLP ANALYTICAL RESULT.

(44) SAMPLE COLLECTED BY BAKER DECEMBER 1994 TO FEBRUARY 1995.

(11) SAMPLE COLLECTED BY ENVIRONMENTAL SCIENCE AND ENGINEERING, INC., MARCH TO APRIL 1994.

ALL CHEMICAL CONCENTRATIONS EXPRESSED AS MICROGRAMS PER LITER (ug/L).

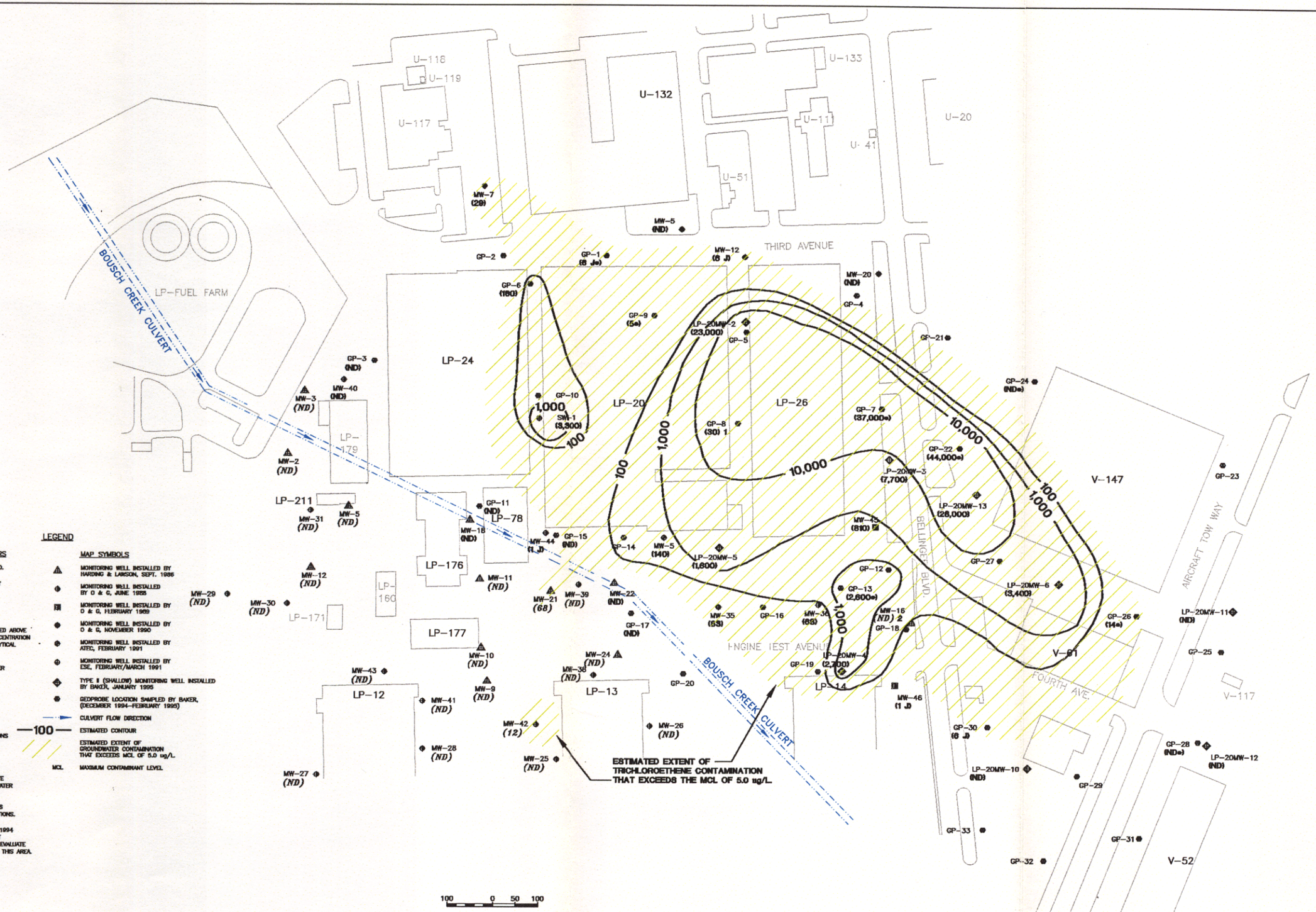
1 DUE TO THE ELEVATED VOC CONCENTRATIONS IN VICINITY THE CHEMICAL CONCENTRATIONS DETECTED IN GP-9 WERE DISREGARDED.

2 THE CONCENTRATION INDICATED IS THE SHALLOW GROUNDWATER SAMPLE ANALYZED BY AN OFF-SITE LABORATORY. THE DEEP GROUNDWATER SAMPLE, COLLECTED DURING THE IN-SITU GROUNDWATER SURVEY AND ANALYZED ON-SITE, INDICATES HIGHER CONTAMINANT CONCENTRATIONS.

MAP SYMBOLS

- MONITORING WELL INSTALLED BY HARDING & LAWSON, SEPT. 1986
- MONITORING WELL INSTALLED BY O & G, JUNE 1988
- MONITORING WELL INSTALLED BY O & G, FEBRUARY 1989
- MONITORING WELL INSTALLED BY O & G, NOVEMBER 1990
- MONITORING WELL INSTALLED BY ATEC, FEBRUARY 1991
- MONITORING WELL INSTALLED BY ESE, FEBRUARY/MARCH 1991
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- GEOPROBE LOCATION SAMPLED BY BAKER, (DECEMBER 1994–FEBRUARY 1995)
- CULVERT FLOW DIRECTION
- —100— ESTIMATED CONTOUR
- ESTIMATED EXTENT OF GROUNDWATER CONTAMINATION THAT EXCEEDS MCL OF 2.0 ug/L.
- MCL MAXIMUM CONTAMINANT LEVEL

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER – SHALLOW AQUIFER	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269029RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE MAY 1995	7-5



LEGEND

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED.

ND – BELOW METHOD DETECTION LIMIT

NOTES:

- GEOPROBE SAMPLE COLLECTED ABOVE CLAY LAYER. CHEMICAL CONCENTRATION INDICATED IS THE CLP ANALYTICAL RESULT.

(29) SAMPLE COLLECTED BY BAKER DECEMBER 1994 TO FEBRUARY 1995.

(12) SAMPLE COLLECTED BY ENVIRONMENTAL SCIENCE AND ENGINEERING, INC., MARCH TO APRIL 1994.

ALL CHEMICAL CONCENTRATIONS EXPRESSED AS MICROGRAMS PER LITER (ug/L).

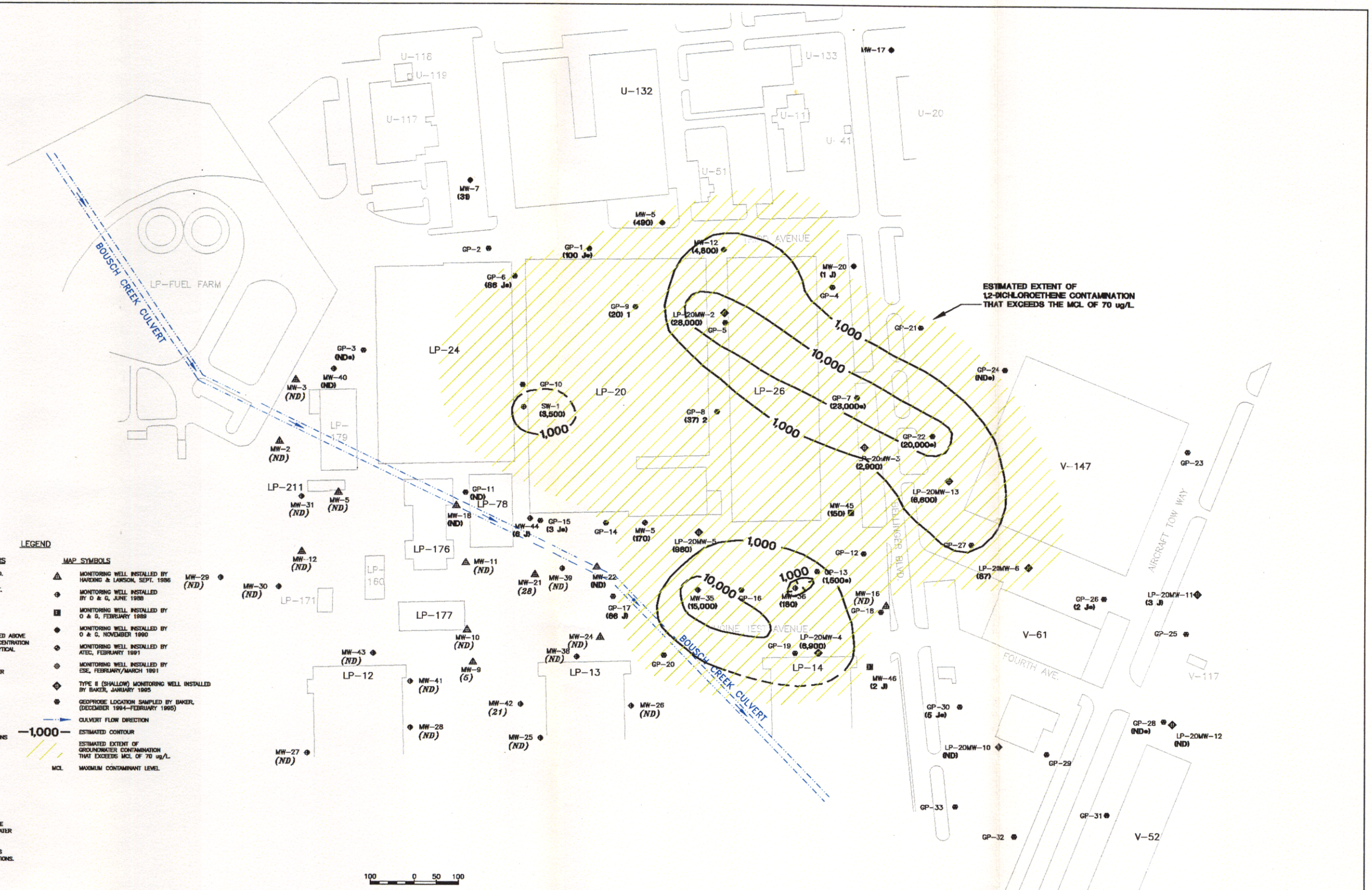
1 THE CONCENTRATION INDICATED IS THE SHALLOW GROUNDWATER SAMPLE ANALYZED BY AN OFF-SITE LABORATORY. THE DEEP GROUNDWATER SAMPLE, COLLECTED DURING THE IN-SITU GROUNDWATER SURVEY AND ANALYZED ON-SITE, INDICATES HIGHER CONTAMINANT CONCENTRATIONS.

2 THE RESULTS OF THE DECEMBER 1994 IN-SITU GROUNDWATER SURVEY AT LOCATION GP-18 WERE USED TO EVALUATE CONTAMINANT CONCENTRATIONS IN THIS AREA.

MAP SYMBOLS

- MONITORING WELL INSTALLED BY HARDING & LARSON, SEPT. 1986
- MONITORING WELL INSTALLED BY O & G, JUNE 1988
- MONITORING WELL INSTALLED BY O & G, FEBRUARY 1989
- MONITORING WELL INSTALLED BY O & G, NOVEMBER 1990
- MONITORING WELL INSTALLED BY ATEC, FEBRUARY 1991
- MONITORING WELL INSTALLED BY ESE, FEBRUARY/MARCH 1991
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- GEOPROBE LOCATION SAMPLED BY BAKER, (DECEMBER 1994–FEBRUARY 1995)
- CULVERT FLOW DIRECTION
- —100— ESTIMATED CONTOUR
- ESTIMATED EXTENT OF GROUNDWATER CONTAMINATION THAT EXCEEDS MCL OF 5.0 ug/L.
- MCL MAXIMUM CONTAMINANT LEVEL

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	TRICHLOROETHENE CONCENTRATIONS IN GROUNDWATER – SHALLOW AQUIFER	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269031RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE MAY 1995	7-6



LEGEND

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED.

ND – BELOW METHOD DETECTION LIMIT.

NOTES:

- GEOPROBE SAMPLE COLLECTED ABOVE CLAY LAYER. CHEMICAL CONCENTRATION INDICATED IS THE CLP ANALYTICAL RESULT.

(31) SAMPLE COLLECTED BY BAKER DECEMBER 1994 TO FEBRUARY 1995.

(21) SAMPLE COLLECTED BY ENVIRONMENTAL SCIENCE AND ENGINEERING, INC., MARCH TO APRIL 1994.

ALL CHEMICAL CONCENTRATIONS EXPRESSED AS MICROGRAMS PER LITER (ug/L).

1 DUE TO THE ELEVATED VOC CONCENTRATIONS IN VICINITY THE CHEMICAL CONCENTRATIONS DETECTED IN GP-9 WERE DISREGARDED.

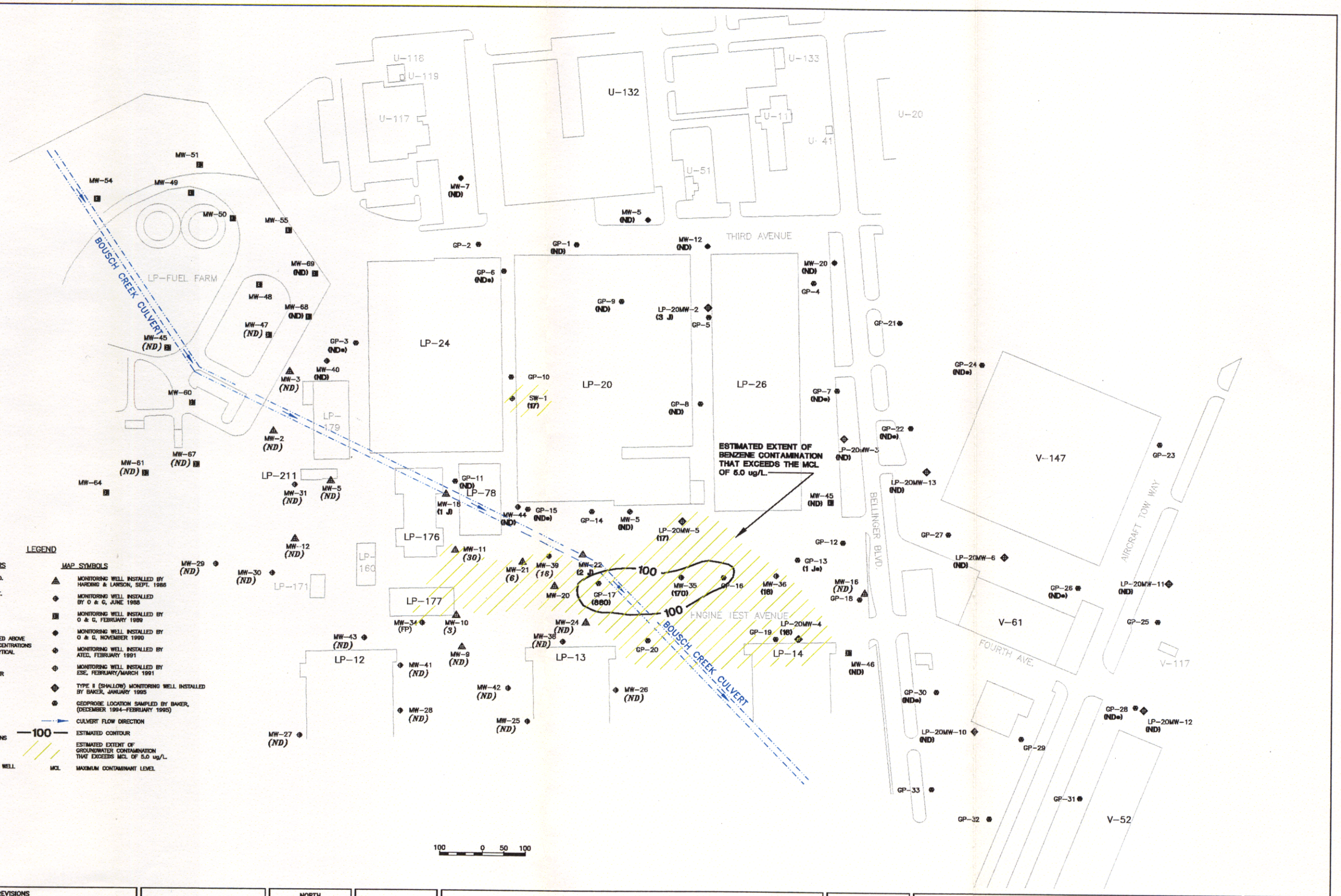
2 THE CONCENTRATION INDICATED IS THE SHALLOW GROUNDWATER SAMPLE ANALYZED BY AN OFF-SITE LABORATORY. THE DEEP GROUNDWATER SAMPLE, COLLECTED DURING THE IN-SITU GROUNDWATER SURVEY AND ANALYZED ON-SITE, INDICATES HIGHER CONTAMINANT CONCENTRATIONS.

MAP SYMBOLS

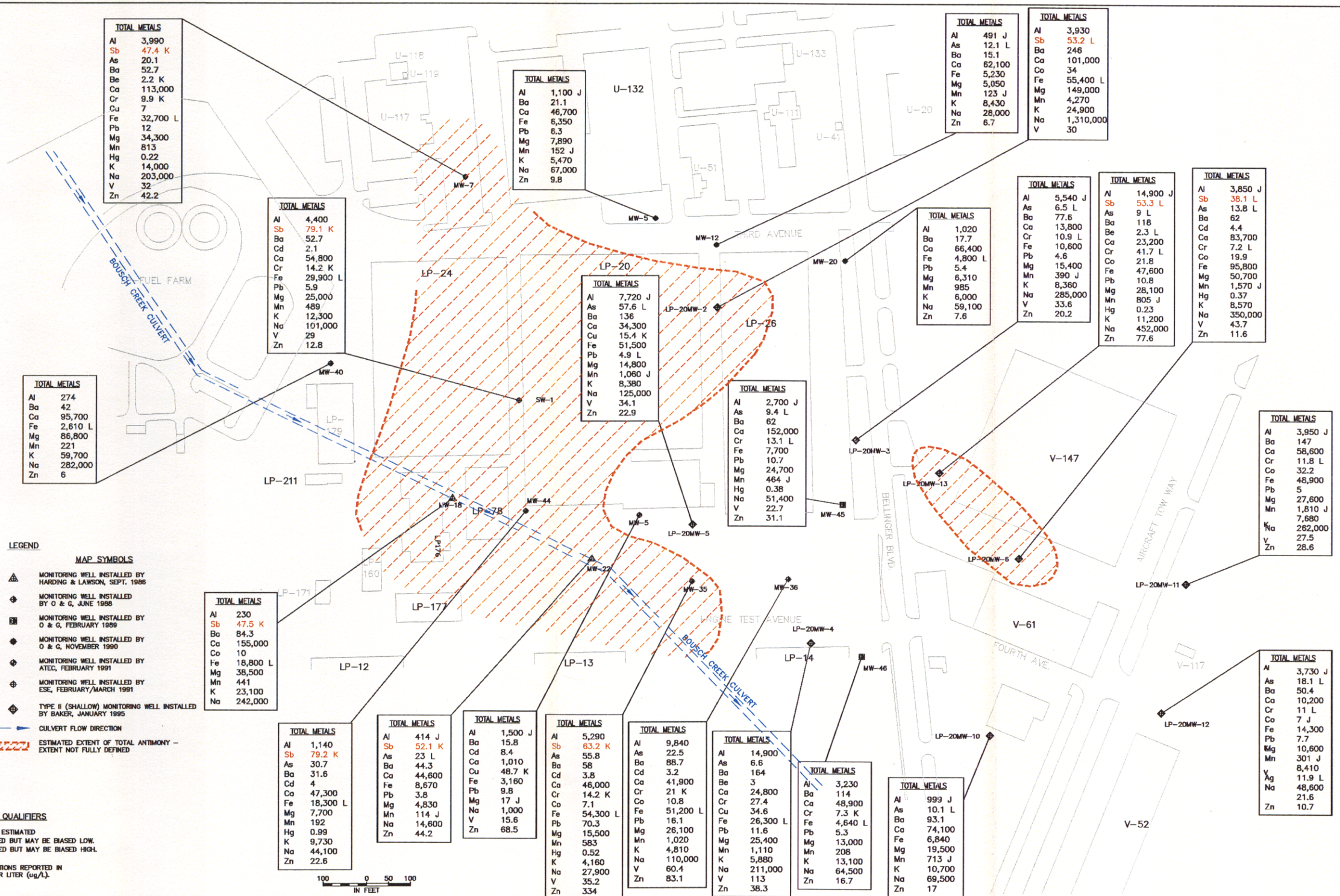
- MONITORING WELL INSTALLED BY HARDING & LAWSON, SEPT. 1986
- MONITORING WELL INSTALLED BY O & G, JUNE 1988
- MONITORING WELL INSTALLED BY O & G, FEBRUARY 1989
- MONITORING WELL INSTALLED BY O & G, NOVEMBER 1990
- MONITORING WELL INSTALLED BY ATEC, FEBRUARY 1991
- MONITORING WELL INSTALLED BY ESE, FEBRUARY/MARCH 1991
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- GEOPROBE LOCATION SAMPLED BY BAKER, (DECEMBER 1994–FEBRUARY 1995)
- CULVERT FLOW DIRECTION
- —1,000— ESTIMATED CONTOUR
- ESTIMATED EXTENT OF GROUNDWATER CONTAMINATION THAT EXCEEDS MCL OF 70 ug/L.

MCL MAXIMUM CONTAMINANT LEVEL.

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	1,2-DICHLOROETHENE (TOTAL) CONCENTRATIONS IN GROUNDWATER – SHALLOW AQUIFER	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269030RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE MAY 1995	7-7



REVISIONS	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269032R1	NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	BENZENE CONCENTRATIONS IN GROUNDWATER – SHALLOW AQUIFER SCALE DATE MAY 1995	FIGURE NO. 7-8



TOTAL METALS

Al	3,990
Sb	47.4 K
As	20.1
Ba	52.7
Be	2.2 K
Ca	113,000
Cr	9.9 K
Cu	7
Fe	32,700 L
Pb	12
Mg	34,300
Mn	813
Hg	0.22
K	14,000
Na	203,000
V	32
Zn	42.2

TOTAL METALS

Al	1,100 J
Ba	21.1
Ca	46,700
Fe	6,350
Pb	6.3
Mg	7,890
Mn	152 J
K	5,470
Na	67,000
Zn	9.8

TOTAL METALS

Al	491 J
As	12.1 L
Ba	15.1
Ca	62,100
Fe	5,230
Mg	5,050
Mn	123 J
K	8,430
Na	28,000
Zn	6.7

TOTAL METALS

Al	3,930
Sb	53.2 L
Ba	246
Ca	101,000
Co	34
Fe	55,400 L
Mg	149,000
Mn	4,270
K	24,900
Na	1,310,000
V	30

TOTAL METALS

Al	4,400
Sb	79.1 K
Ba	52.7
Cd	2.1
Ca	54,800
Cr	14.2 K
Fe	29,900 L
Pb	5.9
Mg	25,000
Mn	489
K	12,300
Na	101,000
V	29
Zn	12.8

TOTAL METALS

Al	1,020
Ba	17.7
Ca	66,400
Fe	4,800 L
Pb	5.4
Mg	6,310
Mn	985
K	6,000
Na	59,100
Zn	7.6

TOTAL METALS

Al	5,540 J
As	6.5 L
Ba	77.6
Ca	13,800
Cr	10.9 L
Fe	10,600
Pb	4.6
Mg	15,400
Mn	390 J
K	8,360
Na	285,000
V	33.6
Zn	20.2

TOTAL METALS

Al	14,900 J
Sb	53.3 L
As	9 L
Ba	118
Be	2.3 L
Ca	23,200
Cr	41.7 L
Co	21.8
Fe	47,600
Pb	10.8
Mg	28,100
Mn	805 J
Hg	0.23
K	11,200
Na	452,000
Zn	77.6

TOTAL METALS

Al	3,850 J
Sb	38.1 L
As	13.8 L
Ba	62
Cd	4.4
Ca	83,700
Cr	7.2 L
Co	19.9
Fe	95,800
Mg	50,700
Mn	1,570 J
Hg	0.37
K	8,570
Na	350,000
V	43.7
Zn	11.6

TOTAL METALS

Al	274
Ba	42
Ca	95,700
Fe	2,610 L
Mg	86,800
Mn	221
K	59,700
Na	282,000
Zn	6

TOTAL METALS

Al	7,720 J
As	57.6 L
Ba	136
Ca	34,300
Cu	15.4 K
Fe	51,500
Pb	4.9 L
Mg	14,800
Mn	1,060 J
K	8,380
Na	125,000
V	34.1
Zn	22.9

TOTAL METALS

Al	2,700 J
As	9.4 L
Ba	62
Ca	152,000
Cr	13.1 L
Fe	7,700
Pb	10.7
Mg	24,700
Mn	464 J
Hg	0.38
Na	51,400
V	22.7
Zn	31.1

TOTAL METALS

Al	3,950 J
Ba	147
Ca	58,600
Cr	11.8 L
Co	32.2
Fe	48,900
Pb	5
Mg	27,600
Mn	1,810 J
K	7,680
Na	262,000
V	27.5
Zn	28.6

TOTAL METALS

Al	230
Sb	47.5 K
Ba	84.3
Ca	155,000
Co	10
Fe	18,800 L
Mg	38,500
Mn	441
K	23,100
Na	242,000

TOTAL METALS

Al	3,730 J
As	18.1 L
Ba	50.4
Ca	10,200
Cr	11 L
Co	7 J
Fe	14,300
Pb	7.7
Mg	10,600
Mn	301 J
K	8,410
Ag	11.9 L
Na	48,600
V	21.6
Zn	10.7

TOTAL METALS

Al	1,140
Sb	79.2 K
As	30.7
Ba	31.6
Cd	4
Ca	47,300
Fe	18,300 L
Mg	7,700
Mn	192
Hg	0.99
K	9,730
Na	44,100
Zn	22.6

TOTAL METALS

Al	414 J
Sb	52.1 K
As	23 L
Ba	44.3
Ca	44,600
Fe	8,670
Pb	3.8
Mg	4,830
Mn	114 J
Na	14,600
Zn	44.2

TOTAL METALS

Al	1,500 J
Ba	15.8
Cd	8.4
Ca	1,010
Cu	48.7 K
Fe	3,160
Pb	9.8
Mg	17 J
Na	1,000
V	15.6
Zn	68.5

TOTAL METALS

Al	5,290
Sb	63.2 K
As	55.8
Ba	58
Cd	3.8
Ca	46,000
Cr	14.2 K
Co	7.1
Fe	54,300 L
Pb	70.3
Mg	15,500
Mn	583
Hg	0.52
K	4,160
Na	27,900
V	35.2
Zn	334

TOTAL METALS

Al	9,840
As	22.5
Ba	88.7
Cd	3.2
Ca	41,900
Cr	21 K
Co	10.8
Fe	51,200 L
Pb	16.1
Mg	26,100
Mn	1,020
K	4,810
Na	110,000
V	60.4
Zn	83.1

TOTAL METALS

Al	14,900
As	6.6
Ba	164
Be	3
Ca	24,800
Cr	27.4
Cu	34.6
Fe	26,300 L
Pb	11.6
Mg	25,400
Mn	1,110
K	5,880
Na	211,000
V	113
Zn	38.3

TOTAL METALS

Al	3,230
Ba	114
Ca	48,900
Cr	7.3 K
Fe	4,640 L
Pb	5.3
Mg	13,000
Mn	208
K	13,100
Na	64,500
Zn	16.7

TOTAL METALS

Al	999 J
As	10.1 L
Ba	93.1
Ca	74,100
Fe	6,840
Mg	19,500
Mn	713 J
K	10,700
Na	69,500
Zn	17

LEGEND

METALS LIST

Al – ALUMINUM
Sb – ANTIMONY
As – ARSENIC
Ba – BARIUM
Be – BERYLLIUM
Cd – CADMIUM
Ca – CALCIUM
Cr – CHROMIUM
Co – COBALT
Cu – COPPER
Fe – IRON
Pb – LEAD
Mg – MAGNESIUM
Mn – MANGANESE
Hg – MERCURY
Ni – NICKEL
K – POTASSIUM
Se – SELENIUM
Ag – SILVER
Na – SODIUM
Tl – THALLIUM
V – VANADIUM
Z – ZINC

MAP SYMBOLS

- MONITORING WELL INSTALLED BY HARDING & LAWSON, SEPT. 1986
- MONITORING WELL INSTALLED BY O & G, JUNE 1988
- MONITORING WELL INSTALLED BY O & G, FEBRUARY 1989
- MONITORING WELL INSTALLED BY O & G, NOVEMBER 1990
- MONITORING WELL INSTALLED BY ATEC, FEBRUARY 1991
- MONITORING WELL INSTALLED BY ESE, FEBRUARY/MARCH 1991
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- CULVERT FLOW DIRECTION
- ESTIMATED EXTENT OF TOTAL ANTIMONY – EXTENT NOT FULLY DEFINED

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

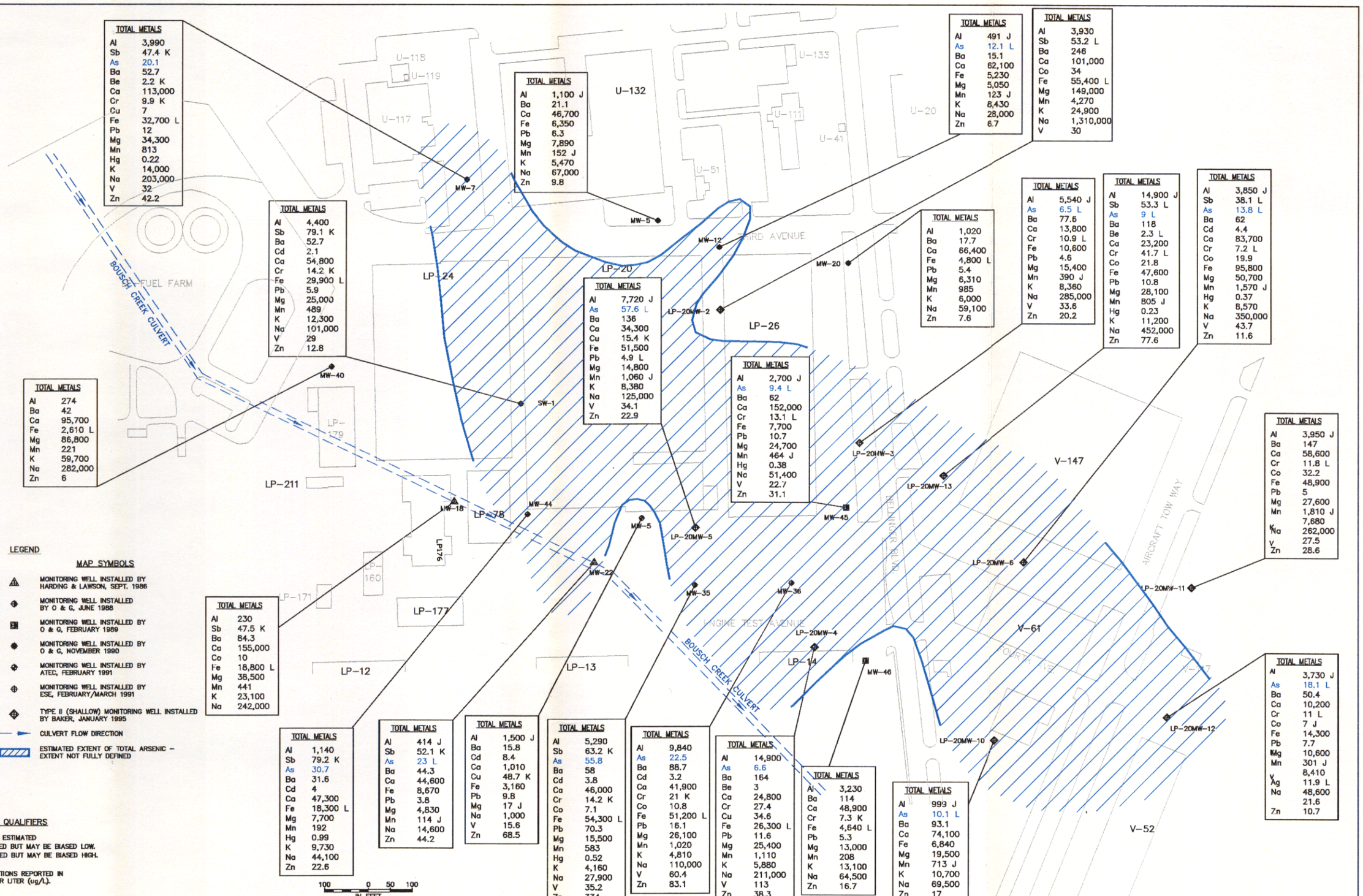
NOTE: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

REVISIONS		NORTH		
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269039RI		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.

