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LETTER TRANSMITTING FINAL REMEDIAL INVESTIGATION REPORT (REDLINE/STRIKEOUT VERSION FOR REVIEW PURPOSES) AND RESPONSE TO COMMENTS FIREFIGHTER TRAINING AREA, LIGHTER AMPHIBIOUS RESUPPLY CARGO (LARC) 60 MAINTENANCE AREA, AND AUTO CRAFT AREA FORT STORY VA
5/23/2002
MALCOLM PIRNIE

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MALCOLM PIRNIE, INC.
INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS & CONSULTANTS

May 23, 2002

Mr. Daniel S. Musel
Remedial Project Manager
U.S. Army Transportation Center
Building 1407, ATZF-PWE
Fort Eustis, Virginia 23604-5332

Re: Final Remedial Investigation Report
Redline/Strikeout Version for Review
Fort Story Sites
Contract DACA31-94-D-0017, D.O.s 17, 20, and 24

Dear Mr. Musel:

Malcolm Pirnie is pleased to provide to Fort Eustis this **Final Remedial Investigation Report** (Redline/Strikeout Version for Review Purposes) and responses to comments (one copy enclosed) for the FTA, LARC 60, and Auto Craft sites at Fort Story, Virginia. Please review the enclosed report and comments and provide us with any recommended changes so that we revise and submit to VDEQ.

We have also enclosed a copy of the Final QCS/AR Addendum for the 2000 sampling event for your review and comment.

It has been a pleasure to provide this document to Fort Eustis. We look forward to further discussions relative to this project.

Very truly yours,

MALCOLM PIRNIE, INC.

Anthony K. Pace
Project Manager

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Enclosures

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RECYCLED PAPER

Comment on the draft "Remedial Investigation Report Firefighter Training Area, LARC 60 Maintenance Area, Auto Craft Building Area, Fort Story" December, 1995.

1. Page 2-10: Section 2.2.10 Investigation Derived Waste Management-Please find attached the Department of Environmental Quality Policy regarding investigation derived wastes.

2. Page 2-14: The PA/SI for several sites included in this RI indicated that pesticides or PCBs were detected. This class of compounds were not evaluated in the RI. Some explanation should be provided as to the reason for not evaluating the pesticide/PCB fraction in this RI. Comments on the ecological risk will also address this point.

3. Page 2-18: It is noted that samples were not collected north of the site. In a comment provided by the staff in October, 1991 it was suggested that the area north of the site be further investigated, even though the contaminant levels were low. Some additional discussion of the determination not to sample in the north area seems appropriate.

4. Page 3-1: Physical Characteristics. This section states that the land features at Fort Story consist of sand ridges, sand flats, and wetland areas. These areas as well as the Chesapeake Bay and Atlantic Ocean are all potential targets and should be addressed in an ecological assessment.

5. Page 3-2, Section 3.1.3: This section states that "surface water on Fort Story is conveyed by drainage ditches or storm water lines to the Chesapeake Bay on the northwestern portion of the facility, to the Atlantic ocean on the northeast portion of the base, to wetland areas adjacent to Broad Bay on the southern portion of the facility". These areas are all potential targets and need to be addressed in an ecological assessment with sampling results included and continued monitoring.

6. Page 3-10: It is not clear why no inorganic analyses were performed for the upgradient well at the Firefighter Training Area.

7. Page 3-11: The first paragraph on this page indicates that arsenic was not detected in the upgradient wells. However, the table on the previous page indicates an arsenic concentration of 40.01 mg/L in well MW-118. The data validation summary table indicates that arsenic was undetected at this well. Please clarify.

8. Page 3-12: Section 3.1.6. Ecology-This section should address fauna as well as flora. It is difficult, or impossible, to know if receptors are exposed to the contaminated media when it is unknown what potential receptors exist on or near the sites. It is recommended that a species inventory be performed at Fort Story to establish potential receptors. Performing site specific inventories would not account for terrestrial animals that range over larger areas.

9. Page 4-1: Section 4 Nature and Extent of Contamination-The results of the quality assurance checks by the U.S. Army Corps of Engineers New England Division (NED) Laboratory should be provided and discussed.

10. Page 4-1: Section 4.1.1 Definition of ARARs-Attached is a preliminary identification of Commonwealth of Virginia ARARs. This information identifies state statutes and regulations which may serve as ARARs. As the site proceeds to the feasibility phase these ARARs may be refined or expanded.

11. Page 4-6: Section 4.3.1 Surface and Subsurface Soils-Is access to this site(s) sufficiently restricted to justify the use of the industrial soil screening criteria?

12. Table 4-5: Fire Training Pit Soils Data-Volatile Organic Compounds. The concentration of acetone in SB04-022 may be sufficient to result in transfer from soil to groundwater.

13. Table 4-5: The concentrations of fluoranthene and pyrene at all sampled soils levels in SB04-022 exceed the Biological Technical Assistance Group (BTAG) screening levels for ecological risk (100 ppb for fluoranthene and pyrene).

14. Table 4-5: The total metals data indicate that levels of arsenic in several soil samples at the Fire Training Pit exceed the EPA Region III Risk Based Concentration (RBC) for residential soils.

15. Table 4-5: From an ecological risk perspective chromium, copper, lead and zinc may pose some concern at the Fire Training Pit and should be compared to the BTAG screening levels.

16. Table 4-6: Fire Training Area-Sediment. The concentration of lead exceeds the BTAG screening level for ecological risk in SD04-001.

17. Page 4-16: Fire Training Area-Groundwater. It is indicated that vinyl chloride concentrations detected by onsite methods could not be confirmed by offsite lab analysis. How

did the New England Division Lab data compare to the onsite lab and the Savannah Lab? Vinyl chloride is a degradation product of perchloroethylene (PCE) and trichloroethylene (TCE) and could be present in future samples even if not confirmed at this time.

18. Page 4-20: This section of the report mentions a change in flow direction from previous determinations. Does this statement relate to the issue in the PA/SI on pages 2-37 and 2-38 concerning a groundwater divide? Please clarify.

19. Table 4-9: Soil Results for the LARC 60 Area. While the data indicate the concentrations are less than the industrial screening level, some consideration should be given to the residential level proposed by EPA since Fort Story is not a restricted access Area. This issue of residential versus industrial will be addressed in the risk assessment section.

20. Table 4-9: Levels of methylene chloride greater than 10 ppb would have the potential to transfer from soil to groundwater. A number of soil boring samples contained methylene chloride concentrations greater than this level and the impact on groundwater should be discussed. The levels of TCE in several samples were also at concentrations at which groundwater would be impacted. Please address TCE in the discussion.

21. Table 4-9: The levels of arsenic in SB06-001 (0-1 ft) and (5 -7 ft) exceed the EPA region III RBC for residential exposure in soil of 0.37 mg/kg.

22. Page 4-23: Twenty-nine soil samples had total petroleum hydrocarbons as heavy oils at concentrations greater than the screening level of 100 mg/kg. What is the impact of these concentrations on the site?

23. Table 4-11: Surface Water Results. The surface water data should be compared to Virginia's Surface Water Standards VR 680-21-00, May 20, 1992.

24. Table 4-12: The groundwater data in Table 4-12 indicates tetrachloroethene (PCE) and trichloroethene (TCE) have MCLs of 5 ppb. Concentrations of PCE and TCE in MW-117 exceed the 5 ppb MCL. Please discuss the impact of these compounds.

25. Table 4-12: The concentrations of total and dissolved arsenic in MW-117 exceeds the Virginia Groundwater Standard as well as the EPA Region III RBC. This should be addressed.

26. Page 4-34: Was vinyl chloride detected in the samples sent to the New England Division Laboratory?

27. Table 4-13: The MCLs for cis 1,2-DCE, toluene, TCE and PCE were exceeded in several groundwater samples. Please discuss the significance of these compounds in groundwater.

28. Table 4-13: Metals concentrations in Table 4-13 should be compared to the Virginia Groundwater Standards. The following metals appear to exceed the standards in one or more groundwater samples: arsenic, cadmium, chromium, lead, and zinc.

29. Page 4-38: While the concentration of PCE, TCE, or DCE may not exceed the 1% to 10 % rule of thumb, the level of solvents present would suggest that the groundwater may be contaminated with DNAPL and if the sampling was expanded the non-aqueous phase may be located.

30. Page 4-39: Some discussion of vinyl chloride as a degradation product seems appropriate since vinyl chloride is one of the final breakdown product of PCE and TCE.

31. Table 4-14: The concentration of methylene chloride and TCE in SB07-001 (0-1 ft) would indicate a potential transfer to groundwater.

32. Table 4-14: The levels of semivolatile organic compounds in soil should be compared to the EPA soil screening levels for transfer from soil to groundwater.

33. Table 4-14: Arsenic exceed the residential screening concentrations for soils compared to the EPA Region III RBC Tables.

34. Page 6-3: Ecological Risk Assessment. A significant exposure pathway which has been overlooked includes groundwater to surface water (i.e., Chesapeake Bay and the Atlantic Ocean) where aquatic receptors could be exposed. Groundwater flow information obtained from the monitoring wells (including the direct push technology) indicates contaminated groundwater from the Fire Training Area (FTA) likely discharges to the Chesapeake Bay, and contaminated groundwater from the LARC 60 Area and the Auto Craft Area likely discharge to the Atlantic Ocean. A preliminary evaluation using EPA Region III's interim guidance should be conducted. The groundwater Contaminants of Potential Concern (COPCs) and the BTAG aquatic marine values should be used to calculate an EEQ (or hazard quotient). The calculated EEQ will dictate whether additional studies are necessary (e.g., modelling studies).

35. Page 6-3: Ecological Risk Assessment

The collection of pesticide and PCB data has been excluded from the Remedial Investigation at all three sites. Data presented in the Preliminary Assessment Report Addendum for Fort Story, VA shows DDT and its metabolites were detected in the surface soil at all three sites. It is also noted that PCBs were detected in the sediments at Site 8, which comprises the drainage outfall line for the LARC maintenance area. Since these chlorinated compounds were detected during an earlier study, this by itself is a valid reason to have included these compounds in the RI. These compounds generally play a significant role in the evaluation for ecological risk. This is considered a data gap.

36. Page 6-3: Ecological Risk Assessment
Relative to the number of surface soil samples/soil borings collected at each site, limited samples were analyzed for total metals. This concern is raised since the metals that have been detected in the surface soils and sediments appear to be the COPCs driving the ecological risk. In fact, when EEQ's are calculated for these contaminants, many of the calculated numbers are well above the values established in the Region III guidance which suggest there is potential for moderate (EEQ $\geq$10) to extreme risk (EEQ $\geq$ 100). With limited metals data, the extent of contamination may not be fully delineated.

37. A shortage of metals data also precludes the use of the 95% Upper Confidence Level (UCL). In order to calculate a statistically valid UCL, a minimum of 7 independent data points at each site for that medium are necessary. This is important because the EEQ calculations derived by VDEQ are based on the maximum concentrations which may be overly conservative (unless hot spots exist).

38. Page 6-5: The third paragraph on this page indicates that there is no opportunity for human contact with subsurface soils as long as they are not disturbed. For the future use scenario, it should be assumed that construction activities may occur in the future and subsurface soils could be brought to the surface and be available for direct contact.

39. Table 6-1: The Region III risk based concentrations (RBCs) should be adjusted to a target hazard quotient of 0.1 for noncarcinogens. (Divide noncarcinogen RBCs by 10.)

40. The RBC values for arsenic on this table are for noncarcinogenic effects. The RBC for carcinogenic effects should also be included.

41. Table 6-2: The values shown as the minimum and maximum

detected concentrations for aluminum in filtered samples have been qualified "R" in the data validation summary tables. It is not clear why they have been included on this table.

42. It is not clear why the frequency of detection column shows a total of three dissolved samples. The summary tables show four samples with and "F" suffix. Does the "F" indicate that the samples were filtered?

43. It is not clear why the detected range for barium is shown as 0.021 - 0.052 mg/l. Sample number 4MW-2SF had a detection of barium of 0.14 mg/L. Please clarify.

44. As noted above, the RBCs on this table should also be adjusted to a target hazard quotient of 0.1

45. Table 6-3: The RBCs on this table should also be adjusted to a target hazard quotient of 0.1 and the RBC for carcinogenic effects for arsenic should also be included. The more conservative of the RBCs for the thallium compounds may be used as a surrogate RBC for thallium.

46. Page 6-7: The exposure assessment should also describe site access controls and surrounding land use. For example, is there housing on the installation? Is the site fenced? Could children or other trespassers access the site?

47. Page 6-8 (Current Situation): Since the aquifer is apparently capable of supporting non-potable uses, at a minimum, the risk due to exposure to groundwater during nonpotable use should be assessed quantitatively for any contaminant that exceeds the screening level.

48. Page 6-8 (Future Land Use): Since the decisions concerning base closure are not made by the facility, continued government ownership cannot be assumed. For risk assessment purposes, the most conservative scenario (residential) should be assumed for future use of the installation. In addition, military and civilian workplace scenarios should be assessed.

49. Page 6-8 (Human Health Evaluation Summary): If the results of the risk-based screen change due to the above comments, a quantitative assessment of risk should be performed for any contaminants that exceed the screening levels. The conclusions should be revised as appropriate.

50. Page 6-10, Section 6, Baseline Risk Assessment FTA site: This section indicates that "because the site has been

highly disturbed from numerous training and operational activities (little or no vegetation is present), and no minimal habitat is available, no pathways for exposure are present. Therefore, no impacts to the environment through contact with surface soils from the site are expected". Due to the lack of vegetative cover, soil contaminants are likely to be transported through the air pathway.

51. Page 6-10, Section 6, Baseline Risk Assessment FTA site: This section indicates that several metals were detected at concentrations above EPA Region III BTAG screening levels in the lowland area. This section also indicates that "because sediment is covered with a minimum of three inches of pine needles and leaves, no exposure pathway is identified for wildlife to the sediment in the lowland area". It is not clear how this would prevent exposure to wildlife. Please provide an explanations to how wildlife and ecological receptors would not be at risk. It is also a valid pathway for the transport and migration of contamination.

52. Page 6-11: The third paragraph on this page indicates that there is no opportunity for human contact with subsurface soils as long as they are not disturbed. For the future use scenario, it should be assumed that construction activities may occur in the future and subsurface soils could be brought to the surface and be available for direct contact.

53. Table 6-7: As noted above, the RBCs on this table should also be adjusted to a target hazard quotient of 0.1 and the RBC for carcinogenic effects for arsenic should also be included. This will effect the conclusion on the top of page 6-12.

54. Table 6-8: As noted above, the RBCs on this table should also be adjusted to a target hazard quotient of 0.1 and the RBC for carcinogenic effects for arsenic should also be included. This will result in additional contaminants exceeding the screening levels.

55. The maximum values listed on Table 6-8 for arsenic, barium, cis-1,2-dichloroethene, trichloroethene, tetrachloroethene, and xylenes could not be verified from the summary tables. Please clarify.

56. It also appears that two detections of 4-methyl-2-pentanone were not included on the hazard assessment table.

57. Table 6-9: As noted above, the RBCs on this table should also be adjusted to a target hazard quotient of 0.1

58. Table 6-10: Summary tables for surface water samples could not be located to verify the table values. Federal Ambient Water Quality Criteria for manganese should also be included on this table.

59. Page 6-14: The third paragraph on this page indicates that additional impacts to groundwater quality due to leaching of tetrachloroethene (PCE) would not be anticipated since the concentration exceeded the soil screening level in only one sample. However, PCE is a contaminant of potential concern in groundwater. Therefore the potential for leaching to groundwater should not be ruled out at this time.

60. Page 6-14, Section 6: This section states that "Methylene chloride is a common laboratory contaminant which may account for the widespread detection in site soils". While it is true that methylene chloride is a common laboratory contaminant, it should not show widespread detection in soils. Was methylene chloride detected in samples sent to the New England Lab? Were lab blanks analyzed which would indicated the level of lab contamination?

61. Page 6-15: The exposure assessment should also describe site access controls and surrounding land use as discussed in a previous comment. Could children or other trespassers wade in the ditch at this site?

62. Page 6-15 (Current Situation): Since the aquifer is apparently capable of supporting non-potable uses, the risk due to exposure to groundwater during nonpotable use should be assessed quantitatively for any contaminants exceeding the screening level.

63. Page 6-16 (Future Land Use): Since the decisions concerning base closure are not made by the facility, continued government ownership cannot be assumed. For risk assessment purposes, the most conservative scenario (residential) should be assumed for future use of the installation. In addition, military and civilian workplace scenarios should be assessed for contaminants that exceed the screening levels.

64. Page 6-16 (Human Health Evaluation Summary): If the results of the risk-based screen change due to the above comments, a quantitative assessment of risk should be performed. The conclusions should be revised as appropriate.

65. Table 6-15: The concentrations shown for fluoranthene, pyrene, and benzo(g,h,i)perylene could not be verified from the summary tables. For metals, it is not clear why there

is only one sample when two are shown on the summary table. If these are duplicate samples, why were they taken on different days? Please discuss how duplicate samples were treated for risk assessment purposes. Why is the nickel detection not included in the hazard assessment? Why is the maximum arsenic concentration shown as 1.3 mg/kg when sample SSB07-004-24 had a detection of 1.5 mg/kg?

66. As noted above, the RBCs on this table should also be adjusted to a target hazard quotient of 0.1 and the RBC for carcinogenic effects for arsenic should also be included. This will result in additional contaminants exceeding the screening levels.

67. Arsenic, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene should be listed as contaminants of potential concern on this table.

68. Page 6-19: The second paragraph on this page indicates that there is no opportunity for human contact with subsurface soils as long as they are not disturbed. For the future use scenario, it should be assumed that construction activities may occur in the future and subsurface soils could be brought to the surface and be available for direct contact.

69. The last paragraph on this page (and the top of the following page) indicates that PAHs were less than the RBCs although the previous paragraph indicates that some PAHs exceeded RBCs. The last paragraph should be modified accordingly.

70. While it is probably true that the levels of PAHs detected at this site are consistent with leaching from asphalt, the levels would also be consistent with used motor oil. Is there any way to definitively link the contaminants to the asphalt cover? It would be preferable to assess risk for those contaminants that exceed RBCs. However, if the installation chooses not to, it should be noted that any decision document related to this site should include a provision to maintain the integrity of the asphalt cover.

71. Page 6-21: The first paragraph on this page states that there is only minimal potential for barium to impact groundwater quality since it was only detected in one sample above the soil screening level. However, metals were analyzed in only a limited number of samples. It is therefore difficult to justify this statement.

72. Page 6-21: The exposure assessment should also describe site access controls and surrounding land use. For example,

is there housing on the installation? Is the site fenced? Could children or other trespassers access the site?

73. Page 6-21 (Current Situation): Since the aquifer is apparently capable of supporting non-potable uses, the risk due to exposure to groundwater during nonpotable use should be assessed quantitatively for any contaminants exceeding the screening level.

74. Page 6-22 (Future Land Use): Since the decisions concerning base closure are not made by the facility, continued government ownership cannot be assumed. For risk assessment purposes, the most conservative scenario (residential) should be assumed for future use of the installation. In addition, military and civilian workplace scenarios should be assessed for contaminants that exceed the screening levels.

75. Page 6-22 (Human Health Evaluation Summary): If the results of the risk-based screen change due to the above comments, a quantitative assessment of risk should be performed. The conclusions should be revised as appropriate.

76. A section presenting an uncertainty analysis should be added to the risk assessment.

77. Page 6-22: Section 6 Baseline Risk Assessment, Ecological Assessment. According to this section, on-site vegetation and wildlife inventories were not conducted as part of this investigation. Ecological inventories should be developed for all of the sites in this investigation.

78. Page 6-23, Section 6, Groundwater/Soil: This section states that "groundwater probably discharges to the Atlantic Ocean", but that "no impacts to the environment through groundwater contact are expected, and no potential ecological risk will be conducted". Due to the Atlantic Ocean being a potential target, an ecological risk assessment should be done to determine the effect, if any that these contaminants are having on it. This section also states that because the site is partially paved and little vegetative cover exists, that no impact to the environment through contact with the surface soils from the site are expected. Due to the lack of vegetative cover, soil contaminants are possibly transported through the air pathway.

79. Table 6-18: In the ERA portion of Section 6 for the Auto Craft Building Area, Table 6-18 does not identify many of the PAHs as "Potential Concern?" Please note that 10 of

these compounds exceed the Fauna BTAG screening levels plus the majority have EEQs >10.

80. Section 7: This section may need revision after revision of the baseline risk assessment.

81. Section 8: The no further action recommendations cannot be supported until human health risk is adequately assessed at the sites. The groundwater at the LARC 60 site is a particular concern. In the section on fate and transport, it was noted that levels of degradation products of tetrachloroethene (PCE) have increased since the PA/SI. Note that vinyl chloride, a degradation product of PCE, is more toxic than the original compound and may be a concern in the future. Therefore, at the very least, continued groundwater monitoring should be considered.

RESPONSE TO VDEQ COMMENTS
DRAFT RI FOR FTA, LARC 60 AND AUTO CRAFT SITES
FORT STORY, VA

COMMENT	RESPONSE
1	Page 2-10: Analytical data obtained from the containerized soil and purge water indicated that the material was not classified as a hazardous waste with the drums subsequently managed as a solid waste. The text will be revised to reflect the results of the analytical data. Future projects at these sites will include IDW management pursuant to the requirements of the VDEQ Policy.
2	Page 2-14: Neither pesticides nor PCBs were detected at concentrations greater than trigger levels established during the PA/SI, and therefore, they were not identified as contaminants of concern and were not included in the RI. In addition, the levels detected during the PA/SI are consistent with levels expected due to normal application in industrial areas for pest and weed control, and not from uncontrolled spills or leaks. The text will be revised to reflect these issues.
3	Page 2-18: It is not clear which site (FTA or Auto Craft) the reference is made since the text at the top of page 2-18 refers to the Auto Craft site while the text at the bottom of the page refers to the FTA site. It is assumed that since Figures 2-10 and 2-11 show the location of samples collected from the area north of the Auto Craft site that the reference is for the FTA. FTA Site - The northern area of the site was investigated in this RI with four DPT points (#1 through #4), one monitoring well (4MW-1), six surface soil (SS-23 through SS-28), and six soil borings (SB-1 through SB-6) sampled in this area of the site with low levels of various contaminants detected. If the area that VDEQ is referencing is the area north of the site then it is unclear why investigations are required there. No samples were collected from the area north of the road (north of where 4MW-1 and SB-1 were installed during this RI) during previous investigations and no documentation is present that suggests that area was used for industrial operations, storage or past disposal.
4	Page 3-1: Agreed. A detailed revised ecological risk assessment (ERA) addressing these issues will be conducted. The findings (Section 7.0 of the RI Report) will be submitted to VDEQ for review prior to issuance of the Final RI Report.
5	Page 3-2: Same as response to Comment #4. We believe that there is sufficient analytical data located within drainage areas and conveyances to assess ecological risk. However, if the ERA indicates that there is a potential risk to downstream receptors (i.e., Chesapeake Bay and/or Atlantic Ocean), then additional investigations may be required. The need for additional sampling (if required) will be stated in Section 9, Recommendations.
6	Page 3-10: Based on the estimated groundwater flow direction stated in the PA/SI, monitoring well 4MW-1 was installed as the upgradient location with all parameters including inorganics analyzed for. However, based upon our evaluation, the groundwater flow direction was determined to be towards the Chesapeake Bay to the north. This change in direction makes 4MW-1 a downgradient well and 4MW-4 the upgradient well, however, inorganics were not analyzed at 4MW-4. The text will be revised to reflect this.

COMMENT	RESPONSE
7	Page 3-11: There was a typo in the table on Page 3-10. The total arsenic concentration should have read <0.01 not 40.01. The table will be revised.
8	Page 3-12: The discussion on ecology will be expanded to include fauna including the identification of endangered species for the Fort Story area. A species inventory was conducted by the USACE in 1993 for the Fort Story/Cape Henry region. This list is included as an appendix to the Draft Fort Story Integrated Natural Resource Management Plan prepared by Horne Engineering and Environmental Services in June 1995. A full fauna survey of Fort Story is not expected to be conducted as part of the ERA. In conjunction with the database established in the Horne report, a biological survey for each site will be conducted. Each site's ecology will be described based on vegetative community. Qualitative vegetative surveys would be performed to note vegetation diversity and abundance (e.g., line intercept or quadrant sampling). Additional faunal surveys (herpetological, avian, and mammalian) would be conducted in the field through limited trapping and incidental occurrence verification. A full list of species that could occur on the base will be included. This list would be compiled from the existing information. By conducting surveys at each site and utilizing the list of species for the region, receptor species can be selected with certainty and species' use of each site can be more accurately determined and fewer assumptions made during the risk modeling process. VDEQ states that site-specific inventories would not account for terrestrial animals that range over larger areas. However, the potential exposure to contaminants for these animals would be reduced due to their larger range and typically these animals are not selected as indicator species. The selection of a species with a smaller range is more conservative and therefore, preferable since the potential risk of exposure is greater
9	Page 4-1: If the results of the USACE NED laboratory analysis are greater for specific compounds than the original sample, the greater results will be reported in the tables in Section 4.0. The raw data results of the NED QA sampling are provided in Appendix D of the Quality Control Summary/ Analytical Results Report (QCS/ARR) and their impacts on data quality discussed in Section 4.2 of the QCS/ARR. Section 4.0 of the RI Report discusses the nature and extent of contamination, not a review of data quality which is discussed in the QCS/ARR.
10	Page 4-1: Agreed. If any of the sites proceed to a Feasibility Study, the ARARs will be refined to a more site-specific basis.
11	Page 4-6: All discussions in Section 4.0 regarding comparison to industrial soil screening criteria are preliminary in nature. The results are compared to the industrial screening criteria only as a means for discussion of the severity or significance of the concentrations detected. The text will be revised to reflect this. The human health risk assessment discusses both the industrial and residential screening criteria and is the primary means for determining impacts. Although screening to residential criteria will be conducted for "future land use" scenario, no residential development at these sites are planned or expected.

COMMENT	RESPONSE
29	Page 4-38: The highest concentrations measured were within the former UST pit where the leaks probably occurred. If the concentrations of the chlorinated organics are not above 1% of the solubility limit at this location, it is unlikely that a DNAPL is present. Numerous groundwater samples have been collected in the shallow and deeper areas of the water table aquifer downgradient of the pit and no DNAPL has been detected. Additional groundwater monitoring in this area is unnecessary.
30	Page 4-39: Agreed. The text will be revised to include a discussion for potential degradation to vinyl chloride. This information will also be included in the fate and transport section.
31	Table 4-14: A detailed discussion of the potential leachability and transfer to groundwater for these compounds is provided in Section 5.
32	Table 4-14: They are compared in the risk assessment on page 6-20. (6-52)
33	Table 4-14: The industrial and residential RBC for arsenic as a carcinogen will be added to the risk assessment and further evaluations will be made to discuss its impacts. (6-53)
34	Page 6-3: Agreed. A revised ERA will include all of these factors and potential receptors.
35	Page 6-3: As stated in the response to Comment #2, neither pesticides nor PCBs were detected at concentrations greater than trigger levels established during the PA/SI, and the levels detected during the PA/SI were consistent with levels expected due to normal application in industrial areas for pest and weed control, and not from uncontrolled spills or leaks. However, a subsequent field investigation included the collection and analysis of soil and groundwater samples for pesticides and PCBs. This data has been included in the revised report. Where?
36	Page 6-3: As stated on page 4-2 in the Final Work Plan dated December 1994, due to their infrequent detection during the PA/SI with concentrations typically lower than the trigger levels, only 20 percent of soil samples were analyzed for total metals to determine whether significant levels were present. If the results of the ERA indicate that metals are at unacceptable levels due to adverse risks to the environment then additional investigation to establish the extent of metal contamination may be necessary.
37	Agreed. The use of the 95th UCL is preferred over the use of maximum concentrations in order to more accurately assess risk. However, because of the 20% screening conducted for metals, insufficient numbers of samples are available to calculate UCLs and maximum concentrations will be used for the quantitative risk assessment calculations.
38	Page 6-5: Agreed. A "future land use" scenario to include potential exposure to soils through residential activities will be evaluated in the revised risk assessment. pg 6-7

COMMENT	RESPONSE
39	Table 6-1: The EPA Region III RBCs for non-carcinogens will be adjusted to a target hazard quotient of 0.1 by dividing the RBCs by a factor of 10 because of the detection of multiple contaminants within each media.
40	RBCs for arsenic have been revised to reflect Sept 2001 RBC Table info.
41	Aluminum not identified as a COPC in groundwater in revised assessment.
42	The "F" designated denotes filtered or dissolved samples. The data summary tables in the QCS/ARR provide the results of MW-211F which is a duplicate sample of MW-112F, thereby, showing 4 samples instead of the 3 shown in Table 4-7 and 6-2 of the RI report. The tables in the RI report show the highest concentration of a given compound detected, whether in the original, duplicate or QA split sample. All analytical data will be reviewed again to ensure that the highest concentration detected for each contaminant is presented in the data tables in Sections 4.0 and 6.0.
43	Tables and text will be revised to show barium concentration of 0.14 mg/l for 4MW-2F.
44	Same as response to Comment #39.
45	Table 6-3: Same as response to Comment #39. The correct RBC for arsenic will be added to the table. The RBCs for thallium have been used.
46	Page 6-7: The exposure assessment discusses site conditions and controls. No additional text to be included.
47	Page 6-8: Since there are no current potable or non-potable users of the groundwater at Fort Story, no quantitative analysis will be conducted for the "Current Situation". An evaluation of the potable use of the aquifer will be made for the "Future land Use" scenario. Only dissolved antimony and manganese exceeded the EPA RBCs for tap water and non-potable exposure would not seem to be of concern.
48	Page 6-8: Residential exposures (including adult and children exposures to groundwater, soil, and sediment) for the "future land use" scenario will be evaluated for the revised human health risk assessment.
49	Page 6-8: Agreed. A quantitative evaluation will be conducted if screening levels are exceeded and exposure pathways are complete.
50	Page 6-10: This pertains to the ecological risk assessment and those habitat issues and exposures have been included in Section 7.