ESTIMATED EXTENTS OF TOTAL ANTIMONY – SHALLOW AQUIFER

SCALE | DATE APRIL 1995

FIGURE NO. 7-9



TOTAL METALS

Al	3,990
Sb	47.4 K
As	20.1
Ba	52.7
Be	2.2 K
Ca	113,000
Cr	9.9 K
Cu	7
Fe	32,700 L
Pb	12
Mg	34,300
Mn	813
Hg	0.22
K	14,000
Na	203,000
V	32
Zn	42.2

TOTAL METALS

Al	1,100 J
Ba	21.1
Ca	46,700
Fe	6,350
Pb	6.3
Mg	7,890
Mn	152 J
K	5,470
Na	67,000
Zn	9.8

TOTAL METALS

Al	491 J
As	12.1 L
Ba	15.1
Ca	62,100
Fe	5,230
Mg	5,050
Mn	123 J
K	8,430
Na	28,000
Zn	6.7

TOTAL METALS

Al	3,930
Sb	53.2 L
Ba	246
Ca	101,000
Co	34
Fe	55,400 L
Mg	149,000
Mn	4,270
K	24,900
Na	1,310,000
V	30

TOTAL METALS

Al	4,400
Sb	79.1 K
Ba	52.7
Cd	2.1
Ca	54,800
Cr	14.2 K
Fe	29,900 L
Pb	5.9
Mg	25,000
Mn	489
K	12,300
Na	101,000
V	29
Zn	12.8

TOTAL METALS

Al	1,020
Ba	17.7
Ca	66,400
Fe	4,800 L
Pb	5.4
Mg	6,310
Mn	985
K	6,000
Na	59,100
Zn	7.6

TOTAL METALS

Al	5,540 J
As	6.5 L
Ba	77.6
Ca	13,800
Cr	10.9 L
Fe	10,600
Pb	4.6
Mg	15,400
Mn	390 J
K	8,360
Na	285,000
V	33.6
Zn	20.2

TOTAL METALS

Al	14,900 J
Sb	53.3 L
As	9 L
Ba	118
Be	2.3 L
Ca	23,200
Cr	41.7 L
Co	21.8
Fe	47,600
Pb	10.8
Mg	28,100
Mn	805 J
Hg	0.23
K	11,200
Na	452,000
Zn	77.6

TOTAL METALS

Al	3,850 J
Sb	38.1 L
As	13.8 L
Ba	62
Cd	4.4
Ca	83,700
Cr	7.2 L
Co	19.9
Fe	95,800
Mg	50,700
Mn	1,570 J
Hg	0.37
K	8,570
Na	350,000
V	43.7
Zn	11.6

TOTAL METALS

Al	274
Ba	42
Ca	95,700
Fe	2,610 L
Mg	86,800
Mn	221
K	59,700
Na	282,000
Zn	6

TOTAL METALS

Al	7,720 J
As	57.6 L
Ba	136
Ca	34,300
Cu	15.4 K
Fe	51,500
Pb	4.9 L
Mg	14,800
Mn	1,060 J
K	8,380
Na	125,000
V	34.1
Zn	22.9

TOTAL METALS

Al	2,700 J
As	9.4 L
Ba	62
Ca	152,000
Cr	13.1 L
Fe	7,700
Pb	10.7
Mg	24,700
Mn	464 J
Hg	0.38
Na	51,400
V	22.7
Zn	31.1

TOTAL METALS

Al	3,950 J
Ba	147
Ca	58,600
Cr	11.8 L
Co	32.2
Fe	48,900
Pb	5
Mg	27,600
Mn	1,810 J
K	7,680
Na	262,000
V	27.5
Zn	28.6

TOTAL METALS

Al	230
Sb	47.5 K
Ba	84.3
Ca	155,000
Co	10
Fe	18,800 L
Mg	38,500
Mn	441
K	23,100
Na	242,000

TOTAL METALS

Al	3,730 J
As	18.1 L
Ba	50.4
Ca	10,200
Cr	11 L
Co	7 J
Fe	14,300
Pb	7.7
Mg	10,600
Mn	301 J
V	8,410
Ag	11.9 L
Na	48,600
	21.6
Zn	10.7

TOTAL METALS

Al	1,140
Sb	79.2 K
As	30.7
Ba	31.6
Cd	4
Ca	47,300
Fe	18,300 L
Mg	7,700
Mn	192
Hg	0.99
K	9,730
Na	44,100
Zn	22.6

TOTAL METALS

Al	414 J
Sb	52.1 K
As	23 L
Ba	44.3
Ca	44,600
Fe	8,670
Pb	3.8
Mg	4,830
Mn	114 J
Na	14,600
Zn	44.2

TOTAL METALS

Al	1,500 J
Ba	15.8
Cd	8.4
Ca	1,010
Cu	48.7 K
Fe	3,160
Pb	9.8
Mg	17 J
Na	1,000
V	15.6
Zn	68.5

TOTAL METALS

Al	5,290
Sb	63.2 K
As	55.8
Ba	58
Cd	3.8
Ca	46,000
Cr	14.2 K
Co	7.1
Fe	54,300 L
Pb	70.3
Mg	15,500
Mn	583
Hg	0.52
K	4,160
Na	27,900
V	35.2
Zn	334

TOTAL METALS

Al	9,840
As	22.5
Ba	88.7
Cd	3.2
Ca	41,900
Cr	21 K
Co	10.8
Fe	51,200 L
Pb	16.1
Mg	26,100
Mn	1,020
K	4,810
Na	110,000
V	60.4
Zn	83.1

TOTAL METALS

Al	14,900
As	6.6
Ba	164
Be	3
Ca	24,800
Cr	27.4
Cu	34.6
Fe	26,300 L
Pb	11.6
Mg	25,400
Mn	1,110
K	5,880
Na	211,000
V	113
Zn	38.3

TOTAL METALS

Al	3,230
Ba	114
Ca	48,900
Cr	7.3 K
Fe	4,640 L
Pb	5.3
Mg	13,000
Mn	208
K	13,100
Na	64,500
Zn	16.7

TOTAL METALS

Al	999 J
As	10.1 L
Ba	93.1
Ca	74,100
Fe	6,840
Mg	19,500
Mn	713 J
K	10,700
Na	69,500
Zn	17

LEGEND

METALS LIST

Al – ALUMINUM
Sb – ANTIMONY
As – ARSENIC
Ba – BARIUM
Be – BERYLLIUM
Cd – CADMIUM
Ca – CALCIUM
Cr – CHROMIUM
Co – COBALT
Cu – COPPER
Fe – IRON
Pb – LEAD
Mg – MAGNESIUM
Mn – MANGANESE
Hg – MERCURY
Ni – NICKEL
K – POTASSIUM
Se – SELENIUM
Ag – SILVER
Na – SODIUM
Tl – THALLIUM
V – VANADIUM
Z – ZINC

MAP SYMBOLS

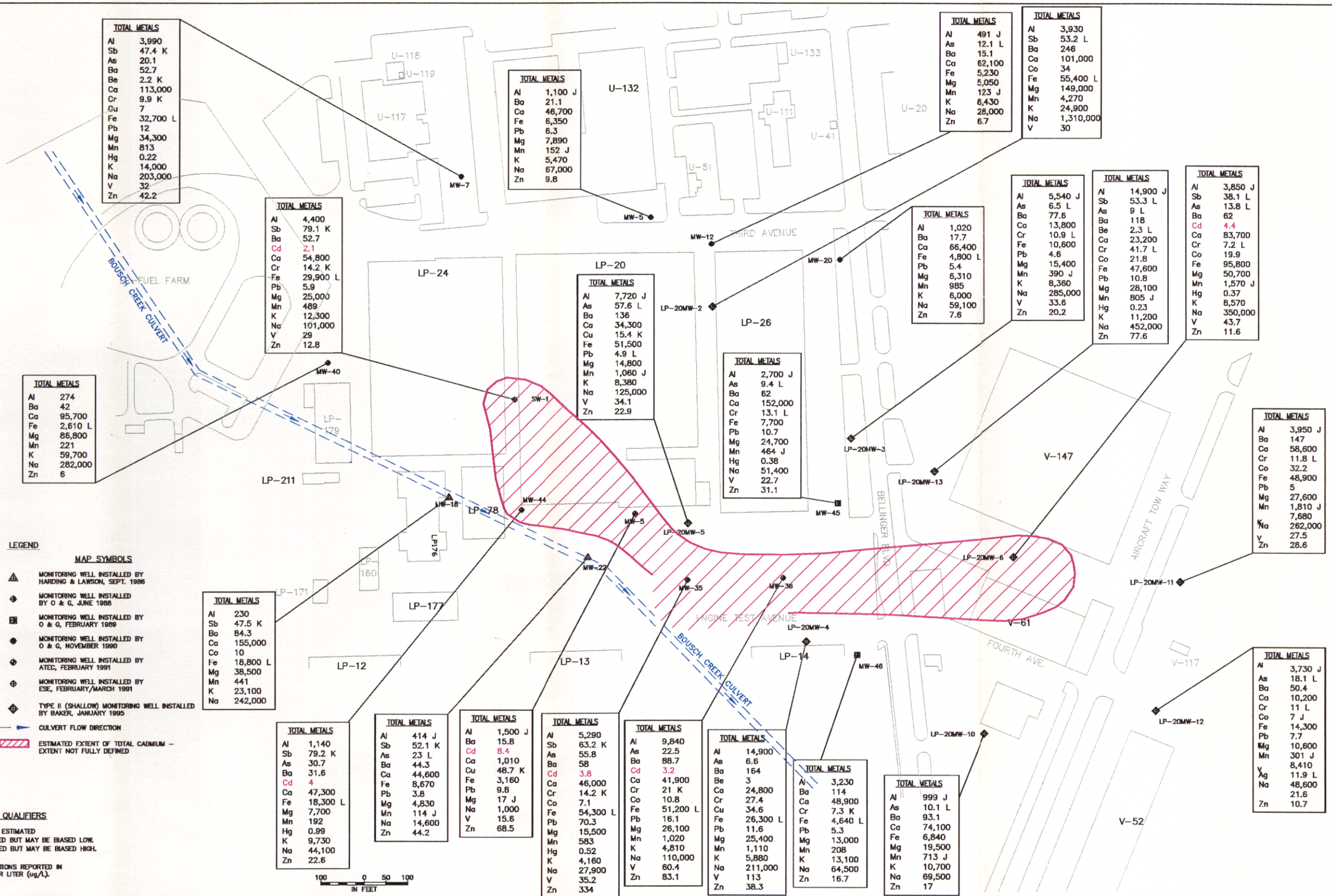
- MONITORING WELL INSTALLED BY HARDING & LAWSON, SEPT. 1986
- MONITORING WELL INSTALLED BY O & G, JUNE 1988
- MONITORING WELL INSTALLED BY O & G, FEBRUARY 1989
- MONITORING WELL INSTALLED BY O & G, NOVEMBER 1990
- MONITORING WELL INSTALLED BY ATEC, FEBRUARY 1991
- MONITORING WELL INSTALLED BY ESE, FEBRUARY/MARCH 1991
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- CULVERT FLOW DIRECTION
- ESTIMATED EXTENT OF TOTAL ARSENIC – EXTENT NOT FULLY DEFINED

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTE: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

REVISIONS		NORTH				FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269044RI			BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TOTAL ARSENIC – SHALLOW AQUIFER SCALE DATE APRIL 1995	7-10



TOTAL METALS

Al	3,990
Sb	47.4 K
As	20.1
Ba	52.7
Be	2.2 K
Ca	113,000
Cr	9.9 K
Cu	7
Fe	32,700 L
Pb	12
Mg	34,300
Mn	813
Hg	0.22
K	14,000
Na	203,000
V	32
Zn	42.2

TOTAL METALS

Al	1,100 J
Ba	21.1
Ca	46,700
Fe	6,350
Pb	6.3
Mg	7,890
Mn	152 J
K	5,470
Na	67,000
Zn	9.8

TOTAL METALS

Al	491 J
As	12.1 L
Ba	15.1
Ca	62,100
Fe	5,230
Mg	5,050
Mn	123 J
K	8,430
Na	28,000
Zn	6.7

TOTAL METALS

Al	3,930
Sb	53.2 L
Ba	246
Ca	101,000
Co	34
Fe	55,400 L
Mg	149,000
Mn	4,270
K	24,900
Na	1,310,000
V	30

TOTAL METALS

Al	4,400
Sb	79.1 K
Ba	52.7
Cd	2.1
Ca	54,800
Cr	14.2 K
Fe	29,900 L
Pb	5.9
Mg	25,000
Mn	489
K	12,300
Na	101,000
V	29
Zn	12.8

TOTAL METALS

Al	7,720 J
As	57.6 L
Ba	136
Ca	34,300
Cu	15.4 K
Fe	51,500
Pb	4.9 L
Mg	14,800
Mn	1,060 J
K	8,380
Na	125,000
V	34.1
Zn	22.9

TOTAL METALS

Al	1,020
Ba	17.7
Ca	66,400
Fe	4,800 L
Pb	5.4
Mg	6,310
Mn	985
K	6,000
Na	59,100
Zn	7.6

TOTAL METALS

Al	5,540 J
As	6.5 L
Ba	77.6
Ca	13,800
Cr	10.9 L
Fe	10,600
Pb	4.6
Mg	15,400
Mn	390 J
K	8,360
Na	285,000
V	33.6
Zn	20.2

TOTAL METALS

Al	14,900 J
Sb	53.3 L
As	9 L
Ba	118
Be	2.3 L
Ca	23,200
Cr	41.7 L
Co	21.8
Fe	47,600
Pb	10.8
Mg	28,100
Mn	805 J
Hg	0.23
K	11,200
Na	452,000
Zn	77.6

TOTAL METALS

Al	3,850 J
Sb	38.1 L
As	13.8 L
Ba	62
Cd	4.4
Ca	83,700
Cr	7.2 L
Co	19.9
Fe	95,800
Mg	50,700
Mn	1,570 J
Hg	0.37
K	8,570
Na	350,000
V	43.7
Zn	11.6

TOTAL METALS

Al	274
Ba	42
Ca	95,700
Fe	2,610 L
Mg	86,800
Mn	221
K	59,700
Na	282,000
Zn	6

TOTAL METALS

Al	2,700 J
As	9.4 L
Ba	62
Ca	152,000
Cr	13.1 L
Fe	7,700
Pb	10.7
Mg	24,700
Mn	464 J
Hg	0.38
Na	51,400
V	22.7
Zn	31.1

TOTAL METALS

Al	3,950 J
Ba	147
Ca	58,600
Cr	11.8 L
Co	32.2
Fe	48,900
Pb	5
Mg	27,600
Mn	1,810 J
K	7,680
Na	262,000
V	27.5
Zn	28.6

TOTAL METALS

Al	230
Sb	47.5 K
Ba	84.3
Ca	155,000
Co	10
Fe	18,800 L
Mg	38,500
Mn	441
K	23,100
Na	242,000

TOTAL METALS

Al	1,140
Sb	79.2 K
As	30.7
Ba	31.6
Cd	4
Ca	47,300
Fe	18,300 L
Mg	7,700
Mn	192
Hg	0.99
K	9,730
Na	44,100
Zn	22.6

TOTAL METALS

Al	414 J
Sb	52.1 K
As	23 L
Ba	44.3
Ca	44,600
Fe	8,670
Pb	3.8
Mg	4,830
Mn	114 J
Na	14,600
Zn	44.2

TOTAL METALS

Al	1,500 J
Ba	15.8
Cd	8.4
Ca	1,010
Cu	48.7 K
Fe	3,160
Pb	9.8
Mg	17 J
Na	1,000
V	15.6
Zn	68.5

TOTAL METALS

Al	5,290
Sb	63.2 K
As	55.8
Ba	58
Cd	3.8
Ca	46,000
Cr	14.2 K
Co	7.1
Fe	54,300 L
Pb	70.3
Mg	15,500
Mn	583
Hg	0.52
K	4,160
Na	27,900
V	35.2
Zn	334

TOTAL METALS

Al	9,840
As	22.5
Ba	88.7
Cd	3.2
Ca	41,900
Cr	21 K
Co	10.8
Fe	51,200 L
Pb	16.1
Mg	26,100
Mn	1,020
K	4,810
Na	110,000
V	60.4
Zn	83.1

TOTAL METALS

Al	14,900
As	6.6
Ba	164
Be	3
Ca	24,800
Cr	27.4
Cu	34.6
Fe	26,300 L
Pb	11.6
Mg	25,400
Mn	1,110
K	5,880
Na	211,000
V	113
Zn	38.3

TOTAL METALS

Al	3,230
Ba	114
Ca	48,900
Cr	7.3 K
Fe	4,640 L
Pb	5.3
Mg	13,000
Mn	208
K	13,100
Na	64,500
Zn	16.7

TOTAL METALS

Al	999 J
As	10.1 L
Ba	93.1
Ca	74,100
Fe	6,840
Mg	19,500
Mn	713 J
K	10,700
Na	69,500
Zn	17

TOTAL METALS

Al	3,730 J
As	18.1 L
Ba	50.4
Ca	10,200
Cr	11 L
Co	7 J
Fe	14,300
Pb	7.7
Mg	10,600
Mn	301 J
K	8,410
Ag	11.9 L
Na	48,600
Zn	21.6
	10.7

LEGEND

METALS LIST

- Al – ALUMINUM
- Sb – ANTIMONY
- As – ARSENIC
- Ba – BARIUM
- Be – BERYLLIUM
- Cd – CADMIUM
- Ca – CALCIUM
- Cr – CHROMIUM
- Co – COBALT
- Cu – COPPER
- Fe – IRON
- Pb – LEAD
- Mg – MAGNESIUM
- Mn – MANGANESE
- Hg – MERCURY
- Ni – NICKEL
- K – POTASSIUM
- Se – SELENIUM
- Ag – SILVER
- Na – SODIUM
- Tl – THALLIUM
- V – VANADIUM
- Z – ZINC

MAP SYMBOLS

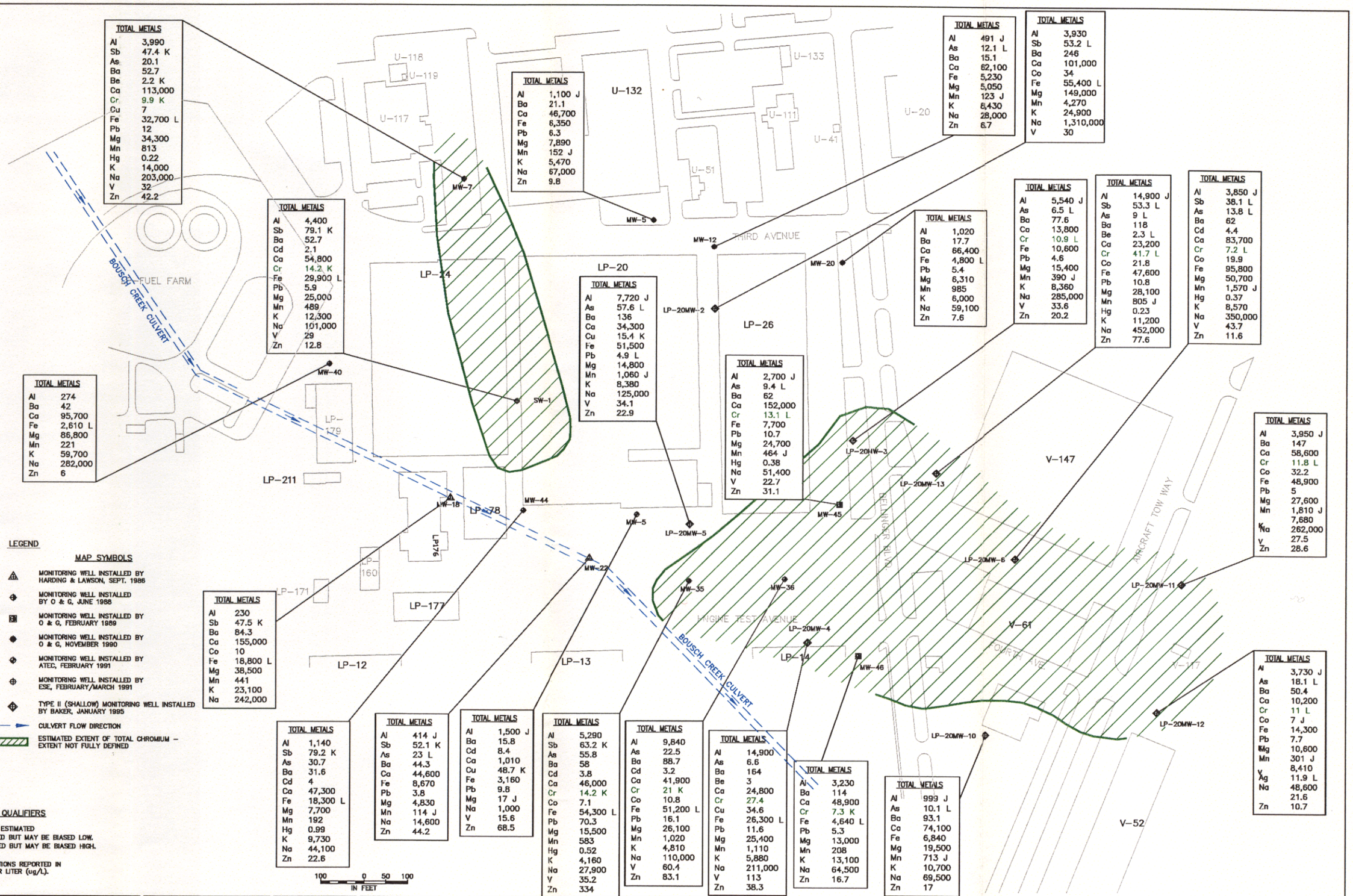
- MONITORING WELL INSTALLED BY HARDING & LAWSON, SEPT. 1986
- MONITORING WELL INSTALLED BY O & G, JUNE 1988
- MONITORING WELL INSTALLED BY O & G, FEBRUARY 1989
- MONITORING WELL INSTALLED BY O & G, NOVEMBER 1990
- MONITORING WELL INSTALLED BY ATEC, FEBRUARY 1991
- MONITORING WELL INSTALLED BY ESE, FEBRUARY/MARCH 1991
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- CULVERT FLOW DIRECTION
- ESTIMATED EXTENT OF TOTAL CADMIUM – EXTENT NOT FULLY DEFINED

LABORATORY QUALIFIERS

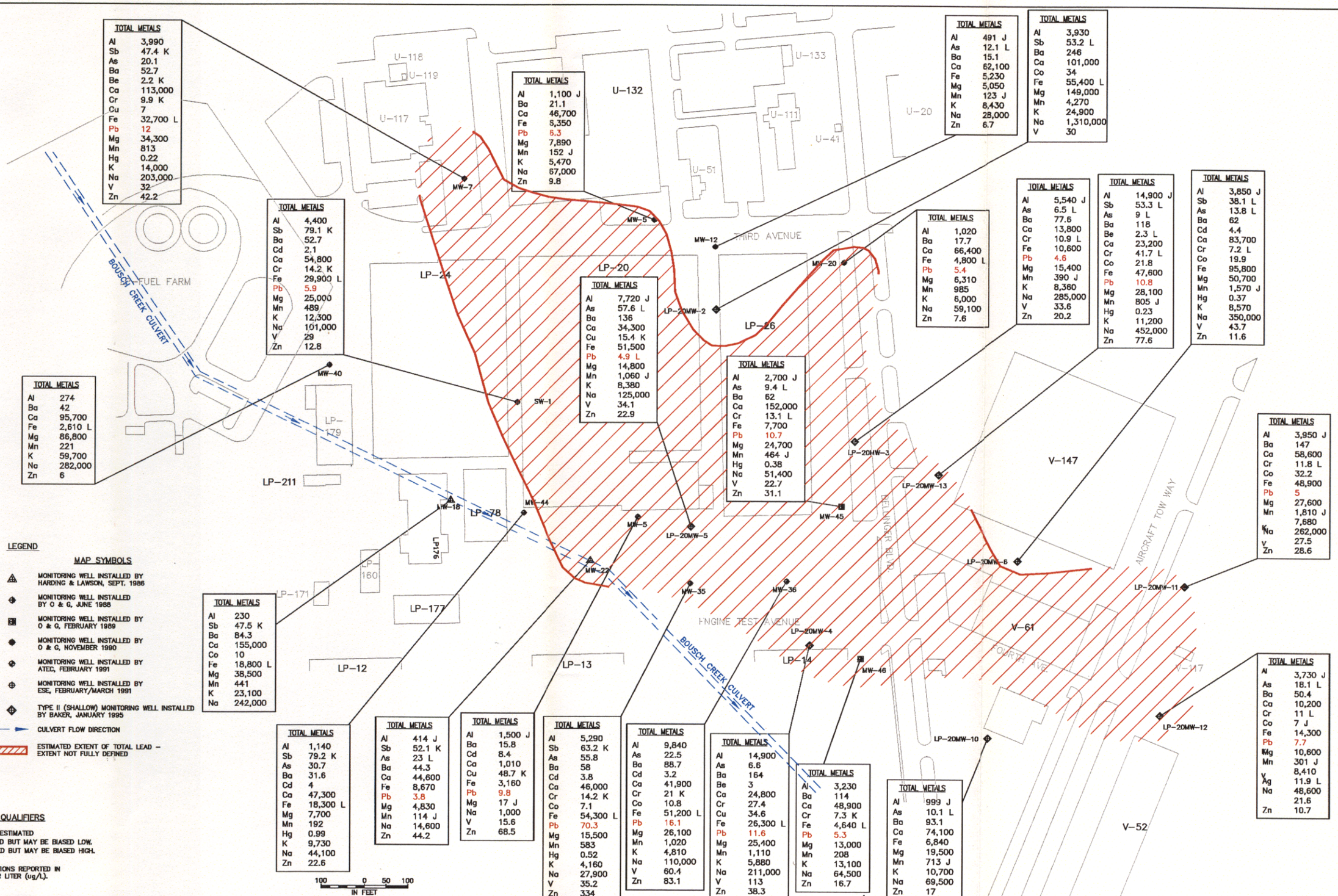
J – ANALYTE DETECTED IS ESTIMATED
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTE: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

REVISIONS		NORTH	BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TOTAL CADMIUM – SHALLOW AQUIFER	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269045RI		BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE APRIL 1995	7-11



REVISIONS		NORTH	BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TOTAL CHROMIUM – SHALLOW AQUIFER	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269047RI		BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE APRIL 1995	7-12



LEGEND

METALS LIST

- Al – ALUMINUM
- Sb – ANTIMONY
- As – ARSENIC
- Ba – BARIUM
- Be – BERYLLIUM
- Cd – CADMIUM
- Ca – CALCIUM
- Cr – CHROMIUM
- Co – COBALT
- Cu – COPPER
- Fe – IRON
- Pb – LEAD
- Mg – MAGNESIUM
- Mn – MANGANESE
- Hg – MERCURY
- Ni – NICKEL
- K – POTASSIUM
- Se – SELENIUM
- Ag – SILVER
- Na – SODIUM
- Tl – THALLIUM
- V – VANADIUM
- Z – ZINC

MAP SYMBOLS

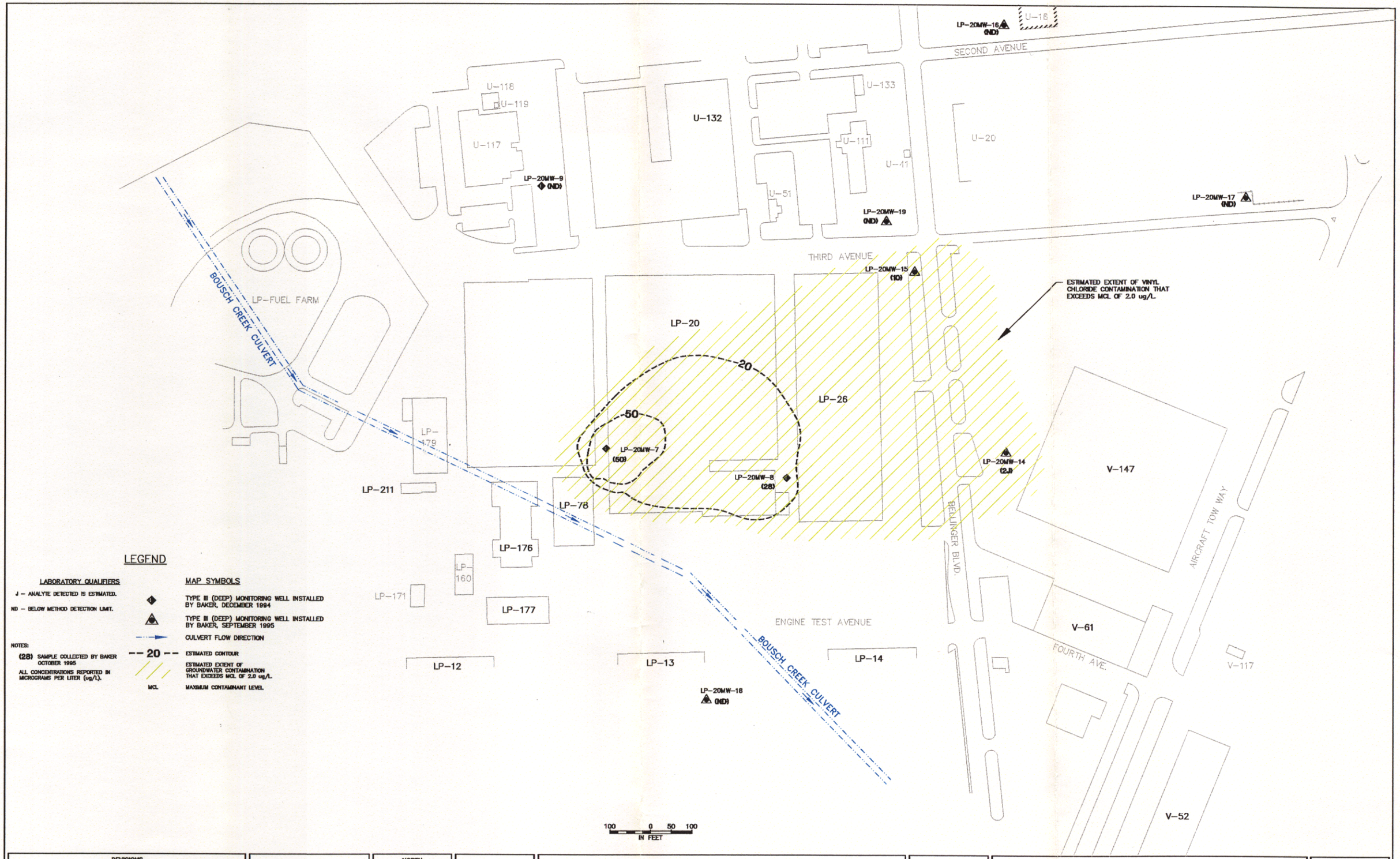
- MONITORING WELL INSTALLED BY HARDING & LAWSON, SEPT. 1986
- MONITORING WELL INSTALLED BY O & G, JUNE 1988
- MONITORING WELL INSTALLED BY O & G, FEBRUARY 1989
- MONITORING WELL INSTALLED BY O & G, NOVEMBER 1990
- MONITORING WELL INSTALLED BY ATEC, FEBRUARY 1991
- MONITORING WELL INSTALLED BY ESE, FEBRUARY/MARCH 1991
- TYPE II (SHALLOW) MONITORING WELL INSTALLED BY BAKER, JANUARY 1995
- CULVERT FLOW DIRECTION
- ESTIMATED EXTENT OF TOTAL LEAD – EXTENT NOT FULLY DEFINED

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTE: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

REVISIONS		NORTH				FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269046RI			BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TOTAL LEAD – SHALLOW AQUIFER SCALE DATE APRIL 1995	7-13



LEGEND

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED.

ND – BELOW METHOD DETECTION LIMIT.

NOTES:

(28) SAMPLE COLLECTED BY BAKER OCTOBER 1995

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

MAP SYMBOLS

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, SEPTEMBER 1995

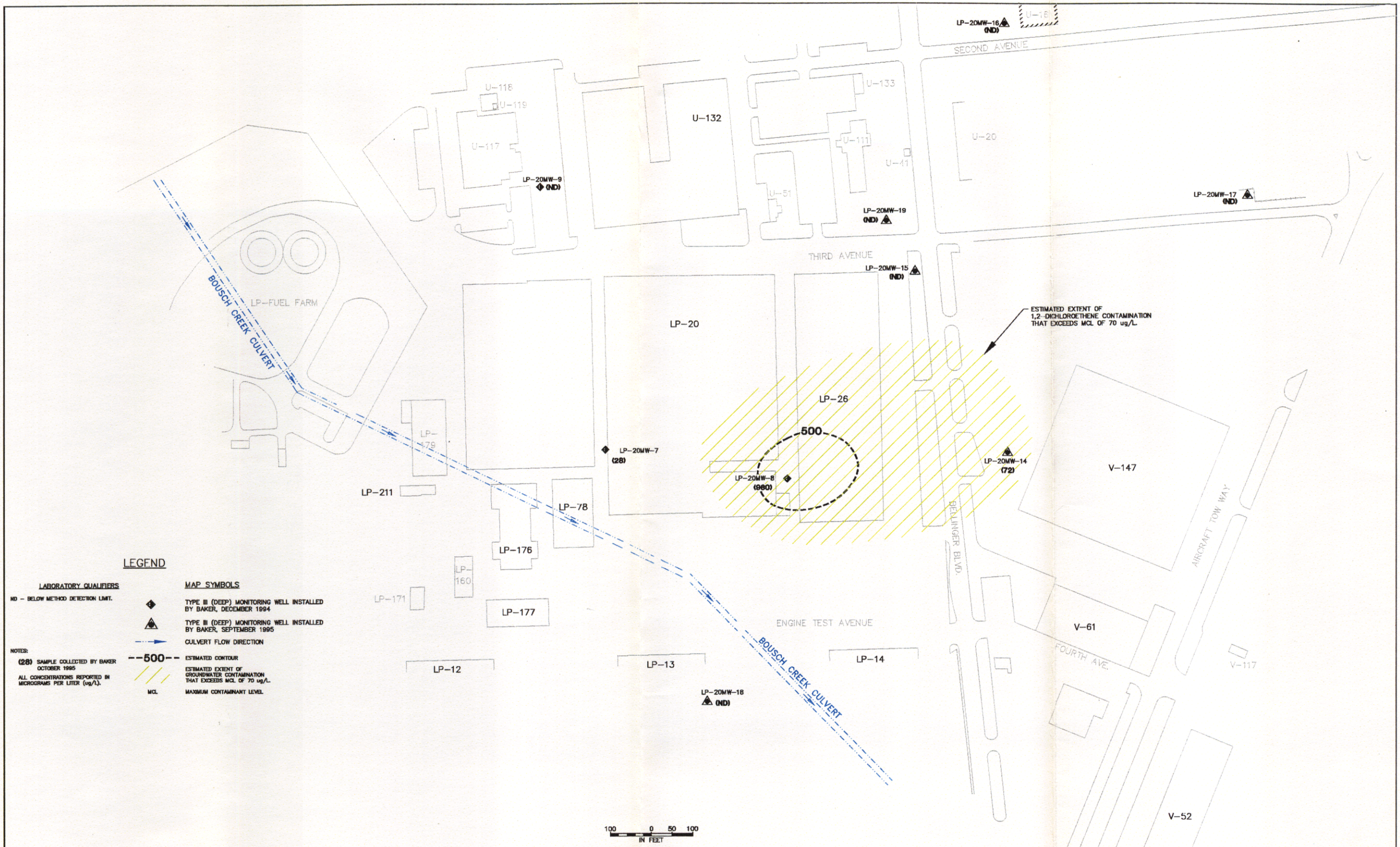
CULVERT FLOW DIRECTION

-- 20 -- ESTIMATED CONTOUR

ESTIMATED EXTENT OF GROUNDWATER CONTAMINATION THAT EXCEEDS MCL OF 2.0 ug/L.

MCL MAXIMUM CONTAMINANT LEVEL

REVISIONS	DRAWN REL REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269059R1	NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER – DEEP AQUIFER SCALE DATE NOVEMBER 1995	FIGURE NO. 7-14



LEGEND

LABORATORY QUALIFIERS

ND – BELOW METHOD DETECTION LIMIT.

NOTES:

(28) SAMPLE COLLECTED BY BAKER OCTOBER 1995

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

MAP SYMBOLS

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, SEPTEMBER 1995

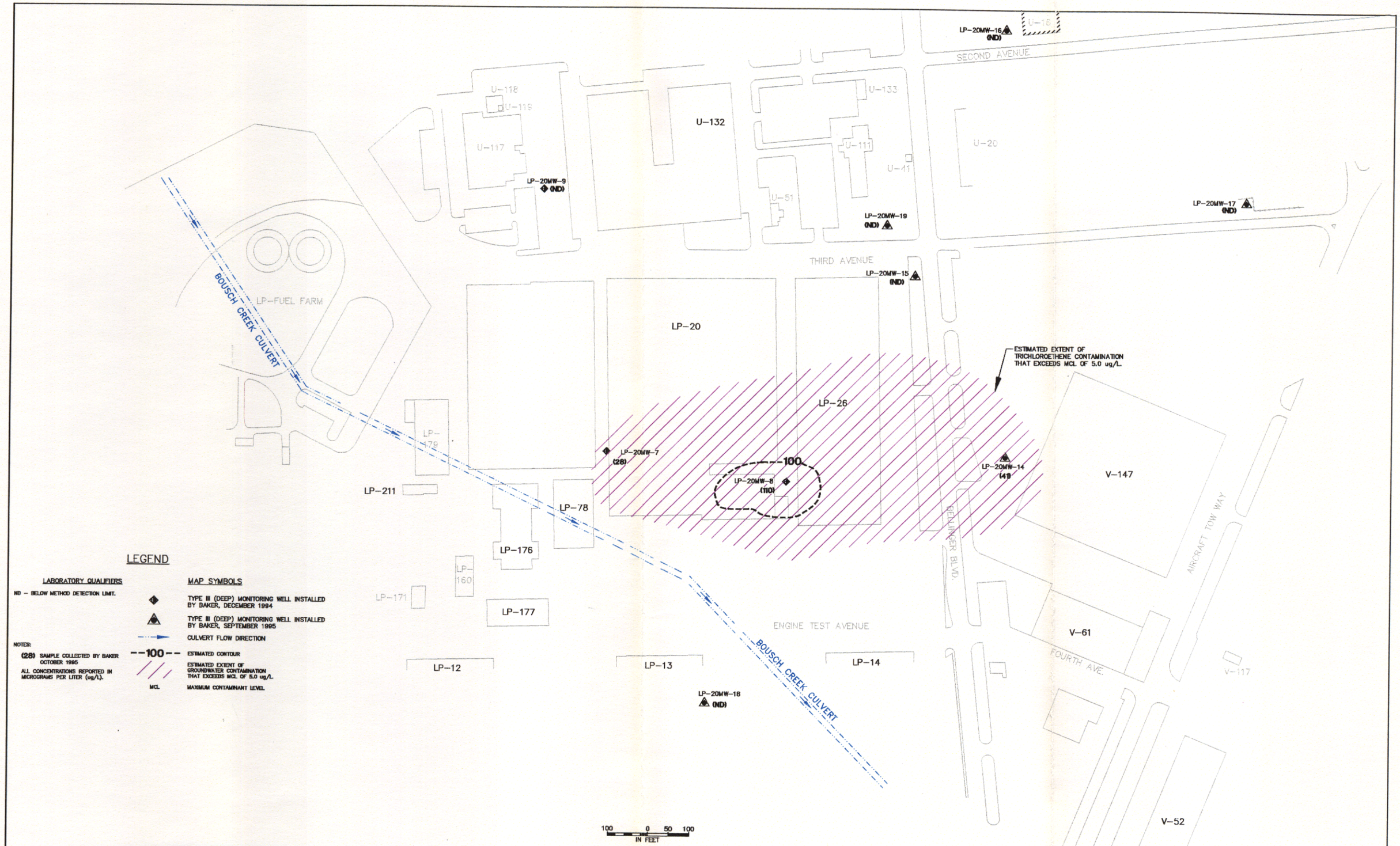
CULVERT FLOW DIRECTION

--500-- ESTIMATED CONTOUR

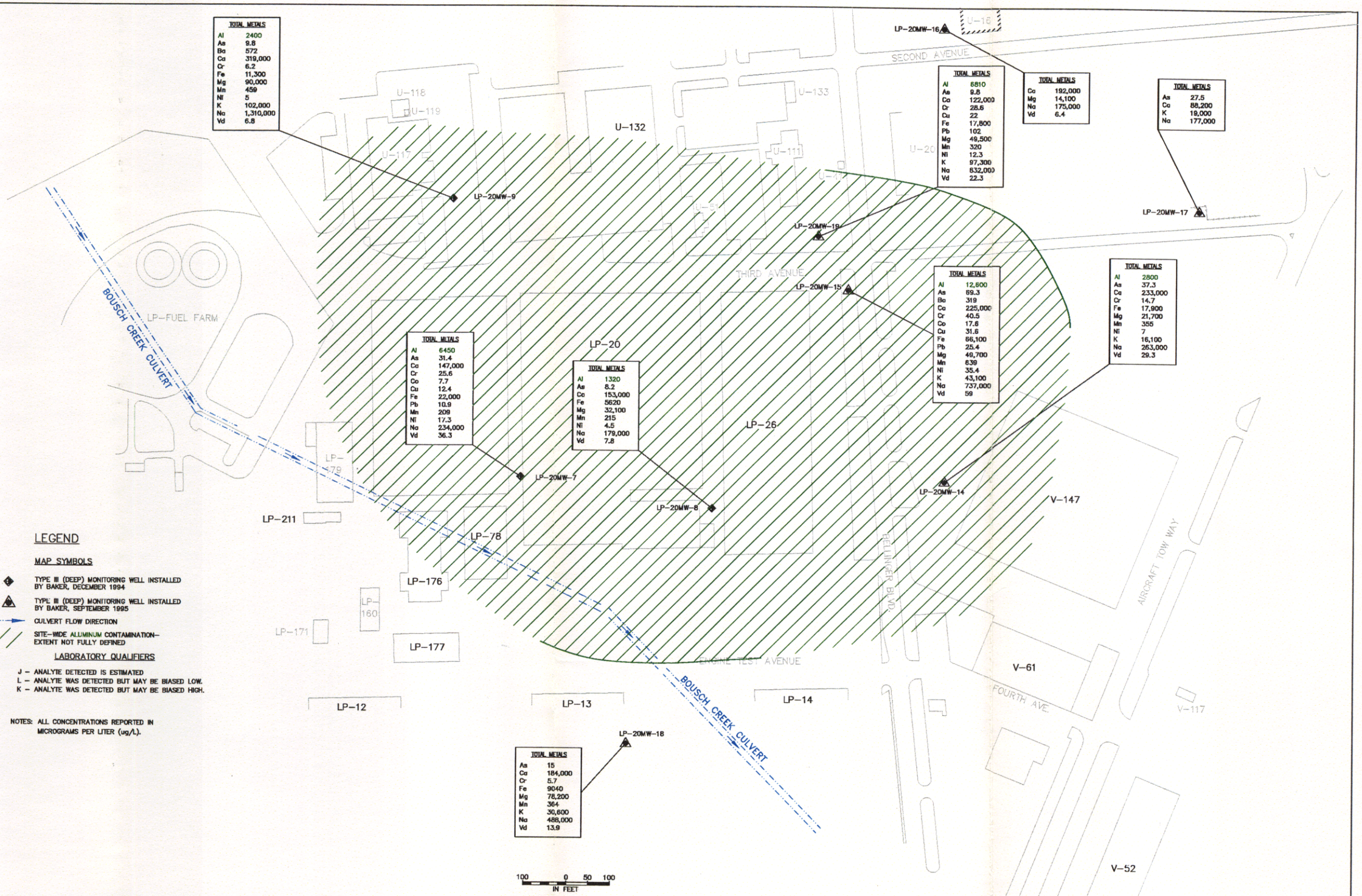
ESTIMATED EXTENT OF GROUNDWATER CONTAMINATION THAT EXCEEDS MCL OF 70 ug/L.

MCL MAXIMUM CONTAMINANT LEVEL

REVISIONS	DRAWN REL REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269060RI	NORTH	BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	1,2-DICHLOROETHENE (TOTAL) CONCENTRATIONS IN GROUNDWATER – DEEP AQUIFER SCALE DATE NOVEMBER 1995	FIGURE NO. 7-15



REVISIONS	DRAWN REL REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269061RI	NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	TRICHLOROETHENE CONCENTRATIONS IN GROUNDWATER – DEEP AQUIFER SCALE DATE NOVEMBER 1995	FIGURE NO. 7-16



LEGEND

METALS LIST

Al – ALUMINUM
Sb – ANTIMONY
As – ARSENIC
Ba – BARIUM
Be – BERYLLIUM
Cd – CADMIUM
Ca – CALCIUM
Cr – CHROMIUM
Co – COBALT
Cu – COPPER
Fe – IRON
Pb – LEAD
Mg – MAGNESIUM
Mn – MANGANESE
Hg – MERCURY
Ni – NICKEL
K – POTASSIUM
Se – SELENIUM
Ag – SILVER
Na – SODIUM
Tl – THALLIUM
V – VANADIUM
Z – ZINC

MAP SYMBOLS

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, SEPTEMBER 1995

CULVERT FLOW DIRECTION

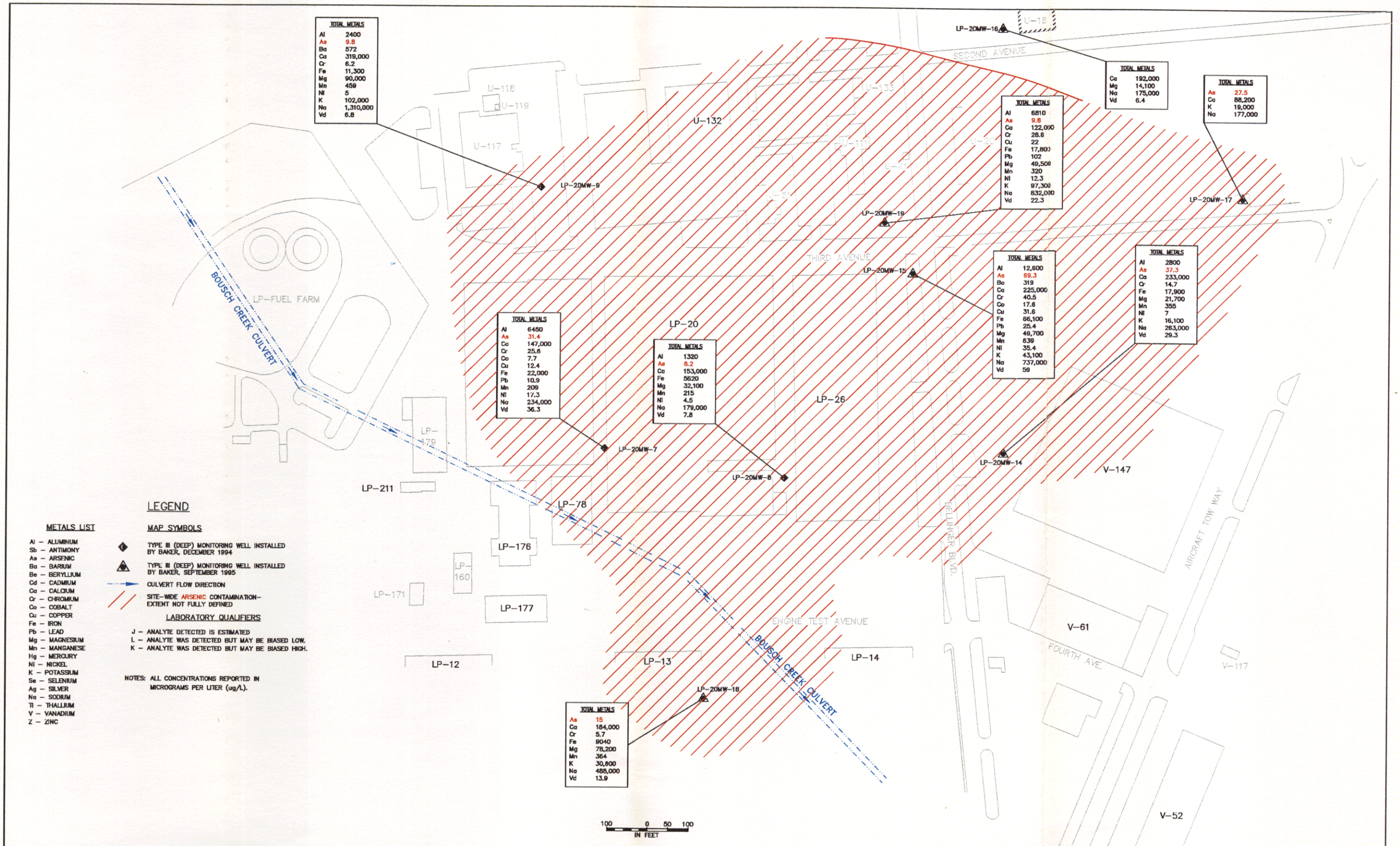
SITE-WIDE ALUMINUM CONTAMINATION– EXTENT NOT FULLY DEFINED

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTES: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

REVISIONS		NORTH					
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269062RI			BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TOTAL ALUMINUM CONCENTRATIONS IN GROUNDWATER – DEEP AQUIFER SCALE DATE NOVEMBER 1995	FIGURE NO. 7-17



LEGEND

METALS LIST

Al – ALUMINUM
Sb – ANTIMONY
As – ARSENIC
Ba – BARIUM
Be – BERYLLIUM
Cd – CADMIUM
Ca – CALCIUM
Cr – CHROMIUM
Co – COBALT
Cu – COPPER
Fe – IRON
Pb – LEAD
Mg – MAGNESIUM
Mn – MANGANESE
Hg – MERCURY
Ni – NICKEL
K – POTASSIUM
Se – SELENIUM
Ag – SILVER
Na – SODIUM
Tl – THALLIUM
V – VANADIUM
Z – ZINC

MAP SYMBOLS

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, SEPTEMBER 1995

CULVERT FLOW DIRECTION

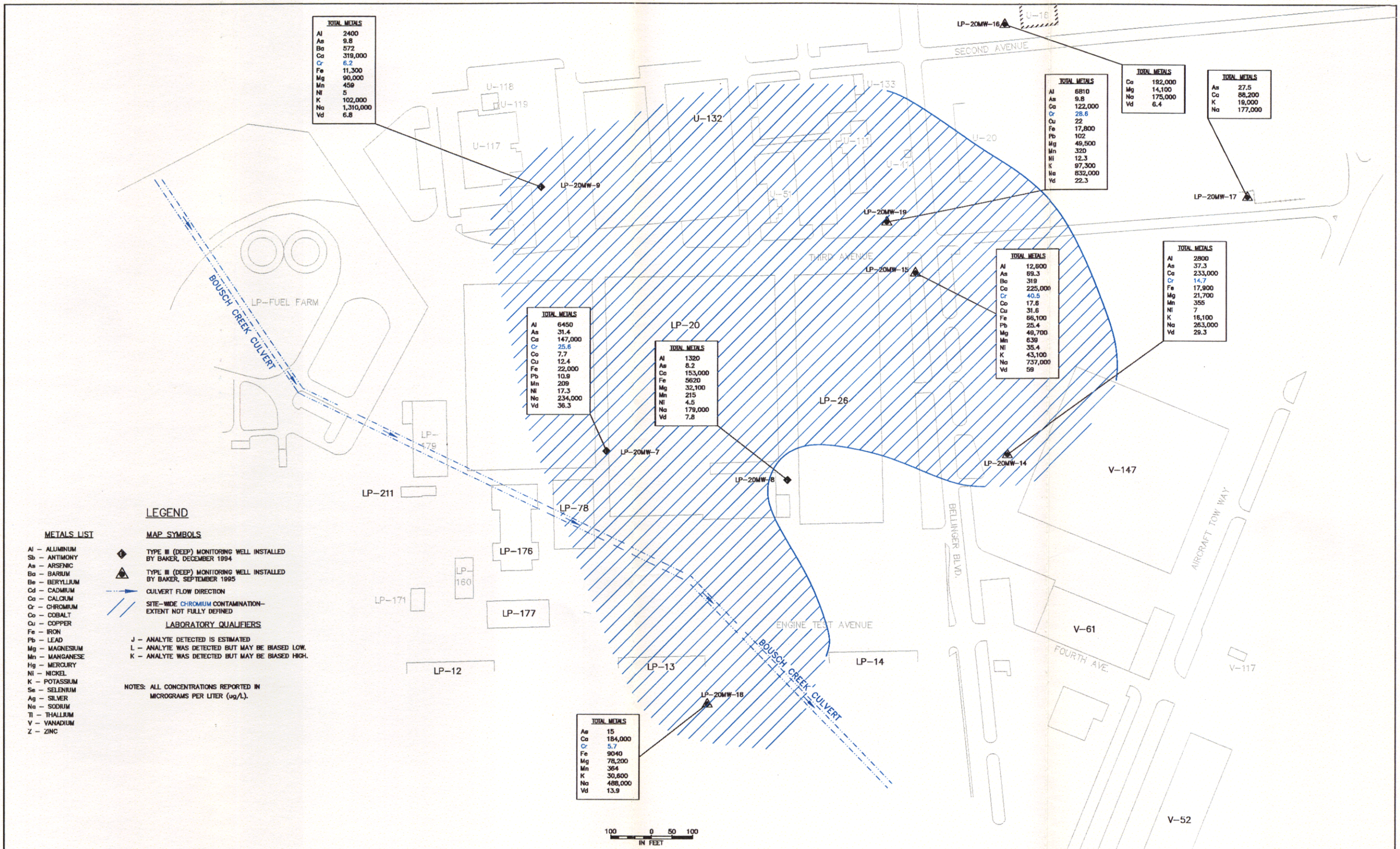
SITE-WIDE ARSENIC CONTAMINATION– EXTENT NOT FULLY DEFINED

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTES: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TOTAL ARSENIC CONCENTRATIONS IN GROUNDWATER – DEEP AQUIFER	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269063RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE NOVEMBER 1995	7-18



LEGEND

METALS LIST

Al – ALUMINUM
Sb – ANTIMONY
As – ARSENIC
Ba – BARIUM
Be – BERYLLIUM
Cd – CADMIUM
Ca – CALCIUM
Cr – CHROMIUM
Co – COBALT
Cu – COPPER
Fe – IRON
Pb – LEAD
Mg – MAGNESIUM
Mn – MANGANESE
Hg – MERCURY
Ni – NICKEL
K – POTASSIUM
Se – SELENIUM
Ag – SILVER
Na – SODIUM
Tl – THALLIUM
V – VANADIUM
Z – ZINC

MAP SYMBOLS

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, DECEMBER 1994

TYPE III (DEEP) MONITORING WELL INSTALLED BY BAKER, SEPTEMBER 1995

CULVERT FLOW DIRECTION

SITE-WIDE CHROMIUM CONTAMINATION– EXTENT NOT FULLY DEFINED

LABORATORY QUALIFIERS

J – ANALYTE DETECTED IS ESTIMATED
L – ANALYTE WAS DETECTED BUT MAY BE BIASED LOW.
K – ANALYTE WAS DETECTED BUT MAY BE BIASED HIGH.

NOTES: ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

REVISIONS		NORTH		BUILDING LP-20 NAVAL BASE, NORFOLK NORFOLK, VIRGINIA	Baker Baker Environmental, Inc.	ESTIMATED EXTENT OF TOTAL CHROMIUM CONCENTRATIONS IN GROUNDWATER – DEEP AQUIFER	FIGURE NO.
	DRAWN WAC REVIEWED DJM S.O.# 62470-269-0000-05100 CADD# 269062RI			BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania		SCALE / DATE NOVEMBER 1995	7-19

8.0 BASELINE RISK ASSESSMENT

8.1 Introduction

As part of the Remedial Investigation (RI) for the Building LP-20 Site, Naval Base Norfolk, the potential public health risks associated with potential current and future exposures to affected environmental media were evaluated. This volume of the RI summarizes the findings with respect to the potential risks resulting from existing conditions at the site.

The risks addressed in this baseline risk assessment (RA) represent the potential public health risks which might result from taking no remedial action at the Building LP-20 Site.

8.1.1 Overview

Review of the data indicated that the contaminants of concern in various media at the Building LP-20 Site were primarily volatile organic compounds (VOCs), including vinyl chloride; semivolatile organic compounds (SVOCs); and heavy metals. The objective of the baseline RA was to estimate the potential human health effects, if any, to humans exposed to chemicals of potential concern at the site. More specifically, the baseline RA was performed for the no action scenario which reflects the present conditions without remedial action. Human exposure routes, dosages, and associated human health effects associated with exposure to the chemicals of potential concern identified at the site were estimated. At the Building LP-20 Site current/future maintenance and public works workers, future construction workers, and future adult and child (ages 1-6 years) military residents were considered to be the potential receptors of concern.

Potential carcinogenic and noncarcinogenic health effects were estimated. Conservative exposure factor assumptions, the most recent toxicity information, and the most current regulatory criteria and standards were used throughout.

The Building LP-20 site is located within the Naval Aviation Depot (NADEP) area of NAS Norfolk. The NADEP area provides support for aircraft maintenance and repair activities associated with NAS Norfolk. Prior to the development of this area in the 1930s, the portion of the NADEP area in the vicinity of Building LP-20 was marshlands associated with Bousch Creek. As this portion of

the base was developed, Bousch Creek was enclosed in a culvert from the area south of NAS to Willoughby Bay.

The land in the vicinity of Building LP-20 is heavily industrialized. The entire area is relatively flat and paved with either asphalt or concrete. The only vegetation present in the area are landscaped zones located along roadways or parking areas.

A system of industrial waste sewers (IWS) in the area transfer industrial wastes generated by the various industrial processes in the area, including those taking place at Building LP-20, to the Industrial Wastewater Treatment Plant (IWTP). Construction activities in the area frequently damage the IWS, workers repairing the breaks can be exposed to COPCs in the soil and groundwater.

Building LP-20 is approximately 460 feet by 390 feet, with a floor area of about 4.1 acres. The building is used for the reconditioning, repair, and testing of turbine engines. The building previously maintained a metal plating operation which has been moved. The types of facilities located in the building and the materials used or stored include: a paint shop, (paints and solvents), two non-destructive testing facilities (penetrants, emulsifiers, and developers), cleaning and blasting shop (solvents, acids, and bases), x-ray shop (film development solution), engine overhaul shop (degreasing solvents), repair shops, and some warehouse operations. In the past, the facility also housed a pretreatment shop and a metal plating shop in which acids, bases, and solvents were used. Many of these facilities discharge waste into the IWS.

There have been many spills and releases of hazardous wastes and wastewater from the Building LP-20 Site over the years. Over the years Building LP-20 has operated USTs, ASTs, and oil/water separators, as well.

8.1.2 Scope of Risk Assessment

Surface soil, subsurface soil, and groundwater samples were collected at the site. A comprehensive, quantitative human health evaluation including the assessment of chemical results from all the media sampled, has been performed for the Building LP-20 site. Tables presenting the frequency and range of chemical constituents and the statistics for exposure concentrations are presented in Appendix O.

The risk assessment evaluates current potential human exposures, as well as future potential human exposures in the event that the area is used as military housing. It is highly unlikely that the building will be used for this purpose. Future potential risk values generated for future residential development are, therefore, presented as conservative estimates of potential human health effects.

8.2 Identification of Chemicals of Potential Concern

A discussion of laboratory analytical results and nature and extent of constituent contamination is presented in Section 6.0 and 7.0, respectively of this report. In the RI report, chemicals detected in environmental media were discussed with respect to applicable Federal and Commonwealth of Virginia standards and/or criteria. In these sections, a preliminary account of analytical results was presented. Chemicals detected in environmental media sampled during the RI were reevaluated to select COPCs for evaluation in the baseline RA. Chemicals selected as COPCs were retained for quantitative evaluation. Chemicals selected as COPCs are discussed in the uncertainty section (Section 8.6) of the baseline RA.

COPC selection was based on the information provided in the USEPA Region III Technical Guidance on the Screening of Exposure Pathways and Selection of Contaminants of Concern, dated January 1993 (USEPA, 1993b) and USEPA's Risk Assessment Guidance for Superfund (RAGS), Volume I. Human Health Evaluation Manual (Part A), Interim Final, December 1989 (USEPA, 1989).

8.2.1 COPC Selection Criteria

Both of the previously mentioned guidance documents provide a number of criteria by which chemical data can be evaluated. The primary criteria used in selecting a chemical as a COPC at the Building LP-20 Site included comparison of maximum detected concentrations with USEPA Region III risk-based COPC screening levels in accordance with USEPA Region III Technical Guidance on the Screening of Exposure Pathways and Selection of Contaminants of Concern (USEPA, January 1993b), chemical prevalence, and site history.

In conjunction with concentration comparisons with USEPA Region III risk-based COPC screening levels and evaluations of chemical prevalence and site history, a comparison to available state and

Federal standards and criteria was conducted. Criteria used in selecting COPCs include available State and Federal Maximum Contaminant Levels (MCLs).

USEPA Region III COPC Screening Levels - Risk-based COPC screening levels were derived by USEPA, Region III in January of 1993 and provided in tabular format to support selection of COPCs and address two major limitations in the COPC selection process presented in RAGS. First, using COPC screening concentrations prioritizes chemical toxicity and focuses the risk assessment on those COPCs and potential exposure routes. Second, using the screening concentration provides an absolute comparison of potential risks associated with the presence of a COPC in a given medium.

COPC screening concentrations were derived using conservative USEPA promulgated default values and the most recent toxicological criteria available. COPC screening levels for potentially carcinogenic and noncarcinogenic chemicals were individually derived based on a target incremental lifetime cancer risk (ICR) of 1×10^{-06} and a target hazard quotient (HQ) of 0.1, respectively. For potential carcinogens, the toxicity criteria applicable to the derivation of COPC screening concentrations are oral and inhalation cancer slope factors; for noncarcinogens, they are chronic oral and inhalation reference doses. These toxicity criteria are subject to change as more updated information and results from the most recent toxicological/epidemiological studies become available. Therefore, the use of toxicity criteria in the derivation of COPC screening levels requires that the screening levels be updated periodically to reflect changes in the toxicity criteria.

Since the last set of COPC screening values was issued by USEPA in March 1994 (USEPA, 1994b), the COPC values can be updated by incorporating information from another set of tables containing risk-based concentrations (RBCs) that are issued by USEPA Region III on a semiannual basis. The RBCs are derived using similar equations and USEPA promulgated default exposure assumptions that were used to derive the COPC screening concentrations. The only difference in the derivation methodologies for the RBC and the COPC values is that the COPC values for noncarcinogens are derived based on a target HQ of 0.1, and the RBC values on a target HQ of 1.0. An updated set of COPC values can, therefore, be obtained by using the most recent carcinogenic RBCs issued semiannually by USEPA Region III and dividing the accompanying noncarcinogenic RBCs by a factor of 10. The COPC values used in the Human Health Risk Assessment were derived from the RBC values issued by USEPA Region III for January - June 1996 (USEPA, 1996a).

Prevalence - The prevalence of a chemical detected in a given environmental medium, as well as the history of site-related activities are other important criteria applied in selecting COPCs at the Building LP-20 Site. The prevalence of a chemical in an environmental medium can be described by the frequency and concentration with which it is detected. A detection frequency greater than 5 percent (e.g., 1 positive detection in 20 samples) was the minimum detection frequency considered in the selection of COPCs in data sets comprised of 20 or more samples. Data sets with fewer than 20 samples were evaluated for any positive detections to determine whether the chemical should be included as a COPC.

Maximum Contaminant Levels (MCLs) - MCLs are potentially enforceable standards for public water supplies promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs have been adopted as enforceable standards for public drinking water systems, and apply to drinking water supplies consumed by a minimum of 25 persons. They have been developed for the prevention of human health effects associated with lifetime exposure (70 year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical and economic feasibility of removing the constituent from a public water supply.

Virginia Drinking Water Standards - Virginia Drinking Water Standards are the maximum contaminant level concentrations of a contaminant in water which is delivered to the users of a public water system. With the exception of nitrate, all inorganic chemical contaminant levels are based on potential adverse health effects resulting from long term exposure to the contaminant in drinking water. The maximum contaminant levels for organics apply to community water supplies, the volatile organics also apply to nontransient, noncommunity water systems.

Essential Nutrients - Despite their inherent toxicity, certain inorganic constituents are essential nutrients. Essential nutrients need not be considered for further evaluation in the baseline RA if they are present in relatively low concentrations (i.e., slightly elevated above naturally occurring levels), or if the constituent is toxic at doses much higher than those which could be assimilated through exposures at the site. Elements considered to be as essential nutrients include calcium, iron, magnesium, sodium, and potassium. Of these, only iron has toxicity criteria established for comparative screening during COPC selection. However, since iron is a naturally abundant essential nutrient, and since, the toxicity criteria established for iron is provisional with medium confidence, iron was not considered for further evaluation in the baseline RA.

8.2.2 Selection of COPCs

Two environmental media (soil and groundwater) were investigated at the Building LP-20 Site. The selection of soil COPCs was stratified for surface and subsurface soil. Tables 8-1 through 8-4 present the selection of COPCs for each environmental medium based on comparisons of USEPA Region III COPC screening concentrations and other applicable criteria, with the maximum detected concentration. Information is presented in these tables only for those constituents detected at least once, in the medium of interest.

The following paragraphs present the rationale for selection of COPCs. Sample locations, analytical results, and corresponding figures are presented in other sections of this RI report.

8.2.2.1 Surface Soil

Surface soil samples were collected and analyzed for VOCs, SVOCs, and inorganics. The sample set collected during the investigation conducted at the Building LP-20 Site included 11 samples. The COPC selection summaries for surface soil are presented in Table 8-1.

Three VOCs (acetone, total 1,2-dichloroethene, and trichloroethene) were detected in the surface soil samples. All were detected at concentrations less than their respective industrial and residential COPC values, and therefore were not retained as surface soil COPCs.

Nineteen SVOCs were detected in the surface soil. 2-Methylnaphthalene, acenaphthene, dibenzofuran, fluorene, phenanthrene, anthracene, carbazole, di-n-butylphthalate, fluoranthene, pyrene, chrysene, bis(2-ethylhexyl)phthalate, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene were detected at concentrations below industrial and residential COPC values. Therefore, these chemicals were not retained as surface soil COPCs. Of the nineteen SVOCs benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and dibenz(a,h)anthracene were detected at concentrations greater than residential COPC values. Therefore these SVOCs were retained as surface soil COPCs for evaluation in the baseline RA.

Metals were detected in all surface soil samples collected. The maximum detected concentrations of barium, cadmium, chromium, cobalt, copper, nickel, vanadium, zinc, and cyanide did not exceed

the corresponding Region III industrial and residential soil COPC values and were not retained as COPCs. The maximum concentration of lead did not exceed the action level for residential soils (USEPA, 1994a) and was not retained as a surface soil COPC. Aluminum, antimony, arsenic, beryllium, and manganese were retained as surface soil COPCs for evaluation in the baseline RA due to exceedances of COPC values.

In summary, the following constituents have been retained as COPCs for surface soil at the Building LP-20 Site:

- Benzo(a)anthracene
- Benzo(b)fluoranthene
- Benzo(a)pyrene
- Dibenz(a,h)anthracene
- Aluminum
- Antimony
- Arsenic
- Beryllium
- Manganese

8.2.2.2 Subsurface Soil

Table 8-2 summarizes the COPC selections performed for constituents detected in subsurface soil. The sample set included twelve samples collected during the investigation at the Building LP-20 Site. All samples were analyzed for VOCs, SVOCs, and inorganics.

Seven VOCs were detected in the subsurface soil samples collected from the site: chloroethane, acetone, carbon disulfide, total 1,2-dichloroethene, 2-butanone, trichloroethene, and toluene. All were detected at concentrations less than industrial and residential COPC values. Consequently, these VOCs were not included as subsurface soil COPCs.

Thirteen SVOCs were detected in the subsurface soil. Acenaphthene, fluorene, phenanthrene, anthracene, carbazole, fluoranthene, pyrene, benzo(a)anthracene, chrysene, bis(2-ethylhexyl)phthalate, benzo(b)fluoranthene, and benzo(k)fluoranthene were detected at

concentrations below industrial and residential COPC values. Of these SVOCs, only benzo(a)pyrene was detected at a concentration greater than the residential COPC value and was retained as a subsurface soil COPC.

Inorganics were detected in all the subsurface soil samples. Barium, cadmium, chromium, cobalt, copper, mercury, manganese, nickel, silver, vanadium, zinc, and cyanide were detected at concentrations less than their corresponding industrial and residential COPC values and were not retained as COPCs. The maximum concentration of lead did not exceed the action level for residential soils (USEPA, 1994a). Therefore, lead was not retained as a subsurface soil COPC. However, aluminum, antimony, arsenic, and beryllium were retained due to exceedances of COPC values.