COMMENT	RESPONSE
51	Page 6-10: A revised ERA will be conducted that addresses these issues.
52	Page 6-11: Same as response for Comment #38.
53	Table 6-7: Same as response to Comment #39. Arsenic RBCs have been revised.
54	Table 6-8: Same as response to Comment #39 for RBCs adjustment and same as response to comment #53 for arsenic RBC.
55	Tables in section 6 have been revised to reflect appropriate concentration ranges.
56	Section 6 tables have been checked and revised as appropriate.
57	Table 6-9: Same as response for Comment #39.
58	Table 6-10: Summary tables for surface water samples were included in the QCS/ARR.
59	Page 6-14: In addition to PCE only exceeding the SSL in 1 of 49 samples, PCE was only detected in 3 of 49 samples. Although PCE is a COPC in groundwater, soil results indicate that the majority of PCE may have already leached out due to a high infiltration rate associated with the sands present in the subsurface. The exceedence of the one PCE result does not justify continued analysis.
60	Page 6-14: Methylene chloride was detected in the USACE NED split samples, however, they had a "B" designation indicating that it was also detected in the lab blank samples. The QC data including lab blanks did not demonstrate widespread methylene chloride detects.
61	Page 6-15: Same as response to Comment #46.
62	Page 6-15: Same as response to Comment #47.
63	Page 6-16: Same as response to Comment #48.
64	Page 6-16: Same as response to Comment #49.

COMMENT	RESPONSE
65	Table 6-15: The fluoranthene result of 5,800 ug/kg and benzo(g,h,i)perylene result of 2,000 ug/kg at SB07-001-01 are correct. The summary table result does not include the results from a dilution sample run. The pyrene result of 11,000 ug/kg reported in Table 4-14 and 6-15 exceeded the calibration range, however, as a conservative approach, the number was used in the risk assessment evaluation. The summary table in URS' Data Validation Report only reports the 9,000 ug/kg result because it was within acceptable reporting quality. Table 6-15 is an evaluation of surface soils. Only 1 metal result was available for surface soils. The greatest concentration whether in original, duplicate, QA split or dilution sample was used in the risk assessment. The nickel result will be added to Table 4-14 and evaluated in the hazard assessment in the revised risk assessment. As previously stated, this hazard assessment addresses potential exposures to surface soils, the arsenic detect of 1.5 mg/kg was in sample SB07-004-24 which is a subsurface sample collected at a depth of 2 to 4 feet below land surface. The evaluation of subsurface soil contaminant concentrations will be addressed in the future land use scenario for construction activities.
66	Same as response to Comment #39 and Comment #53.
67	Arsenic will be added to the COPC list in the revised risk assessment. However, as stated on page 6-19, the PAHs present are the result of leaching from the asphalt. They will be included as COPCs but will be discussed in the uncertainty section.
68	Page 6-19: A future scenario to include exposure through construction activities will not be quantitatively evaluated because the PAH concentrations are not above EPA RBCs for industrial soils.
69	The last paragraph will be revised to state exceedances of the RBCs for some PAHs. 6-53 - should say "RBC" not "TBC"
70	The sampling location (SB07-001) is upgradient of the former Auto Craft building with no historical evidence that any petroleum hydrocarbons were spilled or leaked at this area. However, the PAHs have been included in the revised risk assessment as COPCs.
71	Barium was not detected above EPA RBC values and will not be evaluated further.
72	Page 6-21: Same as response to Comment #46.
73	Page 6-21: Same as response to Comment #47.
74	Page 6-22: Same as response to Comment #48.

COMMENT	RESPONSE
75	Page 6-22: Same as response to Comment #49.
76	A discussion on the uncertainty will be added to the revised risk assessment.
77	Page 6-22: Ecological inventories will be included in the revised ERA in Section 7.
78	Page 6-23: The revised ERA address potential exposures at receptors in the Chesapeake Bay and Atlantic Ocean and through the soil to air pathway as discussed in Section 7.
79	Table 6-18: Agreed. The revised ERA will evaluate exposures to the PAHs.
80	Section 7: This section will be revised based on the results of the revised risk assessment.
81	Section 8: This section will be revised based on the results of the revised risk assessment.

Comments on the responses to comments on "Remedial Investigation Report Firefighter Training Area, LARC 60 Maintenance Area, Auto Craft Building Area, Fort Story December, 1995".

6. The response adequately explains why there were no inorganics analyzed for 4MW-4. However, it does not explain what will be done to fill the resulting data Gap.

35. Were the trigger levels in the PA/SI adequate to determine that there is no potential for either human health or ecological risk? Were data provided that verify that pesticide levels were consistent with levels resulting from pest control (i.e. anthropogenic background). The soil boring within the LARC Maintenance Area contains the DDT metabolite, p,p'DDD at a concentration of 2.9 mg/kg. Additional discussion regarding this issue should be included in the RI document. Additional investigation of all three sites would adequately address the original comment.

36. Were the trigger levels used in the PA/SI adequate to determine that there is no potential for either human health or ecological risk?

59. This explanation should be included in the text of the report.

65. What is the source of the results for fluoranthene, benzo(g,h,i)perylene, and pyrene provided in the report? Surface soil sample SB07-004-24 is apparently mislabeled in the data summary table. This should be corrected or explained.

67., 68., 70. The report should provide a reference that would verify the assumption that the PAHs detected in this area are due to leaching from the asphalt.

RESPONSE TO SECOND SET OF VDEQ COMMENTS
DRAFT RI FOR FTA, LARC 60 AND AUTO CRAFT SITES
FORT STORY, VA

COMMENT	RESPONSE
6	The only dissolved metal at the FTA site that exceeded EPA RBC values for tap water in the risk assessment was dissolved manganese. Although we have not fully delineated the extent of metals in groundwater, based on the relatively low concentrations present, we do not believe that collecting an additional groundwater sample for metals in the upgradient well will provide critical data for the site.
35	Additional soil and groundwater samples were collected in 2000 for pesticide/PCB analysis and the results of this sampling effort are provided in the revised RI Report.
36	The trigger levels for the metals in the PA/SI were based on background data collected from soil borings at Fort Story. BTAG screening levels and EPA RBC values for residential soils for many metals are lower than background levels, and therefore, may not be a true indication of risk caused by site activities. It should be noted that the BTAG screening levels were not in place at the time of the PA/SI. However, if the results of the ecological risk assessment indicate that metals are at unacceptable levels due to adverse risks to the environment then additional investigation to establish the extent of metal contamination may be necessary. However, the concentrations of the metals detected during the RI were typically consistent with facility and regional background data. Further discussions related to risk and comparisons to background will be provided in the RI Report.
59	Agreed. This rationale and discussion have been provided in the revised Final RI Report.
65	The source of fluoranthene and benzo(g,h,i)perylene in the tables and text of the report are dilution analysis conducted by the laboratory. However, as previous stated in our initial response to comments, these dilutions did not meet URS' data validation acceptance criteria, and therefore, they did not report them in their data summary tables provided in the appendices to the QCS/AR Report. Since these two compounds did not exceed the calibration range in the original run, the data from the original run is considered the valid result not the data from the dilution run, therefore, URS only reported the original sample results. We reported the dilution results in our data tables (Tables 4-14 and 6-15) and used these higher numbers as a more conservative approach to risk evaluation. The pyrene result of 11,000 ug/kg reported in Table 4-14 and 6-15 exceeded the calibration range in the original run, however, as a conservative approach, the number was used in the risk assessment evaluation. The summary table in URS' Data Validation Report only reports the 9,000 ug/kg result for the dilution run because it was within acceptable reporting quality and the 11,000 ug/kg result did not meet acceptable validation criteria. In summary, to be on the conservative side, we utilized the maximum concentration detected from original or dilution runs whether the higher number was validated or not, and URS only reported the validated number in their data tables in the appendices. A copy of the laboratory sheet for the original and dilution run are attached for your information. SB07-004-24 is mislabeled as "SSB07-004-24" in the data summary tables. This will be explained in the Final RI Report with a reference to the data summary tables in the QCS/AR Report.

COMMENT	RESPONSE
67, 68, 70	A Health and Safety Survey for "The Use of Petroleum Asphalt in the Paving Industry" was conducted by the University of Texas at Austin, Center for Transportation Research, to assess the environmental health impacts of asphalt paving operations. A summary of the study is provided as follows. A determination of the amount of asphaltic material leached from a simulated road surface under conditions approaching normal rainfall was conducted. Asphalt was mixed and poured into 12 inch square steel plates at 140 degrees C and cured at 21 degrees C for various lengths of time. Simulated rainfall was applied by use of a fine sprinkler hose at an average rate of 1.5 inches per hour. The runoff from one hour of simulation was processed to obtain an asphalt residue. The study showed that considerable asphaltic material could be washed from a road surface during the first few days after application. Although the study reported results in the pounds of asphaltic material that could be washed away, due to the high PAH concentrations in coal tar pitches including 43,000 parts per million (ppm) for fluoranthene, 31,000 ppm for phenanthrene, 29,000 ppm for pyrene, etc., high levels of contaminants are discharged to the environment. Because the asphalt at the Autocraft site is permeable and standing water (as observed during the field investigation) is present on the asphalt after a rain event, it follows that after application, not only was there runoff containing PAHs, water permeated through the asphalt with significant amounts of PAHs leaching into the underlying soils. This information will be included in the text of the revised RI Report.

RESPONSE TO 3rd SET OF VDEQ COMMENTS (SHARON WILCOX REVIEWER)
DRAFT RI FOR FTA, LARC 60 AND AUTO CRAFT SITES
FORT STORY, VA

COMMENT	COMMENT AND RESPONSE
COMMENTS APPLICABLE TO ALL THREE SITES HUMAN HEALTH RISK ASSESSMENT	
1	**Comment:** Section 6.2.1, page 6-4: At the bottom of the page, the phrase "EPA criteria" is used. Please clarify by specifying the criteria used. This phrase was used in the LARC 60 and Auto Craft sections as well. **Response:** The phrase "EPA criteria" has been changed to "EPA RBC criteria" throughout Section 6.
2	**Comment:** Page 6-9, 2nd paragraph, last sentence: Concluding that there are no exposed populations under current conditions is inaccurate. "Exposures, under current conditions will not exceed risk based limits" would be a more appropriate sentence. It is recommended that this sentence be deleted wherever it is used throughout the document as it is inaccurate and possibly misleading. **Response:** This phrase has been revised throughout the text as proposed above.
3	**Comment:** When calculating risks and exposures, it is preferred to assume that the adult resident lived 6 years at the site as a child and 24 years as an adult. This somewhat more conservative, through more in line with the concept of reasonable maximum exposure. **Response:** This changed has been made for all 3 sites.
4	**Comment:** DPT data is not generally accepted for use in human health risk assessments beyond the screening level. **Response:** The risk assessment has been revised to only include the groundwater data from the permanent monitoring wells. The DPT was not used in the revised assessment.
5	**Comment:** The fraction ingested should assume 100% from the contaminated area as the assumption for the resident and the construction worker. **Response:** This change has been made for all 3 sites.
COMMENTS on FTA SITE HUMAN HEALTH RISK ASSESSMENT	
1	**Comment:** The HHR for the FTA did not address the construction worker scenario. While conducting the calculation checks, I also performed a default based calculation for the construction worker and commercial/industrial worker scenarios using maximum detected concentrations for arsenic, manganese, thallium, and tetrachloroethene. The calculated cancer risks did not exceed 1E-5 and the hazard quotient totals did not exceed 1.0.

COMMENT	COMMENT AND RESPONSE
	Response: Since no chemical concentrations exceeded the EPA RBCs for industrial soils, there is no need to calculate industrial or construction worker exposures.
2	**Comment:** The PQL for vinyl chloride was 10 ug/kg for all of the groundwater samples, whereas the MCL is 5 ug/kg. Based upon information provided during our meeting on August 10, 2000, the actual detection limit for vinyl chloride was 2 ug/kg, therefore, it has been shown not to be present at levels exceeding the MCLs. **Response:** Agreed.
3	**Comment:** Regional background data is not sufficient to demonstrate that concentrations at the site are within background limits. As, Tl, and Mn were included as COPCs in my calculations. Use of the maximum concentrations of As, Mn, Tl, and TCE for all pathways for soil and groundwater did not result in a target organ hazard quotient in excess of 1.0. **Response:** Wherever possible in the assessment, a comparison of site metals data is compared against the background data collected by Montgomery Watson during the PA/SI, however, they did not analyze for all metals. In these cases, a comparison to regional background data was made solely for comparison. If concentrations of metals exceeded RBCs or MCLs, they were identified as COPCs and carried through the quantitative risk assessment.
4	**Comment:** Use of the 95% UCL applies only when multiple samples from the same location are being evaluated. In this case it is not appropriate. Please use the maximum value for all constituents where sufficient data is not available on a well by well basis. The significant change will be the use of 78 ug/l for TCE. Total cancer risks approached 1E-4 when using this value for TCE. **Response:** Section 6.5.1 of the RAGS manual states that the 95 percent UCL should be utilized to assess risk from a particular medium for each chemical. This provides for a reasonable exposure assessment. Also, TCE was not detected in the FTA monitoring well data so no assessment of it has been conducted.
5	**Comment:** Section 6.2.1, page 6-5 Inorganics: The last sentence of the 1st paragraph states that a summary of the background data for the FFT can be found in Appendix H. Appendix H contains a chart that duplicated the information presented in this paragraph. Please include a discussion of the number of samples taken to determine background, the sample locations, and the individual sample results. A summary table would suffice. **Response:** The text and tables from the Montgomery Watson Fort Story PA/SI has been added to Appendix H for the background samples.
6	**Comment:** Page 6-5, VOCs: Use of frequency of detection to eliminate benzene as a COPC is questionable. However, since use of the groundwater will have to be restricted due to the presence of another VOC, TCE, it will not significantly affect the ultimate decision making process. **Response:** As noted in the revised assessment (using well data only), neither benzene nor TCE were detected in the wells and therefore, are not COPCs in the assessment.

COMMENT	COMMENT AND RESPONSE
7	**Comment:** Vinyl chloride is a decomposition product of TCE. Though it was not detected, the groundwater should continue to be monitored, as the presence of detectable amounts of vinyl chloride would most likely elevate the maximum cancer risk above 1E-4. **Response:** Neither vinyl chloride nor TCE were detected in the monitoring wells during sampling in 1995 and 2000. Therefore, no further monitoring is necessary
8	**Comment:** When recalculating the risks using the maximum concentrations, it was noted that different assumptions were used in the shower model presented in the report than are used in the VDEQ model. The results for volatile intakes was significantly higher with our model; however, the results did not exceed 1E-04 for cancer to any target population. An electronic copy of the shower model has been sent via e-mail to Tony Pace at Malcolm Pirnie. **Response:** Received e-mail but did not use for FTA site because only COPCs in groundwater were metals with minimal volatility expected.
9	**Comment:** When recalculating the HQs for the different intake pathways using the most recent oral reference dose for manganese, 0.02 mg/kg/day, instead of the former value of 0.005 mg/kg/day, there were no pathways exceeding a HQ of 1.0. **Response:** Updated RfD for manganese used in the revised risk assessment.
10	**Comment:** Given the levels of risk demonstrated, it is suggested that groundwater monitoring continue until such time as it can be reliably demonstrated that TCE and vinyl chloride are not present above MCLs. It has been noted that the most recent sets of groundwater monitoring data have not detected either TCE or vinyl chloride. **Response:** Neither TCE nor vinyl chloride has been detected from monitoring well samples during the 1995 and 2000 sampling events. Therefore, no further monitoring is necessary
COMMENTS on LARC 60 SITE HUMAN HEALTH RISK ASSESSMENT	
1	**Comment:** Page 6-32, 3rd paragraph – The last sentence states that there are no exposed populations. This is not an accurate statement. The paragraph provides the necessary information. The concluding statement is best left out as it is misleading. Similar statements are made in other sections of this document and should be corrected. **Response:** This statements have been deleted.
2	**Comment:** Page 6-33, 3rd paragraph under Future Land use – The report should consider wading in surface water (in the ditch) as a potential future exposure route for children and adults. **Response:** Text has been added to this section discussing the possible scenario.

COMMENT	COMMENT AND RESPONSE
3	**Comment:** The report should also address construction worker risk from incidental soil ingestion, skin absorption, particulate inhalation, and groundwater volatilization. Before any construction work were to occur at this site involving subsurface excavation, this scenario should be evaluated to ensure that no unacceptable risks are present for the workers. The commercial industrial worker scenario should also be evaluated. **Response:** Because the EPA RBCs for industrial soils were not exceeded for the surface and subsurface soils and the sediment, there is no need to evaluate these exposure scenarios.
4	**Comment:** Page 6-46, Uncertainty – It is agreed that a larger data set for dissolved metals in groundwater would reduce the uncertainty regarding the risks posed by manganese and arsenic in groundwater. However, it has not been demonstrated that these levels are consistent with background levels of these chemicals. **Response:** Agreed. No mention of metals data as compared to background has been provided in the uncertainty section. In fact, several of the samples (primarily MW-117) have metals concentrations clearly above background.
5	**Comment:** The updated reference dose for manganese will significantly reduce the HQ, though it will still exceed 1.0 due to arsenic. Future groundwater sampling would need to demonstrate, statistically, that the concentrations reflect background in order to remove manganese and arsenic from the list of COPCs. Use of the maximum concentration of the organic COPCs, as recommended, will also elevate the HQ value. **Response:** Updated RfDs have been used in the revised assessment. At this point, as discussed in the revised report, manganese and arsenic have not been removed from the list of COPCs.
6	**Comment:** The use of the 95th UCL is not applicable to the current set of groundwater data for the LARC site. It is appropriate for use when multiple samples have been obtained from the same well. Use of the maximum concentration data will significantly increase the contribution of the organic COPCs to cancer risk. **Response:** See response to FTA comment #4. However, due to the statistical variation in the data, which resulted in a non-parametric evaluation, the maximum concentration was utilized for the majority of the COPCs in groundwater.
7	**Comment:** Section 6.3.5 – Use of maximum levels for the COPCs, will likely change the contribution to the exposure hazard index from arsenic and manganese to the organic COPCs. **Response:** See revised assessment for changes.
8	**Comment:** Section 6.3.5 – Use of maximum levels for the COPCs, will likely change the contribution to the total cancer risk from arsenic and manganese to the organic COPCs. **Response:** See revised assessment for changes.

COMMENT	COMMENT AND RESPONSE
9	**Comment:** Section 6.3.5 – No demonstration has been made in the document that natural attenuation would be sufficient to reduce the concentrations of contaminants below the MCLs. **Response:** References to this have been removed from the text.
10	**Comment:** Due to the relatively high concentrations in one particular area, and the high risks posed by these concentrations, it appears reasonable to conduct some sort of remedial action at the site. **Response:** A feasibility study (including a groundwater treatability study) will be initiated shortly to discuss possible remedial options for the groundwater at the site.
COMMENTS on AUTO CRAFT BUILDING AREA HUMAN HEALTH RISK ASSESSMENT	
1	**Comment:** There is some confusion regarding which wells/DPT sample locations the various detected compounds were from. When trying to compare the data in Table 6-26 of this report to the data in Tables 4-15 and 4-16 of the RI Report, dated December 1995, it did not appear to match. If was not clear if there was another round of sampling. Please reference the raw data sources for all data used for FFT, LARC, and Auto Craft risk assessments in the text or as a footnote to a table. It is important to be able to check the validated data and know the locations of the wells/DPT points. **Response:** As previously discussed, the revised report only includes the monitoring well data in the quantitative risk assessment.
2	**Comment:** Again, use of the 95% UCL across different wells is not appropriate at this site. Please use the maximum values detected. **Response:** Due to the limited number of wells at the site, the maximum groundwater values are used in the revised risk assessment.
3	**Comment:** Please provide additional information to support the conclusions that the PAHs found in the surface soil originated from the asphalt pavement. Discussion of types of activities that produce PAHs and the fact that they are known not to have occurred at this site would be supportive. **Response:** A Health and Safety Survey for "The Use of Petroleum Asphalt in the Paving Industry" was conducted by the University of Texas at Austin, Center for Transportation Research, to assess the environmental health impacts of asphalt paving operations. A summary of the study is provided as follows. A determination of the amount of asphaltic material leached from a simulated road surface under conditions approaching normal rainfall was conducted. Asphalt was mixed and poured into 12 inch square steel plates at 140 degrees C and cured at 21 degrees C for various lengths of time. Simulated rainfall was applied by use of a fine sprinkler hose at an average rate of 1.5 inches per hour. The runoff from one hour of simulation was processed to obtain an asphalt residue. The study showed that considerable asphaltic material could be washed from a road surface during the first few days after application. Although the study reported results in the pounds of asphaltic material that could be washed away, due to the high PAH concentrations in coal tar pitches including 43,000 parts per million (ppm) for fluoranthene, 31,000 ppm for phenanthrene, 29,000 ppm for pyrene, etc., high levels of contaminants are discharged to the environment.

COMMENT	COMMENT AND RESPONSE
	Because the asphalt at the Auto Craft site is permeable and standing water (as observed during the field investigation) is present on the asphalt after a rain event, it follows that after application, not only was there runoff containing PAHs, water permeated through the asphalt with significant amounts of PAHs leaching into the underlying soils. The above information has been included in the text of Section 6.4.1 of the RI Report. However, it should be noted, that these PAHs were quantitatively evaluated in the revised risk assessment but their presence and mitigating factors are discussed in the Uncertainties section.
4	**Comment:** When the updated reference dose for manganese is used, and when maximum concentrations for COPCs are applied, the total exposure index does not exceed 1.0. **Response:** The updated reference doses for the COPCs have been included in the revised risk assessment.
5	**Comment:** When the maximum groundwater contaminant concentration values are used along with the more conservative parameters (shower model and all pathways included), the maximum target population total lifetime cancer risk is calculated to be in the order of 1E-5. Levels of contaminants detected at this site do not appear to pose an unacceptable risk to human health. **Response:** Revised risk assessment agrees.

of the RfD.

The ratio of the estimate of the CDI to the health-protective criterion (CDI/RfD) is called the hazard quotient (USEPA, 1989a). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, the greater the level of concern.

RfDs for oral exposure are available for most chemicals. For dermal exposure, however, RfDs are not available. In their absence, the oral RfDs are used and adjusted to reflect absorbed dose. This allows for comparison between exposure estimated as absorbed doses and toxicity values expressed as absorbed doses. The absorption efficiencies identified for the COPCs have been estimated at the following rates:

- Antimony – 2%
- Arsenic – 41%
- Iron – 15%
- Manganese – 4%
- Cis 1,2-DCE – 100%
- MIBK – 80%
- Toluene – 80%
- Vinyl chloride – 100%
- 2-Methylnaphtalene – 80%
- Naphthalene – 80%

These rates were obtained from the Risk Assessment Information System (RAIS) database. The RAIS is a U.S. Department of Energy database of information developed from data from the USEPA Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST) and other literature sources. A copy of the absorption efficiencies is provided in **Appendix I.**

The RfDs are multiplied by the absorption efficiencies to come up with the adjusted RfDs. The adjusted RfDs are presented in **Table 6-21.**

Except for a few COPCs, reference doses for inhalation exposure, referred to as RfDi, are typically not available. However, it should be noted that the only inhalation pathway identified for the site is for VOCs and SVOCs during showering activities. The EPA RBC table identifies those compounds considered VOCs and SVOCs. Identified RfDi for these compounds are provided as follows:

- Cis 1,2-DCE – None identified
- MIBK – 2.00E-02
- Toluene – 1.14E-01
- 2-Methylnaphthalene – None identified

- Naphthalene – 9.00E-04
- Vinyl chloride – 2.8E-02 (adult and child)

~~Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. A RfDi is only available for ethyl benzene and toluene.~~

Carcinogenic Effects

Regardless of the mechanism of effect, risk assessment methods generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk assessment methods require extrapolation from high dose animal studies to evaluate low dose exposures to humans. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis.

Through application of this approach, the USEPA has derived estimates of incremental excess cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and the fitting of those dose-response data to a low dose extrapolation model. The CPS (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in **Table 6-22** and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in **Table 6-22**.

To arrive at an estimate of incremental cancer risk, the following equation is used (USEPA, 1989a):

Risk = CDI x CPS
where:

Risk = a unitless probability (e.g., 2×10^{-5} or 2 in 100 thousand) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
CPS = Cancer Potency Slope expressed in $(mg/kg\text{-}day)^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). This approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values. The adjusted CPS values are presented in **Table 6-22**.

Except for a few COPCs, cancer potency slope factors for inhalation exposure, referred to as CPSi, are typically not available. However, it should be noted that the only inhalation pathway identified for the site is for VOCs and SVOCs during showering activities. Identified CPSi for these compounds are provided as follows:

- Cis 1,2-DCE: Non-carcinogenic
- MIBK: Non-carcinogenic
- Toluene: Non-carcinogenic
- 2-Methylnaphthalene: Non-carcinogenic
- Naphthalene: Non-carcinogenic
- Vinyl chloride: 3.00E-02 (child)
- Vinyl chloride: 1.5E-02 (adult)

~~CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. A CPSi is only available for PCE and TCE.~~

Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and cancer effects posed by multiple chemicals. This approach assumes that subthreshold exposures to several chemicals at the same time could result in an adverse health effect. It assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect by the same mechanism of action. In this evaluation, the hazard quotients of a mixture of chemicals which can have different effects are used as a screening-level approach, as recommended by the USEPA (USEPA, 1989a). This approach is likely to overestimate the potential for effects.

For the assessment of carcinogenic risks, the individual risks associated with exposure to each contaminant are summed. This represents an approximation of the precise equation for combining risks which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens. This additive approach assumes independence of action by the contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.3.4 Risk Characterization

The final step in the HHRA is the characterization of risk. Here the toxicity and exposure assessments are summarized and combined into quantitative and qualitative expressions of risk. Potential noncarcinogenic effects are characterized by comparing intakes and toxicity values, while carcinogenic risks are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

The USEPA (1989a) recommends absorption efficiency adjustments to ensure that the site exposure estimate (CDI) and the toxicity criteria (RfD and CPS) are both expressed as absorbed doses or both expressed as intakes (administered doses). All CDI calculations are provided in **Appendix I**. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-23 presents the chemical-specific hazard quotients for each pathway involving ~~surface~~ soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in **Table 6-23**. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in **Table 6-23**, the total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for both adults and children. Thus, adverse non-carcinogen health effects in these residential populations are likely. The majority of this risk is associated with ingestion of cis 1,2-DCE, arsenic and iron ~~manganese~~ in groundwater and the inhalation of naphthalene in groundwater during showering activities. In addition, exposure to the COPCs ~~arsenic and manganese~~ in groundwater is the only exposure scenario above the criterion.

Cancer Risks

Table 6-24 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in ~~surface~~ soils and groundwater is about 3~~7~~ in 10 thousand (3×10^{-4}) for adults and 2~~3~~ in 10 thousand (2×10^{-4}) for children. These values are greater than the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component for adult and child exposures is ingestion of the COPC (especially arsenic) in groundwater. ~~In addition, exposure to arsenic, PCE and TCE in groundwater is the only exposure scenario above the criterion.~~

Uncertainty

Some uncertainty is inherent in the process of conducting predictive, quantitative health risk assessments. Environmental sampling and analysis, fate and transport modeling and human exposure modeling are all prone to uncertainty, as are the available toxicity values used to characterize risk. Such uncertainty is generally related to the limitations of the sampling in terms of the number and distribution of samples and analytical information in terms of systematic or random errors used to characterize a site, the estimation procedures and the input variables and assumptions used in the assessment.

There are uncertainties in every step of the risk assessment process; uncertainties that relate to this human health evaluation may be noted. Selection of the chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. Additional uncertainties are inherent in the exposure assessment for individual chemicals and exposure routes.

There is also some uncertainty in the derivation of health effects criteria in the toxicity assessment. In most cases, the criteria are derived from the extrapolation from laboratory animal data to the human condition. This may have the effect of either overestimating or underestimating the risk.

For the LARC 60 site, some important uncertainties that may influence the results of the HHRA include:

- Although a limited data set (11 surface and subsurface soil samples) for arsenic ~~and manganese~~ in soils at the site was available, as previously stated in Section 6.3.1, arsenic ~~and manganese~~ concentrations (range of 0.86 to 1.1 mg/kg in only 3 detects) in soils are consistent with the 2.1 mg/kg UCL for arsenic in the background soils data.

- ~~Limited data set for dissolved arsenic and manganese in groundwater. Only 4 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 530 ug/ for manganese and 40 ug/l for arsenic were used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved metals would present a larger data set and provide for a more accurate analysis of risk.~~

- ~~Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. Dissolved results may be biased high based on the filtering limitations.~~

- ~~VOC estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. These VOCs were detected infrequently (cis 1,2-DCE - 4 of 33 samples, ethyl benzene 4 of 29 samples, PCE - 3 of 33 samples, toluene - 3 of 29 samples, TCE - 4 of 33 samples and xylenes - 3 of 29 samples). Analysis with a lower PQL may more accurately estimate VOC concentrations and subsequent risk.~~

- The noncancer and cancer risk estimates for the VOCs, SVOCs, and some metals (antimony, arsenic, and iron) in groundwater may be biased high because of the use of the maximum concentration for these COPCs. The concentrations of these contaminants in monitoring well MW-117 were much higher than in the other wells which resulted in a non-parametric statistical evaluation of the data and the resulting 95th UCL was equal to or exceeded the maximum concentration. This well is located within the former excavation of the leaking UST and the presence of some free product in this area (based on the free product investigation discussed in Section 4) may also be influencing the dissolved phase groundwater data.

- The presence of one detect of naphthalene (32 ug/l) in monitoring well 6MW-3S greatly increased the risk associated with the inhalation of COPCs during showering activities. Naphthalene accounted for approximately 81 percent of the inhalation risk at the site. Again, the use of this maximum concentration of 32 ug/l may have biased the risk on the high side.