In summary, the following constituents have been retained as COPCs for subsurface soil at the Building LP-20 Site:

- Benzo(a)pyrene
- Aluminum
- Antimony
- Arsenic
- Beryllium

8.2.2.3 Shallow Groundwater

Table 8-3 summarizes the COPC selections performed for constituents detected in the shallow groundwater. Thirty-seven shallow groundwater samples were analyzed for VOCs, while twenty-one shallow groundwater samples were analyzed for SVOCs, unfiltered (total) and filtered (dissolved) inorganics.

Twenty-one VOCs were detected in the shallow groundwater. Chloroethane, acetone, carbon disulfide, 2-butanone, 4-methyl-2-pentanone, and total xylenes were detected at concentrations less than tap water COPC values and were not retained as shallow groundwater COPCs. 2-Hexanone was detected infrequently (1 out of 37 samples) in the shallow groundwater and was not retained as a COPC. Chloromethane, vinyl chloride, 1,1-dichloroethene, 1,1-dichloroethane, total 1,2-

dichloroethene, chloroform, 1,2-dichloroethane, 1,1,1-trichloroethane, trichloroethene, 1,1,2-trichloroethane, benzene, tetrachloroethene, toluene, and ethylbenzene were detected at concentrations greater than tap water COPC values and/or groundwater criteria or standards; therefore, these chemicals were retained as shallow groundwater COPCs.

Eight SVOCs were detected in the shallow groundwater. Phenol, 2,4-dimethylphenol, naphthalene, 2-methylnaphthalene, acenaphthene, diethylphthalate, and carbazole were detected at concentrations less than tap water COPC values and were not retained as shallow groundwater COPCs. Bis(2-ethylhexyl)phthalate was detected at concentrations greater than its tap water COPC value, and was retained as a COPC.

Inorganics were detected in most of the groundwater samples collected. Twenty unfiltered (total) metals were detected in the shallow groundwater. Barium, cobalt, copper, mercury, silver, and zinc were detected at concentrations less than tap water COPC values and/or groundwater criteria or standards; therefore, these chemicals were not retained as shallow groundwater COPCs. Aluminum, antimony, arsenic, beryllium, cadmium, chromium, lead, manganese, and vanadium exceeded tap water COPC values and/or groundwater criteria or standards and were retained as COPCs in the shallow groundwater.

Seventeen filtered (dissolved) metals were detected in the shallow groundwater. Aluminum, barium, cobalt, lead, mercury, nickel, vanadium, and zinc were detected at concentrations less than tap water COPC values and/or groundwater criteria or standards and were not retained as COPCs. Antimony, arsenic, cadmium, and manganese exceeded tap water COPC values and/or groundwater criteria or standards and were retained as shallow groundwater COPCs.

In summary, the following constituents have been retained as COPCs for the shallow groundwater at the Building LP-20 Site:

- Chloromethane
- Vinyl Chloride
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- 1,2-Dichloroethene (total)

- Chloroform
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- Trichloroethene
- 1,1,2-Trichloroethane
- Benzene
- Tetrachloroethene
- Toluene
- Ethylbenzene
- Bis(2-Ethylhexyl)phthalate
- Aluminum (total)
- Antimony (total and dissolved)
- Arsenic (total and dissolved)
- Beryllium (total)
- Cadmium (total and dissolved)
- Chromium (total)
- Lead (total)
- Manganese (total and dissolved)
- Vanadium (total)

8.2.2.4 Deep Groundwater

Table 8-4 summarizes the COPC selection performed for constituents detected in the deep groundwater. Eight deep groundwater samples collected during the Building LP-20 investigation were analyzed for VOCs, SVOCs, unfiltered (total) and filtered (dissolved) inorganics. Although there was one background well for deep groundwater it was not utilized in the RA as a conservative measure.

Eight VOCs were detected in the deep groundwater samples. Acetone did not exceed its tap water COPC value and was not retained as a COPC. Toluene and xylene did not exceed respective tap water COPC screening values or MCLs, and were therefore, not retained as COPCs. Vinyl chloride, 1,1-dichloroethene, total 1,2-dichloroethene, trichloroethene and benzene exceeded tap water COPC values and/or groundwater criteria or standards and were retained as deep groundwater COPCs.

Two SVOCs (2-methylnaphthalene and acenaphthene) were detected in the deep groundwater.

Neither were detected at concentrations less than tap water COPC values and were therefore not retained as deep groundwater COPCs.

Inorganics were detected in most of the groundwater samples collected. Fifteen unfiltered (total) metals were detected in the deep groundwater. Cobalt, copper and nickel were detected at concentrations less than tap water COPC values and/or groundwater criteria or standards; therefore, these inorganics were not retained as deep groundwater COPCs. Aluminum, arsenic, barium, chromium, lead, manganese, and vanadium exceeded tap water COPC values and/or groundwater criteria or standards, and were therefore, retained as COPCs in the deep groundwater.

Nine filtered (dissolved) metals were detected in the deep groundwater. Selenium was detected at a concentration less than the corresponding tap water COPC values, as well as Federal and Commonwealth groundwater standards. Therefore, selenium was not retained as a COPC. However, arsenic, barium and manganese exceeded tap water COPC values and were retained as deep groundwater COPCs.

In summary, the following constituents have been retained as COPCs for deep groundwater at the Building LP-20 Site:

- Vinyl Chloride
- 1,1-Dichloroethene
- 1,2-Dichloroethene, total
- Trichloroethene
- Benzene
- Aluminum (total)
- Arsenic (total and dissolved)
- Barium (total and dissolved)
- Chromium (total)
- Lead (total)
- Manganese (total and dissolved)
- Vanadium (total)

8.2.3 Summary of COPCs

The following presents a comprehensive list of all selected COPCs, by media, identified at the Building LP-20 Site.

- **Surface Soil:** benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, dibenz(a,h)anthracene, aluminum, antimony, arsenic, beryllium, and manganese

- **Subsurface Soil:** benzo(a)pyrene, aluminum, antimony, arsenic, and beryllium

- **Shallow Groundwater:** chloromethane, vinyl chloride, 1,1-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethene (total), chloroform, 1,2-dichloroethane, 1,1,1-trichloroethane, trichloroethene, 1,1,2-trichloroethane, benzene, tetrachloroethene, toluene, ethylbenzene, bis(2-ethylhexyl)phthalate, aluminum (total), antimony (total and dissolved), arsenic (total and dissolved), beryllium (total), cadmium (total and dissolved), chromium (total), lead (total), manganese (total and dissolved), and vanadium (total)

- **Deep Groundwater:** vinyl chloride, 1,1-dichloroethene, 1,2-dichloroethene (total), trichloroethene, benzene, aluminum (total), arsenic (total and dissolved), barium (total and dissolved), chromium (total), lead (total), manganese (total and dissolved), and vanadium (total)

8.3 Exposure Assessment

The exposure assessment addresses each current and future potential exposure pathway in groundwater, surface soil, subsurface soil and air. To determine whether human exposure could occur at the Building LP-20 Site in the absence of remedial action, an exposure assessment which identifies potential exposure pathways and human receptors was conducted. The following four elements were considered to determine whether a complete exposure pathway was present: a source and mechanism of chemical release; an environmental retention or transport medium; a point of potential human contact with the contaminated medium; and an exposure route (e.g., ingestion) at the contact point.

The exposure scenarios presented in the following sections are used to estimate individual risks. Both reasonable maximum exposure (RME) and central tendency (CT) exposure were evaluated for each scenario utilized in this assessment. As a result, the exposure scenarios presented include both RME and CT assumptions for the input parameters in the dose evaluation equations. Thus for each chemical, under each exposure scenario, a range of chemical intakes is calculated that is defined by the CT and RME assumptions. However, it should be noted that the availability of USEPA-established CT assumptions is somewhat limited. For parameters which no CT assumptions are established, the same value used for the RME scenario was applied. Unless otherwise noted, all the statistical data associated relevant equations for assessing intakes and exposure factors were obtained from the Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation (RAGS) (USEPA, 1989), Exposure Factors Handbook (USEPA, 1989a), Dermal Exposure Assessment: Principles and Applications, Interim Report (USEPA, 1992a), and Standard Default Exposure Factors, Interim Final (USEPA, 1991).

8.3.1 Characterization of Exposure Setting

The Building LP-20 site is located within the Naval Aviation Depot (NADEP) area of NAS Norfolk. The site is situated in a heavily developed area which includes industrial and military activities. As part of the BRAC plan, portions of the NADEP in the vicinity of Building LP-20 will be realigned under a new tenant command. This will involve the demolition of some buildings and the utilization of the remaining buildings by the new command. The buildings to be demolished are still undecided.

The Norfolk climate is classified as oceanic with mild winters and long, warm summers with high humidity. Temperatures average 78.6°F in summer and 41.2°F in January. Average annual precipitation is approximately 44 inches. Precipitation is well distributed throughout the year with the heaviest rain occurring during July and August.

Wind direction is predominantly from the southwest, although ocean breezes from the east are common. Wind velocities typically do not exceed 12 knots with highest velocities occurring as land breezes rarely exceeding 20 knots.

8.3.2 Identification of Human Receptors

Current potential human receptors exposed to COPCs detected in environmental media include maintenance and industrial workers who are exposed during routine maintenance work.

Future potential human receptors to COPCs include future on-site workers (evaluated concurrently with current on-site workers), construction workers and adult and child (ages 1 to 6 years) military residents. Future construction workers can potentially be exposed to COPCs detected in environmental media during excavation and building activities. Although future residential development of Building LP-20 Site is highly unlikely, a future military resident scenario was evaluated in the event that the building be used for base housing . This exposure scenario is purely hypothetical for purposes of conservative estimates only. Since most of the site is currently covered with concrete and asphalt, it was assumed that future residents may be exposed to small areas of soil in the event that some of the pavement be removed.

Although human exposures are unlikely, groundwater was evaluated for potential potable and non-potable uses. Potable uses include, but are not limited to use of groundwater as drinking water and use of groundwater for washing, bathing and showering. Future adult residents were conservatively evaluated for non-potable exposures to groundwater. Such activities include car washing and lawn watering. Current/future maintenance and industrial workers and future construction workers were evaluated for non-potable exposures to groundwater COPCs via accidental ingestion and dermal contact during work activities. Young children were not evaluated for non-potable residential use because it is anticipated that they will not be engaging in activities (car washing) associated with non-potable use.

8.3.3 Identification of Potential Exposure Pathways

8.3.3.1 Chemical Fate and Transport

This section discusses the potential release and migration of COPCs between or within media. The potential for a chemical to migrate spatially and persist in environmental media is important in the estimation of exposure.

The distribution relationships for a chemical between the environmental compartments of air, water and soil can be evaluated using a series of equilibrium constants. By utilizing the physiochemical properties of a constituent, it is possible to estimate a chemical's expected environmental distribution and its ultimate environmental fate.

The environmental mobility and persistence of a chemical will be influenced primarily by its physical and chemical properties and the chemistry of the medium in which it occurs. Table 8-5 presents the physical and chemical properties associated with the organic COPCs including specific gravity, vapor pressure, water solubility, octanol water partition coefficient, soil sediment adsorption coefficient, Henry's Law constant, and mobility index. Calculated values, obtained using approximation methods, are presented when literature values are unavailable. A discussion of the environmental significance of each of these properties follows.

- Vapor pressure is an indication of the rate at which a chemical will volatilize. It is of primary significance as a removal mechanism at environmental interfaces such as surface soil air and surface water air. Volatilization is not a significant removal mechanism when evaluating groundwater in an aquifer and subsurface soils. Vapor pressures for monocyclic aromatics, such as benzene, toluene and xylenes, are higher than vapor pressures for PCBs. Chemicals with higher vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures. Volatilization is a significant loss process for volatile organic compounds in surface soils and surface water.

- Water solubility is used to determine the rate at which a chemical can be solubilized and potentially leached from soil by infiltrating precipitation. In general, more soluble chemicals are more readily leached than less soluble chemicals. The water solubilities presented in Table 8-5 indicate that the volatile organic chemicals are several orders of magnitude more soluble than semivolatile organic compounds such as polycyclic aromatic hydrocarbons.

- The octanol water partition coefficient (K_{ow}) is a measure of the equilibrium partitioning of chemicals between octanol and water. A linear relationship between the octanol water partition coefficient and the uptake of chemicals by fatty tissues of animal and human receptors (the bioconcentration factor, BCF) has been determined (Lyman et al., 1982). The coefficient is also useful in characterizing the sorption of compounds by organic soils where experimental values are not available. The octanol water partition coefficient also is used to estimate bioconcentration factors in aquatic organisms.

- The soil sediment adsorption coefficient (K_{oc}) is an indication of the tendency of a chemical to adhere to soil particles containing organic carbon. Chemicals with high soil sediment adsorption coefficients generally have low water solubilities and vice

versa. This parameter may be used to infer the relative rates at which the more mobile chemicals (monocyclic aromatics) are transported in the aqueous media. Chemicals such as PCBs are relatively immobile in the environment and are preferentially bound to the soil. These compounds are not subject to aqueous transport to the extent as compounds with higher water solubilities.

- Specific gravity is the ratio of the weight of a given volume of pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Its primary use is to determine whether a constituent will have a tendency to float or sink (as an immiscible liquid) in water if it is present as a pure compound or at concentrations which exceed its water solubility.

- Both vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. The ratio of these two parameters (Henry's Law constant) is used to calculate the equilibrium constituent concentrations in the vapor (air) phase versus the liquid (water) phase for the dilute solutions commonly encountered in environmental settings.

A quantitative assessment of mobility has been developed (Laskowski, 1983) that uses water solubility (S), vapor pressure (VP), and the organic carbon partition coefficient (K_{oc}). This value is referred to as the Mobility Index (MI). It is calculated as follows:

$$MI = \log\ [(S\ x\ VP)/K_{oc}]$$

A scale to evaluate MI is presented by Ford and Gurba (1984) as the following:

Relative MI	Mobility Description
MI > 5	Extremely mobile
0 < MI < 5	Very mobile
-5 < MI < 0	Slightly mobile
-10 < MI < -5	Immobile
MI <-10	Very immobile

The MIs for the potential COPCs are also presented in Table 8-5.

The following paragraphs summarize the site-specific fate and transport data for the potential COPCs at the Building LP-20.

Volatile Organic Compounds

Predominant volatile organic COPCs at the Building LP-20 site can be divided into two distinct classes: (1) volatile aromatics and (2) chlorinated methanes, ethanes and ethenes.

Volatile aromatic COPCs identified at the site include benzene, toluene, and ethylbenzene. The common structure of these chemicals is the benzene ring. Toluene is a methyl substituted benzene ring. Ethylbenzene is an ethyl substituted benzene ring.

Chlorinated methanes include chloromethane and chloroform. Chlorinated ethanes and ethenes include trichloroethene, tetrachloroethane, 1,1-dichloroethane, 1,1-dichloroethene, vinyl chloride, 1,2-dichloroethane, total 1,2-dichloroethene, 1,1,1-trichloroethane and 1,1,2-trichloroethane. Vinyl chloride, 1,2-dichloroethene and 1,2-dichloroethane are most likely present as a result of the degradation of higher chlorinated ethenes and ethanes.

Volatile organics tend to be very mobile in environmental media as indicated by their presence in groundwater throughout the Building LP-20 Site. Their inherent mobility and relatively high MIs result from high water solubilities, high vapor pressures, low K_{oc} and K_{ow} values. The MIs estimated for the volatile COPCs identified at the site range from -0.01 (ethylbenzene) to 5.9 (chloromethane). These MIs indicate that the mobilities of the volatile COPCs range from slightly mobile to extremely mobile. Volatile organics do not tend to persist in environmental media because photolysis, oxidation and biodegradation figure significantly in their removal. They are seldom detected in surface soils (0 to 6 inches) where volatilization and other removal processes predominate. This is the case at the Building LP-20 Site.

Semivolatile Organic Compounds

In general, SVOCs are somewhat less mobile than the VOCs by virtue of their lower vapor pressures and lower water solubilities. K_{oc} and K_{ow} values for SVOCs are generally greater in magnitude than those for the VOCs, indicating the tendency for this class of compounds to adsorb strongly to soils and sediments. Table 8-5 shows that MI values for semivolatile COPCs at the Building LP-20 Site range from -20 (dibenz(a,h)anthracene) to -12 (bis(2-ethylhexyl)phthalate). These indicate that the semivolatile organic COPCs at the Building LP-20 Site are very immobile in environmental media.

Inorganics

Different inorganic species behave differently in various environmental media. In general, inorganics can be transported through air, adhering to blowing dusts, or move through surface water and groundwater as dissolved salts. Inorganics can also be carried with flowing waters on suspended solids or attached to colloidal materials.

The most complicated pathway for inorganic chemicals is migration in subsurface soils and groundwater, where oxidation reduction potential (Eh) and pH play critical roles. Table 8-6 presents an example of how mobilities depend on Eh and pH. Soils at the Building LP-20 site are relatively basic; therefore, inorganics in the surface and subsurface soils should be low to medium in mobility.

8.3.3.2 Potential Migration Pathways

This section identifies the potential migration routes of COPCs at the Building LP-20 Site. These mechanisms were identified through an evaluation of the analytical results and known site characteristics.

Groundwater

Contaminants which come into contact with groundwater can migrate off site under the influence of groundwater flow. Migration through groundwater is dependent on the chemical nature of the contaminant and the chemical and physical nature of the aquifer. Groundwater flow velocity (a function of hydraulic gradient and conductivity), groundwater chemistry, and the chemical make up of the aquifer are all factors which affect contaminant migration. Mobility of a contaminant in groundwater is particularly influenced by it's solubility and the organic carbon partition coefficient. Compounds that have high solubility and low K_{oc} values such as vinyl chloride tend to be more mobile in groundwater than those with low solubility and high K_{oc} values such as PCBs.

Shallow groundwater samples were obtained by Geoprobe™ and Type II well installation. The Geoprobe™ samples were analyzed for volatile organic compounds only. These results were combined with the results for volatiles from the Type II monitoring wells.

The shallow aquifer is not used as a drinking water source. However, the deep aquifer (Yorktown) is used as a potable source of drinking water in the Norfolk area, though not in the vicinity of the site. There are no private industrial or residential wells within a one mile radius of the site. There is a confining clay layer the thickness of which ranges from 8 to 52 feet; however, since there is contamination in the deep aquifer, the shallow and the deep aquifers may be interconnected.

Soil

Inorganic and organic compounds were detected in the surface and subsurface soils at the Building LP-20 Site. The factors which control contaminant migration through soil are dependent on site hydrology, as well as the chemical and physical nature of the contaminants and of the soil. Some of the factors which influence the migration of chemicals in soil include pH, oxidation reduction reactions (Eh), particle size distribution, pore size distribution, lime content, content of organic matter, concentration of ions or salts, aerobic and anaerobic conditions, presence or absence of hydrous oxides, vegetative cover, topography and climate.

Air

There are two potential release mechanisms to be considered in evaluating the atmospheric pathway: the release of COPCs adsorbed onto dust particulates (i.e., fugitive dust emissions) and volatilization of contaminants from groundwater. The transport mechanism is the air, and the potential exposure points are the areas of human activity on and adjacent to the Building LP-20 Site.

Fugitive Dust Emissions.

This air pathway was evaluated as a source of exposure at outdoor locations at the site. Evaluation of this pathway introduces a large degree of conservatism into the baseline RA since much of the site is either paved or grass-covered. These conditions would normally preclude the generation and emissions of fugitive dusts.

Air exposure may occur when surface soils become airborne due to wind erosion or vehicular traffic. It is assumed that potential human receptors at the site may inhale soil particulates while engaging in outdoor activities. This assumption was applied to both current and future scenarios.

Volatilization

The results of the groundwater sampling investigation performed at the Building LP-20 Site indicated detectable concentrations of VOCs. It was assumed that detected indoor air concentrations can occur from volatilization of organic COPCs from groundwater during showering by future adult and child residents. Under the non-potable use scenario, volatilization of organic COPCs from groundwater can also occur during outdoor non-potable use activities, e.g., lawn watering and car washing. However, due to the infinite dilution of volatized COPCs expected to occur in outdoor air, this pathway was not evaluated as a significant migration pathway.

The existing building at the Building LP-20 site is constructed upon a thick concrete slab with no basement. The potential may exist for volatilization from the underlying plume into the ground floor through fine cracks in the slabs, expansion joints and drains. However; air sampling was not performed for two reasons. First, the buildings are very large and well ventilated. Second, solvents and chemicals are routinely used in Building LP-20; therefore, air sampling could not delineate between air concentrations originating from on-going activities at the site, and concentrations that have volatilized into the building from the underlying groundwater plume. However, an evaluation of the potential inhalation of organics that volatilize from groundwater used for showering (as discussed in the previous paragraph) was performed that addresses the groundwater-to-air migration pathway in a highly conservative manner.

8.3.3.3 Potential Exposure Pathways

Potential exposures to current and future maintenance and industrial workers could occur by accidental ingestion and dermal contact with COPCs in surface and subsurface soils during routine maintenance activities. Although the area is either paved or grass covered, thus, limiting the potential for dust emission, fugitive dust inhalation was evaluated for the sake of conservatism for these receptors. The potential for ingestion and dermal contact with COPCs in shallow and deep groundwater while working at the site would also be expected to affect these receptors.

Future construction workers could potentially be exposed to COPCs by incidental ingestion of and dermal contact with surface and subsurface soils during excavation and construction activities. Inhalation of fugitive dusts released from surface and subsurface soils would also be expected to

affect construction workers. The potential for ingestion of and dermal contact with COPCs in groundwater while working on the site was evaluated as well.

Future residential development of the Building LP-20 Site is highly unlikely. For purpose of conservatism the possibility that the site might be used as housing for adult and child military residents was evaluated. Adult and child military residents could be exposed to small areas of surface soil upon removal of pavement which they could contact during outdoor activities. Therefore, these receptors were evaluated for accidental ingestion of and dermal contact with surface soils. If subsurface soils were excavated, resident adults and children may come into contact with them; therefore future residents were evaluated for accidental ingestion of and dermal contact with subsurface soil. Although the use of groundwater is highly unlikely, shallow and deep groundwater could be used as either a potable or non-potable source in the future. Therefore, future adult and child residents were evaluated for accidental ingestion of and dermal contact with shallow and deep groundwater during bathing. Since several VOCs were present in groundwater, future residents were also evaluated for inhalation of volatile COPCs in the home during showering. However, inhalation of these VOCs was not evaluated for the non-potable use activities.

8.3.4 Quantification of Exposure

8.3.4.1 Concentrations Used in the Estimate of Exposure

The concentration used in the estimation of a chronic daily intake (CDI) must be representative of the type of exposure being considered. Potential exposures to a media such as soil, groundwater, surface water, or sediments at any exposure location may be considered as having equal probabilities of occurrence, as an individual moves randomly across the site or area of concern. Therefore, for these media, the concentration term for a constituent in the intake equation can be reasonably estimated as the arithmetic average concentration of site sampling data. USEPA supplemental risk assessment guidance (1992c) states that the average concentration is an appropriate estimator for the exposure concentration for two reasons: 1) carcinogenic and chronic noncarcinogenic toxicity criteria are based on lifetime average exposures; and 2) the average concentration is most representative of the concentration that would be contacted over time. Risks for average concentrations and exposure input parameters were calculated. The average values are noted parenthetically in the exposure assumption tables (Tables 8-7 to 8-10). Carcinogenic risks and

hazard indices are noted parenthetically in Tables 8-14 to 8-20. However, uncertainty is inherent in the estimation of the true average constituent concentration at a site.

In order to account for this uncertainty and to be health protective, USEPA risk assessment guidance (1989) requires that an upper bound estimate of the arithmetic mean concentration, be used to calculate CDI. This estimate, which should be in the high end of the concentration frequency distribution, is called the reasonable maximum exposure (RME) concentration. The RME concentration is defined as the highest concentration that could reasonably be expected to be contacted via a given pathway over a long-term exposure period. A conservative estimate of the arithmetic average concentration that best represents the RME concentration is the 95 percent upper confidence limit of the arithmetic mean concentration (95% UCL). In order to estimate the 95% UCL for a data set, the best distributional assumption should be identified (i.e., normal versus lognormal) for that data.

One means for estimating the distribution of a data set is to plot frequency versus concentration value, or log-transformed concentration value for each COPC in each data set. However, this can be a time-and paper-consuming task. Therefore, in accordance with recommended USEPA supplemental risk assessment guidance (USEPA, 1992c), a basic statistical method, the W-Test (Gilbert, 1987), was utilized to determine if data sets can be described by normal or lognormal distributions. As a result, a normal or lognormal 95% UCL of the media-specific sample result for a COPC was utilized to calculate the CDI. For exposure areas with limited amounts of data or extreme variability in measured data, the RME (i.e., 95% UCL) can be greater than the maximum measured concentration. Therefore, in cases where the RME for a contaminant exceeds the maximum detected value in a given data set, the maximum result was used in the estimate of exposure. In some instances, the results of the W-Test indicate that a data set may be described by both a normal and a lognormal distribution. In this case, the greater of the normal and lognormal 95% UCLs was used as the concentration term. If the 95% UCLs for both the normal and the lognormal concentrations exceeded the maximum detected concentration, the maximum concentration was used. In instances where the W-Test indicates that a data set is neither normally or lognormally distributed, the maximum detected concentration was used. The results of the W-Test for this baseline RA are presented with the data and statistics in Appendix O. The following equations were used to calculate 95% UCLs for normally and lognormally distributed data sets.

The 95% UCL for a data set best described by a normal distribution was calculated using the following equation (USEPA, 1992c):

$$95\%\ UCL = x + t\ (s/n^{0.5})$$

Where: x = Mean concentration
t = Student t statistic
s = Standard deviation
n = Number of samples

The 95% UCL for a data set best described by a lognormal distribution was calculated using the following equation (USEPA, 1992c):

$$95\%\ UCL = \exp[x + 0.5s^2 + sH/(n-1)^{0.5}]$$

Where: x = mean of the log-transformed data
s = Standard deviation of the log-transformed data
H = H-Statistic
n = Number of samples

Exposure concentrations in groundwater, in both the shallow and deep zones, were obtained from data for individual monitoring wells. Maximum groundwater concentrations (for sample sizes less than 10) and 95% UCL concentrations were evaluated over a site-wide area from numerous well locations to estimate potential risks associated with shallow and deep groundwater. This assumes that a receptor may install a well at any on-site location in the future.

In addition to calculating RME concentrations described by maximum and 95% UCL concentrations, the concentration representing the CT for each data set and distribution was approximated by the estimating the median of detected concentrations (CT concentrations). The CT concentrations were then utilized to calculate chemical intakes for the CT case scenarios. The median concentration was used, since by definition, the median is a true representation of central location in a data set, regardless of distribution. This is because the median is equal to the 50 percentile of a data set, where 50 percent of the measured values in that data set are less than that value and the other 50 percent of the measured values are greater than that value. Often times, the mean is considered to be the most popular choice for representing CT. For a normal distribution, the mean adequately represents the location of CT, since the mean and the median are closely correlated. However, this

is not the case for data sets that are skewed, such as most environmental data sets. As a data set skews to the right, the mean becomes greater than the median. Likewise, as a data set skews to the left, the mean becomes less than the median.

Only detected concentrations were utilized, and not half-detection limit values, in the calculation of the median in order to avoid median values that exceed corresponding maximum detected values. This could occur in any data set where some reported detection limits (and corresponding half-detection limit values) exceed the maximum detected concentration due to sample matrix, dilution effects or high percent moisture in solid samples. In such cases the maximum would be used as the exposure concentration for the calculation of CT intakes. In many of the RME scenarios, the maximum was already used as the RME concentration. Defaulting to the maximum as both the RME and CT exposure concentration for any particular scenario would only serve to blur any distinction between RME and CT, especially in intake equations where there is only limited to no availability of USEPA-established values for CT exposure input parameters.

For current/future on-site workers and future construction workers, organics and unfiltered inorganics COPCs were used to assess potential risks. For future residents, organics and filtered (dissolved) inorganic COPCs were used because it is the most likely exposure scenario. It assumes that unfiltered water will be filtered before residents use it.

For results reported as "nondetect" (e.g., ND, U, etc.), a value of one half of the sample-specific detection limit was used to calculate the 95% UCL. A value of half the detection limit was assigned to nondetects when estimating the 95% UCL because the actual value could be between zero and a value just below the detection limit. Ninety-five percent UCLs were calculated only for the constituents detected in at least one sample collected from the environmental medium of interest.

Reported concentrations that were less than the detection limit were used to calculate the mean and the 95% UCL concentration used in the quantitative risk assessment. Typically, these values are qualified with a " J" meaning that the value is estimated. Data qualified " J" for any reason were used in the calculation of the 95% UCL. Reported concentrations qualified with an "R" were rejected from the data set.

In order to quantatively assess the inhalation of contaminants volatilized from shower water, the model developed by Foster and Chrostowski (1987) (Appendix P) was utilized. Air concentrations of organics that may volatilize from domestic groundwater while showering, were modeled by estimating the following: the generation rate of chemical releases into air based on a two-film gas liquid mass transfer theory; the buildup (shower on) and decay (shower off) of VOCs in shower room air; and the concentrations of airborne VOCs inhaled while the shower is both on and off. The airborne VOC concentrations estimated by the model were then used as a concentration term in determining CDIs resulting from inhalation of shower room air. Relevant equations and spreadsheets that were used to estimate VOC shower air concentrations are presented in Appendix P.

8.3.4.2 Estimation of Daily Chronic Intake

The equations for estimating exposure to site contaminants for the various identified exposure pathways are as follows.

Groundwater

Ingestion of Potable and Non-Potable Groundwater

The daily intake associated with the direct potential ingestion of the chemicals of potential concern in groundwater under a potable use scenario was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{Cw \ x \ IR \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:	CDI	=	Chronic Daily Intake, mg/kg/day
	Cw	=	Chemical concentration in water, mg/L
	IR	=	Ingestion rate, L/day
	EF	=	Frequency of exposure, days/year
	ED	=	Exposure duration, years
	BW	=	Average body weight, kg
	AT	=	Averaging time, days

The same equation was used to calculate the daily intake of chemicals of potential concern under a non-potable use scenario except the ingestion rate of 0.05 L/hour (USEPA, 1989) was multiplied

by the exposure time of 2.6 hours/day (Professional Judgement) and was substituted for IR in the above equation.

Dermal Contact with Groundwater

The dermally absorbed dose associated with potential dermal contact with COPCs in groundwater was calculated using the following equation (USEPA, 1989):

$$DAD = \frac{Cw \ x \ Kp \ x \ A \ x \ EF \ x \ ED \ x \ ET \ x \ CF}{BW \ x \ AT}$$

Where:	DAD	=	Dermally absorbed dose, mg/kg/day
	Cw	=	Chemical Concentration in water (mg/L)
	Kp	=	Chemical specific dermal permeability constant (cm/hour)
	A	=	Surface area of exposed skin, cm^2
	EF	=	Exposure frequency, days/year
	ED	=	Exposure duration, years
	ET	=	Exposure Time (hours/day)
	CF	=	Conversion factor (1 liter/1,000 cm^3)
	BW	=	Average body weight, kg
	AT	=	Averaging time, days

The steady-state model was used in estimating DAD for both inorganic and organic COPCs.

Inhalation Volatilized Organic COPCs during Showering

The chronic daily intake resulting from the inhalation of COPCs that volatilize from water during showering was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{Ca \ x \ RR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:	CDI	=	Chronic Daily Intake, mg/kg/day
	Ca	=	Chemical concentration in air, mg/m^3, as determined from Foster and Chrostowski Shower Model (1987)
	RR	=	Respiration rate, m^3/day
	ET	=	Exposure Time (hours/event)
	EF	=	Frequency of exposure, days/year
	ED	=	Exposure duration, years

BW	=	Average body weight, kg
AT	=	Averaging time, days

Surface Soils and Subsurface Soils

Accidental Ingestion of Soils and Sediments

The daily intake associated with the potential accidental ingestion of COPCs detected in surface and subsurface soils was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{Cs \ x \ IR \ x \ CF \ x \ FI \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:	CDI	=	Chronic Daily Intake, mg/kg/day
	Cs	=	Chemical concentration in soil mg/kg
	IR	=	Ingestion rate, mg/day
	CF	=	Conversion Factor, 10^{-6} kg/mg
	FI	=	Fraction of soil ingested from site, unitless
	EF	=	Frequency of exposure, days/year
	ED	=	Exposure duration, years
	BW	=	Average body weight, kg
	AT	=	Averaging time, days

Dermal Contact with Soils

The dermally absorbed dose associated with the potential dermal contact of COPCs in surface and subsurface soils was calculated using the following equation (USEPA, 1992a):

$$DAD = \frac{Cs \ x \ CF \ x \ AF \ x \ ABS \ x \ A \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:	DAD	=	Dermally absorbed dose, mg/kg/day
	Cs	=	Chemical concentration in soil, mg/kg
	CF	=	Conversion factor, 10^{-6} kg/mg
	AF	=	Soil to Skin Adherence Factor, mg/cm^2
	ABS	=	Absorbance factor, unitless
	A	=	Surface area of exposed skin, cm^2
	EF	=	Exposure frequency, days/year
	ED	=	Exposure duration, years
	BW	=	Average body weight, kg
	AT	=	Averaging time, days

Inhalation of Fugitive Dusts Emanating from Surface Soils and Excavated Subsurface Soils

The chronic daily intake resulting from the inhalation of COPCs adsorbed onto fugitive dust particulates was estimated using the following equation (USEPA, 1989):

$$CDI = \frac{Ca \ x \ RR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT}$$

Where:	CDI	=	Chronic Daily Intake, mg/kg/day
	Ca	=	Chemical concentration in air as fugitive dusts, mg/m^3
	RR	=	Respiration rate, m^3/day
	ET	=	Exposure time (hrs/day)
	EF	=	Frequency of exposure, days/year
	ED	=	Exposure duration, years
	BW	=	Average body weight, kg
	AT	=	Averaging time, days

The air concentration (Ca) of a chemical in fugitive dust emissions was estimated by multiplying the soil concentration of the chemical (Cs) by the default particulate emission factor (PEF = 6.79×10^8 m^3/kg) obtained from USEPA (1994d).

8.3.4.3 Exposure Factors Used To Derive Chronic Daily Intakes and Dermally Absorbed Doses

Tables 8-7 through 8-10 present the RME factors used in the estimation of potential chronic daily intakes for COPCs retained for each environmental medium. USEPA promulgated exposure factors were used in conjunction with USEPA standard default exposure factors. When USEPA exposure factors were not available, best professional judgment and site-specific information were used to derive a conservative and defensible value. The following paragraphs present the selection of exposure factors for each receptor group evaluated at the Building LP-20 Site. Since not many CT values have been established by USEPA, as can be seen in the tables, only the RME values are discussed.

Current and Future On-site Workers

Exposure factors for current and future maintenance and industrial workers are presented in Table 8-7. On-site employees could potentially contact COPCs present in surface soil, subsurface soil and groundwater during routine maintenance work. On-site workers could potentially contact COPCs present in surface and subsurface soil via accidental ingestion, dermal contact and inhalation of fugitive dusts onto which COPCs have been adsorbed. For the accidental soil ingestion pathway, an ingestion rate (IR) of 50 mg/day was (USEPA, 1991) assumed. For dermal contact a skin surface area (A) of 4,100 cm^2 (USEPA, 1992a) was used. This value corresponds to a maximum case skin surface area for an adult male wearing a short-sleeved shirt, long pants and shoes. Areas assumed available for contact include the head, forearms, and hands. Experimentally derived absorbance values for classes of chemicals were used in determining dermally absorbed doses (DADs). The following summarizes these values as the percent of chemical estimated to be absorbed through the skin and into the bloodstream.

VOCs	-	0.05% (Vapor Pressures > 95.2 mm/Hg)
		3% (Vapor Pressures < 95.2 mm/Hg)
SVOCs	-	10%
Arsenic	-	3.2%
Inorganics	-	1%

Each of these values represent the upper limits of their respective absorbance ranges as presented in USEPA (1995a). For the inhalation of fugitive dusts route a respiration rate of 0.83 m^3/hour (USEPA, 1989a) and an exposure time (ET) of 10 hours/day was assumed (Professional Judgement).

On-site workers could potentially contact COPCs present in shallow and deep groundwater via accidental ingestion and dermal contact. For the accidental ingestion route, an ingestion rate of 0.05 L/day (Professional Judgement) was used. For dermal contact with groundwater, equations and chemical-specific permeability constants (Kp) presented by USEPA (1992a) were used to estimate steady-state absorption of organic and inorganic COPCs. A value of 20,000 cm^2 (USEPA, 1992a) for A (the skin surface area) was used. This value is based upon total body surface area available for contact. An exposure time of 1.0 hours/day (Professional Judgement) was assumed. An

exposure duration (ED) and exposure frequency (EF) of 25 years (USEPA, 1991) and 250 days/year (USEPA, 1991), respectively was assumed for all media. An averaging time for noncarcinogens (AT_{nc}) and an averaging time for carcinogens (AT_c) of 9,125 days (USEPA, 1989) and 25,550 days (USEPA, 1989), respectively was assumed for all media. A body weight (BW) of 70 kg (USEPA, 1989) was assumed.

Future Construction Workers

Exposure factors for future construction workers are presented in Table 8-8. Future construction workers could potentially contact COPCs present in surface soil, subsurface soil and groundwater during excavation and construction activities. Construction workers could potentially contact COPCs present in surface and subsurface soil via accidental ingestion, dermal contact and inhalation of fugitive dusts onto which COPCs have been adsorbed. For the accidental soil ingestion pathway an IR of 480 mg/day (USEPA, 1989a) was assumed. For dermal contact a skin surface area of 4,100 cm^2 (USEPA, 1989) was used. This value corresponds to a maximum case skin surface area for an adult male wearing a short-sleeved shirt, long pants, and shoes. Areas assumed available for contact include the head, forearms, and hands. Experimentally derived absorbance values for classes of chemicals were used in determining DADs. The following summarizes these values as the percent of chemical estimated to be absorbed through the skin and into the bloodstream.

VOCs	-	0.05% (Vapor Pressures > 95.2 mm/Hg) and 3% (Vapor Pressures < 95.2 mm/Hg)
SVOCs	-	10%
Arsenic	-	3.2%
Inorganics	-	1%

Each of these values represent the upper limits of their respective absorbance ranges as presented in USEPA (1995a). For the inhalation of fugitive dusts route, a respiration rate of 1.25 m^3/hour (USEPA, 1989a) and an exposure time of 10 hours/day (Professional Judgement) were assumed.

Future construction workers could potentially contact COPCs present in groundwater via accidental ingestion and dermal contact. For the accidental ingestion route, an ingestion rate of 0.5 L/day (USEPA, 1989) was used. For dermal contact with groundwater, equations and chemical-specific

permeability constants presented by USEPA (1989) were used to estimate steady-state absorption of organic and inorganic COPCs. A value of 4,100 cm^2 (USEPA, 1989a) for A (the skin surface area) was used. This value is based upon a maximum case skin surface area for an adult male wearing a short-sleeved shirt, long pants and shoes. Areas assumed available for contact include the head, forearms and hands. An exposure time of 2.6 hours/day (USEPA, 1989) was assumed. An ED and EF of 1 year (USEPA, 1991) and 250 days/year (USEPA, 1991), respectively was assumed for all media. An AT_{nc} and AT_c of 365 days (USEPA, 1989) and 25,550 days (USEPA, 1989), respectively was assumed for all media. A body weight of 70 kg (USEPA, 1989) was assumed.

Future Military Residents

Exposure factors for future adult and child military residents are presented in Table 8-9. Future residents could potentially contact COPCs present in surface soils, if small areas of surface soils are exposed from beneath the concrete and asphalt. Exposure to subsurface soils may occur during outdoor activities if excavation and construction are occurring at the site. Although it is unlikely, shallow and deep groundwater may be used as potable water exposing residents in the future. Future residents could potentially contact COPCs present in surface and subsurface soil via accidental ingestion and dermal contact. For the accidental soil ingestion pathway, an IR of 100 mg/day and 200 mg/day was assumed for adult and child (ages 1-6 years), respectively (USEPA, 1989). For dermal contact a skin surface area of 5,000 cm^2 and 2,006 cm^2 was used for adults and children, respectively (USEPA, 1992a). These values represent 25 percent of total body surface area. Experimentally derived absorbance values for classes of chemicals were used in determining DADs. The following summarizes these values as the percent of chemical estimated to be absorbed through the skin and into the bloodstream.

VOCs	-	0.05% (Vapor Pressures > 95.2 mm/Hg) and 3% (Vapor Pressures < 95.2 mm/Hg)
SVOCs	-	10%
Arsenic	-	3.2%
Inorganics	-	1%

Each of these values represent the upper limits of their respective absorbance ranges as presented in USEPA (1995a). Future residents could potentially contact COPCs present in groundwater used

for potable purposes via ingestion of drinking water, dermal contact and by volatilization of COPCs in shower water. For the accidental ingestion route, an ingestion rate of 2 L/day and 1 L/day was used for adult and child residents, respectively (USEPA, 1989). For dermal contact with groundwater, equations and chemical-specific permeability constants presented by USEPA (1989) were used to estimate steady-state absorption of organic and inorganic COPCs. Values of 20,000 cm^2 and 8,023 cm^2 (USEPA, 1992a) for skin surface areas were assumed for adult and child residents, respectively. These values correspond to the skin surface area available for whole body exposure during bathing activities. An ET of 0.2 hours/event was assumed. For the inhalation of VOCs in shower air route, a respiration rate of 0.83 m^3/hour (USEPA, 1989a) and an ET of 0.2 hours/event (Professional Judgement) were assumed for both adult and child residents. An ED and EF of 4 years (Professional Judgement) and 350 days/year (USEPA, 1991), respectively were assumed for both adults and children for all media. An AT_{nc} and AT_c of 1,460 days (USEPA, 1989) and 25,550 days (USEPA, 1989), respectively, were used for adults and children for all media. Body weights of 70 kg and 15 kg were assumed for adult and child residents, respectively (USEPA, 1989).

Future adult residents could potentially contact COPCs present in groundwater while engaging in non-potable uses such as washing cars or watering lawns. Exposure factors for this scenario are presented in Table 8-10. It was conservatively assumed that activities (i.e., car washing and lawn watering) involving non-potable groundwater usage could occur 28 days per year (EF), or four times per month from April through October. The USEPA exposure time (ET) for surface water, 2.6 hours, was assumed for each event (Professional Judgement). The USEPA ingestion rate (IR) of 50 ml/hour (USEPA, 1989) was used as a conservative estimate of accidental groundwater ingestion. When this ingestion rate is multiplied by an exposure time of 2.6 hours/day (Professional Judgement) an IR of 0.13 L/day is obtained for substitution into the daily intake equation for accidental ingestion of groundwater COPCs. The adult skin surface area (A) available for dermal contact was estimated to be 5,000 cm^2 (USEPA, 1989a), representing 25 percent of the total body surface area. Equations and chemical-specific permeability constants (Kp) were used to estimate the steady-state absorption of organic and inorganic COPCs by skin exposed to groundwater. The exposure duration was estimated to be 4 years (Professional Judgement). The AT_{nc}, AT_c and adult body weight were the same as those for the potable use scenario.

8.4 Toxicity Assessment

Section 8.3 presented potential exposure pathways and receptors for this baseline RA. This section will review the available toxicological information for COPCs retained for quantitative evaluation.

8.4.1 Toxicological Evaluation

The purpose of this section is to identify the potential health and environmental effects associated with potential exposure to the COPCs. A toxicological evaluation characterizes the inherent toxicity of a compound. It consists of the review of scientific data to determine the nature and extent of the potential human health and environmental effects associated with potential exposure to the various chemicals. The end product is a collection of toxicological profiles for the COPCs. These toxicological profiles provide the qualitative weight-of-evidence that demonstrate whether facility COPCs pose any actual or potential health and/or environmental effects.

Toxicological profiles addressing the COPCs at the Building LP-20 Site are presented in Appendix Q. In these toxicological profiles, the available human and animal data are presented. Human data from occupational exposures are often insufficient for determining quantitative indices of toxicity because of uncertainties in exposure estimates, and inherent difficulties in determining causal relationships established by epidemiological studies. For this reason, animal bioassays are conducted under controlled conditions and their results are extrapolated to humans. There are several stages to this extrapolation. First, to account for species differences, conversion factors are used to extrapolate from test animals to humans. Second, the relatively high doses administered to test animals must be extrapolated to the lower doses more typical of human exposures. For potential noncarcinogens, safety factors and modifying factors are applied to animal results when developing acceptable human doses. For potential carcinogens, mathematical models are used to extrapolate effects at high doses to effects at lower doses. Epidemiological data can then be used for inferential purposes to establish the credibility of the experimentally derived indices.

Toxic effects considered in these profiles include noncarcinogenic (toxic) and potentially carcinogenic health effects as well as environmental effects. Toxicological endpoints, routes of exposure, and doses in humans and/or animal studies are discussed. Potential carcinogenic health effects are associated with exposure to a potential carcinogen. Routes of exposure and doses in

humans and/or animal studies are provided. Also considered is the USEPA's weight-of-evidence of a compound's carcinogenicity (i.e., Group A, known human carcinogens; Group-B, probable human carcinogens; Group C, possible human carcinogens; Group D, not classifiable as to its carcinogenicity).

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

8.4.2 Dose-Response Evaluation

An important component of the risk assessment process is the relationship between the dose of a compound (amount to which an individual or population is potentially exposed) and the potential for adverse health effects resulting from exposure to that dose. Dose-response relationships provide a means by which potential public health impacts may be evaluated. Standard reference doses (RfDs) and/or carcinogenic slope factors (CSFs) have been developed for many of the COPCs. This section provides a brief description of these parameters.

Reference Doses (RfDs) and Reference Concentrations (RfCs) - The RfDs and RfCs (developed for inhalation) are developed for chronic and/or subchronic human exposure to chemicals and are based solely on the noncarcinogenic effects of chemical substances. These values are defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that are likely to be without an appreciable risk of adverse effects during a lifetime. The RfD is usually expressed as dose (mg) per unit body weight (kg) per unit time (day). The RfC is expressed as dose (mg) per cubic meter of air (m^3). They are generally derived by dividing a no-observed-(adverse)-effect-level (NOAEL or NOEL) or a lowest observed-adverse-effect-level (LOAEL) for the critical toxic effect by an appropriate "uncertainty factor (UF)." Effect levels are determined from laboratory or epidemiological studies. The UF is based on the availability of toxicity data.

Uncertainty factors usually consist of multiples of 10, where each factor represents a specific area of uncertainty naturally present in the extrapolation process. These UFs are presented below and were taken from RAGS (USEPA, 1989).

- A UF of 10 is used to account for variation in the general population and is intended to protect sensitive subpopulations (e.g., elderly, children).

- A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.

- A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.

- A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to UFs, a modifying factor (MF) is applied to each reference dose and is defined as:

A MF ranging from >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The default value for the MF is 1.

Thus, the RfD incorporates the certainty of the evidence for chronic human health effects. Even if applicable human data exist, the RfD still maintains a margin of safety such that chronic human health effects are not underestimated.

Carcinogenic Slope Factor (CSF) - CSFs are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen (USEPA, 1989). This factor is generally reported in units of $(mg/kg/day)^{-1}$ and is derived through an assumed low-dosage linear multistage model and an extrapolation from high to low dose-

responses determined from animal studies. The value used in reporting the slope factor is the upper 95 percent confidence limit.

CSFs can also be derived from USEPA promulgated unit risk values for air and/or water. CSFs derived from unit risks cannot, however, be applied to environmental media other than the medium considered in the unit risk estimate.

These slope factors are also accompanied by weight-of-evidence classifications which designate the strength of the evidence that the COPC is a potential human carcinogen. Table 8-11 describes these weight-of-evidence categories.

Quantitative indices of toxicity and USEPA weight-of-evidence classifications are presented in Table 8-12 for the identified COPCs. Dermally-adjusted health-based criteria are presented in Table 8-13. The hierarchy (USEPA, 1989) for choosing these values was:

- Integrated Risk Information System (IRIS) (USEPA, 1996b)
- Health Effects Assessment Summary Table (HEAST) (USEPA, 1995b)
- National Center for Environmental Assessment (formerly ECAO.)

The IRIS data base is updated monthly and contains both verified RfDs, RfCs and CSFs. The USEPA has formed an RfD work group to review existing data used to derive RfDs and RfCs. Once this task has been completed the verified RfD appears in IRIS. Like the RfD Work Group, the USEPA has also formed the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work group to review and validate toxicity values used in developing CSFs. Once the slope factors have been verified via extensive peer review, they also appear in the IRIS data base.

HEAST, on the other hand, provides both interim (unverified) and verified RfDs, RfCs and CSFs. This document is published quarterly and incorporates any applicable changes to its data base.

8.5 Risk Characterization

This section presents quantitative estimates of potential human health effects associated with the Building LP-20 Site. Sections 8.5.2 through 8.5.4 present and discuss the estimated incremental

lifetime cancer risks (ILCRs) and hazard indices (HIs) for identified potential receptor groups which could be exposed to COPCs by the exposure pathways presented previously in Section 8.3.

8.5.1 Potential Human Health Effects

Quantitative risk calculations for potentially carcinogenic compounds estimate (inferentially) the potential incremental lifetime cancer risk levels for an individual. This unit of risk refers to a potential cancer risk that is above the background cancer risk in unexposed individuals. For example, an incremental lifetime cancer risk level of 1×10^{-06} indicates that an exposed individual has an increased probability of developing cancer of one in one-million, subsequent to exposure, over the course of a lifetime. A simpler way of understanding an inferential, incremental cancer risk is to apply the value of a community of exposed individuals. For example, an inferential incremental lifetime cancer risk level of 1×10^{-06} indicates that one additional case of cancer may occur in a population of one million exposed individuals.

The potential incremental lifetime cancer risk level to an individual is estimated from the following relationship:

$$ICR = \sum_{i=1}^{n} CDI_i \times CSF_i$$

where CSF_i is the cancer slope factor [$(mg/kg/day)^{-1}$] for compound i, and CDI_i is the chronic daily intake (mg/kg/day) for compound i. The cancer slope factor is defined in most instances as an upper 95 percentile confidence limit of the probability of a carcinogenic response based on experimental animal data; the CDI is defined as the exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time (i.e., seven years to a lifetime). The above equation was derived assuming that cancer is a non-threshold process and that the potential excess risk level is proportional to the cumulative intake over a lifetime.

The above equation is only valid at relatively low risk levels. When estimated risks associated with an exposure pathway are high (i.e., greater than 0.01), the following non-linear equation was used.

$$ICR = \sum_{i=1}^{n} [1 - \exp(-CDI \ x \ CSF)]$$

Estimated ICR values were compared to the target risk range of 1×10^{-04} to 1×10^{-06} which represents USEPA's opinion on what are generally acceptable levels (USEPA, 1989).

In contrast to the above approach for potentially carcinogenic effects, quantitative risk calculations for noncarcinogenic compounds assume that a threshold toxicological effect exists. Therefore, the potential for noncarcinogenic effects is calculated by comparing chronic daily intake levels with reference doses.

Noncarcinogenic effects are estimated by calculating the Hazard Index (HI) which is defined as:

$$HI = \sum_{i=1}^{n} HQ_i$$

$$\text{where: } HQ_i = CDI_i/RfD_i$$

where HQ_i is the hazard quotient for chemical i, CDI_i is the chronic daily intake (mg/kg/day) of compound i, and RfD_i is the reference dose (mg/kg/day) of compound i over a prolonged period of exposure.

A value of 1.0 (unity) is considered an acceptable criterion to which all estimated HIs are compared. The HI is calculated by comparing estimated chronic daily intakes with threshold levels below which there is minimal potential for noncarcinogenic health effects. Any HI equal to or exceeding 1.0 suggests that noncarcinogenic health effects are possible. HI values below 1.0 suggest that systemic adverse health effects will not occur subsequent to exposure.

The estimated RME and CT potential risks and hazard indices for potential human exposure pathways presented in Section 8.3 are summarized in Tables 8-14 through 8-20. The RME risks and hazard indices are discussed in the following sections. Central tendency estimates were only

calculated where pathway RME values resulted in unacceptable risk values. Quantitative risk calculations for specific COPCs are provided in Appendix R.

8.5.2 Current/Future On-Site Maintenance and Industrial Workers

On-site workers could be exposed to COPCs at the Building LP-20 Site, by the following media and pathways: surface soils (accidental ingestion, dermal contact, and inhalation of fugitive dusts); subsurface soils (accidental ingestion, dermal contact, and inhalation of fugitive dusts); shallow groundwater (accidental ingestion and dermal contact); and deep groundwater (accidental ingestion and dermal contact). Groundwater exposures were evaluated for the sake of conservatism using organic and total (unfiltered) inorganic concentrations. ILCR and HI values are presented for current/future on-site workers in Tables 8-14 and 8-15.

Table 8-14 shows that subsurface soil ILCRs and HIs were within USEPA's target cancer risk range and did not exceed unity respectively for the maintenance and industrial workers. However, ILCRs for shallow groundwater and surface soil and the HI for shallow groundwater exceed the target risk range. Current/future maintenance and industrial workers exposed to shallow groundwater via accidental ingestion (ILCR = 5.5×10^{-03}) and dermal contact (2.2×10^{-02}) exhibited a total ILCR of 2.7×10^{-02}. The constituent contributing most predominantly to accidental ingestion risk was vinyl chloride (91.1 percent). The COPCs associated with most risk for the dermal pathway were vinyl chloride (82.5 percent) and 1,1-dichloroethene (13.7 percent).

Current/future maintenance and industrial workers exposed to shallow groundwater via accidental ingestion (HI = 5.6) and dermal contact (39) exhibited a total HI of 45, which exceeds unity, indicating that adverse systemic effects may occur. The constituents contributing most predominantly to the HI for the accidental ingestion and dermal pathways were 1,2-dichloroethene (total) and trichlorethene. The blood is the target of 1,2-dichloroethene (total) with decreased hematocrit and hemoglobin levels. The target of trichloroethene is the liver.

Current/future maintenance and industrial workers contacting surface soil exhibited a total ILCR of 1.4×10^{-04} with the ILCR for dermal contact (1.3×10^{-04}) being associated with the most risk. The COPCs contributing most predominantly to risk were beryllium (53.8 percent), arsenic (28.6 percent), and benzo(a)pyrene (10.1 percent).

Table 8-15 shows that current/future maintenance and industrial workers exposed to deep groundwater via accidental ingestion (ILCR = 3.5×10^{-05}) and dermal contact (7.4×10^{-05}) exhibited a total ILCR of 1.1×10^{-04} which exceeds USEPA's target cancer risk range. Constituents contributing most predominantly to accidental ingestion risk were arsenic (51.2 percent) and vinyl chloride (46.8 percent). COPCs associated with most risk for the dermal contact pathway were vinyl chloride (81.5 percent) and arsenic (10.3 percent).

8.5.3 Future Construction Workers

Future construction workers could be exposed to COPCs at the Building LP-20 Site, by the following media and pathways: surface soils (accidental ingestion, dermal contact, and inhalation of fugitive dusts); subsurface soils (accidental ingestion, dermal contact, and inhalation of fugitive dusts); and shallow groundwater (accidental ingestion and dermal contact). Accidental exposure to shallow groundwater was evaluated for the sake of conservatism using organic and total (unfiltered) inorganic concentrations. ILCR and HI values are presented for future construction workers by well location in Table 8-16.

For the future construction worker, all ILCRs and HIs estimated for subsurface soil were within USEPA's target cancer risk range and did not exceed unity, respectively. However risks estimated for shallow groundwater and surface soil exceed USEPA's risk criteria.

Future construction workers exposed to shallow groundwater via accidental ingestion (ILCR = 2.2×10^{-04}) and dermal contact (4.7×10^{-04}) exhibited a total ILCR of 7.0×10^{-04}. The constituent contributing most predominantly to accidental ingestion risk was vinyl chloride (91.1 percent). The COPCs associated with most risk for the dermal pathway were vinyl chloride (82.5 percent) and 1,1-dichloroethene (13.7 percent).

Future construction workers exposed to shallow groundwater via accidental ingestion (HI = 5.6) and dermal contact (21) exhibited a total HI of 27, which exceeds unity, indicating that adverse noncarcinogenic effects may occur. The constituents contributing most predominantly to the HI for the accidental ingestion and dermal pathways were 1,2-dichloroethene (total) and trichloroethene. The blood is the target of 1,2-dichloroethene (total) with decreased hematocrit and hemoglobin levels. The target of trichloroethene is the liver.

Future construction workers exposed to surface soil via accidental ingestion (HI = 1.1) and dermal contact (0.52) exhibited a total HI of 1.6, which exceeds 1.0. The constituents contributing most predominantly to the HI for the accidental ingestion and dermal pathways were arsenic, antimony and manganese; however, the individual HQs estimated for these metals were less than 1.0. The target of arsenic is the skin causing keratosis and hyperpigmentation. Antimony targets the whole body and blood causing increased mortality and altered blood chemistry. Manganese targets the central nervous system. Since these metals target different organs, it is unlikely that adverse systemic effects would occur subsequent to exposure.

8.5.4 Future Adult and Child (Ages 1-6) Military Residents

Future adult and child military residents could be exposed to COPCs at the Building LP-20 Site, by the following media and pathways: surface soils (ingestion and dermal contact); subsurface soils (ingestion and dermal contact); shallow groundwater (ingestion, dermal contact, and inhalation); and deep groundwater (ingestion, dermal contact, and inhalation). Although future residential development of Building LP-20 Site is highly unlikely, a future military resident scenario was evaluated in the event that the building be used for base housing . This exposure scenario is purely hypothetical for purposes of conservative estimates only. Since most of the site is currently covered with concrete and asphalt, it was assumed that future residents may be exposed to small areas of soil in the event that some of the pavement be removed. Potable use of shallow and deep groundwater was evaluated for the sake of conservatism. Potential groundwater exposures were evaluated using organic and dissolved (filtered) inorganic concentrations. ILCR and HI values are presented for future residents in Tables 8-17 to 8-20.

For future adult and child military residents, all ILCRs and HIs were within USEPA's target cancer risk range and did not exceed unity, respectively, with the exception of the ILCRs for adults and children exposed to shallow and deep groundwater, the ILCR for children exposed to surface soil, HIs for adults and children exposed to shallow groundwater, the HIs for adults and children exposed to surface soil, and children exposed to subsurface soil.

Table 8-17 shows that future adult residents exposed to carcinogenic COPCs in shallow groundwater, used for potable purposes, via ingestion (ILCR $=5.0 \times 10^{-02}$), dermal contact (9.8×10^{-04}) and inhalation (2.7×10^{-02}) exhibited a total ILCR of 7.8×10^{-02}. The constituent contributing

most predominantly to ingestion risk was vinyl chloride (91.4 percent). The COPCs associated with most risk for the dermal pathway were vinyl chloride (82.8 percent) and 1,1-dichloroethene (13.8 percent). For the inhalation pathway vinyl chloride (85.2 percent) and 1,1-dichlorethene (10.2 percent) were the major contributors to risk.

Future resident children exposed to carcinogenic COPCs in shallow groundwater, used for potable purposes, via ingestion (1.2×10^{-01}), dermal contact (1.8×10^{-03}), and inhalation (1.4×10^{-02}) exhibited a total ILCR of 2.6×10^{-01}. The constituent contributing most predominantly to ingestion risk was vinyl chloride (91.6 percent). The COPCs associated with most risk for the dermal pathway were vinyl chloride (82.8 percent) and 1,1-dichloroethene (13.8 percent). The major contributors to inhalation risk were vinyl chloride (86.6 percent) and 1,1-dichloroethene (9.2 percent).

Future child military residents exposed to carcinogenic COPCs in surface soil via ingestion (6.4×10^{-05}) and dermal contact (6.4×10^{-05}) exhibited a total ILCR of 1.3×10^{-04}. The major contributor to ingestion risk was arsenic (85.7 percent). The COPCs contributing most predominantly to dermal risk were beryllium (53.8 percent), arsenic (28.6 percent), and benzo(a)pyrene (10.1 percent).

Future adult military residents exposed to noncarcinogenic COPCs in shallow groundwater, used for potable purposes, by ingestion (310), dermal contact (11) and inhalation (45) exhibited a total HI of 370, which exceeds USEPA's acceptable target value of 1.0, indicating that adverse noncarcinogenic effects may occur. The constituents contributing most predominantly to the ingestion and dermal contact HIs were trichloroethene and total 1,2-dichloroethene. The target organ of trichloroethene is the liver. The blood is the target of 1,2-dichloroethene (total) causing decreased hematocrit and hemoglobin levels. Benzene was the major contributor to inhalation risk causing adverse effects on the liver, blood, and nervous system.

Future child military residents exposed to noncarcinogenic COPCs in shallow groundwater, used for potable purposes, by ingestion (720), dermal contact (20) and inhalation (210) exhibited a total HI of 960, which exceeds USEPA's acceptable target value of 1.0, indicating that adverse noncarcinogenic effects may occur. The constituents contributing most predominantly to the ingestion and dermal contact HIs were trichloroethene and 1,2-dichloroethene (total). The target

organ of trichloroethene is the liver. The blood is the target of 1,2-dichloroethene (total) causing decreased hematocrit and hemoglobin levels. Benzene was the major contributor to inhalation risk causing adverse effects on the liver, blood, and nervous system.

Future adult military residents exposed to noncarcinogenic COPCs in surface soil exhibited a total HI of 1.2. Neither the HI estimated for the ingestion pathway (HI = 0.32) or that estimated for the dermal pathway (HI = 0.89) exceed unity. Arsenic ,antimony and manganese were the COPCs contributing most predominantly to the both the ingestion and dermal HIs. The skin is the target organ of arsenic causing keratosis and hyperpigmentation; antimony affects the whole body and the blood causing increased mortality and altered blood chemistry; and manganese targets the central nervous system. Since the ingestion and dermal HQs estimated for each of these metals are less than unity and are non-additive (due to different target organs), and due to the conservative nature of the exposure assumptions employed in estimating risks for these scenarios, it is unlikely that adverse systemic effects will occur following exposure to surface soil by adult residents.

Future child military residents exposed to noncarcinogenic COPCs in surface soil exhibited a total HI of 4.7, with the HIs estimated for both the ingestion and dermal pathways (3.0 and 1.7, respectively) exceeding unity. Arsenic, antimony and manganese were the COPCs contributing most predominantly to both the ingestion and dermal HIs, with the ingestion of arsenic resulting in the only HQ exceeding unity. The skin is the target organ of arsenic causing keratosis and hyperpigmentation; antimony affects the whole body and the blood causing increased mortality and altered blood chemistry; and manganese targets the central nervous system. Since the ingestion and dermal HQs estimated for antimony and manganese are less than unity and are non-additive (due to different target organs), it is unlikely that adverse systemic effects will occur following residential child exposures to these metals in surface soil. However, it is possible that adverse systemic effects, i.e., keratosis and hyperpigmentation, may result as a consequence of exposures to arsenic concentrations detected in surface soil.

Future resident military children exposed to noncarcinogenic COPCs in subsurface soil exhibited a total HI of 1.9 with the HI for the ingestion pathway (1.3) exceeding 1.0. Antimony (60.4 percent), arsenic (28.3 percent), and aluminum (11.2 percent) were the constituents contributing most predominantly to the ingestion HI. Antimony affects the whole body and the blood causing increased mortality and altered blood chemistry. Arsenic targets the skin causing keratosis and

hyperpigmentation. The target organ of aluminum is unavailable. Since the ingestion HQs estimated for each of these metals are less than unity and are non-additive (due to different target organs), and due to the conservative nature of the exposure assumptions employed in estimating risks for this scenario, it is unlikely that adverse systemic effects will occur following exposure to surface soil by child residents.

Table 8-18 shows that ILCRs and HIs for deep groundwater exposures of future adult and child military residents also exceeded USEPA's target cancer risk range and unity, respectively. Future resident adults and children exhibited total ILCRs of 3.0×10^{-04} and 9.0×10^{-04}, respectively with risks estimated for the ingestion pathway (adults = 2.1×10^{-04}; children = 5.0×10^{-04}) and the inhalation pathway (children = 3.9×10^{-4}) exceeding USEPA's target cancer risk range. The constituents contributing most predominantly to the ingestion risks for both adults and children were vinyl chloride (69.3 percent) and arsenic (27.7 percent); whereas the constituent contributing most predominantly to the inhalation risk for children was vinyl chloride (90.4 percent).

Future resident adults and children exhibited total deep groundwater HIs of 7.4 and 19, respectively, with risks estimated for the ingestion pathway (adults = 6.4; children = 15) and the inhalation pathway (children = 4.2) exceeding unity. The COPCs contributing most predominantly to the ingestion HIs were 1,2-dichloroethene (total) (49.3 percent) and arsenic (39 percent). The HQs estimated for both COPCs exceeded unity. The target of 1,2-dichloroethene (total) is the blood causing decreased hemocrit and hemoglobin levels. The skin is the target organ of arsenic causing keratosis and hyperpigmentation. The COPC contributing exclusively to the inhalation HI was benzene.

Future resident adults were also evaluated by a non-potable use of shallow and deep groundwater scenario. Non-potable uses include car washing and lawn watering. Since young children are unlikely to engage in non-potable use activities they were not evaluated.

Table 8-19 shows that future adult residents exposed to shallow groundwater via a non-potable use scenario exhibited a total ILCR of 5.1×10^{-04}. ILCRs for the ingestion and dermal pathways were 2.5×10^{-04} and 2.6×10^{-04}, respectively. The COPC contributing most predominantly to ingestion risk was vinyl chloride (91.2 percent). The constituents associated with most risk for the dermal pathway were vinyl chloride (81.3 percent) and 1,1-dichloroethene (13.5 percent).

Future adult residents exposed to shallow groundwater engaging in non-potable uses exhibited a total HI of 4.4. HIs for the ingestion and dermal pathways were 1.6 and 2.8, respectively. The constituents contributing most predominantly to the ingestion and dermal HIs were trichloroethene and 1,2-dichloroethene (total), with only the HQ estimated for dermal exposures to trichloroethene exceeding unity. The liver, which is the target organ for trichloroethene, may be adversely affected following dermal exposures to adults using shallow groundwater for non-potable purposes.

Table 8-20 shows that no unacceptable risks were estimated to result from non-potable use of deep groundwater by future resident military adults.

8.6 Sources of Uncertainty

Uncertainties are encountered throughout the process of performing a risk assessment. This section discusses the sources of uncertainty inherent in the following elements of the public health evaluation performed for the Building LP-20 Site:

- Sampling and Analysis
- Selection of COPCs
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Chemicals not quantitatively evaluated

Uncertainties associated with this risk assessment are discussed in the following paragraphs. Table 8-21 summarizes the potential effects of certain uncertainties on the estimation of human health risks and ecological effects.

8.6.1 Sampling and Analysis

The development of a risk assessment depends on the reliability of, and uncertainties with, the analytical data available to the risk assessor. These, in turn, are dependent on the operating procedures and techniques applied to the collection of environmental samples in the field and their subsequent analyses in the laboratory. To minimize the uncertainties associated with sampling and analysis at the Building LP-20 Site, USEPA approved sampling and analytical methods were employed. Data were generated in most cases using USEPA's Statement of Work for CLP. Samples

were analyzed for target compound list (TCL) organics, target analyte list (TAL) inorganics, and cyanide. Samples were taken from locations specified in the approved Work Plan along with the necessary QA/QC samples.

Analytical data are limited by the precision and accuracy of the methods of analysis. The statistical methods used to compile and analyze the data (mean concentrations, detection frequencies) are subject to the overall uncertainty in data measurement. Furthermore, chemical concentrations in environmental media fluctuate over time and with respect to sampling location. Analytical data must be sufficient to consider the temporal and spatial characteristics of contamination at the site with respect to exposure.

8.6.2 Selection of COPCs

The selection of COPCs is performed in a risk assessment following the evaluation of data. Analytical data must also be comprehensive in order to address the COPCs associated with the site. Types of COPCs encountered at the Building LP-20 site include volatile organics, semivolatile organics, and inorganic constituents.

Soil and groundwater COPCs for the Building LP-20 Site were selected based on comparisons of maximum detected concentrations with Region III COPC screening concentrations as the primary criterion, in conjunction with prevalence.