6.3.5 LARC 60 Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

- ~~The~~ The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for adults and children with the majority (approximately 99.9 percent) of this risk associated with exposure to ~~ingestion of~~ COPCs ~~arsenic and manganese~~ in groundwater. The noncancer risk associated with the COPC (arsenic only) in soil is less than the criterion of 1.0 for both adults and children. ~~However, ingestion of arsenic and manganese from groundwater is the only adult and child exposure scenario above the criterion.~~

A summary of the **Carcinogenic Risk** for future residential land use is provided below:

- The estimated cancer risk for exposure to chemicals in ~~surface~~ soils and groundwater is about ~~3~~7 in 10 thousand for adults and 2 in 10 thousand for children. The greatest component for adults ~~and children~~ exposures is ingestion of arsenic in groundwater (98 percent of total risk). ~~In~~ In addition, the risk associated with exposure to contaminated groundwater from arsenic and vinyl chloride~~, PCE and TCE~~ is greater than the USEPA remediation goal.

- ~~The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 10 thousand for children. The greatest components for child exposures are ingestion of arsenic in groundwater (98 percent of total risk). In addition, exposure to contaminated groundwater from arsenic, PCE and TCE is greater than the USEPA remediation goal.~~

- Potential risk is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

- ~~Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentrations of VOCs in groundwater due to natural attenuation would not be expected to be above USEPA MCLs at that time.~~

- ~~Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater. However, under the current land use, there are no risks from the metals in the groundwater.~~

Because arsenic was detected in site soils at concentrations consistent with the background soils as previously discussed, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Therefore, upon removal of arsenic as a COPC, the risk levels become less than the criterion of 1.0 and 10^{-6}, and no further action related to the soils at this site (based on human health risk) is warranted. Additional studies in the form of a feasibility study are warranted for the groundwater risk associated with the site.

#9

#7

6.4 AUTO CRAFT BUILDING AREA

6.4.1 Hazard Identification

Numerous groundwater and surface soil samples were collected from this site and analyzed for various chemical contaminants. **Figures 2-9 and 2-10** provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in Tables 6-25 through 6-27 to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select chemicals of potential concern for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

Emphasis is given in the ensuing evaluation to chemical contamination in the surface and subsurface soil throughout the site and groundwater underlying the site as these environmental media are regarded as having the greatest potential for human contact. ~~Chemical contamination in the subsurface soils are discussed in the context of the potential for exposure from future excavation of these soils and continued or further degradation of groundwater from leaching.~~

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III RBC Criteria and Virginia Petroleum Program Criteria are included in **Table 6-25** as TBC criteria for purposes of comparison. A total of six surface soil samples were collected during the field investigation.

VOCs

All concentrations of VOCs were less than EPA RBC criteria, and therefore, are not selected as COPC.

SVOCs

As shown in **Table 6-25**, the concentrations of several PAHs including benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene in surface soils exceeded EPA RBC criteria for residential soils at one location (SB07-001 located beneath the parking lot). The concentration of benzo(a)pyrene at SB07-001 also exceeded the industrial soil RBC. ~~,~~ H~~h~~owever, as stated in Section 4.5.1.1, their concentrations are probably related to the presence of an asphalt parking lot placed on top of surface soils around the former building.

A Health and Safety Survey for "The Use of Petroleum Asphalt in the Paving Industry" was conducted by the University of Texas at Austin, Center for Transportation Research, to assess the environmental health impacts of asphalt paving operations. A summary of the study is provided as follows.

#3

A determination of the amount of asphaltic material leached from a simulated road surface under conditions approaching normal rainfall was conducted. Asphalt was mixed and poured into 12 inch square steel plates at 140 degrees C and cured at 21 degrees C for various lengths of time. Simulated rainfall was applied by use of a fine sprinkler hose at an average rate of 1.5 inches per hour. The runoff from one hour of simulation was processed to obtain an asphalt residue.

The study showed that considerable asphaltic material could be washed from a road surface during the first few days after application. Although the study reported results in the pounds of asphaltic material that could be washed away, due to the high PAH concentrations in coal tar pitches including 43,000 parts per million (ppm) for fluoranthene, 31,000 ppm for phenanthrene, 29,000 ppm for pyrene, etc., high levels of contaminants are discharged to the environment.

Because the asphalt at the Autocraft site is permeable and standing water (as observed during the field investigation) is present on the asphalt after a rain event, it follows that after application, not only was there runoff containing PAHs, water permeated through the asphalt with significant amounts of PAHs leaching into the underlying soils.

In addition, there are no records or history associated with the site's activities that would suggest contamination in this area upgradient of the former building.

~~Because they are not believed to be related to activities at the site, they are not selected as COPC. The presence of PAHs would be expected in all shallow soils beneath asphalted areas at other locations (bowling lanes parking lot, admin building parking lots, etc.) at Fort Story as well. Each of these areas would not be considered a "hazardous waste site" requiring a human health risk assessment and potential remediation.~~

Although the PAH contamination at the site is probably related to the asphalt parking lot and not related to site activities, the risk associated with these PAHs will be quantified further in this assessment but additional discussion will be provided in the uncertainties section.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in three of six surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. BTEX and PAHs, hazardous constituents of petroleum products, will be the compounds evaluated in determining petroleum contamination risk, and as stated previously, their concentrations were less than EPA RBC criteria.

#69

Inorganics

Arsenic, iron, and manganese exceeded the RBC values for residential soils but did not exceed the industrial soil criteria.

Arsenic was detected in the only surface soil sample collected at a concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic level detected in the surface soils is consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in **Appendix H**.

Manganese and iron were~~as~~ detected in the only surface soil sample collected at a concentration of 170 and 9,100 mg/kg, respectively, which are greater than the EPA RBC for residential soil. Therefore, these metals are also selected as COPCs in surface soils.

~~Although no background 95th percentile UCL was established by Montgomery Watson during performance of the PA/SI, the USGS regional soils data indicates an observed range of less than 0.2 to 7,000 mg/kg with a mean of 290 mg/kg. Therefore, the manganese level detected in the surface soils is consistent with regional background soils.~~

~~Although consistent with background levels, for the purposes of risk analysis, arsenic and manganese are selected as COPCs based on their exceedence of the residential soil criteria.~~

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in **Table 6-26** along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC Criteria. Only the dissolved inorganic data is presented in **Table 6-26**. Total inorganic data are influenced by the percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment is not available for transport with flowing groundwater and would also be filtered out if drinking water wells were installed in this area.

Ten (10) groundwater samples (6 DPT and 4 monitoring well samples) were collected from the upper aquifer during the field investigation. The number of results for each chemical may vary due to the analysis of different compounds at different locations. However, in that DPT data is typically used for screening purposes, only the groundwater data collected from the permanent monitoring wells will be included in the risk analysis.

VOCs

Chloroform was detected in excess of the Virginia Groundwater Protection Level and EPA RBC criteria. Although chloroform was detected in only 1 of 4 ~~10~~ samples and in a concentration less than the 100 ug/l MCL for total trihalomethanes, it is selected as a COPC. ~~Although detected, methylene chloride concentrations were less than the EPA screening criteria.~~

No other VOCs were detected in the monitoring well samples.

SVOCs

No SVOCs were detected in the monitoring well samples.

~~Two SVOCs were detected during groundwater sampling however only bis(2-ethylhexyl)phthalate was detected in excess of the EPA RBC criteria. Therefore, it is selected as a COPC.~~

TPH

TPH was not detected in any of the groundwater samples collected from the monitoring wells.

Inorganics

Dissolved iron was detected at a concentration~~s~~ greater than the EPA RBC, EPA Secondary MCLs and Virginia Groundwater Criteria~~. However, these standards were established for aesthetic qualities only,~~ and therefore, iron is ~~not~~ selected as a COPC.

Dissolved manganese was detected at a concentration greater than the EPA RBC, and therefore, is selected as a COPC.

Combined Surface and Subsurface Soils ~~and Soil Leachability~~

To evaluate the potential exposures to surface and subsurface soils (i.e., future excavation activities and residential development) ~~and for the potential leaching of contaminants form soil to groundwater~~, as shown in **Table 6-27**, soil analytical data was compared against EPA RBCs for residential and industrial soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria are included in **Table 6-27** as TBC criteria for purposes of comparison. A total of 18 soil samples were collected during the field investigation.

VOCs

All VOC concentrations were less than the EPA RBC for industrial and residential soils.

~~Methylene chloride and PCE exceeded EPA SSLs but were detected in only 1 of 18 samples collected and only in shallow soils (0 to 1 foot depth) at one location beneath the asphalt parking lot. The potential for impacts to groundwater quality through leaching is minimal.~~

SVOCs

As shown in **Table 6-27**, the concentrations of several PAHs including benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene in surface and subsurface soils exceeded EPA RBC criteria for residential soils at one location (SB07-001 located beneath the parking lot). The concentration of benzo(a)pyrene at SB07-001 also exceeded the industrial soil RBC. However, as stated in Section 4.5.1.1, their concentrations are probably related to the presence of an asphalt parking lot placed on top of surface soils around the former building.

Although the PAH contamination at the site is probably related to the asphalt parking lot and not related to site activities, the risk associated with these PAHs will be quantified further in this assessment but additional discussion will be provided in the uncertainties section.

~~Benzo(a)pyrene and dibenz(a,h)anthracene exceeded EPA RBC for industrial soils. However, these contaminants were only detected in shallow soils at one location beneath the asphalt parking lot and as previously discussed, are related to asphalt leaching rather than site conditions..~~

~~Benzo(a)anthracene, chrysene, and benzo(b)flouranthene exceeded EPA SSLs. However, these contaminants were only detected in shallow soils (0 to 1 foot depth) at one location beneath the asphalt parking lot. Their concentration greatly decreases with depth and the potential for impacts to groundwater quality through additional leaching is minimal.~~

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 6 of 18 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, BTEX and PAHs, which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. Except for the

soils impacted by the asphalt leaching, their concentrations were less than EPA RBC and SSL criteria.

Inorganics

Arsenic, iron, and manganese exceeded the RBC values for residential soils but did not exceed the industrial soil criteria.

Arsenic was detected in the only surface soil sample collected at a concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic level detected in the surface soils is consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in **Appendix H**.

Manganese and iron were detected in the only surface soil sample collected at a concentration of 170 and 9,100 mg/kg, respectively, which are greater than the EPA RBC for residential soil. Therefore, these metals are also selected as COPCs in surface soils.

~~Barium was detected in only 1 of 4 samples (82 mg/kg at surface soil sample at soil boring #4) above the 32 mg/kg EPA SSL. The USGS reports the observed barium range in their study was 15 to 1,000 mg/kg with a mean of 300 mg/kg. The barium concentration of 82 mg/kg was detected in the surface soil sample (0 to 1 foot sample) at soil boring #4 while only 7.9 mg/kg of barium was detected in the subsurface soil at the same boring collected at a depth of 2 to 4 feet below land surface indicating little leaching of barium through the unsaturated zone since the site activities ceased over 7 years ago. Therefore, the barium levels do not indicate a potential leaching problem.~~

Chemicals of Potential Concern

~~Arsenic and manganese in surface soils and chloroform, bis(2-ethylhexyl)phthalate, and dissolved manganese in groundwater are the COPCs identified during the hazard identification of the Auto Craft media.~~

The COPCs identified for the Auto Craft site are presented as follows:

- Surface and subsurface soil: Benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, arsenic, iron, and manganese
- Groundwater: Chloroform, iron, and manganese

Potential risk associated with the COPC will be further evaluated in the exposure assessment section.

6.5.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the surface and subsurface soils and groundwater COPCs that are present at or migrating from the Auto Craft site.

Potentially Exposed Populations

As part of the exposure assessment, it is important to characterize the potentially exposed populations at or near the site with regard to the current situation and potential future conditions.

Current Situation

The fenced, paved area of the site is currently used as a vehicle impoundment area. The grassy areas located north of the site are unused properties. Fort Story personnel are present at the site for approximately one day per week for only a few minutes. However, because the only surface and subsurface soil COPCs identified were several PAHs, arsenic, iron, and manganese due to exceedence of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Although the grassy areas north of the site are not fenced, potential exposures to the general public and/or trespassers would not be significant because their presence on the site would not be expected to be for only a short time and not routine. There is a sidewalk located along Atlantic Avenue but during our field investigations, little pedestrian traffic was observed. ~~Therefore, there are **no exposed populations to the surface soils at the Auto Craft site under the current situation.**~~ Therefore, exposures to surface and subsurface soils, under current conditions should not exceed risk-based limits.

Groundwater is not used in the vicinity of the site for drinking, process, or production purposes. The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located approximately 4,500 feet (cross groundwater flow gradient) from the site at the LARC 60 Maintenance Area of which water is obtained for nonpotable uses only. ~~Therefore, there are **currently no exposed populations to the groundwater at the Auto Craft site.**~~ Therefore, exposures to groundwater, under current conditions should not exceed risk-based limits since there are current uses of the groundwater.

Future Land Use

Although construction or excavation activities could be conducted in the future, except for PAHs

resulting from asphalt leaching, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. In addition, there are several undeveloped areas adjacent to the site where additional base housing could be constructed. Therefore, as for future conditions, potentially exposed populations include residential exposures to the surface and subsurface soils and groundwater at the LARC 60 site.

Exposure Pathways

The potential exposure pathways for future land use at the Auto Craft site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.

- Residential exposure (adults and children) to **contaminated soil** through ingestion of and dermal contact with chemicals.

Data Limitations and Uncertainties

The limitations and uncertainties associated with the analytical data for the site were reviewed during data validation to ensure that appropriate and reliable data are selected for use in estimating human exposure.

Samples and their duplicates are not considered as separate sampling events. Rather a chemical-specific value representing the maximum value of the sample and its duplicate is used. This may result in a conservative estimate of exposure. However, since relatively few duplicate samples were collected, the overall impact on risk estimates should be minimal.

For purposes of this HHRA, if a COPC was not detected in a sample, it is assumed to be present at 1/2 the practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant Intake

See the text in the "Estimates of Contaminant Intake" section (Section 6.2.2) for the FTA site for a discussion of sample data uses and statistical equations.

~~Evaluation of the exposure pathways described above involves the estimation of several parameters such as skin surface area available for contact; skin permeability factors; exposure time, frequency, and duration; soil-to-skin adherence factors; ingestion rates; as well as the contaminant concentrations in the specific media of concern. **Table 6-5** represents a general equation for calculating chemical intakes (chronic daily intakes or CDI) and defines the intake variables in terms of chemical-related, population-related and evaluation-determined parameters.~~

~~The USEPA recommends that estimates of contaminant intake be developed to portray reasonable maximum exposures (RME) which might be expected to occur under current and future site conditions. Accordingly, the highest exposure that might reasonably be expected to occur at the site, one that is well above the average case of exposure but within the range of possibility should be considered.~~

~~The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the contaminant concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative" concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence limits, etc. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:~~

~~$UCL = e^{\{x + 0.5s^*s + Sh/\sqrt{(n-1)}\}}$~~
~~where:~~

~~UCL = 95th percent upper confidence limit on the mean~~
~~e = constant (natural log)~~
~~x = the mean of the log transformed data~~
~~s = the standard deviation of the log transformed data~~
~~H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean~~
~~n = sample size~~

~~As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be conducted for data sets of 5 or greater.~~

~~Therefore, for the surface soil COPCs of arsenic and manganese, the maximum concentration will be used because only 1 surface soil sample was collected.~~

~~Therefore, for the groundwater COPC of manganese, the maximum concentration will be used because only 2 dissolved groundwater samples for metals analysis were collected.~~

~~The 95th percentile UCL concentrations were computed for chloroform and bis(2-ethylhexyl)phthalate in groundwater to estimate the mean concentration.~~

Because only four groundwater samples were analyzed for chloroform and only two for metals, the maximum concentrations of the identified groundwater COPCs will be utilized in the quantitative assessment. In addition, only 4 soil samples were collected and analyzed for total metals, and therefore, the maximum concentration will be utilized for the metallic soil COPCs.