Region III COPC screening concentrations are based on exposure assumptions and equations that are intended to introduce conservatism in the risk assessment process by changing the COPC screening method from a relative toxicity screen of RAGS to an absolute comparison of risk. However, the use of the Region III COPC screening concentrations results in the application of a set of non-site-specific assumptions in the determination of COPCs at the Building LP-20 Site. At the Building LP-20 Site future residential development is not considered an expected land use. The application of the residential COPC screening concentrations to soil and groundwater COPC selections would, therefore, tend to result in a list of COPCs that could be considered overly conservative for a military base. The use of conservative COPC selections in the baseline RA ensures the protection of public health in that the results of the baseline RA are incorporated into the determination of remedial alternatives and remedial action objectives in the Feasibility Study.

8.6.3 Exposure Assessment

In performing exposure assessments, uncertainties arise from two main sources. First, uncertainties arise in estimating the fate of a compound in the environment, including estimating release and transport in a particular environmental medium. Second, uncertainties arise in the estimation of chemical intakes resulting from contact by a receptor with a particular medium.

To estimate an intake, certain assumptions must be made about exposure concentrations, exposure events, exposure durations, and the corresponding assimilation of constituents by the receptor. Exposure factors have been generated by the scientific community and have undergone review by the USEPA. The USEPA has published an Exposure Factors Handbook which contains the best and latest values. Regardless of the validity of these exposure factors, they have been derived from a range of values generated by studies of limited numbers of individuals. In all instances, values used in this risk assessment, scientific judgments, and conservative assumptions agree with those of the USEPA.

The use of a Reasonable Maximum Exposure (RME) approach, designed as not to underestimate daily intakes, was employed throughout this risk assessment. The use of normal and lognormal 95 percent upper confidence estimates of the arithmetic mean or maximum values as the concentration term in estimating the CDI reduces the potential for underestimating exposure at the Building LP-20 Site. Recent research using Monte-Carlo estimation techniques indicates that USEPA's RME represents the 98 to 99.99 percent upper limit of the estimated risk distribution.

The potential inhalation of fugitive dusts from affected soils was estimated in the BRA using USEPA's Rapid Assessment of Exposure to Particulate Emissions from Surface Contaminated Sites (Cowherd et al. 1985). The PEF relates the concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from surface contamination. This relationship is derived by Cowherd (1985). The particulate emissions from contaminated sites are due to wind erosion, and therefore, depend on erodibility of the surface material. A USEPA default value of $6.79 \times 10^8 m^3/kg$ was used as the PEF in evaluating the inhalation of site fugitive dust emissions in this risk assessment.

Shallow and deep groundwater samples were analyzed for organic and total (unfiltered) and dissolved (filtered) inorganic constituents. Data for organic and unfiltered inorganic constituents were used in the evaluation of accidental exposures to future civilian workers under a non-potable use scenario. Filtered groundwater data were not used to evaluate this scenario since actual exposure conditions are best represented by the data for unfiltered samples. Likewise, data for organic and filtered inorganics were used in estimating risks to future on-site residents who may hypothetically use the shallow aquifer as a potable source of drinking water. Filtered rather than unfiltered inorganics were used since the former is more representative of actual exposure conditions "at the tap" than the latter. However, it should be noted that the shallow aquifer is currently not being used as a potable source of water, nor is it expected to be used as such in the future. Therefore, evaluation of the hypothetical residential drinking water scenario results in an overestimation of human health risk that errs on the side of health conservation.

Dermal groundwater risks that would be expected to result from bathing were evaluated for both young children and adults. However, this may overestimate actual risks for adults since adults usually tend to shower, rather than bathe. Dermal exposure via bathing is considered much more significant than showering since the water contact time with skin, and consequently, the risk of dermal absorption, is assumed to be much greater during bathing. As a result, dermal exposures resulting from showering may be insignificant, due to short contact time, relative to bathing.

8.6.4 Toxicological Assessment

In making quantitative estimates of the toxicity of varying dosages of compounds to human receptors, uncertainties arise from two sources. First, data on human exposure and the subsequent effects are usually insufficient, if they are available at all. Human exposure data usually lack adequate concentration estimations and suffer from inherent temporal variability. Therefore, animal studies are often used and new uncertainties arise from the process of extrapolating animal results to humans. Second, to obtain observable effects with a manageable number of experimental subjects, high doses of a compound are often used. In this situation, a high dose means that high exposures are used in the experiment with respect to most environmental exposures. Therefore, when applying the results of the animal experiment to the human condition, the effects at the high doses must be extrapolated to approximate effects at lower doses.

In extrapolating effects from high doses in animals to low doses in people, scientific judgment and conservative assumptions are employed. In selecting animal studies for use in dose-response calculations, the following factors are considered:

- Studies are preferred where the animal closely mimics human pharmacokinetics.
- Studies are preferred where dose intake most closely mimics the intake route and duration for humans.
- Studies are preferred which demonstrate the most sensitive response to the compound in question.

For compounds believed to cause threshold effects (i.e., noncarcinogens) safety factors are employed in the extrapolation of effects from animals to humans and from high doses to low doses. In deriving carcinogenic potency factors, the 95 percent upper confidence value is promulgated by the agency to prevent underestimation of potential risk.

The use of conservative assumptions, results in quantitative indices of toxicity that are not expected to underestimate potential toxic effects, but may overestimate these effects by an order of magnitude or more.

8.6.5 Human Risk Characterization

The risk characterization bridges the gap between risk assessment and risk management, ultimately providing impetus for the remediation of the site.

Other uncertainties associated with risk characterization include the assumption of chemical additivity and the inability to predict synergistic or antagonistic interactions between COPCs. These uncertainties are inherent in any inferential risk assessment. USEPA promulgated inputs to the quantitative risk assessment and toxicological indices are calculated to be protective of the human receptor and to err conservatively, so as to not underestimate the potential human health risks.

Surface and subsurface soils were evaluated for the maintenance and industrial workers, future on-site military residents (adult and young child) and the future construction workers. Exposures to surface and subsurface soils usually represent two separate scenarios that should be evaluated separately, and the resulting risks be considered as non-additive. However, in this RA, resulting surface and subsurface soil risks were summed into the total site risk. The uncertainty introduced by this methodology results in an overestimation of total site risk to these receptors, thus erring in favor of health conservatism.

8.7 Summary

8.7.1 Chemicals of Potential Concern

The following items summarize COPCs identified in soil and groundwater media at the LP-20 site:

- Based on the results of the surface soil investigation, as well as the toxicological evaluations primarily PAHs and metals were the COPCs identified in the surface soils of the Building LP-20 Site. Potentially carcinogenic PAHs (benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and dibenz(a,h)anthracene), aluminum, antimony, arsenic, beryllium, and manganese were determined to be COPCs for the Building LP-20 Site.

- For subsurface soils benzo(a)pyrene, aluminum, antimony, arsenic, and beryllium were identified as COPCs.

- For shallow groundwater primarily volatile organic compounds and metals were identified as COPCs. The volatile organic compounds include: chloromethane, vinyl chloride, 1,1,-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethene (total), chloroform, 1,2-dichloroethane, 1,1,1-trichloroethane, trichloroethene, 1,1,2-trichloroethane, benzene, tetrachloroethene, toluene, and ethylbenzene. One SVOC bis(2-ethylhexyl)phthalate was also retained as a COPC. The unfiltered inorganic COPCs identified were: aluminum, antimony, arsenic, beryllium, cadmium, chromium, lead, manganese, and vanadium. Filtered inorganic COPCs include: antimony, arsenic, cadmium, and manganese.

- The COPCs identified in deep groundwater consisted primarily of volatile organic compounds and metals. The volatile organic compounds include: vinyl chloride, 1,1,-dichloroethene, 1,2-dichloroethene (total), trichloroethene, and benzene. The unfiltered inorganic COPCs include aluminum, arsenic, barium, vanadium, chromium, lead, and manganese. The filtered inorganic COPCs identified were arsenic, barium and manganese.

8.7.2 Receptors and Exposure Pathways

The following items summarize potential human receptors and associated exposure pathways evaluated in the baseline RA:

- Current/Future Maintenance and Public Works Workers
  - Accidental ingestion of surface soils
  - Dermal contact with surface soils
  - Inhalation of fugitive dusts from surface soils
  - Accidental ingestion of subsurface soils
  - Dermal contact with subsurface soils
  - Inhalation of fugitive dusts from subsurface soils
  - Accidental ingestion of shallow groundwater
  - Dermal contact with shallow groundwater
  - Accidental ingestion of deep groundwater
  - Dermal contact with deep groundwater

- Future Construction Workers
  - Accidental ingestion of surface soils
  - Dermal contact with surface soils
  - Inhalation of fugitive dusts from surface soils
  - Accidental ingestion of subsurface soils
  - Dermal contact with subsurface soils
  - Inhalation of fugitive dusts from subsurface soils

- Accidental ingestion of shallow groundwater
- Dermal contact with shallow groundwater

- Future Adult and Child (Ages 1-6 years) Military Residents
  - Accidental ingestion of surface soils
  - Dermal contact with surface soils
  - Accidental ingestion of subsurface soils
  - Dermal contact with subsurface soils
  - Ingestion of shallow groundwater
  - Dermal contact with shallow groundwater
  - Inhalation of shallow groundwater COPCs in shower air
  - Ingestion of deep groundwater
  - Dermal contact with deep groundwater
  - Inhalation of deep groundwater COPCs in shower air

8.7.3 Summary of Risk Assessment Results

The following subsections summarize RA results for the RME scenarios. RA results for both the RME and CT scenarios are summarized in Tables 8-14 through 8-20.

8.7.3.1 Current/Future Maintenance and Public Works Workers

Shallow Groundwater

Current/future maintenance and industrial workers exposed to shallow groundwater exhibited a total ILCR of 2.7×10^{-02} which exceeds USEPA's target cancer risk range. The carcinogenic constituents contributing most predominantly to accidental ingestion and dermal contact risk were vinyl chloride and 1,1-dichloroethene. Current/future maintenance and industrial workers exposed to shallow groundwater also exhibited a total HI of 45, which exceeds unity, indicating that adverse noncarcinogenic effects may occur. The noncarcinogenic constituents contributing most predominantly to both accidental ingestion and dermal contact HIs were 1,2-dichloroethene (total) and trichloroethene.

Deep Groundwater

Current/future maintenance and industrial workers exposed to carcinogenic COPCs in deep groundwater exhibited a total ILCR of 1.1 x 10^{-04}. Constituents contributing most predominantly to the accidental ingestion and dermal risks were arsenic and vinyl chloride. No unacceptable noncarcinogenic risks were estimated for non-potable deep groundwater exposures to this receptor group.

Soil

Current/future maintenance and industrial workers contacting surface soil exhibited a total ILCR of 1.4 x 10^{-04} with the dermal pathway being associated with most risk. The COPCs associated with most risk were beryllium, arsenic and benzo(a)pyrene. No unacceptable subsurface soil risks were estimated for this receptor group.

8.7.3.2 Future Construction Workers

Shallow Groundwater

Future construction workers accidentally exposed to carcinogenic COPCs in shallow groundwater exhibited a total ILCR of 7.1 x 10^{-04}. The constituents contributing most predominantly to accidental ingestion and dermal risks were vinyl chloride and 1,1-dichloroethene. Future construction workers exposed to noncarcinogenic COPCs in shallow groundwater exhibited a total HI of 27. The constituents contributing most predominantly to the HI for both the accidental ingestion and dermal pathways were 1,2-dichloroethene (total) and trichloroethene.

Soil

Future construction workers exposed to noncarcinogenic COPCs in surface soil via accidental ingestion exhibited a total HI of 1.1. The COPCs contributing most predominantly to this HI value were arsenic, antimony and manganese. Since the HQs estimated for these metals were less than unity, and since they target different organs, it is unlikely that adverse systemic effects would occur to this receptor subsequent to surface soil exposure. No unacceptable carcinogenic risks were

estimated for surface soil exposures to this receptor group. In addition, no unacceptable carcinogenic or noncarcinogenic subsurface soil risks were estimated for this receptor group.

8.7.3.3 Future On-Site Adult and Child (Ages 1-6 Years) Military Residents

Although future residential development of Building LP-20 Site is highly unlikely, a future military resident scenario was evaluated in the event that the building be used for base housing . This exposure scenario is purely hypothetical for purposes of conservative estimates only. Since most of the site is currently covered with concrete and asphalt, it was assumed that future residents may be exposed to small areas of soil in the event that some of the pavement be removed. Potable use of shallow and deep groundwater was evaluated for the sake of conservatism.

Shallow Groundwater - Potable Use

Future adult residents exposed to carcinogenic COPCs in shallow groundwater used for potable purposes exhibited a total ILCR of 7.8×10^{-02}. The constituent contributing most predominantly to ingestion risk was vinyl chloride. The carcinogenic COPCs associated with most risk for both the dermal and inhalation pathways were vinyl chloride and 1,1-dichloroethene. Ingestion, dermal and inhalation exposures to noncarcinogenic COPCs in shallow groundwater resulted in a total HI of 370. The constituents contributing most predominantly to both ingestion and dermal contact HIs were trichloroethene and 1,2-dichloroethene (total). The major contributor to inhalation risk was benzene.

Future resident children exposed via ingestion, dermal and inhalation pathways to carcinogenic COPCs in shallow groundwater exhibited a total ILCR of 2.6×10^{-01}. The COPC contributing the most predominantly to ingestion risk was vinyl chloride. The constituents associated with most risk for both the dermal and inhalation pathways were vinyl chloride and 1,1-dichloroethene. Ingestion, dermal and inhalation exposures to noncarcinogenic COPCs in shallow groundwater resulted in a total HI of 960. The constituents contributing most predominantly to ingestion and dermal contact HIs were trichloroethene and 1,2-dichloroethene (total). Benzene was the major contributor to inhalation risk.

Deep Groundwater - Potable Use

Future resident adults and children exposed to carcinogenic COPCs in deep groundwater, via ingestion and inhalation, exhibited total ILCRs of 3.0×10^{-04} and 9.0×10^{-04}, respectively. The constituents contributing most predominantly to risk for both adults and children were vinyl chloride and arsenic. Ingestion and inhalation exposures to noncarcinogic COPCs in deep groundwater resulted in total HIs of 7.4 and 19 to adults and children, respectively. The COPCs contributing most predominantly to the HIs were 1,2-dichloroethene (total), benzene and arsenic.

Shallow and Deep Groundwater - Non-Potable Use

Since it is unlikely that groundwater will ever be used for potable purposes, future resident adults were also evaluated under shallow and deep groundwater non-potable use scenarios. Future adult residents exposed to carcinogenic COPCs in shallow groundwater via a non-potable use scenario exhibited a total ILCR of 5.1×10^{-04}. The COPCs contributing most predominantly to ingestion and dermal risk were vinyl chloride, and vinyl chloride and 1,1-dichloroethene, respectively. Exposures to noncarcingenic COPCs in shallow groundwater during non-potable uses resulted in a total HI of 4.4. The constituents contributing most predominantly to ingestion and dermal HIs were trichloroethene and 1,2-dichloroethene (total).

At deep monitoring well location LPMW8, all ILCRs and HIs estimated for non-potable use were within USEPA's acceptable risk criteria.

Surface Soil

Future adult military residents exposed to noncarcinogenic COPCs in surface soil exhibited a total HI of 1.2. Neither the HI estimated for the ingestion pathway (HI = 0.32) or that estimated for the dermal pathway (HI = 0.89) exceed unity. Arsenic ,antimony and manganese were the COPCs contributing most predominantly to the both the ingestion and dermal HIs. Since the ingestion and dermal HQs estimated for each of these metals are less than unity and are non-additive (due to different target organs), and due to the conservative nature of the exposure assumptions employed in estimating risks for these scenarios, it is unlikely that adverse systemic effects will occur following exposure to surface soil by adult residents.

Future child residents exposed to carcinogenic COPCs in surface soil, via ingestion and dermal contact, exhibited a total ILCR of 1.3×10^{-04}. The major contributor to ingestion risk was arsenic. The COPCs contributing most predominantly to dermal risk were beryllium, arsenic and benzo(a)pyrene. Ingestion and dermal exposures to noncarcinogenic COPCs in surface soil resulted in a total HI of 4.7, with arsenic, antimony and manganese contributing the most predominantly to the total HI. However, since the HQs for antimony and manganese are less than unity and are non-additive, any adverse systemic effects following exposure would only be expected from arsenic.

Subsurface Soil

Future resident children exposed to subsurface soil exhibited a total HI of 1.9 with the HI for the ingestion pathway exceeding 1.0. Antimony, arsenic and aluminum were the constituents contributing most predominantly to the ingestion HI.

8.7.3.4 Overall Summary

Based on evaluation of the above receptors and exposure pathways, the COPCs that were major percent contributors, by medium include:

Shallow Groundwater

Vinyl chloride

1,1-Dichloroethene

1,2-Dichloroethene (total)

Trichloroethene

Benzene

Deep Groundwater

Arsenic

Vinyl Chloride

Benzene

1,2-Dichloroethene (total)

Surface Soil

Beryllium

Arsenic

Benzo(a)pyrene

Subsurface Soil

None

SECTION 8.0 TABLES

TABLE 8-1

SUMMARY OF COPC SELECTION
SURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		USEPA Region III Soil COPC Selection Criteria		Nos. of Selection Criteria Exceedences		Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections	Industrial COPC Screening Level	Residential COPC Screening Level	Industrial COPC Screening Level	Residential COPC Screening Level	
Volatile Organic Compounds (µg/kg):							
Acetone (n)	4/11	5J-1,000	20,000,000	780,000	0	0	No
1,2-dichloroethene (total) (n)	1/11	26J	1,800,000	70,000	0	0	No
Trichloroethene (c)	2/11	4J-46	520,000	58,000	0	0	No
Semivolatile Organic Compounds (µg/kg):							
2-Methylnaphthalene[1] (n)	1/11	2,300	8,200,000	310,000	0	0	No
Acenaphthene (n)	1/11	860	12,000,000	470,000	0	0	No
Dibenzofuran (n)	1/11	470J	820,000	31,000	0	0	No
Fluorene (n)	2/11	390-740	8,200,000	310,000	0	0	No
Phenanthrene[1] (n)	5/11	87J-3,300	8,200,000	310,000	0	0	No
Anthracene (n)	2/11	46J-1,400	61,000,000	2,300,000	0	0	No
Carbazole (c)	1/11	110J	290,000	32,000	0	0	No
Di-n-butylphthalate (n)	1/11	54J	20,000	780	0	0	No
Fluoranthene (n)	4/11	95J-4,500	8,200,000	310,000	0	0	No

TABLE 8-1 (Continued)

SUMMARY OF COPC SELECTION
SURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		USEPA Region III Soil COPC Selection Criteria		Nos. of Selection Criteria Exceedences		Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections	Industrial COPC Screening Level	Residential COPC Screening Level	Industrial COPC Screening Level	Residential COPC Screening Level	
Pyrene (n)	5/11	37J-2,100	6,100,000	230,000	0	0	No
Benzo(a)anthracene (c)	4/11	49J-2,200	7,800	880	0	1	Yes
Chrysene (c)	4/11	46J-1,900	780,000	88,000	0	0	No
bis-(2-Ethylhexyl)phthalate (c)	2/11	68J-94J	410,000	46,000	0	0	No
Benzo(b)fluoranthene (c)	3/11	140J-1,300	7,800	880	0	1	Yes
Benzo(k)fluoranthene (c)	3/11	120J-1,400	78,000	8,800	0	0	No
Benzo(a)pyrene (c)	3/11	130J-610J	780	88	0	3	Yes
Indeno(1,2,3-cd)pyrene (c)	2/11	64J-440J	7,800	880	0	0	No
Dibenz(a,h)anthracene (c)	1/11	100J	780	88	0	1	Yes
Benzo(g,h,i)perylene[1] (n)	2/11	63J-84J	8,200,000	310,000	0	0	No
Inorganics (mg/kg):							
Aluminum (n)	11/11	395-12,500	1E+05	7,800	0	2	Yes
Antimony (n)	1/11	12.4L	82	3.1	0	1	Yes
Arsenic[2] (c)	8/11	1.8-49.7	3.8	0.43	4	8	Yes
Barium (n)	11/11	1.9-203	14,000	550	0	0	No
Beryllium (c)	3/11	0.48L-1.1	1.3	0.15	0	3	Yes

TABLE 8-1 (Continued)

SUMMARY OF COPC SELECTION
SURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		USEPA Region III Soil COPC Selection Criteria		Nos. of Selection Criteria Exceedences		Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections	Industrial COPC Screening Level	Residential COPC Screening Level	Industrial COPC Screening Level	Residential COPC Screening Level	
Cadmium (n)	3/11	0.5L-0.85L	100	3.9	0	0	No
Calcium (n)	11/11	296J-388,000J	NA	NA	--	--	No
Chromium[3] (n)	11/11	2L-28.3	1,000	39	0	0	No
Cobalt (n)	9/11	2-11.1	12,000	470	0	0	No
Copper (n)	7/11	2.4-19.2	8,200	310	0	0	No
Iron (n)	11/11	1,070-42,900	61,000	2,300	0	10	No[5]
Lead (n)	11/11	1.3-90.6	NA	400[4]	--	0	No
Magnesium (n)	11/11	132-8,980	NA	NA	--	--	No
Manganese (n)	11/11	8.3K-609K	4,700	180	0	2	Yes
Nickel (n)	3/11	6.5-15.8	4,100	160	0	0	No
Potassium (n)	7/11	441K-8,180	NA	NA	--	--	No
Sodium (n)	7/11	86.3-3,960	NA	NA	--	--	No
Vanadium (n)	9/11	6.7-50.8	1,400	55	0	0	No
Zinc (n)	11/11	6.4K-487	61,000	2,300	0	0	No
Cyanide (n)	1/6	0.72L	4,100	160	0	0	No

TABLE 8-1 (Continued)

SUMMARY OF COPC SELECTION
SURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Notes:

(1) USEPA Region III COPC Screening Level for naphthalene used as a surrogate.
(2) Industrial and residential COPC screening level based on a CSF of 1.5 $(mg/kg/day)^{-1}$.
(3) Chromium was evaluated as the hexavalent state.
(4) Lead action level for residential soils.
(5) Iron was not retained as a COPC since it is an essential nutrient.
(n) Chemical was evaluated as a noncarcinogen. USEPA Region III COPC Screening Level derived based on a target hazard quotient of 0.1.
(c) Chemical was evaluated as a potential carcinogen. USEPA Region III COPC Screening Level derived based on a target risk level of $1x10^{-06}$.
NA No toxicity criteria available for derivation of USEPA Region III COPC Screening Level.
-- Not Applicable.

TABLE 8-2

SUMMARY OF COPC SELECTION
SUBSURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		USEPA Region III Soil COPC Selection Criteria		Nos. of Selection Criteria Exceedences		Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections	Industrial COPC Screening Level	Residential COPC Screening Level	Industrial COPC Screening Level	Residential COPC Screening Level	
Volatile Organic Compounds (µg/kg):							
Chloroethane (n)	1/12	7J	82,000,000	3,100,000	0	0	No
Acetone (n)	5/12	33J-5,400	20,000,000	780,000	0	0	No
Carbon Disulfide (n)	1/12	2J	20,000,000	780,000	0	0	No
1,2-Dichloroethene (total) (n)	1/12	56	1,800,000	70,000	0	0	No
2-Butanone (n)	1/12	3J	100,000,000	4,700,000	0	0	No
Trichloroethene (c)	1/12	40	520,000	58,000	0	0	No
Toluene (n)	1/12	3J	41,000,000	1,600,000	0	0	No
Semivolatile Organic Compounds (µg/kg):							
Acenaphthene (n)	1/12	150J	12,000,000	470,000	0	0	No
Fluorene (n)	1/12	110J	8,200,000	310,000	0	0	No
Phenanthrene[1] (n)	1/12	860	8,200,000	310,000	0	0	No
Anthracene (n)	1/12	230J	61,000,000	2,300,000	0	0	No
Carbazole (c)	1/12	95J	290,000	32,000	0	0	No
Fluoranthene (n)	1/12	1,500	8,200,000	310,000	0	0	No
Pyrene (n)	1/12	480J	6,100,000	230,000	0	0	No

TABLE 8-2 (Continued)

SUMMARY OF COPC SELECTION
SUBSURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		USEPA Region III Soil COPC Selection Criteria		Nos. of Selection Criteria Exceedences		Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections	Industrial COPC Screening Level	Residential COPC Screening Level	Industrial COPC Screening Level	Residential COPC Screening Level	
Benzo(a)anthracene (c)	1/12	730J	7,800	880	0	0	No
Chrysene (c)	1/12	630J	780,000	88,000	0	0	No
bis-(2-Ethylhexyl)phthalate (c)	1/12	520J	410,000	46,000	0	0	No
Benzo(b)fluoranthene (c)	1/12	480J	7,800	880	0	0	No
Benzo(k)fluoranthene (c)	1/12	450J	78,000	8,800	0	0	No
Benzo(a)pyrene (c)	1/12	130J	780	88	0	1	Yes
Inorganics (mg/kg):							
Aluminum (n)	12/12	856-19,600	100,000	7,800	0	3	Yes
Antimony (n)	1/12	24.8L	82	3.1	0	1	Yes
Arsenic[2] (c)	11/12	1.1-13.3	3.8	0.43	3	11	Yes
Barium (n)	12/12	4.4-291	14,000	550	0	0	No
Beryllium (c)	1/12	0.94	1.3	0.15	0	1	Yes
Cadmium (n)	3/12	0.45L-0.83L	100	3.9	0	0	No
Calcium (n)	11/12	384J-118,000J	NA	NA	--	--	No
Chromium[3] (n)	12/12	1.7L-27.4	1,000	39	0	0	No
Cobalt (n)	9/12	2.3-11.9	12,000	470	0	0	No
Copper (n)	10/12	0.91-15	8,200	310	0	0	No

TABLE 8-2 (Continued)

SUMMARY OF COPC SELECTION
SUBSURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		USEPA Region III Soil COPC Selection Criteria		Nos. of Selection Criteria Exceedences		Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections	Industrial COPC Screening Level	Residential COPC Screening Level	Industrial COPC Screening Level	Residential COPC Screening Level	
Iron (n)	12/12	1,560-15,700J	61,000	2,300	0	11	No[5]
Lead (n)	12/12	1.6-22.7	NA	400[4]	--	0	No
Magnesium (n)	11/12	261-3,010	NA	NA	--	--	No
Manganese (n)	12/12	10.5J-129J	4,700	180	0	0	No
Mercury (n)	1/12	0.11	61	2.3	0	0	No
Nickel (n)	5/12	5.8L-10L	4,100	160	0	0	No
Potassium (n)	8/12	169-2,580	NA	NA	--	--	No
Silver (n)	1/12	6.1K	1,000	39	0	0	No
Sodium (n)	8/12	93.7-2,050	NA	NA	--	--	No
Vanadium (n)	11/12	6.7-34.5	1,400	55	0	0	No
Zinc (n)	1/12	6.7K-127	61,000	2,300	0	0	No
Cyanide (n)	2/8	0.71L-1.2L	4,100	160	0	0	No

TABLE 8-2 (Continued)

SUMMARY OF COPC SELECTION
SUBSURFACE SOILS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Notes:

(1) USEPA Region III COPC Screening Level for naphthalene used as a surrogate.
(2) Industrial and residential COPC screening levels based on a CSF of 1.5 $(mg/kg/day)^{-1}$.
(3) Chromium was evaluated as the hexavalent state.
(4) Lead action level for residential soils.
(5) Iron was not retained as a COPC since it is an essential nutrient.
(n) Chemical was evaluated as a noncarcinogen. USEPA Region III COPC Screening Level derived based on a target hazard quotient of 0.1.
(c) Chemical was evaluated as a potential carcinogen. USEPA Region III COPC Screening Level derived based on a target risk level of $1x10^{-06}$.
NA No toxicity criteria available for derivation of USEPA Region III COPC Screening Level.
-- Not Applicable.

TABLE 8-3

SUMMARY OF COPC SELECTION
SHALLOW GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range[1]		Region III COPC Screening Level (Tap Water)	MCLs[2]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Volatile Organic Compounds (mg/L):									
Chloromethane (c)	1/33	24	1.4	NA	NA	1	--	--	Yes
Vinyl Chloride (c)	18/36	2J-15,000	0.019	2	2	18	17	17	Yes
Chloroethane (n)	2/37	29-690	860	NA	NA	0	--	--	No
Acetone (n)	11/37	6J-180J	370	NA	NA	0	--	--	No
Carbon Disulfide (n)	1/37	2J	2.1	NA	NA	0	--	--	No
1,1-Dichloroethene (c)	16/37	3J-3,600	0.044	7	7	16	14	14	Yes
1,1-Dichloroethane (n)	17/37	1J-1,300J	81	NA	NA	6	--	--	Yes
1,2-Dichloroethene (total) (n)	29/37	1J-28,000	5.5	NA	70[3]	23	--	18	Yes
Chloroform (c)	8/37	1J-220J	0.15	NA	100	8	--	1	Yes
1,2-Dichloroethane (c)	6/37	2J-120	0.12	5	5	6	4	4	Yes
2-Butanone (n)	4/37	8J-34J	190	NA	NA	0	--	--	No
1,1,1-Trichloroethane (n)	8/37	1J-560	130	200	200	3	2	2	Yes
Trichloroethene (c)	22/37	1J-44,000	1.6	5	5	20	20	20	Yes
1,1,2-Trichloroethane (c)	7/37	2J-53	0.19	NA	5	7	--	2	Yes
Benzene (c)	10/37	1J-860	0.36	5	5	10	6	6	Yes
4-Methyl-2-Pentanone (n)	2/37	3J-7J	290	NA	NA	0	--	--	No
2-Hexanone	1/37	4J	NA	NA	NA	--	--	--	No

TABLE 8-3 (Continued)

SUMMARY OF COPC SELECTION
SHALLOW GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range[1]		Region III COPC Screening Level (Tap Water)	MCLs[2]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Tetrachloroethene (c)	4/37	1J-3J	1.1	NA	5	3	--	0	Yes
Toluene (n)	8/37	1J-1,200	75	NA	1,000	2	--	1	Yes
Ethylbenzene (n)	3/37	26-530	130	NA	700	1	--	0	Yes
Xylene (total) (n)	8/7	1J-530J	1,200	NA	10,000	0	--	0	No
Semivolatile Organic Compounds (mg/L):									
Phenol (n)	3/21	2J-36	2,200	NA	NA	0	--	--	No
2,4-Dimethylphenol (n)	1/21	3J	73	NA	NA	0	--	--	No
Naphthalene (n)	3/21	5J-33	150	NA	NA	0	--	--	No
2-Methylnaphthalene[4] (n)	4/21	2J-11	150	NA	NA	0	--	--	No
Acenaphthene (n)	3/21	2J-13	220	NA	NA	0	--	--	No
Diethylphthalate (n)	3/21	2J-20	2,900	NA	NA	0	--	--	No
Carbazole (c)	2/21	2J-3J	3.4	NA	NA	0	--	--	No
bis-(2-Ethylhexyl)phthalate (c)	7/21	2J-100	4.8	NA	NA	4	--	--	Yes

TABLE 8-3 (Continued)

SUMMARY OF COPC SELECTION
SHALLOW GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range[1]		Region III COPC Screening Level (Tap Water)	MCLs[2]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Total Inorganics (µg/L):									
Aluminum (n)	21/21	230-14,900	3700	NA	NA	11	--	--	Yes
Antimony (n)	8/21	38.1L-79.2K	1.5	NA	6	8	--	8	Yes
Arsenic[5] (c)	13/21	6.5L-57.6L	0.0445	50	50	13	2	2	Yes
Barium (n)	21/21	15.1-246	260	1,000	2,000	0	0	0	No
Beryllium (c)	2/21	2.3L-3	0.016	NA	4	2	--	0	Yes
Cadmium (n)	6/21	2.1-8.4	1.8	10	5	6	0	1	Yes
Calcium (n)	21/21	1,010-155,000	NA	NA	NA	--	--	--	No
Chromium[5] (n)	11/21	7.2L-41.7L	18	50	100	3	0	0	Yes
Cobalt (n)	7/21	7.1-34	220	NA	NA	0	--	--	No
Copper (n)	3/21	15.4K-48.7K	150	NA	1,300[7]	0	--	0	No
Iron (n)	21/21	3,160-95,800	1,100	NA	NA	21	--	--	No[8]
Lead (n)	15/21	3.8-70.3	NA	50	15[7]	--	1	2	Yes
Magnesium (n)	20/21	4,830-149,000	NA	NA	NA	--	--	--	No
Manganese (n)	21/21	17J-4,270	84	NA	NA	20	--	--	Yes
Mercury (n)	5/21	0.23-0.99	1.1	2	2	0	0	0	No
Potassium (n)	18/21	4,160-24,900	NA	NA	NA	--	--	--	No
Silver (n)	1/21	11.9L	18	50	NA	0	0	--	No

TABLE 8-3 (Continued)

SUMMARY OF COPC SELECTION
SHALLOW GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range[1]		Region III COPC Screening Level (Tap Water)	MCLs[2]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Sodium (n)	21/21	1,000-1,310,000	NA	NA	NA	--	--	--	No
Vanadium (n)	12/21	15.6-113	26	NA	NA	9	--	--	Yes
Zinc (n)	19/21	6.7-334	1,100	NA	NA	0	--	--	No
Dissolved Inorganics (µg/L):									
Aluminum (n)	5/21	2.51J-34.9J	3,700	NA	NA	0	--	--	No
Antimony (n)	9/21	44.4L-95	1.5	NA	6	9	--	9	Yes
Arsenic[5] (c)	9/21	6.9L-45.5L	0.0445	50	50	9	0	0	Yes
Barium (n)	19/21	15.8-197	260	1,000	2,000	0	0	0	No
Cadmium (n)	3/21	2.2-3.1	1.8	10	5	3	0	0	Yes
Calcium (n)	20/21	12,600-152,000	NA	NA	NA	--	--	--	No
Cobalt (n)	6/21	8.8-29.5	220	NA	NA	0	--	--	No
Iron (n)	20/21	13.1-80,300	1,100	NA	NA	13	--	--	No[8]
Lead (n)	1/21	10.2	NA	50	15[6]	--	0	0	No
Magnesium (n)	20/21	4,820-157,000	NA	NA	NA	--	--	--	No
Manganese (n)	21/21	6.6J-4,440	84	NA	NA	19	--	--	Yes
Mercury (n)	1/21	0.27	1.1	2	2	0	0	0	No

TABLE 8-3 (Continued)

SUMMARY OF COPC SELECTION
SHALLOW GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range[1]		Region III COPC Screening Level (Tap Water)	MCLs[2]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Nickel (n)	3/21	32.6-39.4	73	NA	100	0	--	0	No
Potassium (n)	18/21	3,270-25,100	NA	NA	NA	--	--	--	No
Sodium (n)	21/21	475-1,320,000	NA	NA	NA	--	--	--	No
Vanadium (n)	1/21	20.7	26	NA	NA	0	--	--	No
Zinc (n)	2/21	6.1-30.5	1,100	NA	NA	0	--	--	No

Notes:

(1) For volatile organic compounds Geoprobe™ results were combined with shallow groundwater results.
(2) All are primary MCLs.
(3) MCL for cis-1,2-dichloroethylene used as a surrogate.
(4) Region III COPC screening level for naphthalene used as a surrogate.
(5) Industrial and residential COPC screening levels based on a CSF of 1.5 $(mg/kg/day)^{-1}$.
(6) Region III COPC Screening Level is for chromium in the hexavalent state (Cr^{+6}).
(7) Action Level.
(8) Iron was not retained as a COPC since it is an essential nutrient.
(n) Chemical was evaluated as a noncarcinogen. USEPA Region III COPC Screening Level derived based on a target hazard quotient of 0.1.
(c) Chemical was evaluated as a potential carcinogen. USEPA Region III COPC Screening Level derived based on a target risk level of $1x10^{-06}$.
NA Not Available.
-- Not Applicable.

TABLE 8-4

SUMMARY OF COPC SELECTION
DEEP GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		Region III COPC Screening Level (Tap Water)	MCLs[1]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Volatile Organic Compounds (µg/L):									
Vinyl Chloride (c)	4/8	2J-50	0.019	2	2	4	3	3	Yes
Acetone (n)	1/8	3J	370	NA	NA	0	--	--	No
1,1-Dichloroethene (c)	1/8	4J	0.044	7	7	1	0	0	Yes
1,2-Dichloroethene (total) (n)	3/8	28-960	5.5	NA	70[2]	3	--	2	Yes
Trichloroethene (c)	3/8	28-110	1.6	5	5	3	3	3	Yes
Benzene (c)	2/8	3J-19	0.36	5	5	2	1	1	Yes
Toluene (n)	1/8	4J	75	NA	1,000	0	--	0	No
Xylene (n)	1/8	4J	1200	NA	10,000	0	--	0	No
Semivolatile Organic Compounds (µg/L):									
2-Methylnaphthalene[3]	1/8	1J	150	NA	NA	0	--	--	No
Acenaphthene	1/8	2J	220	NA	NA	0	--	--	No
Total Inorganics (µg/L):									
Aluminum (n)	6/8	1320-12,600	3,700	NA	NA	3	--	--	Yes
Arsenic [4] (c)	7/8	8.2-69.3	0.0445	50	50	7	1	1	Yes
Barium (n)	2/8	319-572	260	1,000	2,000	2	0	0	Yes
Calcium (n)	8/8	88,200-319,000	NA	NA	NA	--	--	--	No

TABLE 8-4 (Continued)

SUMMARY OF COPC SELECTION
DEEP GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		Region III COPC Screening Level (Tap Water)	MCLs[1]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Chromium[5] (n)	5/8	6.2-40.5	18	50	100	3	0	0	Yes
Cobalt (n)	2/8	7.7-17.6	220	NA	NA	0	--	--	No
Copper (n)	3/8	12.4-31.6	150	NA	1300	0	--	0	No
Iron (n)	6/8	5,620-66,100	1,100	NA	NA	6	--	--	No[6]
Lead	3/8	10.9-102	NA	50	15	--	1	2	Yes
Magnesium (n)	6/8	14,100-90,000	NA	NA	NA	--	--	--	No
Manganese (n)	6/8	209-639	84	NA	NA	6	--	--	Yes
Nickel (n)	6/8	4.5-35.4	73	NA	100	0	--	0	No
Potassium (n)	5/8	16,100-102,000	NA	NA	NA	--	--	--	No
Sodium (n)	8/8	175,000-1,310,000	NA	NA	NA	--	--	--	No
Vanadium (n)	7/8	6.4-59	26	NA	NA	3	--	--	Yes
Dissolved Inorganics (µg/L):									
Arsenic (c)	3/8	14.8-25.3	0.0445	50	50	3	0	0	Yes
Barium (n)	2/8	202-492	260	1,000	2,000	1	0	0	Yes
Calcium (n)	8/8	73,900-291,000	NA	NA	NA	--	--	--	No
Iron (n)	1/8	1,550	1,100	NA	NA	1	--	--	No[6]
Magnesium (n)	7/8	13,600-83,200	NA	NA	NA	--	--	--	No

TABLE 8-4 (Continued)

SUMMARY OF COPC SELECTION
DEEP GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Parameter	Parameter Frequency/Range		Region III COPC Screening Level (Tap Water)	MCLs[1]		Nos. of Detected Concentrations Exceeding Selection Criteria			Retained as COPC? (Yes/No)
	No. of Positive Detects/No. of Samples	Range of Positive Detections		State of Virginia	Federal SDWA	Region III COPC Screening Level (Tap Water)	State of Virginia	Federal SDWA	
Manganese (n)	7/8	75-380	84	NA	NA	6	--	--	Yes
Potassium (n)	8/8	10,800-102,000	NA	NA	NA	--	--	--	No
Selenium (n)	1/8	5.5K	18	10	50	0	0	0	No
Sodium (n)	4/8	261,000-1,190,000	NA	NA	NA	--	--	--	No

Notes:

(1) All are primary MCLs.
(2) MCL for cis-1,2-dichloroethylene used as a surrogate.
(3) Region III COPC screening level for naphthalene used as a surrogate.
(4) Industrial and residential COPCs screening levels based on a CSF of 1.5 $(mg/kg/day)^{-1}$.
(5) Region III COPC Screening Level is for chromium in the hexavalent state (Cr^{+6}).
(6) Iron was not retained as a COPC since it is an essential nutrient.
(n) Chemical was evaluated as a noncarcinogen. USEPA Region III COPC Screening Level derived based on a target hazard quotient of 0.1.
(c) Chemical was evaluated as a potential carcinogen. USEPA Region III COPC Screening Level derived based on a target risk level of $1x10^{-06}$.
NA Not Available.
-- Not Applicable.

TABLE 8-5

PHYSICAL AND CHEMICAL PROPERTIES FOR ORGANIC CHEMICALS OF POTENTIAL CONCERN
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Constituents	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Log K_{oc}	Log K_{ow}	Specific Gravity (g/cm^3)	Henry's Law Constant ($atm\text{-}m^3/mole$)	Mobility Index
VOCs:							
Benzene	$9.52 \times 10^{+01}$ (1)	$1.75 \times 10^{+03}$ (1)	1.92 (1)	2.12 (1)	0.879 (2)	5.59×10^{-03} (1)	3.3
Chloroform	$1.51 \times 10^{+02}$ (1)	$8.20 \times 10^{+03}$ (1)	1.49 (1)	1.97 (1)	1.489 (2)	2.87×10^{-03} (1)	4.6
Chloromethane	$4.31 \times 10^{+03}$)1)	$6.50 \times 10^{+03}$ (1)	1.54 (1)	0.95 (1)	--	4.40×10^{-02} (1)	5.9
1,1-Dichloroethane	$1.82 \times 10^{+02}$ (1)	$5.50 \times 10^{+03}$ (1)	1.48 (1)	1.79 (1)	1.174 (2)	4.31×10^{-03} (1)	4.5
1,1-Dichloroethene	$6.00 \times 10^{+02}$ (1)	$2.25 \times 10^{+03}$ (1)	1.81 (1)	1.84 (1)	1.218 (2)	3.40×10^{-02} (1)	4.3
1,2-Dichloroethane	$6.40 \times 10^{+01}$ (1)	$8.52 \times 10^{+03}$ (1)	1.15 (1)	1.48 (1)	1.250 (2)	9.78×10^{-04} (1)	4.6
1,2-Dichloroethene (total)	$2.00 \times 10^{+02}$ (2)	$6.00 \times 10^{+02}$ (2)	2.26 (2)	1.48 (2)	1.218 (2)	6.56×10^{-03} (2)	2.8
Ethylbenzene	7.00 (1)	$1.52 \times 10^{+02}$ (1)	3.04 (1)	3.15 (1)	0.867 (2)	6.43×10^{-03} (1)	-0.01
Tetrachloroethene	$1.78 \times 10^{+01}$ (1)	$1.50 \times 10^{+02}$ (1)	2.56 (1)	2.6 (1)	1.626 (2)	2.59×10^{-02} (1)	0.87
Toluene	$2.81 \times 10^{+01}$ (1)	$5.35 \times 10^{+02}$ (1)	2.48 (1)	2.73 (1)	0.867 (2)	$2.81 \times 10^{+01}$ (1)	1.7
1,1,1-Trichloroethane	$1.23 \times 10^{+02}$ (1)	$1.50 \times 10^{+03}$ (1)	2.18 (1)	2.5 (1)	1.350 (2)	1.44×10^{-02} (1)	3.1
1,1,2-Trichloroethane	$3.00 \times 10^{+01}$ (1)	$4.50 \times 10^{+03}$ (1)	1.75 (1)	2.47 (1)	1.44 (2)	1.17×10^{-03} (1)	3.4
Trichloroethene	$5.79 \times 10^{+01}$ (1)	$1.10 \times 10^{+03}$ (1)	2.10 (1)	2.38 (1)	1.46 (2)	9.10×10^{-03} (1)	2.7
Vinyl Chloride	$2.66 \times 10^{+03}$ (1)	$2.67 \times 10^{+03}$ (1)	1.76 (1)	1.38 (1)	0.9121 (2)	8.19×10^{-02} (1)	5.1
SVOCs:							
Benzo(a)anthracene	2.20×10^{-08} (1)	5.70×10^{-03} (1)	6.14 (1)	5.60 (1)	--	1.16×10^{-06} (1)	-16
Benzo(b)fluoranthene	5.00×10^{-07} (1)	1.40×10^{-02} (1)	5.74 (1)	6.06 (1)	--	1.19×10^{-05} (1)	-14
Benzo(a)pyrene	5.60×10^{-09} (1)	1.20×10^{-03} (1)	6.74 (1)	6.06 (1)	--	1.55×10^{-06} (1)	-18
Dibenz(a,h)anthracene	1.00×10^{-10} (1)	5.00×10^{-04} (1)	6.52 (1)	6.80 (1)	--	7.33×10^{-08} (1)	-20
Bis(2-Ethylhexyl)phthalate	2.0×10^{-07} (3)	4.0×10^{-01} (3)	5.0 (3)	4.2 - 5.11 (3)	0.99 (2)	1.1×10^{-05} (3)	-12

Notes: -- = Value not available.

(1) U.S. Environmental Protection Agency, 1986. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response. Washington, D.C. October 1986. EPA 540/1-86-060.

(2) Verscheuren, 1983.

(3) Groundwater Chemicals Desk Reference. John H. Montgomery and Linda M. Welkon. Lewis Publishers. Chelsea, Michigan. 1980.

TABLE 8-6

RELATIVE MOBILITIES OF INORGANICS AS A FUNCTION OF ENVIRONMENTAL CONDITIONS (Eh, pH)
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Relative Mobility	Environmental Conditions			
	Oxidizing	Acidic	Neutral/Alkaline	Reducing
Very High			Se	
High	Se, Zn	Se, Zn, Cu, Ni, Hg, Ag		
Medium	Cu, Ni, Hg, Ag, As, Cd	As, Cd	As, Cd	
Low	Pb, Ba, Se	Pb, Ba, Be	Pb, Ba, Be	
Very Low	Fe, Cr	Cr	Cr, Zn, Cu, Ni, Hg, Ag	Cr, Se, Zn, Cu, Ni, Hg, Pb, Ba, Be, Ag

Notes:

Se = Selenium
Zn = Zinc
Cu = Copper
Ni = Nickel
Hg = Mercury
Ag = Silver
As = Arsenic
Cd = Cadmiun
Ba = Barium
Pb = Lead
Fe = Iron
Cr = Chromium
Be = Beryllium

Source: Swartzbaugh, et al. "Remediating Sites Contaminated with Heavy Metals." Hazardous Materials Control, November/December 1992.

TABLE 8-7

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR CURRENT/FUTURE ON-SITE MAINTENANCE AND INDUSTRIAL WORKERS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Input Parameter	Media	Units	RME (CT) Input Value	RME Comments/References
ED, Exposure Duration	Soil	year	25 (5)	USEPA, 1991
	Groundwater	year	25 (5)	USEPA, 1991
EF, Exposure Frequency	Soil	day/year	250 (219)	USEPA, 1991
	Groundwater	day/year	250 (219)	USEPA, 1991
ET, Exposure Time	Soil	hours/day	10 (NA)	Professional Judgement
	Groundwater	hours/day	1.0 (NA)	Professional Judgement
IR, Ingestion Rate	Soil	mg/day	50 (NA)	USEPA, 1991
	Groundwater	L/day	0.05 (NA)	Professional Judgement
RR, Respiration Rate(1)	Air	m^3/hour	0.83 (NA)	USEPA, 1989a
A, Skin Surface Area	Soil	cm^2	4,100(2) (3,160)	USEPA, 1992a
	Groundwater	cm^2	20,000 (20,000)	USEPA, 1992a
AT, Averaging Time	Soil	day	9,125 (1,825)	USEPA, 1989
At_{nc}, noncarcinogenic	Groundwater	day	9,125 (1,825)	USEPA, 1989
At_c, carcinogenic	All media	day	25,550	USEPA, 1989
ABS, Absorbance Factor	Soil	NA	Chemical-Specific(4)	USEPA, 1995a
PC, Permeability Constant	Groundwater	cm/hour	Chemical-Specific	USEPA, 1992a
AF, Adherence Factor	Soil	mg/cm^2	1 (NA)	USEPA, 1989

TABLE 8-7
(Continued)

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR CURRENT/FUTURE ON-SITE MAINTENANCE AND INDUSTRIAL WORKERS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Input Parameter	Media	Units	RME (CT) Input Value	RME Comments/References
BW, Body Weight	Soil	Kg	70 (NA)	USEPA, 1989
	Groundwater	Kg	70 (NA)	USEPA, 1989
FI, Fraction Ingested	Soil	unitless	1 (NA)	USEPA, 1989

References:

USEPA, 1995a. Assessing Dermal Exposure from Soil.

USEPA, 1992a. Dermal Exposure Assessment: Principles and Applications - Interim Report.

USEPA, 1991. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposre Factors." Interim Final.

USEPA, 1989. Risk Assessment Guidance for Superfund Volume I - Human Health Evaluation Manual (Part A) Interim Final.

USEPA, 1989a. Exposure Factors Handbook.

Notes:

(1) Inhalation of fugitive dusts will be evaluated.

(2) Maximum case skin surface area for an adult male individual wearing a short-sleeved shirt, long pants, and shoes. Areas assumed available for contact include the head, forearms, and hands.

(3) Total body surface area considered to be available for contact.

(4) The following USEPA Region III default absorbance factors will be applied to estimate dermal intake of COPCs in soil (USEPA, 1995a):

VOCs (Vapor Pressures > 95.2 mmHg) - 0.05%
(Vapor Pressures < 95.2 mmHg) - 3%
SVOCs - 10%
Arsenic - 3.2%
Inorganics - 1%

NA = Not Applicable

TABLE 8-8

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR FUTURE CONSTRUCTION WORKERS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Input Parameter	Media	Units	RME (CT) Input Value	Comments/References
ED, Exposure Duration	Soil	year	1.0 (NA)	USEPA, 1991
	Groundwater	year	1.0 (NA)	USEPA, 1991
EF, Exposure Frequency	Soil	day/year	250 (219)	USEPA, 1991
	Groundwater	day/year	250 (219)	USEPA, 1991
ET, Exposure Time	Soil	hours/day	10 (NA)	Professional Judgement
	Groundwater	hours/day	2.6 (NA)	USEPA, 1989
IR, Ingestion Rate	Soil	mg/day	480 (NA)	USEPA, 1991
	Groundwater	L/day	0.05 (NA)	USEPA, 1989
RR, Respiration Rate(1)	Air	m^3/hour	1.25 (NA)	USEPA, 1989a
A, Skin Surface Area	Soil	cm^2	4,100(2) (3,160)	USEPA, 1992a
	Groundwater	cm^2	4,100(2) (3,160)	USEPA, 1989a
AT, Averaging Time	Soil	day	365 (NA)	USEPA, 1989
At_{nc}, noncarcinogenic	Groundwater	day	365 (NA)	USEPA, 1989
At_c, carcinogenic	All media	day	25,550 (NA)	USEPA, 1989

TABLE 8-8
(Continued)

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR FUTURE CONSTRUCTION WORKERS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Input Parameter	Media	Units	RME (CT) Input Value	Comments/References
ABS, Absorbance Factor	Soil	NA	Chemical-Specific(3)	USEPA, 1995a
PC, Permeability Constant	Groundwater	cm/hour	Chemical-Specific	USEPA, 1992a
AF, Adherence Factor	Soil	mg/cm^2	1 (NA)	USEPA, 1992a
BW, Body Weight	Soil	Kg	70 (NA)	USEPA, 1989
	Groundwater	Kg	70 (NA)	USEPA, 1989
FI, Fraction Ingested	Soil	unitless	1 (NA)	USEPA, 1989

References:

USEPA, 1995a. Assessing Dermal Exposure from Soil.

USEPA, 1992a. Dermal Exposure Assessment: Principles and Applications - Interim Report.

USEPA, 1991. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors." Interim Final.

USEPA, 1989. Risk Assessment Guidance for Superfund Volume I - Human Health Evaluation Manual (Part A) Interim Final.

USEPA, 1989a. Exposure Factors Handbook.

TABLE 8-8
(Continued)

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR FUTURE CONSTRUCTION WORKERS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Notes:

(1) Inhalation of fugitive dusts will be evaluated.

(2) Maximum case skin surface area for an adult male individual wearing a short-sleeved shirt, long pants, and shoes. Areas assumed available for soil contact include the head, forearms, and hands.

(3) The following USEPA Region III default absorbance factors will be applied to estimate dermal intake of COPCs in soil (USEPA, 1995a):

VOCs (Vapor Pressures > 95.2 mmHg) - 0.05%
(Vapor Pressures < 95.2 mmHg) - 3%
SVOCs - 10%
Arsenic - 3.2%
Inorganics - 1%

NA = Not Applicable

TABLE 8-9

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR FUTURE MILITARY RESIDENTS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER (POTABLE USE) BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Input Parameter	Media	Units	RME (CT) Input Value		Comments/ References
			Young Child (ages 1-6 yrs)	Adult	
ED, Exposure Duration	All Media	year	4 (NA)	4 (NA)	Professional Judgement
EF, Exposure Frequency	Soil	day/year	350 (350)	350 (350)	USEPA, 1991
	Groundwater/ Shower Air	day/year	350 (234)	350 (234)	USEPA, 1991
EV, Event Frequency	Groundwater	event/day	1 (NA)	1 (NA)	Professional Judgement
ET, Exposure Time	Groundwater/ Shower Air	hours/ event	0.2 (NA)	0.2 (NA)	Professional Judgement
IR, Ingestion Rate	Soil	mg/day	200 (100)	100 (50)	USEPA, 1989
	Groundwater	L/day	1 (NA)	2 (1.4)	USEPA, 1991
A, Skin Surface Area	Soil	cm^2	2,006[1] (1,744)	5,000[1] (5,000)	USEPA, 1992a
	Groundwater	cm^2	8,023[2] (6,978)	20,000[2] (20,000)	USEPA, 1992a
RR, Respiration Rate	Shower Air	m^3/hour	0.83[3] (NA)	0.83[3] (NA)	USEPA, 1989
ABS, Absorbance Factor	Soil	NA	Chemical-Specific[4]	Chemical-Specific[4]	USEPA, 1995a
AF, Adherence Factor	Soil	mg/cm^2-event	1 (NA)	1 (NA)	USEPA, 1992a
PC, Permeability Constant	Groundwater	cm/hour	Chemical-Specific	Chemical-Specific	USEPA, 1992a
AT, Averaging Time Noncarcinogenic	All Media	day	1,460 (NA)	1,460 (NA)	USEPA, 1989
AT, Averaging Time Carcinogenic	All Media	day	25,550	25,550	USEPA, 1989

TABLE 8-9 (Continued)

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR FUTURE MILITARY RESIDENTS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER (POTABLE USE) BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Input Parameter	Media	Units	RME (CT) Input Value		Comments/ References
			Young Child (ages 1-6 yrs)	Adult	
BW, Body Weight	All Media	Kg	15 (NA)	70 (NA)	USEPA, 1989
FI, Fraction Ingested	Soil	unitless	1	1	USEPA, 1989

References:

USEPA, 1995a. Assessing Dermal Exposure from Soil.

USEPA, 1992a. Dermal Exposure Assessment: Principles and Applications - Interim Report.

USEPA, 1991. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors." Interim Final.

USEPA, 1989. Risk Assessment Guidance for Superfund Volume I - Human Health Evaluation Manual (Part A) Interim Final.

USEPA, 1989a. Exposure Factors Handbook.

Notes:

(1) Represents 25% of total body surface area.

(2) Skin surface area available for whole body exposure during bathing and swimming activities.

(3) Average respiration rates estimated for age groups.

(4) The following USEPA Region III default absorbance factors will be applied to estimate dermal intake of COPCs in soil (USEPA, 1995a):

VOCs (Vapor Pressures > 95.2 mmHg) - 0.05%
(Vapor Pressures < 95.2 mmHg) - 3%
SVOCs - 10%
Arsenic - 3.2%
Inorganics - 1%

NA = Not Applicable

TABLE 8-10

REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT) INPUT VALUES FOR FUTURE MILITARY RESIDENTS POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SUBSURFACE SOIL AND GROUNDWATER (NON-POTABLE USE) BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Input Parameter	Media	Units	RME (CT) Input Value		Comments/ References
			Young Child (ages 1-6 yrs)	Adult	
ED, Exposure Duration	All Media	year	4 (NA)	4 (NA)	Professional Judgement
EF, Exposure Frequency	Soil	day/year	350 (350)	350 (350)	USEPA, 1991
	Groundwater	day/year	NA	28[1] (NA)	Professional Judgement
ET, Exposure Time	Groundwater	hours/day	2.6 (NA)	2.6 (NA)	Professional Judgement
IR, Ingestion Rate	Soil	mg/day	200 (100)	100 (50)	USEPA, 1989
	Groundwater	L/day	NA	0.13[2] (NA)	USEPA, 1989
A, Skin Surface Area	Soil	cm^2	2,006[3] (1,744)	5,000[3] (5,000)	USEPA, 1992a
	Groundwater	cm^2	NA	5,000[3] (NA)	USEPA, 1989a
ABS, Absorbance Factor	Soil	NA	Chemical-Specific[4]	Chemical-Specific[4]	USEPA, 1995a
AF, Adherence Factor	Soil	mg/cm^2-event	1 (NA)	1 (NA)	USEPA, 1992a
PC, Permeability Constant	Groundwater	cm/hour	NA	Chemical-Specific	USEPA, 1992a
AT, Averaging Time Noncarcinogenic	All Media	day	1,460 (NA)	1,460 (NA)	USEPA, 1989
AT, Averaging Time Carcinogenic	All Media	day	25,550	25,550	USEPA, 1989
BW, Body Weight	All Media	Kg	15 (NA)	70 (NA)	USEPA, 1989
FI, Fraction Ingested	Soil	unitless	1	1	USEPA, 1989

TABLE 8-10 (Continued)

**REASONABLE MAXIMUM EXPOSURE (RME) AND CENTRAL TENDENCY EXPOSURE (CT)
INPUT VALUES FOR FUTURE MILITARY RESIDENTS
POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL,
SUBSURFACE SOIL AND GROUNDWATER (NON-POTABLE USE)
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269**

References:

USEPA, 1995a. Assessing Dermal Exposure from Soil.

USEPA, 1992a. Dermal Exposure Assessment: Principles and Applications - Interim Report.

USEPA, 1991. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors." Interim Final.

USEPA, 1989. Risk Assessment Guidance for Superfund Volume I - Human Health Evaluation Manual (Part A) Interim Final.

USEPA, 1989a. Exposure Factors Handbook.

Notes:

(1) Assumed activities (primarily car washing) involving non-potable groundwater usage could occur 28 days per year, or 4 times per month during April through October.

(2) Ingestion rate equals 0.05 L/hr for 2.6 hours/day.

(3) Represents 25% of total body surface area.

(4) The following USEPA Region III default absorbance factors will be applied to estimate dermal intake of COPCs in soil (USEPA, 1995a):

VOCs (Vapor Pressures > 95.2 mmHg) - 0.05%
(Vapor Pressures < 95.2 mmHg) - 3%
SVOCs - 10%
Arsenic - 3.2%
Inorganics - 1%

NA = Not Applicable

TABLE 8-11

USEPA WEIGHT-OF-EVIDENCE CATEGORIES FOR POTENTIAL CARCINOGENS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

USEPA Category	Description of Group	Description of Evidence
Group A	Human Carcinogen	Sufficient evidence of carcinogenicity in humans from epidemiological studies to support a casual association between exposure and carcinogenicity.
Group B1	Probable Human Carcinogen	Limited evidence of carcinogenicity in humans from epidemiological studies.
Group B2	Probable Human Carcinogen	Sufficient evidence of carcinogenicity in animals, inadequate or lack of evidence of carcinogenicity in humans.
Group C	Possible Human Carcinogen	Limited evidence of carcinogenicity in animals, inadequate or lack of evidence of carcinogenicity in humans.
Group D	Not classified as to human carcinogenicity	Inadequate evidence of carcinogenicity in animals, inadequate or lack of evidence or carcinogenicity in humans.
Group E	No evidence of carcinogenicity in humans	No evidence or carcinogenicity in at least two adequate animal tests or in both epidemiological and animal studies.

TABLE 8-12

TOXICITY FACTORS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Constituents	Oral CSF (mg/kg/day)$^{-1}$	Inhal. CSF (mg/kg/day)$^{-1}$	Oral RfD (mg/kg/day)	Inhal. RfD (mg/kg/day)	USEPA WOE	Target Organ	Critical Effect
Volatile Organic Compounds:							
Benzene	2.90E-02 (i)	2.90E-02 (i)	--	1.71E-03 (e)	A	Liver & Blood	Neurotoxic Effects
Chloroform	6.10E-03 (i)	8.05E-02 (i)	1.00E-02 (i)	--	B2	Central Nervous System	Effects
Chloromethane	1.30E-02 (h)	6.30E-03 (h)	--	--	C	--	--
1,1-Dichloroethene	6.00E-01 (h)	1.75E-01 (i)	9.00E-03 (i)	--	C	Liver	Lesions
1,1-Dichloroethane	--	--	1.00E-01 (h)	1.43E-01 (a)	C	--	None observed
1,2-Dichlordethene (total)	--	--	9.00E-03 (h)	--	D	Blood	Decreased hematocrit and hemoglobin
1,2-Dichloroethane	9.10E-02 (i)	9.10E-02 (i)	--	2.86E-03 (e)	B2	Circulatory System	Sarcoma
Ethylbenzene	--	--	1.00E-01 (i)	2.86E-01 (i)	D	--	Neurological and respiratory depresseion
Tetrachloroethene	5.20E-02 (e)	2.03E-03 (e)	1.00E-02 (i)	--	B2	Liver	--
Toluene	--	--	2.00E-01 (i)	1.14E-01 (i)	D	Central Nervous System	Effects
1,1,1-Trichloroethane	--	--	9.00E-02 (w)	2.86E-01 (w)	D	Central Nervous System	Effects
1,1,2-Trichloroethane	5.70E-02 (i)	5.60E-02 (i)	4.00E-03 (i)	--	C		Hepatotoxicity; hepatocellular carcinomas

TABLE 8-12 (Continued)

TOXICITY FACTORS
BUILDING LP-20 SITE
BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Constituents	Oral CSF (mg/kg/day)$^{-1}$	Inhal. CSF (mg/kg/day)$^{-1}$	Oral RfD (mg/kg/day)	Inhal. RfD (mg/kg/day)	USEPA WOE	Target Organ	Critical Effect
Trichloroethene	1.10E-02 (w)	6.00E-03 (e)	6.00E-03 (e)	--	B2	Liver	--
Vinyl Chloride	1.90E+00 (h)	3.00E-01 (h)	--	--	A	Lung	Tumors
Semivolatile Organic Compounds:							
Benzo(a)anthracene	7.30E-01 (e)	6.10E-01 (e)	--	--	B2	--	--
Benzo(b)fluoranthene	7.30E-01 (e)	6.10E-01 (e)	--	--	B2	--	--
Benzo(a)pyrene	7.30E+00 (i)	6.10E+00 (w)	--	--	B2	--	--
Dibenz(a,h)anthracene	7.30E+00 (e)	6.10E+00 (e)	--	--	B2	--	--
Bis(2-ethylhexyl)phthalate	1.40E-02 (i)	--	2.00E-02 (i)	--	B2	Liver	Carcinomas and adenomas
Inorganics:							
Aluminum	--	--	1.00E+00 (e)	--	--	--	--
Antimony	--	--	4.00E-04 (i)	--	D	Whole Body/Blood	Increased mortality/altered chemistry
Arsenic	1.50E+00 (i)	1.51E+01 (i)	3.00E-04 (i)	--	A	Skin	Keratosis/ hyperpigmentation
Barium	--	--	7.00E-02	1.43E-04	D	Cardiovascular system	Increased blood pressure
Beryllium	4.30E+00 (i)	8.40E+ 00 (i)	5.00E-03 (i)	--	B2	--	None observed

TABLE 8-12 (Continued)

TOXICITY FACTORS
BUILDING LP-20 SITE
BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Constituents	Oral CSF (mg/kg/day)$^{-1}$	Inhal. CSF (mg/kg/day)$^{-1}$	Oral RfD (mg/kg/day)	Inhal. RfD (mg/kg/day)	USEPA WOE	Target Organ	Critical Effect
Cadmium	--	6.30E+00 (i)	5.00E-04 (i)	--	B1	Renal Cortex	Significant proteinuris
Chromium VI	--	4.20E+01 (i)	5.00E-03 (i)	--	A	--	None observed
Lead	--	--	--	--	B2	--	--
Manganese	--	--	2.40E-02 (i)	1.43E-05 (i)	D	CNS/Lungs	Adverse Effects
Vanadium	--	--	7.00E-03 (h)	--	D	Respiratory Tract	--

Notes:

i = Integrated Risk Information System (IRIS), 1996b
e = Environmental Criteria and Assessment Office (ECAO) (as cited from USEPA, Region III RBC Tables, January - June 1996)
h = Health Effects Assessment Summary Tables (HEAST), 1995b
a = HEAST Alternative Method, 1995b
w = Withdrawn from IRIS or HEAST
o = Other EPA documents
-- = Not available
WOE = Weight of Evidence.

TABLE 8-13

SUMMARY OF DERMALLY-ADJUSTED HEALTH-BASED CRITERIA*
BUILDING LPO-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA

COPCs	Percent Absorbed(1)	Oral RfD mg/kg/d	Oral RfD (Dermally-Adjusted) mg/kg/d	Oral CSF $(mg/kg/d)^{-1}$	Oral CSF (Dermally-Adjusted) $(mg/kg/d)^{-1}$
Volatile Organic Compounds:					
Chloromethane	80%	--	--	1.30E-02	1.62E-02
Vinyl Chloride	80%	--	--	1.90E+00	2.37E+00
1,1-Dichloroethene	80%	9.00E-03	7.20E-03	6.00E-01	7.5E-01
1,1-Dichloroethane	80%	1.00E-01	8.00E-02	--	--
1,2-Dichloroethene (total)	80%	9.00E-03	7.2E-03	--	--
Chloroform	80%	1.00E-02	8.00E-03	6.10E-03	7.62E-03
1,2-Dichloroethene	80%	--	--	9.10E-02	1.14E-01
1,1,1-Trichloroethane	80%	9.00E-02	7.20E-02	--	--
Trichloroethene	80%	6.00E-03	4.80E-03	1.10E-02	1.37E-02
1,1,2-Trichloroethane	80%	4.00E-03	3.2E-03	5.70E-02	7.12E-02
Benzene	80%	--	--	2.90E-02	3.62E-02
Tetrachloroethene	80%	1.00E-02	8.00E-03	5.20E-02	6.5E-02
Toluene	80%	2.00E-01	1.60E-01	--	--
Ethylbenzene	80%	1.00E-01	8.00E-02	--	--
Semivolatile Organic Compounds:					
Benzo(a)anthracene	50%	--	--	7.30E-01	1.46E+00
Benzo(a)pyrene	50%	--	--	7.30E+00	1.46E+01
Benzo(b)fluoranthene	50%	--	--	7.30E-01	1.46E+00
Bis(2-ethylhexyl)phthalate	50%	2.00E-02	1.00E-02	1.40E-02	2.80E-02
Dibenz(a,h)anthracene	50%	--	--	7.30E+00	1.46E+-1
Dibenzofuran	50%	4.00E-03	2.00E-03	--	--
Inorganics:					
Aluminum	20%	1.00E+00	2.00E-01	--	--
Antimony	20%	4.00E-04	8.00E-05	--	--
Arsenic	95%	3.00E-04	2.85E-04	1.50E+00	1.58E+00
Barium	100%	7.00E-02	7.00E-02	--	--
Beryllium	1%	5.00E-03	5.00E-05	4.3	430
Cadmium (water)	5%	5.00E-04	2.50E-05	--	--

TABLE 8-13 (Continued)

SUMMARY OF DERMALLY-ADJUSTED HEALTH-BASED CRITERIA*
BUILDING LPO-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA

COPCs	Percent Absorbed[1]	Oral RfD mg/kg/d	Oral RfD (Dermally-Adjusted) mg/kg/d	Oral CSF $(mg/kg/d)^{-1}$	Oral CSF (Dermally-Adjusted) $(mg/kg/d)^{-1}$
Chromium	20%	5.00E-03	1.00E-03	--	--
Lead	20%	--	--	--	--
Manganese	5%	2.40E-02	1.20E-03	--	--
Vanadium	20%	7.00E-03	1.40E-03	--	--

Notes:

[1] Region III recommended values, Region IV recommended values or other sources (default values are 80% for VOCs, 50% for SVOCs/PCBs/Pesticides, and 20% for Inorganics).