Eighteen soil samples were collected and analyzed for the PAH COPCs, and therefore, the 95th UCL has been calculated for these COPCs. These UCL calculations are provided in **Appendix I**. The results of the UCL calculations with comparison to the maximum concentration detected are provided in **Table 6-28**.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In **Appendix J**, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

Surface and Subsurface Soil

Tables 6-7a and 6-7b present the parameters and assumptions used in assessing potential exposures to chemicals in surface and subsurface soil. Minimal exposures due inhalation are typically present for metals, and therefore, this exposure pathway is not evaluated. The assumptions made for exposure to chemicals through ingestion and dermal contact are the same as those provided in the discussion for the FTA site in Section 6.2.2, except that the dermal absorption factor for the PAHs is 10 percent.

~~Table 6-7 presents the parameters and assumptions used in assessing potential exposures to chemicals in surface soil. Minimal exposures due to dermal contact and inhalation are typically present for metals, and therefore, these exposure pathways are not evaluated. In addition, arsenic and manganese did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:~~

- ~~In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).~~
- ~~The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.~~
- ~~The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).~~
- ~~An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).~~
- ~~The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).~~
- ~~The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:~~
  - ~~When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.~~

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.4.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8, 6-9, and 6-20 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water through ingestion, dermal contact, and inhalation. In the evaluation of exposures resulting from ground water via ingestion of and dermal contact, the factors and assumptions provided in the FTA assessment are used while the factors and assumptions for inhalation are provided in the LARC 60 assessment.

Tables 6-8 through 6-10 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of, dermal contact or inhalation, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as

described as follows:

- When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in **Appendix I**.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as

described as follows:

- When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be 30m^3 in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

  Chemical concentration in air (mg/m^3) = CW x CF x WV x 1/RV
  where:

  CW = chemical concentration in water (ug/l)
  CF = conversion factor (1E-03 mg/ug)
  WV = volume of water (200 liters)
  RV = room volume (30 m^3)

  The concentration in air for the chemicals of potential concern are presented in Table 6-20. All concentration-in-air calculations are provided in **Appendix I**.

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating

exposure time.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.4.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.4.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves (1) determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and (2) characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used when available. These include verified reference doses (RfDs) for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slopes (CPSs) for the evaluation of cancer risk from lifetime exposure. Each of these are discussed below.

Sources of toxicological guidance information, in order of preference, include: (1) IRIS (Integrated Risk Information System) which is a USEPA database containing current health risk and regulatory information for many chemicals (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

The inherent toxicity of the COPC for the HHRA is briefly summarized in **Appendix J.**

Non-Carcinogenic Effects

The potential for non-cancer health effects associated with chemical exposure is evaluated by comparing an estimated intake (such as chronic daily intake or CDI) over a specified time period with a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical.

The RfDs for the COPC used for the characterization of chronic non-cancer risk via oral exposure routes are presented in **Table 6-29**, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD and any uncertainty of modifying factors used in the derivation of the RfD.

The ratio of the estimate of the CDI to the health-protective criterion (CDI/RfD) is called the hazard quotient (USEPA, 1989a). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, the greater the level of concern.

RfDs for oral exposure are available for most chemicals. For dermal exposure, however, RfDs are not available. In their absence, the oral RfDs are used and adjusted to reflect absorbed dose. This allows for comparison between exposure estimated as absorbed doses and toxicity values expressed as absorbed doses. The absorption efficiencies identified for the COPCs have been estimated at the following rates:

- Arsenic – 41%
- Iron – 15%
- Manganese – 4%
- Chloroform – 20%
- PAH COPCs – 31%

These rates were obtained from the Risk Assessment Information System (RAIS) database. The RAIS is a U.S. Department of Energy database of information developed from data from the USEPA Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST) and other literature sources. A copy of the absorption efficiencies is provided in **Appendix I.**

The RfDs are multiplied by the absorption efficiencies to come up with the adjusted RfDs. The adjusted RfDs are presented in **Table 6-29.**

Except for a few COPCs, reference doses for inhalation exposure, referred to as RfDi, are typically not available. However, it should be noted that the only inhalation pathway identified for the site is for chloroform and PAHs during showering activities. The EPA RBC table identifies those compounds considered VOCs and SVOCs. Identified RfDi for these compounds are provided as follows:

- Chloroform: 8.6E-05
- PAH COPCs: None identified

Carcinogenic Effects

Regardless of the mechanism of effect, risk assessment methods generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk assessment methods require extrapolation from high dose animal studies to evaluate low dose exposures to humans. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis.

Through application of this approach, the USEPA has derived estimates of incremental excess cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and the fitting of those dose-response data to a low dose extrapolation model. The CPS (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in **Table 6-30** and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in **Table 6-30**.

To arrive at an estimate of incremental cancer risk, the following equation is used (USEPA, 1989a):

$$Risk = CDI \times CPS$$

where:

Risk = a unitless probability (e.g., 2 x 10^{-5} or 2 in 100 thousand) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
CPS = Cancer Potency Slope expressed in $(mg/kg\text{-}day)^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). This approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values.

Except for a few COPCs, cancer potency slope factors for inhalation exposure, referred to as CPSi, are typically not available. However, it should be noted that the only inhalation pathway identified for the site is for chloroform during showering activities. Identified CPSi for this compound is provided as follows:

- Chloroform: 8.1E-02

~~CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. However, a CPSi is available for chloroform.~~

Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and cancer effects posed by multiple chemicals. This approach assumes that subthreshold exposures to several chemicals at the same time could result in an adverse health effect. It assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect by the same mechanism of action. In this evaluation, the hazard quotients of a mixture of chemicals which can have different effects are used as a screening-level approach, as recommended by the USEPA (USEPA, 1989a). This approach is likely to overestimate the potential for effects.

For the assessment of carcinogenic risks, the individual risks associated with exposure to each contaminant are summed. This represents an approximation of the precise equation for combining risks which accounts for the joint probabilities of the same individual developing cancer as a

consequence of exposure to two or more carcinogens. This additive approach assumes independence of action by the contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.4.4 Risk Characterization

The final step in the HHRA is the characterization of risk. Here the toxicity and exposure assessments are summarized and combined into quantitative and qualitative expressions of risk. Potential noncarcinogenic effects are characterized by comparing intakes and toxicity values, while carcinogenic risks are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

The USEPA (1989a) recommends absorption efficiency adjustments to ensure that the site exposure estimate (CDI) and the toxicity criteria (RfD and CPS) are both expressed as absorbed doses or both expressed as intakes (administered doses). All CDI calculations are provided in **Appendix I**. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-31 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in **Table 6-31**. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in **Table 6-31**, the total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is greater ~~less~~ than the criterion of 1.0 for both adults and children~~but greater than the criterion for children~~. Thus, adverse non-carcinogen health effects in this residential population (adults and children) are likely. The majority of this risk is associated with inhalation of chloroform ~~ingestion of manganese~~ in groundwater. ~~In addition, ingestion of manganese in groundwater is the only exposure scenario above the criterion.~~ The hazard quotient

(1.7) for the ingestion of iron in groundwater for children was just above the criterion of 1.0 also.

Cancer Risks

Table 6-32 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 64 in 100,000~~1 million~~ (6×10^{-5}) for adults and 5 ~~3~~ in 100,000 ~~1 million~~ (5×10^{-5}) for children. These values are within the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component for adult exposure is inhalation of chloroform in groundwater ~~that was the only exposure scenario within the USEPA remediation goal~~. For child exposures, both ingestion of arsenic in soils and inhalation of chloroform in groundwater were within the USEPA remediation goal.

Uncertainty

Some uncertainty is inherent in the process of conducting predictive, quantitative health risk assessments. Environmental sampling and analysis, fate and transport modeling and human exposure modeling are all prone to uncertainty, as are the available toxicity values used to characterize risk. Such uncertainty is generally related to the limitations of the sampling in terms of the number and distribution of samples and analytical information in terms of systematic or random errors used to characterize a site, the estimation procedures and the input variables and assumptions used in the assessment.

There are uncertainties in every step of the risk assessment process; uncertainties that relate to this human health evaluation may be noted. Selection of the chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. Additional uncertainties are inherent in the exposure assessment for individual chemicals and exposure routes.

There is also some uncertainty in the derivation of health effects criteria in the toxicity assessment. In most cases, the criteria are derived from the extrapolation from laboratory animal data to the human condition. This may have the effect of either overestimating or underestimating the risk.

For the Auto Craft site, some important uncertainties that may influence the results of the HHRA include:

- Limited data set for arsenic and manganese in soils at the site. Only 1 surface soil sample was analyzed for metals. However, these levels were consistent with background soils data as discussed in Section 6.4.1.

- Limited data set for dissolved manganese in groundwater. Only 2 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 80 ug/ for manganese was used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved metals would present a larger data set and provide for a more accurate analysis of risk.

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. Dissolved results may be biased high based on the filtering limitations.

- VOC estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. Chloroform was detected infrequently (1 of 10 samples). Analysis with a lower PQL may more accurately estimate VOC concentrations and subsequent risk. It should be noted that the chloroform concentration (11 ug/l) detected was less than the USEPA MCL (100 ug/l) for total trihalomethanes indicating that the level present in the groundwater would meet acceptable criteria for a drinking water distribution system.

6.4.5 Auto Craft Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

~~- The total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is less than the criterion for adults but greater than the criterion of 1.0 for children with the majority (approximately 77 percent) of this risk associated with ingestion of manganese in groundwater which was the only exposure scenario above the criterion.~~

The total exposure hazard index for adults and children was greater than the criterion of 1.0 with inhalation of chloroform exceeding the criterion for adults and children with ingestion of iron exceeding the criterion for children as well.

A summary of the **Carcinogenic Risk** for future residential land use is provided below:

- The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about ~~4 in 1 million~~ 6 in 100,000 for adults. The greatest component for adults exposures is inhalation of chloroform in groundwater (92~~60~~ percent of total risk) which was within the USEPA remediation goal.

- The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about ~~3 in 1 million~~ 5 in 100,000 for children. The greatest components for child exposures are ingestion of arsenic (although levels are consistent with background) in soils (5~~36~~ percent of total risk) and inhalation of chloroform (86 percent of total risk) in groundwater ~~(47 percent of total risk)~~.

- Potential risk above acceptable criteria is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

- Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentration of chloroform in groundwater due to natural attenuation would be expected to decrease. It currently is below the USEPA MCL for total trihalomethanes.

- Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater and surface soils for future residential development.

Because arsenic was detected in site soils at concentrations consistent with the background soils as previously discussed, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Chloroform was only detected in one groundwater sample at the site and in a concentration (11 ug/L) below the USEPA MCL for total trihalomethanes. Therefore, upon removal of arsenic and chloroform as COPCs, the risk levels become less than the criterion of 1.0 and 10^{-6}, and no further action related to this site (based on human health risk) is warranted.

7.1 OVERVIEW AND OBJECTIVES

This section presents an assessment of potential environmental risks associated with contaminants detected at 3 sites on Fort Story: FTA, LARC 60, and Auto Craft Sites. The primary objective of the ecological risk assessment is to identify and characterize the potential risks posed to wildlife receptors as a result of contaminant releases. Secondary objectives are: to document dominant flora and fauna associated with the site; to determine the contaminants of potential concern being released from the site; to identify potential pathways for receptor exposure; and to determine if any response action might be necessary at the site, from an ecological perspective.

Statutory authority for this assessment is found in CERCLA as amended by the Superfund Amendments and Reauthorization Act (SARA). The evaluation follows guidance contained in the following documents:

- U.S. Environmental Protection Agency's (USEPA) *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual* (USEPA, 1989)
- *Framework for Ecological Risk Assessment* (USEPA, 1992)
- *Procedural Guidelines for Ecological Risk Assessments at U.S. Army Sites Volume I* (Wentsel et. al., 1994).

According to current USEPA guidance, the following steps were completed for the risk assessment at each site:

- Problem Formulation
    - Qualitative characterization of natural resources
    - Identification of chemicals of potential concern
    - Identification of potential exposure pathways
    - Identification of ecological endpoints
    - Development of conceptual ecological site model
- Exposure assessment providing quantitative or qualitative exposure scenarios for selected ecological receptors
- Ecological effects assessment summarizing toxicity reference values for selected ecological receptors
- Characterization of risk

- Estimation of risk uncertainty

Chemical analyses were performed on environmental media, including soil, sediment, surface water, and ground water, where applicable at each site. The conclusions derived from this study focus on identifying potential adverse risks to species, habitats, and populations in the environment, and is not a quantitative determination of risk. The risk assessment addresses potentially significant risks to the following biological groups and resources associated with the area: vascular vegetation, wildlife, threatened and endangered species, and wetlands. Significant habitats and wetlands on the base are identified. Cover types and species inventories for each investigated site and its immediately adjacent areas are also included.

As preceding sections of this RI have indicated, a substantial amount of site-specific data on chemical and physical information was developed to characterize the types, location, and concentrations of chemicals in the environmental media. Validated chemical analytical results were used in all ecological risk analyses. Contaminant toxicity levels to terrestrial and avian species were derived from technical literature. Chemical profiles for chemicals of potential concern are included in Appendix K.

7.2 PROBLEM FORMULATION

Problem formulation is the first phase of ecological risk assessment and establishes the goals, breadth, and focus of the assessment (USEPA, 1992). The process involves a series of interrelated steps to identify potential stressors, pathways, and ecological effects. Ecological endpoints appropriate for the site are then derived, and an ecological conceptual site model is formulated. This model is a set of working hypotheses regarding the potential pathways and effects of site-related stressors on ecosystems of concern.

Problem formulation is based on information collected during the Remedial Investigation. This phase of the ecological risk assessment is presented in four parts: ecosystems of concern; potential stressors, exposure pathways, and ecological effects; ecological endpoints and; the conceptual model.

Initially, field studies were conducted and the ecology of the sites and surrounding areas were characterized. This characterization involved the identification of plant and animal communities as well as observations of any actual or potential effects of chemical and/or physical stress on these biological resources.

The second step in problem formulation involves the identification of the interrelationships between potential stressors, exposure pathways, and ecological effects for the identified ecosystems of concern. Chemical and/or physical stressors are identified, potential pathways for migration of

Chemicals of Potential Concern

~~Arsenic in surface soil and sediment, thallium in sediment and dissolved manganese and PCE in groundwater~~ Arsenic and iron in surface and subsurface soil, antimony and manganese in groundwater, and arsenic, iron, and thallium in sediment are the COPCs identified during the hazard identification of the FTA media. Potential risk associated with each COPC will be further evaluated in the exposure assessment section.

6.2.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the surface and subsurface soils, sediment and groundwater COPCs that are present at or migrating from the FTA.

Potentially Exposed Populations

As part of the exposure assessment, it is important to characterize the potentially exposed populations at or near the site with regard to the current situation and potential future conditions.

Current Situation

The site is currently used as a training area for heavy equipment operations and for unloading and loading of heavy equipment on the loading rack in the southeast corner of the site. Fort Story personnel are present at the site for approximately two days per week. However, because the only surface and subsurface soils COPC identified ~~was~~ were arsenic and iron due to exceedence of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Although the site is not in a restricted area and not fenced, potential exposures to the general public and/or trespassers would not be significant because their presence on the site would not be expected to be for only a short time and not routine. During the four weeks that the investigations were conducted at the site, a few public and/or off-duty personnel were observed at the site walking their dogs or jogging. However, their time spent on-site was limited to less than 30 minutes during their visit. ~~Therefore, there are **no exposed populations to the surface soils at the FTA site under the current situation.**~~ Therefore, exposures to surface and subsurface soils, under current conditions should not exceed risk-based limits.

Groundwater is not used in the vicinity of the site for drinking, process, or production purposes. The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to

withdrawal from a single well located approximately 4,000 feet (cross groundwater flow gradient) from the site at the LARC 60 Maintenance Area; the water is obtained for nonpotable uses only. As discussed in Section 5.0, migration potential is minimal due to the very low vertical gradient present across the FTA site. There has been little or no migration of contaminants in the groundwater over the past 5 years based on a comparison of data from Montgomery-Watson's study in 1990 and data from Malcolm Pirnie's studies~~y~~ in 1995 and 2000. VOC concentrations have decreased substantially due to numerous subsurface mechanisms such as biodegradation, volatilization, and dispersion. ~~Therefore, there are **no exposed populations to the groundwater at the FTA site under the current situation.**~~ Therefore, exposures to groundwater, under current conditions will not exceed risk-based limits since there are no current uses of the groundwater.

In addition to the discussion for surface and subsurface soils provided above, there are no expected exposures to the sediment located in the lowlying wooded area south of the site. ~~Therefore, there are **no exposed populations to the sediment in the wooded area south of the FTA site under the current situation.**~~ Therefore, exposures to sediment, under current conditions will not exceed risk-based limits.

Future Land Use

Although construction or excavation activities could be conducted in the future, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. Therefore, as for future conditions, potentially exposed populations include residential exposures to the contaminated media at the FTA site.

Exposure Pathways

The potential exposure pathways for future land use at the FTA site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water and~~,~~ dermal contact with ~~and inhalation of volatilized~~ chemicals while bathing or showering. Inhalation is not considered a significant pathway for groundwater because the identified COPCs (antimony and manganese) are not considered volatile compounds.

- Residential exposure (adults and children) to **contaminated soil** through ingestion of and dermal contact with chemicals.

- Residential exposure (adults and children) to **contaminated sediment** through ingestion of and dermal contact with chemicals.

Data Limitations and Uncertainties

The limitations and uncertainties associated with the analytical data for the site were reviewed during data validation to ensure that appropriate and reliable data are selected for use in estimating human exposure.

Samples and their duplicates are not considered as separate sampling events. Rather a chemical-specific value representing the maximum value of the sample and its duplicate is used. This may result in a conservative estimate of exposure. However, since relatively few duplicate samples were collected, the overall impact on risk estimates should be minimal.

For purposes of this HHRA, if a COPC was not detected in a sample, it is assumed to be present at 1/2 the practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant Intake

Evaluation of the exposure pathways described above involves the estimation of several parameters such as skin surface area available for contact; skin permeability factors; exposure time, frequency, and duration; soil-to-skin adherence factors; ingestion rates; as well as the contaminant concentrations in the specific media of concern. **Table 6-5** represents a general equation for calculating chemical intakes (chronic daily intakes or CDI) and defines the intake variables in terms of chemical-related, population-related and evaluation-determined parameters.

The USEPA recommends that estimates of contaminant intake be developed to portray reasonable maximum exposures (RME) which might be expected to occur under current and future site conditions. Accordingly, the highest exposure that might reasonably be expected to occur at the site, one that is well above the average case of exposure but within the range of possibility should be considered.

~~The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the contaminant concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative"~~

~~concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence limits, etc. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:~~

~~$UCL = e^{\{x + 0.5s^*s + Sh/\sqrt{(n-1)}\}}$~~
~~where:~~

~~UCL = 95th percent upper confidence limit on the mean~~
~~e = constant (natural log)~~
~~x = the mean of the log transformed data~~
~~s = the standard deviation of the log transformed data~~
~~H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean~~
~~n = sample size~~

~~As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be conducted for data sets of 5 or greater.~~

The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the contaminant concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative" concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence limits, etc. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. The 95th UCL of the arithmetic mean will be calculated and used as the reasonable concentration. Three types of confidence limits are available: parametric, log-normal, and non-parametric. The type of confidence limit that will be applied depends upon the data distribution of the constituent being evaluated (e.g., normal [parametric], log-normal, and non-normal [non-parametric]). Statistical limits

for each constituent data set were employed as detailed below by the following procedures.

1. Initially, all data sets are assumed normally distributed, and the following steps were completed.
   - The assumption of normality of the data was tested using the Shapiro-Wilk Test of Normality.
   - If the data set was determined to be normally distributed (by passing the normality test), a Parametric Confidence Limit was calculated.
2. If the data set initially failed the Test of Normality, the following steps were followed.
   - All data was convert to natural logarithms.
   - The log-adjusted data was then tested for normality using the Shapiro-Wilk Test of Normality.
   - If the log-adjusted data was determined to be normally distributed (by passing the normality test), the data set was said to be log-normally distributed.
   - A lognormal confidence limit was applied to the log-normal data sets.
3. If the data set was neither normally distributed nor log-normally distributed the following steps were followed.
   - The data set was said to be distribution-free (non-parametric or non-normal).
   - A non-parametric confidence limit was applied to the distribution-free data sets.

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the CRQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be conducted for data sets of five samples or greater.

Therefore, for the groundwater COPCs of antimony and manganese, the maximum concentration will be used because only four ~~3~~ dissolved groundwater samples were collected in 2000 with one well only sampled in 1995 and these two data sets should not be combined statistically.

Because exposures to the COPCs (arsenic, iron, and thallium) in the soil and sediment (actually soils from a lowlying area adjacent to the site) would be similar, these data sets will be combined for the risk analysis which creates a data set of 18 soil/sediment samples.

The 95th percentile UCL concentrations were computed for arsenic, iron, and thallium in surface soils, subsurface soils, and sediment ~~and PCE in groundwater~~ to estimate the mean concentration. UCL calculations are provided in **Appendix I**. The results of the UCL calculations with comparison to the maximum concentration detected are provided in **Table 6-6**.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In **Appendix J**, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

~~Surface~~ Soil and Sediment

Table~~s~~ 6-7a and 6-7b present~~s~~ the parameters and assumptions used in assessing potential exposures to chemicals in ~~surface~~ soil and sediment. Minimal exposures due to ~~dermal contact and~~ inhalation are typically present for metals, and therefore, thi~~s~~ese exposure pathway~~s~~ is ~~are~~ not evaluated. ~~In addition, arsenic did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant.~~ The following summarize the assumptions made for exposure to chemicals in soil through ingestion and dermal contact:

Ingestion

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).

- The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that ~~50~~ 100 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of ~~30~~ 24 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

    - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

    - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.2.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Dermal Contact

Adults:

- The value cited as the 50th percentile for exposure to hands, forearms, neck, and head is 3,600 cm^2 (USEPA, 1997).

- The soil to skin adherence factor (AF) used is 0.20 mg/cm^2. No specific skin AFs were listed in the 1997 USEPA Exposure Factors Handbook for residential adults so a default value of 0.20 as recommended by EPA Region III was selected.

- For the dermal contact with soil pathway, the absorption factor (ABS) is 3.2% for arsenic and 1% for other metals (USEPA, 1995b).

- The exposure frequency, exposure duration, body weight and averaging time values are the same as those used for the ingestion pathway.

Children:

- A skin surface area (SA) of 2,074 cm^2 is used for this pathway. This is 25% of the 50th percentile total body surface area for children ages 3 to 9 (USEPA, 1989a). The 25% of the total body area selection is recommended in the EPA Dermal Exposures Assessment: Principles and Applications Interim Report, dated January 1992.

- The soil to skin adherence factor (AF) used for children is 0.20 mg/cm^2. No specific skin AFs were listed in the 1997 USEPA Exposure Factors Handbook for children playing in soil so a default value of 0.20 as recommended by EPA Region III was selected.

- For the dermal contact with soil pathway, the absorption factor (ABS) is 3.2% for arsenic and 1% for other metals (USEPA, 1995b).

Exposure frequency and duration, body weight and averaging time assumptions were previously discussed.

Groundwater

Tables 6-8 and ~~through~~ **6-9~~10~~** present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of~~,~~ or dermal contact ~~or inhalation~~, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

#3

- An exposure duration (ED) of 24~~30~~ years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

- When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

- Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in **Appendix I**.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

#3

- An exposure duration (ED) of ~~30~~ 24 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

- When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

~~*Inhalation*~~

~~• For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be 30m^3 in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:~~

~~Chemical concentration in air (mg/m^3) = CW x CF x WV x 1/RV~~
~~where:~~

~~CW = chemical concentration in water (ug/l)~~
~~CF = conversion factor (1E-03 mg/ug)~~
~~WV = volume of water (200 liters)~~
~~RV = room volume (30 m^3)~~

~~The concentration in air for the chemicals of potential concern are presented in Table 6-6. All concentration-in-air calculations are provided in Appendix I.~~

~~• An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).~~

~~• Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.~~

- ~~The exposure frequency (EF) for residential populations (adult and children) is assumed to be~~

exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.2.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.2.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves (1) determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and (2) characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used when available. These include verified reference doses (RfDs) for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slopes (CPSs) for the evaluation of cancer risk from lifetime exposure. Each of these are discussed below.

Sources of toxicological guidance information, in order of preference, include: (1) IRIS (Integrated Risk Information System) which is a USEPA database containing current health risk and regulatory

information for many chemicals (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

The inherent toxicity of the COPC for the HHRA is briefly summarized in **Appendix J.**

Non-Carcinogenic Effects

The potential for non-cancer health effects associated with chemical exposure is evaluated by comparing an estimated intake (such as chronic daily intake or CDI) over a specified time period with a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations that are likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical.

The RfDs for the COPC used for the characterization of chronic non-cancer risk via oral exposure routes are presented in **Table 6-**1011, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD and any uncertainty of modifying factors used in the derivation of the RfD.

The ratio of the estimate of the CDI to the health-protective criterion (CDI/RfD) is called the hazard quotient (USEPA, 1989a). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, the greater the level of concern.

RfDs for oral exposure are available for most chemicals. For dermal exposure, however, RfDs are not available. In their absence, the oral RfDs are used and adjusted to reflect absorbed dose. This allows for comparison between exposure estimated as absorbed doses and toxicity values expressed as absorbed doses. The absorption efficiencies identified for the COPCs have been estimated at the following rates.

- Antimony – 2%
- Arsenic – 41%
- Iron – 15%
- Manganese – 4%
- Thallium – 15%

These rates were obtained from the Risk Assessment Information System (RAIS) database. The RAIS is a U.S. Department of Energy database of information developed from data from the USEPA

Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST) and other literature sources. A copy of the absorption efficiencies is provided in **Appendix I.**

The RfDs are multiplied by the absorption efficiencies to come up with the adjusted RfDs. The adjusted RfDs are presented in **Table 6-10.**

~~Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. However, a RfDi does not currently exist for PCE so no non-carcinogenic evaluation of the risks associated with inhalation of volatilized chemicals in groundwater will be made.~~

Carcinogenic Effects

Regardless of the mechanism of effect, risk assessment methods generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk assessment methods require extrapolation from high dose animal studies to evaluate low dose exposures to humans. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis.

Through application of this approach, the USEPA has derived estimates of incremental excess cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and the fitting of those dose-response data to a low dose extrapolation model. The CPS (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per (mg/kg-day)$^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in **Table 6-1112** and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in **Table 6-1112**.

To arrive at an estimate of incremental cancer risk, the following equation is used (USEPA, 1989a):

Risk = CDI x CPS
where:

Risk = a unitless probability (e.g., 2 x 10^{-5} or 2 in 100 thousand) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
CPS = Cancer Potency Slope expressed in (mg/kg-day)$^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). This approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values.

~~CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. However, there does exist a CPSi for PCE, and therefore, an evaluation of carcinogenic risk for the inhalation of volatilized chemicals will be made.~~

Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and cancer effects posed by multiple chemicals. This approach assumes that subthreshold exposures to several chemicals at the same time could result in an adverse health effect. It assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect by the same mechanism of action. In this evaluation, the hazard quotients of a mixture of chemicals which can have different effects are used as a screening-level approach, as recommended by the USEPA (USEPA, 1989a). This approach is likely to overestimate the potential for effects.

For the assessment of carcinogenic risks, the individual risks associated with exposure to each contaminant are summed. This represents an approximation of the precise equation for combining risks which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens. This additive approach assumes independence of action by the contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.2.4 Risk Characterization

The final step in the HHRA is the characterization of risk. Here the toxicity and exposure assessments are summarized and combined into quantitative and qualitative expressions of risk. Potential noncarcinogenic effects are characterized by comparing intakes and toxicity values, while carcinogenic risks are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

The USEPA (1989a) recommends absorption efficiency adjustments to ensure that the site exposure estimate (CDI) and the toxicity criteria (RfD and CPS) are both expressed as absorbed doses or both expressed as intakes (administered doses). All CDI calculations are provided in **Appendix I**. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-1213 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in **Table 6-**1213. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in **Table 6-**1213, the total exposure hazard index for ~~ingestion of soils and~~ ingestion of and dermal contact with chemicals in soils and groundwater is 0.60 for adults and 0.66 for children which are less than the criterion of 1.0 for adults and children. ~~but greater than the criterion of 1.0 for children.~~ Thus, adverse non-carcinogen health effects in these ~~this~~ residential populations (adult and children) are ~~is~~ unlikely. ~~The majority of this risk is associated with ingestion of manganese in groundwater. In addition, exposure to manganese in groundwater is the only exposure scenario above the criterion.~~

Cancer Risks

Table 6-1314 presents estimated chemical-specific and total pathway cancer risks calculated for ~~ingestion of soils and~~ ingestion of~~,~~ and dermal contact with~~, and inhalation of~~ chemicals in soil and groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in ~~surface~~ soils and groundwater is about 1.54 in 1 million for adults and 2.73 in 1 million for children. These values are within but on the lower end

of the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. ~~The greatest component (only component within the USEPA remediation goal) for adults exposures is ingestion of PCE in groundwater (3 in 1 million).~~ The ingestion of and dermal contact with arsenic in ~~surface~~ soils ~~(1.5 in 1 million) and ingestion of PCE in groundwater (1.3 in 1 million)~~ are the greatest exposure pathways for adults and children. ~~Risks associated with both of these child exposure scenarios are within the USEPA remediation goal.~~

Uncertainty

Some uncertainty is inherent in the process of conducting predictive, quantitative health risk assessments. Environmental sampling and analysis, fate and transport modeling and human exposure modeling are all prone to uncertainty, as are the available toxicity values used to characterize risk. Such uncertainty is generally related to the limitations of the sampling in terms of the number and distribution of samples and analytical information in terms of systematic or random errors used to characterize a site, the estimation procedures and the input variables and assumptions used in the assessment.