-- = Not applicable
* = Only oral toxicity values were dermally adjusted; inhalation toxicity values were not adjusted. The following equations were used:
Dermally-adjusted RfD = oral RfD*percent absorbed
Dermally-adjusted CSF = oral CSF/percent absorbed

TABLE 8-14

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR CURRENT AND FUTURE MAINTENANCE AND INDUSTRIAL WORKERS REASONABLE MAXIMUM EXPOSURES (RMEs) AND CENTRAL TENDENCY EXPOSURES (CTs)[1] NON-POTABLE USE OF SHALLOW GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Pathway	Receptor	
	Adult Workers	
	HI	ILCR
Shallow Groundwater [2]		
Accidental Ingestion	5.6 (0.14)	5.5×10^{-03} (3.2×10^{-05})
Dermal Contact	39 (16)	2.2×10^{-02} (1.3×10^{-04})
Subtotal	45	2.7×10^{-02}
Surface Soil		
Ingestion	0.11	1.5×10^{-05}
Dermal Contact	0.52	1.3×10^{-04} (6.4×10^{-06})
Inhalation[3]	<0.01	3.3×10^{-08}
Subtotal	0.63	1.4×10^{-04}
Subsurface Soil		
Ingestion	0.05	3.2×10^{-06}
Dermal Contact	0.19	6.7×10^{-05}
Inhalation[3]	--	6.0×10^{-09}
Subtotal	0.24	7.0×10^{-05}
TOTAL	**46**	**2.7×10^{-02}**

Notes:

(1) Values in parentheses represent CT exposure assumptions.
(2) Risk values derived using total (unfiltered) inorganic concentrations.
(3) Fugitive dusts.

TABLE 8-15

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR CURRENT/FUTURE MAINTENANCE AND INDUSTRIAL WORKERS REASONABLE MAXIMUM EXPOSURES (RMEs) AND CENTRAL TENDENCY EXPOSURES (CTs)[1] NON-POTABLE USE OF DEEP GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Pathway	Receptor	
	Adult Workers	
	HI	ILCR
Deep Groundwater[2] Ingestion	0.21	$3.5x10^{-05}$
Dermal Contact	0.52	$7.4x10^{-05}$
Subtotal	0.73	$1.1x10^{-04}$
Surface Soil Ingestion	0.11	$1.5x10^{-05}$
Dermal Contact	0.52	$1.3x10^{-04}$ ($6.4x10^{-06}$)
Inhalation[3]	<0.01	$3.3x10^{-08}$
Subtotal	0.63	$1.4x10^{-04}$
Subsurface Soil Ingestion	0.05	$3.2x10^{-06}$
Dermal Contact	0.19	$6.7x10^{-05}$
Inhalation[3]	--	$6.0x10^{-09}$
Subtotal	0.24	$7.0x10^{-05}$
TOTAL	**1.6**	**$3.2x10^{-04}$**

Notes:

(1) Values in parentheses represent CT exposure assumptions.
(2) Risk values derived using total (unfiltered) inorganic concentrations.
(3) Fugitive Dusts.

TABLE 8-16

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE CONSTRUCTION WORKERS
REASONABLE MAXIMUM EXPOSURES (RMEs) AND CENTRAL TENDENCY EXPOSURES (CTs)[1]
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Pathway	Receptor	
	Adult Workers	
	HI	ILCR
Shallow Groundwater[2]		
Accidental Ingestion	5.6 (0.14)	2.2×10^{-04} (6.4×10^{-06})
Dermal Contact	21 (0.67)	4.7×10^{-04} (1.1×10^{-05})
Subtotal	27	7.1×10^{-04}
Surface Soil		
Ingestion	1.1 (0.26)	5.8×10^{-06}
Dermal Contact	0.52	5.0×10^{-06}
Inhalation[3]	<0.01	2.0×10^{-09}
Subtotal	1.6	1.1×10^{-05}
Subsurface Soil		
Ingestion	0.48	1.2×10^{-06}
Dermal Contact	0.19	2.7×10^{-06}
Inhalation[3]	--	3.6×10^{-10}
Subtotal	0.67	3.9×10^{-06}
TOTAL	**$2.9 \times 10^{+01}$**	**7.2×10^{-04}**

Notes:

(1) Values in parentheses represent CT exposure assumptions.
(2) Risk values derived using total (unfiltered) inorganic concentrations.
(3) Fugitive Dusts.

TABLE 8-17

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE ADULT AND YOUNG CHILD (AGES 1-6 YRS) MILITARY RESIDENTS REASONABLE MAXIMUM EXPOSURES (RMEs) AND CENTRAL TENDENCY EXPOSURES (CTs)[1]
POTABLE USE OF SHALLOW GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Pathway	Receptors			
	Adults		Children (1-6 yrs)	
	HI	ILCR	HI	ILCR
Shallow Groundwater[2]				
Ingestion	310 (5.2)	5.0×10^{-02} (8.2×10^{-04})	730 (17)	1.2×10^{-01} (9.9×10^{-02})
Dermal Contact	11 (0.12)	9.8×10^{-04} (2.1×10^{-05})	20 (0.19)	1.8×10^{-03} (3.4×10^{-05})
Inhalation[3]	45 (0.68)	2.7×10^{-02} (5.7×10^{-04})	210 (3.2)	1.4×10^{-01} (2.6×10^{-03})
Subtotal	370	7.8×10^{-02}	960	2.6×10^{-01}
Surface Soil				
Ingestion	0.32	6.8×10^{-06}	3.0 (0.35)	6.4×10^{-05}
Dermal Contact	0.89	3.4×10^{-05}	1.7 (0.41)	6.4×10^{-05}
Subtotal	1.2	4.1×10^{-05}	4.7	1.3×10^{-04}
Subsurface Soil				
Ingestion	0.14	1.4×10^{-06}	1.3 (0.49)	1.3×10^{-05}
Dermal Contact	0.33	1.8×10^{-05}	0.62	3.4×10^{-05}
Subtotal	0.47	1.9×10^{-05}	1.9	4.7×10^{-05}
TOTAL	**370**	**7.8×10^{-02}**	**970**	**2.6**

Notes:

(1) Values in parentheses represent CT exposure assumptions.
(2) Risk values derived using dissolved (filtered) inorganic concentrations.
(3) Shower model; Foster and Chrostowski, 1987.

TABLE 8-18

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE ADULT AND YOUNG CHILD (AGES 1-6 YRS) MILITARY RESIDENTS REASONABLE MAXIMUM EXPOSURES (RMEs) AND CENTRAL TENDENCY EXPOSURES (CTs)[1]
POTABLE USE OF DEEP GROUNDWATER
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK, VIRGINIA
CONTRACT TASK ORDER 0269

Pathway	Receptors			
	Adults		Children (1-6 yrs)	
	HI	ILCR	HI	ILCR
Deep Groundwater[2]				
Ingestion	6.4 (1.0)	2.1×10^{-04} (4.7×10^{-05})	15 (3.5)	5.0×10^{-04} (1.6×10^{-04})
Dermal Contact	0.10	3.1×10^{-06}	0.19	5.8×10^{-06}
Inhalation[3]	0.89	8.4×10^{-05}	4.2 (2.4)	3.9×10^{-04} (1.6×10^{-04})
Subtotal	7.4	3.0×10^{-04}	19	9.0×10^{-04}
Surface Soil				
Ingestion	0.32	6.8×10^{-06}	3.0 (0.35)	6.4×10^{-05}
Dermal Contact	0.89	3.4×10^{-05}	1.7 (0.41)	6.4×10^{-05}
Subtotal	1.2	4.1×10^{-05}	4.7	1.3×10^{-04}
Subsurface Soil				
Ingestion	0.14	1.4×10^{-06}	1.3 (0.49)	1.3×10^{-05}
Dermal Contact	0.33	1.8×10^{-05}	0.62	3.4×10^{-05}
Subtotal	0.47	1.9×10^{-05}	1.9	4.7×10^{-05}
TOTAL	**9.1**	**3.6×10^{-04}**	**26**	**1.1×10^{-03}**

Notes:

(1) Values in parentheses represent CT exposure assumptions.
(2) Risk values derived using dissolved (filtered) inorganic concentrations.
(3) Shower model; Foster and Chrostowski, 1987.

TABLE 8-19

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE ADULT AND YOUNG CHILD (AGES 1-6 YRS) MILITARY RESIDENTS REASONABLE MAXIMUM EXPOSURES (RMEs) AND CENTRAL TENDENCY EXPOSURES[1] NON-POTABLE USE OF SHALLOW GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Pathway	Receptors			
	Adults		Children (1-6 yrs)	
	HI	ILCR	HI	ILCR
Shallow Groundwater[2]				
Ingestion	1.6 (0.06)	2.5×10^{-04} (9.1×10^{-06})	NA	NA
Dermal Contact	2.8 (0.04)	2.6×10^{-04} (8.2×10^{-06})	NA	NA
Subtotal	4.4	5.1×10^{-04}	NA	NA
Surface Soil				
Ingestion	0.32	6.8×10^{-06}	3.0 (0.35)	6.4×10^{-05}
Dermal Contact	0.89	3.4×10^{-05}	1.7 (0.41)	6.4×10^{-05}
Subtotal	1.2	4.1×10^{-05}	4.7	1.3×10^{-04}
Subsurface Soil				
Ingestion	0.14	1.4×10^{-06}	1.3 (0.49)	1.3×10^{-05}
Dermal Contact	0.33	1.8×10^{-05}	0.62	3.4×10^{-05}
Subtotal	0.47	1.9×10^{-05}	1.9	4.7×10^{-05}
TOTAL	**6.1**	**5.7×10^{-04}**	**6.6**	**1.8×10^{-04}**

(1) Values in parentheses represent CT exposure assumptions.
(2) Risk values derived using dissolved (filtered) inorganic concentrations.
NA = Not applicable

TABLE 8-20

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE ADULT AND YOUNG CHILD (AGES 1-6 YRS) MILITARY RESIDENTS REASONABLE MAXIMUM EXPOSURES (RMEs) AND CENTRAL TENDENCY EXPOSURES[1] NON-POTABLE USE OF DEEP GROUNDWATER BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

Pathway	Receptors			
	Adults		Children (1-6 yrs)	
	HI	ILCR	HI	ILCR
Deep Groundwater				
Ingestion	0.038	$1.3x10^{-06}$	NA	NA
Dermal Contact	0.38	$1.0x10^{-05}$	NA	NA
Subtotal	0.42	$1.2x10^{-05}$	NA	NA
Surface Soil				
Ingestion	0.32	$6.8x10^{-06}$	3.0 (0.35)	$6.4x10^{-05}$
Dermal Contact	0.89	$3.4x10^{-05}$	1.7 (0.41)	$6.4x10^{-05}$
Subtotal	1.2	$4.1x10^{-05}$	4.7	$1.3x10^{-04}$
Subsurface Soil				
Ingestion	0.14	$1.4x10^{-06}$	1.3 (0.49)	$1.3x10^{-05}$
Dermal Contact	0.33	$1.8x10^{-05}$	0.62	$3.4x10^{-05}$
Subtotal	0.47	$1.9x10^{-05}$	1.9	$4.7x10^{-05}$
TOTAL	**2.1**	**$7.2x10^{-05}$**	**6.6**	**$1.8x10^{-04}$**

(1) Values in parentheses represent CT exposure assumptions.
(2) Risk values derived using dissolved (filtered) inorganic concentrations.
NA = Not applicable

TABLE 8-21

SUMMARY OF UNCERTAINTIES IN THE RESULTS OF THE HUMAN HEALTH ASSESSMENT BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

	Potential Magnitude for Over-Estimation of Risks	Potential Magnitude for Under-Estimation of Risks	Potential Magnitude for Over or Under-Estimation of Risks
Environmental Sampling and Analysis Sufficient samples may not have been taken to characterize the media being evaluated.			Low
Systematic or random errors in the chemical analysis may yield erroneous data.			Low
Surface soil, subsurface soil and groundwater samples were not analyzed for pesticides and PCBs.		Low	
Selection of COPCs The use of USEPA Region III COPC screening concentrations in selecting COPCs in soil, groundwater, air, and sediments.			Low
Exposure Assessment The standard assumptions regarding body weight, exposure period, life expectancy, population characteristics, and lifestyle may not be representative of the actual exposure situations.			Moderate
The use of the 95th percentile upper confidence level data ion the estimation of the RME.	Moderate		
Assessing future residential property use when the likelihood of residential development is low.	High		
The amount of media intake is assumed to be constant and representative of any actual exposure.			Low

TABLE 8-21 (Continued)

SUMMARY OF UNCERTAINTIES IN THE RESULTS OF THE HUMAN HEALTH ASSESSMENT BUILDING LP-20 SITE NAVAL BASE, NORFOLK, VIRGINIA CONTRACT TASK ORDER 0269

	Potential Magnitude for Over-Estimation of Risks	Potential Magnitude for Under-Estimation of Risks	Potential Magnitude for Over or Under-Estimation of Risks
Toxicological Assessment Toxicological indices derived from high dose animal studies, extrapolated to low dose human exposure.	Moderate		
Lack of promulgated toxicological indices for inhalation pathway.		Low	
Risk Characterization Assumption of additivity in the quantitation of cancer risks without consideration of synergism, antagonism, promotion and initiation.			Moderate
Assumption of additivity in the estimation of systemic health effects without consideration of synergism, antagonism, etc.			Moderate
Additivity of risks by individual exposure pathways (dermal and ingestion and inhalation).			Low
Additivity of risks estimated for surface soil and subsurface soil exposures.	Low		
Compounds not quantitatively evaluated.		Low	

Notes:

Low - Assumptions categorized as "low" may effect risk estimates by less than one order of magnitude.

Moderate - Assumptions categorized as "moderate" may effect estimates of risk by between one and two orders or magnitude.

High - Assumptions categorized as "high" may effect estimates of risk by more than two orders of magnitude.

Source: Risk Assessment Guidance for Superfund, Volume 1, part A: Human Health Evaluation Manual. USEPA, 1989.

9.0 SUMMARY OF FINDINGS

Site history, previous investigations, and RI findings confirm that contamination from past activities in the vicinity of Building LP-20 have impacted soil and groundwater (shallow water table aquifer and Yorktown Aquifer). The primary constituents of concern in soils are SVOCs and metals. The primary constituents of concern in groundwater are VOCs, although, SVOCs and inorganic compounds were also detected. Table 9-1 presents a summary of RI findings. Soil and groundwater contamination is attributed to several sources/past activities.

- Past storage and distribution systems for a variety of petroleum products such as gasoline, waste oils, and aviation fuels (JP-5) are known to have leaked at various locations.

- Past storage and disposal of chemical solvents used in cleaning, painting, and metal plating operations performed in the Building LP-20 area where poor practices or accidents resulted in leaks or spills

- Accidental releases of waste fluids via breaks in the IWS caused during construction activities in the area.

9.1 Soils

VOCs, SVOCs, and metals attributable to past storage and disposal practices and incidents have been confirmed in surface and subsurface soils collected in the following areas:

- The vicinity of Building LP-20
- North of Building LP-26 near Bellinger Boulevard
- The vicinity of Building V-147
- Near the intersection of Bellinger Boulevard and Aircraft Tow Way.

TCE, PAHs, beryllium, antimony, aluminum, and arsenic were predominant in surface soils. Acetone, TCE, 1,2-DCE (total), PAHs, aluminum, antimony, arsenic, beryllium, iron, and manganese were present in significant concentrations in site subsurface soils.

Available evidence suggests that contaminants in the four above areas defined are attributable to unrelated incidents/activities. The majority of the metal concentrations detected are likely naturally occurring.

9.2 Shallow Aquifer

The shallow aquifer has been impacted by past activities/occurrences. Two separate contaminant plumes are present:

- A chlorinated solvent plume is located in the vicinity of Buildings LP-20 and LP-26. This plume extends north of Bellinger Boulevard and east of Building LP-14, and consists of three major contaminants: vinyl chloride (maximum - 15,000 μg/L), 1,2-DCE (total) (28,000 μg/L), and TCE (44,000 μg/L).

- A petroleum (benzene) contamination plume (including smaller areas of free product) extends north from Building LP-176 to Bellinger Boulevard and east from Building LP-22 to Building LP-14.

Other areas of solvent and petroleum contamination were detected in the vicinity of Building LP-13 and the LP Fuel Farm, respectively. However, these areas of contamination are not associated with the Building LP-20 site.

The physical nature of the contaminants (specific gravity) and the geologic conditions of the site (coarse sands and a confining clay layer) have influenced the contaminant distribution patterns. The clay layer beneath the site, in conjunction with a medium- to coarse-grained sand zone, appears to have created preferential pathways for the contaminants to migrate away from apparent source areas. Suspected scouring of the clay layer, which has created a "bowl" configuration, appears to be causing VOCs to accumulate in the area north of Bellinger Boulevard, but may be inhibiting the contaminants from migrating farther north of the Aircraft Tow Way. A fairly sharp "drop" in the clay surface near Building LP-14 also appears to be providing a pathway for the plume to migrate eastward; however, the eastern extent of contamination in the vicinity of LP-14 was not fully defined during this investigation.

In the area near Buildings LP-13 and LP-14, both solvent and petroleum plumes are present. An evaluation of the vertical distribution of the contamination indicate that the DNAPL contaminants have migrated toward the base of the shallow aquifer. Therefore, the contaminants appear to migrate beneath the Bousch Creek Culvert and likely provide a limited influence to the surface water quality within the culvert. At this time, it is not understood if and to what degree the separate-phase petroleum contaminants are also influencing the surface water quality within the culvert.

Distribution of SVOCs was irregular over the central portion of the site. Generally, SVOCs were detected in low concentrations or absent in the wells sampled on the periphery of the site. The SVOC detected in the highest concentration was bis(2-ethylhexyl)phthalate (100 μg/L). Other SVOCs such as naphthalene and phenol were typically detected at concentrations less than 5.0 μg/L.

Although concentrations of metals such as aluminum, calcium, iron, magnesium, manganese, potassium, and sodium are elevated in comparison to applicable standards, there is no evidence to suggest that these metals are not naturally occurring. In fact, the metals concentrations of these constituents were consistent with those quantified during recently completed Camp Allen Landfill and CD Landfill remedial investigations, suggesting NAVBASE-wide shallow aquifer conditions.

Arsenic, aluminum, and vanadium appear to be distributed over the entire study area. Cadmium contamination appears as an elongated plume between Buildings LP-24 and LP-20 (most likely the result of breaks in the IWS lines). Chromium was found in two separate plumes; a large plume extending from just northeast of Building LP-20 to beyond Aircraft Tow Way and a smaller plume between Buildings LP-20 and LP-24. Lead is present in shallow groundwater in the vicinity of Building LP-20; however, distribution of lead east of the site has not been defined. The presence of lead in groundwater may be the result of leaking underground storage tanks which may have contained leaded gasoline. Antimony was found in two separate plumes; a large plume extending from west of Building LP-20 to beyond the Bousch Creek culvert and a smaller plume between Bellinger Boulevard and Aircraft Tow Way. Beryllium was detected in three separate areas over the site; west of Building LP-20, north of Building LP-26, and west of Building LP-14.

Aquifer test results indicate that the water table aquifer is very productive. Therefore, multiple recovery wells would be required to remediate or contain the contamination plume. Pretreatment

will be required to reduce the high iron concentrations present in the event that a groundwater recovery system is selected as the remediation alternative.

9.3 Yorktown Aquifer

VOCs were detected in six of the nine monitoring wells installed into the upper portion of the Yorktown Aquifer. Predominant contaminants include vinyl chloride, TCE, 1,2-DCE (total), and benzene. The horizontal and vertical extent of contamination is relatively defined as shown on Figure 6-10. Contamination is associated with past activities performed in the vicinity of Building LP-20 and not from an off-site source. Several possible factors may have attributed to the presence of contaminants in the lower aquifer:

- Contaminants from the shallow aquifer have migrated through the clay layer (which could be breached in places or semi-confined) and into the Yorktown Aquifer.

- Contaminant migration may have been aided by construction methods (support piles) used during expansion of the area.

Inorganics such as iron, manganese, and sodium were present in concentrations that exceeded water quality criteria. However, due to the local marine environment, the presence of aluminum, calcium, iron, magnesium, manganese, potassium and sodium may simply reflect natural conditions. Other metals (arsenic, chromium, lead, and vanadium) are not present in sufficient concentration to determine whether the Yorktown Aquifer has been impacted by inorganic contaminants.

9.4 Risk Assessment

Various dermal, inhalation, and ingestion exposure pathways associated with soil and groundwater contamination were developed as part of the risk assessment (RA) evaluation. The potential receptors evaluated were: current/future maintenance and industrial workers; future construction workers; and future adult and child (ages 1-6 years) military residents.

9.4.1 Current/Future Maintenance and Public Works Workers

Shallow Groundwater

Current/future maintenance and industrial workers exposed to shallow groundwater exhibited a total ILCR of 2.7×10^{-02} which exceeds USEPA's target cancer risk range. The carcinogenic constituents contributing most predominantly to accidental ingestion and dermal contact risk were vinyl chloride and 1,1-DCE. Current/future maintenance and industrial workers exposed to shallow groundwater also exhibited a total HI of 45, which exceeds unity, indicating that adverse noncarcinogenic effects may occur. The noncarcinogenic constituents contributing most predominantly to both accidental ingestion and dermal contact HIs were 1,2-DCE (total) and trichloroethene.

Deep Groundwater

Current/future maintenance and industrial workers exposed to carcinogenic COPCs in deep groundwater exhibited a total ILCR of 1.1×10^{-04}. Constituents contributing most predominantly to the accidental ingestion and dermal risks were arsenic and vinyl chloride. No unacceptable noncarcinogenic risks were estimated for non-potable deep groundwater exposures to this receptor group.

Soil

Current/future maintenance and industrial workers contacting surface soil exhibited a total ILCR of 1.4×10^{-04} with the dermal pathway being associated with most risk. The COPCs associated with most risk were beryllium, arsenic and benzo(a)pyrene. No unacceptable subsurface soil risks were estimated for this receptor group.

9.4.2 Future Construction Workers

Shallow Groundwater

Future construction workers accidentally exposed to carcinogenic COPCs in shallow groundwater exhibited a total ILCR of 7.1×10^{-04}. The constituents contributing most predominantly to accidental ingestion and dermal risks were vinyl chloride and 1,1-DCE. Future construction workers exposed to noncarcinogenic COPCs in shallow groundwater exhibited a total HI of 27. The constituents contributing most predominantly to the HI for both the accidental ingestion and dermal pathways were 1,2-DCE (total) and TCE.

Soil

Future construction workers exposed to noncarcinogenic COPCs in surface soil via accidental ingestion exhibited a total HI of 1.1. The COPCs contributing most predominantly to this HI value were arsenic, antimony and manganese. Since the HQs estimated for these metals were less than unity, and since they target different organs, it is unlikely that adverse systemic effects would occur to this receptor subsequent to surface soil exposure. No unacceptable carcinogenic risks were estimated for surface soil exposures to this receptor group. In addition, no unacceptable carcinogenic or noncarcinogenic subsurface soil risks were estimated for this receptor group.

9.4.3 Future On-Site Adult and Child (Ages 1-6 Years) Military Residents

Although future residential development of Building LP-20 Site is highly unlikely, a future military resident scenario was evaluated in the event that the building be used for base housing . This exposure scenario is purely hypothetical for purposes of conservative estimates only. Since most of the site is currently covered with concrete and asphalt, it was assumed that future residents may be exposed to small areas of soil in the event that some of the pavement be removed. Potable use of shallow and deep groundwater was evaluated for the sake of conservatism.

Shallow Groundwater - Potable Use

Future adult residents exposed to carcinogenic COPCs in shallow groundwater used for potable purposes exhibited a total ILCR of 7.8×10^{-02}. The constituent contributing most predominantly to ingestion risk was vinyl chloride. The carcinogenic COPCs associated with most risk for both the dermal and inhalation pathways were vinyl chloride and 1,1- DCE. Ingestion, dermal and inhalation exposures to noncarcinogenic COPCs in shallow groundwater resulted in a total HI of 370. The constituents contributing most predominantly to both ingestion and dermal contact HIs were trichloroethene and 1,2-DCE (total). The major contributor to inhalation risk was benzene.

Future resident children exposed via ingestion, dermal and inhalation pathways to carcinogenic COPCs in shallow groundwater exhibited a total ILCR of 2.6×10^{-01}. The COPC contributing the most predominantly to ingestion risk was vinyl chloride. The constituents associated with most risk for both the dermal and inhalation pathways were vinyl chloride and 1,1-DCE. Ingestion, dermal and inhalation exposures to noncarcinogenic COPCs in shallow groundwater resulted in a total HI of 960. The constituents contributing most predominantly to ingestion and dermal contact HIs were trichloroethene and 1,2-DCE (total). Benzene was the major contributor to inhalation risk.

Deep Groundwater - Potable Use

Future resident adults and children exposed to carcinogenic COPCs in deep groundwater, via ingestion and inhalation, exhibited total ILCRs of 3.0×10^{-04} and 9.0×10^{-04}, respectively. The constituents contributing most predominantly to risk for both adults and children were vinyl chloride and arsenic. Ingestion and inhalation exposures to noncarcinogenic COPCs in deep groundwater resulted in total HIs of 7.4 and 19 to adults and children, respectively. The COPCs contributing most predominantly to the HIs were 1,2-DCE (total), benzene and arsenic.

Shallow and Deep Groundwater - Non-Potable Use

Since it is unlikely that groundwater will ever be used for potable purposes, future resident adults were also evaluated under shallow and deep groundwater non-potable use scenarios. Future adult residents exposed to carcinogenic COPCs in shallow groundwater via a non-potable use scenario exhibited a total ILCR of 5.1×10^{-04}. The COPCs contributing most predominantly to ingestion and

dermal risk were vinyl chloride, and 1,1-DCE, respectively. Exposures to noncarcingenic COPCs in shallow groundwater during non-potable uses resulted in a total HI of 4.4. The constituents contributing most predominantly to ingestion and dermal HIs were TCE and 1,2-DCE (total).

At deep monitoring well location LPMW8, all ILCRs and HIs estimated for non-potable use were within USEPA's acceptable risk criteria.

Surface Soil

Future adult military residents exposed to noncarcinogenic COPCs in surface soil exhibited a total HI of 1.2. Neither the HI estimated for the ingestion pathway (HI = 0.32) or that estimated for the dermal pathway (HI = 0.89) exceed unity. Arsenic ,antimony and manganese were the COPCs contributing most predominantly to the both the ingestion and dermal HIs. Since the ingestion and dermal HQs estimated for each of these metals are less than unity and are non-additive (due to different target organs), and due to the conservative nature of the exposure assumptions employed in estimating risks for these scenarios, it is unlikely that adverse systemic effects will occur following exposure to surface soil by adult residents.

Future child residents exposed to carcinogenic COPCs in surface soil, via ingestion and dermal contact, exhibited a total ILCR of 1.3×10^{-04}. The major contributor to ingestion risk was arsenic. The COPCs contributing most predominantly to dermal risk were beryllium, arsenic and benzo(a)pyrene. Ingestion and dermal exposures to noncarcinogenic COPCs in surface soil resulted in a total HI of 4.7, with arsenic, antimony and manganese contributing the most predominantly to the total HI. However, since the HQs for antimony and manganese are less than unity and are non-additive, any adverse systemic effects following exposure would only be expected from arsenic.

Subsurface Soil

Future resident children exposed to subsurface soil exhibited a total HI of 1.9 with the HI for the ingestion pathway exceeding 1.0. Antimony, arsenic and aluminum were the constituents contributing most predominantly to the ingestion HI.

9.4.4 Overall Summary

Based on evaluation of the above receptors and exposure pathways, the COPCs that were major percent contributors, by medium include:

Shallow Groundwater

Vinyl chloride

1,1-DCE

1,2-DCE (total)

TCE

Benzene

Deep Groundwater

Arsenic

Vinyl Chloride

Benzene

1,2-DCE (total)

Surface Soil

Beryllium

Arsenic

Benzo(a)pyrene

Subsurface Soil

None

SECTION 9.0
TABLES

TABLE 9-1

SUMMARY OF REMEDIAL INVESTIGATION FINDINGS
BUILDING LP-20 SITE
NAVAL BASE, NORFOLK VIRGINIA
CONTRACT TASK ORDER 0269

Media	Primary Contaminants	Location
Shallow Soil	VOCs: Trichloroethene	Between Buildings LP-20 and LP-26
	SVOCs: Benzo(a)pyrene Benzo(a)anthracene, Benzo(b)fluoranthene, and Dibenz(a,h)anthracene	Between Buildings LP-20 and LP-26 North of Bellinger Boulevard
	Metals: Antimony Aluminum, Arsenic, Beryllium, and Manganese	North of Building LP-26 Between Building V-52 and V-117 Site-wide distribution
Deep Soil	VOCs: Acetone, Trichloroethene, and 1,2-Dichloroethene (total)	Between Buildings LP-20 and LP-26 and north of Bellinger Boulevard
	SVOCs: Benzo(a)anthracene, Benzo(b)fluoranthene, Dibenz(a,h)anthracene and Benzo(a)pyrene	Adjacent to Building V-147
	Metals: Aluminum, Antimony, Arsenic and Beryllium	Adjacent to Building LP-20 and north of Building V-147
Shallow Groundwater (Columbia Aquifer)	VOCs: Vinyl Chloride, Trichloroethene, and 1,2-Dichloroethene (total) Benzene	Adjacent to Buildings LP-20 and LP-26 and north of Bellinger Boulevard North from LP-176 to Bellinger Boulevard and east from Buildings LP-22 to LP-14
	Metals: Antimony, Arsenic, Beryllium, Cadmium, Chromium, Lead Aluminum and Vanadium	Building LP-20 and vicinity Site-wide distribution
Deep Groundwater (Yorktown Aquifer)	VOCs: Vinyl Chloride, Trichloroethene, and 1,2-Dichloroethene (total) Benzene	Adjacent to Building LP-20 West of Building LP-24
	Metals: Aluminum, Arsenic, Chromium, Lead, and Vanadium	Adjacent to Building LP-20 and west of Building LP-24

Notes:

VOCs = Volatile organic compounds
SVOCs = Semivolatile organic compounds

10.0 DATA LIMITATIONS

In general, the data collected during the RI have sufficiently characterized near-surface and subsurface soil and groundwater in the water table and Yorktown aquifers in the vicinity of Building LP-20. However, certain data limitations have been recognized subsequent to evaluation of existing and newly generated information. Note that the site has been characterized according to the constraints of the original scope of work and subsequent addendums to the scope of work, which targeted the investigation to focus on Building LP-20 and its immediate proximity.

The following briefly summarizes areas of realized data limitations.

- Soils - The investigation was limited to the area in the immediate vicinity of Building LP-20 west of the Bousch Creek Culvert; therefore, horizontal extent of soil contamination east of the culvert in the vicinity of Buildings LP-13 and LP-14 has not been fully determined.

- Groundwater - Both the shallow (water table) aquifer and the Yorktown Aquifer beneath Building LP-20 appear to have been adversely impacted by past activities/incidents. However, several adjacent impacted areas outside the limits of this investigation have also been identified, but may not have been fully characterized:

  - South and west of Building U-132 - extent of VOC contamination has not been defined south and west of this location.

  - East of Building LP-14 - The eastern extent of contamination identified in the vicinity of LP-14 has not been fully defined. TCE and 1,2-DCE (total), with specific gravities greater than 1.0, tend to migrate vertically within a saturated zone. Because the clay layer in this area was encountered at a lower elevation (50 feet bgs), contamination could potentially extend farther east below the zone monitored by well MW-46 (VOCs were not detected, but could be present beneath the screened interval of this well).

- South of Building LP-13 - Previous groundwater sampling indicates elevated VOCs in this area. These contaminants do not appear to be related to the main VOC plume associated with Building LP-20.

- Yorktown Aquifer - Because two monitoring wells (LP-20MW-7 and LP-20MW-14) located south and north of Building LP-20 had detected concentrations of VOCs, the full horizontal extent of organic contaminants was not defined.

- Surface water and sediment - A surface water/sediment investigation was not included in the original scope of work because surface water is not present at the site. However, contaminants may impact local storm drains and/or the Bousch Creek Culvert which extends north/south beneath the site. The degree of impact of groundwater contaminants in Bousch Creek might depend, in part, on the tidal cycle and integrity of the structure.

  Surface water and sediment in Willoughby Bay at the Bousch Creek outfall will be characterized during a separate pending study associated with the Camp Allen Landfill Site. Depending upon the findings of that study regarding conditions in Bousch Creek, expanded investigation of surface water and sediments within the subsurface drainage system may be warranted.

11.0 RECOMMENDATIONS

The Building LP-20 Site has been sufficiently characterized to complete the next phase of the process - the Feasibility Study. Specific limitations to site data were noted in Section 10. Primary among these is the incomplete characterization of the horizontal extent of contaminants within the shallow aquifer detected east of the site (near Building LP-14).

Although the horizontal extent of contamination in the Yorktown Aquifer is not fully established, the aquifer has been investigated sufficiently to complete the FS. Therefore, further investigations of the Yorktown Aquifer are not recommended.

It is suggested that the recognized data limitations (extent of VOC contamination east of the site) be re-evaluated subsequent to the FS for inclusion (as appropriate) in a Pre-Design stage of the Remedial Design.

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