There are uncertainties in every step of the risk assessment process; uncertainties that relate to this human health evaluation may be noted. Selection of the chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. Additional uncertainties are inherent in the exposure assessment for individual chemicals and exposure routes.

There is also some uncertainty in the derivation of health effects criteria in the toxicity assessment. In most cases, the criteria are derived from the extrapolation from laboratory animal data to the human condition. This may have the effect of either overestimating or underestimating the risk.

For the FTA site, some important uncertainties that may influence the results of the HHRA include:

- Although a limited data set for arsenic in soils at the site was available, as previously stated in Section 6.2.1, arsenic concentrations in soils are consistent with Fort Story and USGS regional background soils data.

- Limited data set for dissolved manganese in groundwater. Only ~~3~~ four dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 81 ug/l was used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved manganese would present a larger data set and provide for

a more accurate analysis of risk.

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. As shown on the Groundwater Sampling Form in **Appendix C** of the RI report for monitoring well 4MW-2S where the 81 ug/l dissolved manganese result was detected, the sample collected was extremely turbid (310 NTUs) which may impact filter efficiency due to the passing of some turbid under the filter into the sample container. Dissolved results may be biased high based on the filtering limitations.

~~• PCE estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. PCE was not detected in 29 of the 31 groundwater sampling locations at the site. Analysis with a lower PCE PQL may more accurately estimate PCE concentrations and subsequent risk.~~

6.2.5 FTA Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized below.

A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

- The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is less than the criterion of 1.0 for adults and children.

~~• The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for children. However, ingestion of manganese from groundwater is the only child exposure scenario above the criterion.~~

A summary of the **Carcinogenic Risk** for future residential land use is provided below:

- The estimated cancer risk for exposure to chemicals in ~~surface~~ soils and groundwater is about 1.54 in 1 million for adults and 2.7 in 1 million for children. The greatest component for adults and children exposures is ingestion of and dermal contact with arsenic in soils which accounts for 100 percent of the cancer risk. However, as previously stated, arsenic concentrations are consistent with background. ~~PCE in groundwater (2.69 in 1 million - 75 percent of total risk) which is within the USEPA remediation goal.~~

~~• The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 1 million for children. The greatest components for child exposures are ingestion of arsenic (although detected at levels consistent with background) in surface soils (1.5 in 1 million - 54 percent of total risk) and ingestion of PCE in groundwater (1.26 in 1 million - 45 percent of total risk). These child exposure scenarios are within the USEPA remediation goal.~~

- Potential risk is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

- Concentrations of volatile organics decreased by about one order of magnitude from the 1991 PA/SI sampling event to the 1995 RI sampling event and then to the 2000 sampling event with natural attenuation expected to continue this trend. No organics were detected above the USEPA MCLs during the 2000 sampling event. ~~Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentrations of PCE in groundwater due to natural attenuation would not be expected to be above USEPA MCLs at that time.~~

- ~~Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater. However, under current land use, there are no risks from the metals in the groundwater.~~

Because arsenic was detected in site soils at concentrations consistent with the background soils as previously discussed, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Therefore, upon removal of arsenic as a COPC, the risk levels become less than the criterion of 1.0 and 10^{-6}, and no further action related to this site (based on human health risk) is warranted.

6.3 LARC 60 MAINTENANCE AREA

6.3.1 Hazard Identification

Numerous groundwater, surface soil, surface water and sediment samples were collected from this site and analyzed for various chemical contaminants. **Figures 2-7 and 2-8** provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in **Tables 6-1415 through 6-1819** to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select COPCs for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

Emphasis is given in the ensuing evaluation to chemical contamination in the surface and subsurface soil throughout the site, sediment and surface water near the site and groundwater underlying the site as these environmental media are regarded as having the greatest potential for human contact. ~~Chemical contamination in the subsurface soils are discussed in the context of the potential for exposure from future excavation of these soils and continued or further degradation of groundwater from leaching.~~

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III Risk-based Concentration (RBC) Criteria EPA and Virginia Petroleum Program Criteria are included in **Table 6-14~~15~~** as TBC criteria for purposes of comparison. A total of 22 surface soil samples were collected during the initial field investigation in 1995 with analysis for VOCs, SVOCs, TPH, and metals while eight surface soil samples were collected in 2000 for pesticide and PCB analysis only to address data gaps in the VDEQ comment letter, dated February 6, 1996.

VOCs and SVOCs

All concentrations of VOCs and SVOCs were less than EPA RBC criteria, and therefore, they are not selected as COPCs.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 17 of 22 surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. BTEX and PAHs, which are hazardous constituents of petroleum products, will be the primary compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA RBC criteria.

PCBs

PCBs were not detected in any of the eight surface soil samples, and therefore, are not selected as COPCs.

Pesticides

Seven pesticides (beta BHC, alpha and gamma chlordane, DDD, DDE, DDT, and dieldrin) were detected in the soil samples collected at the LARC 60 site. However, as shown in **Table 6-14**, concentrations did not exceed EPA RBC criteria, and therefore, pesticides are not selected as COPCs.

Inorganics

Arsenic ~~and manganese~~ exceeded the RBC values for residential soils but did not exceed the industrial soils criteria.

Arsenic was detected in only 1 of 5 surface soil samples at a concentration of 1.1 mg/kg with a mean concentration of 0.6 mg/kg for all surface soil samples. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the surface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in **Appendix H**.

~~Manganese concentrations in surface soils ranged from 2.4 to 120 mg/kg with a mean concentration of 29 mg/kg. Although no background 95th percentile UCL was established by Montgomery Watson during performance of the PA/SI, the USGS regional soils data indicates an observed range of less than 0.2 to 7,000 mg/kg with a mean of 290 mg/kg. Therefore, the manganese levels detected in the surface soils are consistent with regional background soils.~~

Although consistent with background levels, for the purposes of risk analysis, arsenic ~~and manganese are~~ is selected as a COPC~~s~~ based on its ~~their~~ exceedence of the residential soils criteria.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in **Table 6-15~~16~~** along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC Criteria. Only the dissolved inorganic data is presented in **Table 6-15~~16~~**. Total inorganic data are influenced by percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment is not available for transport with flowing groundwater and would also be filtered out if drinking water wells were installed in this area.

Thirty-three (33) groundwater samples (25 DPT and 8 monitoring well samples) were collected from the upper aquifer during the 1995 field investigation and analyzed for VOCs, SVOCs, TPH, and tota and dissolved metals while six wells were resampled in 2000 with analysis for VOCs, pesticides, PCBs, and total and dissolved metals. Groundwater samples were also collected from three temporary well points during a free-product investigation. However, because no QA/QC samples were collected and data validation was not conducted, these results will not be used during the risk assessment process. The number of results for each chemical may vary due to the analysis of different compounds at different locations. However, in that DPT data is typically used for screening

purposes, only the groundwater data collected from the permanent monitoring wells will be included in the risk analysis. The 2000 sampling event data will be utilized in place of the 1995 data when the same constituents were analyzed (i.e., VOCs and dissolved metals).

VOCs

Cis 1,2-dichloroethene (cis 1,2-DCE), methyl isobutyl ketone (MIBK), toluene, and vinyl chloride were detected above the EPA screening criteria as presented in **Table 6-15**, and therefore, are selected as COPCs. Ethylbenzene, trichloroethene (TCE), and xylenes were detected in select wells but at concentrations less than screening criteria, and therefore, are not selected as COPCs in groundwater.

~~Acetone, carbon disulfide, methylene chloride, and vinyl acetate were detected in only 1 of 29 samples and in concentrations less than risk screening criteria, and therefore, they are not selected as COPC.~~

~~Chloroform was detected in only 1 of 29 samples but at a concentration greater than the EPA RBC of 0.15 ug/l. However, because of its infrequent detection (3 percent), it is not selected as a COPC.~~

~~MIBK was detected in two samples but in concentrations less than risk screening criteria, and therefore, it is not selected as a COPC.~~

~~p-Isopropyl toluene, 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene were detected in one QA split sample analyzed by the USACE NED lab but in concentrations less than risk screening criteria, and therefore, they are not selected as COPC.~~
~~Ethyl benzene, xylenes, toluene, PCE, cis 1,2-dichloroethene (cis 1,2-DCE), and TCE were detected in excess of screening criteria, and therefore, they are selected as COPC.~~

SVOCs

2-Methylnaphthalene and naphthalene were detected above the EPA screening criteria as presented in **Table 6-15**, and therefore, are selected as COPCs. No other SVOCs were detected in the groundwater samples from the monitoring wells.

~~SVOCs were not detected in any of the groundwater samples in excess of screening criteria, and therefore, are not selected as COPC.~~

TPH

Although TPH exceeded the Virginia Groundwater Standard of 1 mg/l in 4 of 32 groundwater samples, only one of the petroleum product hazardous constituents, toluene, exceeds risk screening criteria. The risk associated with petroleum hydrocarbons will be further evaluated based on toluene as previously discussed.

Pesticides/PCBs

No pesticides or PCBs were detected in the six monitoring wells sampled in 2000.

Inorganics

Dissolved antimony was detected above the EPA RBC of 1.5 ug/l in 2 of 6 samples, and is selected as a COPC. However, it should be noted that antimony concentrations are lower than the USEPA MCL of 6 ug/l in all samples.

Dissolved manganese was detected at a concentration greater than the EPA RBC of 73 ug/l ~~risk screening criteria~~ in three ~~1~~ of six ~~4~~ samples collected in 2000, and therefore, is selected as a COPC.

Although detected at concentrations less than the EPA MCL ~~and Virginia Groundwater Quality Standards and Protection Levels~~, dissolved arsenic was detected in 1 of 6 ~~4~~ samples in excess of the EPA RBC ~~criteria~~ of 0.045 ug/l ~~as a non-carcinogen and carcinogen~~, and therefore, is selected as a COPC.

Dissolved iron was detected at concentrations greater than the EPA RBC of 2,200 ug/l in 4 of 6 samples, and is selected as a COPC.

No other dissolved metals were detected above EPA and VDEQ risk screening criteria as presented in **Table 6-15**.

~~Dissolved iron was detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, as these standards were established for aesthetic qualities only for drinking water supplies, iron is not selected as a COPC. No other dissolved inorganics were detected in concentrations greater than risk screening criteria.~~

Sediment

Sediment sampling was conducted to evaluate the nature of contamination in the sediment in the drainage ditch north of the Sandbox. Sediment samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for sediment cleanup, EPA Region III RBC Criteria for industrial and residential soils and Virginia Petroleum Program Criteria are included in **Table 6-**16~~17~~ as TBC criteria for purposes of comparison. A total of two sediment samples were collected during the field investigation.

VOCs and SVOCs

No VOCs or SVOCs were detected in sediment samples at the site, and therefore, they are not selected as COPC.

TPH

TPH exceeded the 100 mg/kg TBC criterion in both sediment samples. Because TPH is typically used as an indicator of contamination, it will not be used during this quantitative risk assessment. BTEX and PAH concentrations, as previously discussed, were not detected.

Inorganics

All concentrations of inorganics were less than EPA RBC criteria, and therefore, are not selected as COPC.

Surface Water

Surface water sampling was conducted to evaluate the nature of contamination in the surface water in the drainage ditch north of the Sandbox. Samples were collected from the surface of the standing water in the ditch. Virginia Surface Water Quality Standards and EPA Ambient Water Quality Criteria are included in **Table 6-**17~~18~~ as ARARs for purposes of comparison. A total of two surface water samples were collected during the field investigation.

VOCs

Acetone was the only VOC detected in surface water samples. No surface water quality standards have been established for acetone, however, concentrations (30 and 35 ug/l) were less than EPA RBC criteria of 37,000 ug/l for tap water. Therefore, acetone is not selected as a COPC.

SVOCs and TPH

No TPH or SVOCs were detected in surface water samples at the site, and therefore, they are not selected as COPC.

Inorganics

~~Iron and m~~Manganese concentrations were greater than Virginia surface water quality criteria for human health consumption of water and fish and the EPA RBC of 73 ug/l, and therefore, ~~they~~ it is ~~are~~ selected as a COPC. Because iron concentrations exceeded the Virginia surface water quality criteria for human health consumption of water and fish, it is selected as a COPC in surface water.

No other inorganics were detected at concentrations greater than water quality standards.

Combined Surface and Subsurface Soils ~~and Soil Leachability~~

To evaluate the potential exposures to surface and subsurface soils (i.e., future excavation activities and residential development) ~~and for the potential leaching of contaminants form soil to groundwater~~,

as shown in **Table 6-1819**, soil analytical data was compared against EPA RBCs for industrial and residential soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria are included in **Table 6-1819** as TBC criteria for purposes of comparison. A total of 49 soil samples were collected during the field investigation.

VOCs

All concentrations of VOCs were less than EPA RBC criteria for industrial and residential soils, and therefore, no VOCs are selected as COPCs in soils.

~~PCE concentrations exceeded the SSLs in only 1 of 49 soil samples collected and was detected in only 3 of 49 soil samples. Although PCE is a groundwater COPC, soil results indicate that the majority of the PCE has already volatilized and/or leached out due to a high percolation rate due to the presence of medium to fine grained sands present at the LARC 60 site. Two DPT groundwater points were sampled adjacent to SB-20 where the one PCE exceedance (71 ug/kg) occurred with no PCE detected in groundwater. The source of the PCE in the groundwater is the area near the former UST pit not the area near SB-20 which is located in the Sandbox. The one exceedance occurred at a depth of 4 to 5 feet below grade which is at the water table interface in this area, and therefore, due to the high percolation rate and mixing in the groundwater, it is unlikely that the PCE at that location still exists or could be detected in groundwater. Therefore, additional impacts to groundwater quality through further leaching would not be anticipated.~~

~~Although the methylene chloride concentrations detected in site soils exceeded the SSLs, no methylene chloride has been detected in groundwater at the site which indicates that currently no significant leaching has occurred even though the sands are highly permeable. A more detailed description of methylene chloride leachability is provided on page 5-14.~~

~~SVOCs and Inorganics~~

No SVOCs were detected at concentrations above EPA RBCs for industrial or residential soils, and therefore, no SVOCs are selected as COPCs in site soils.

~~SVOC and inorganic concentrations did not exceed EPA RBC for industrial soils or EPA Region III SSLs for Transfers to Groundwater.~~

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 29 of 49 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this

quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethyl benzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA RBC criteria.

PCBs

PCBs were not detected in any of the eight surface soil samples, and therefore, are not selected as COPCs.

Pesticides

Seven pesticides (beta BHC, alpha and gamma chlordane, DDD, DDE, DDT, and dieldrin) were detected in the soil samples collected at the LARC 60 site. However, as shown in **Table 6-14**, concentrations did not exceed EPA RBC criteria, and therefore, pesticides are not selected as COPCs.

Inorganics

Arsenic exceeded the RBC value of 0.34 mg/kg for residential soils but did not exceed the industrial soils criteria. Arsenic was detected in only 3 of 11 surface and subsurface soil samples at a concentration range of 0.86 to 1.1 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the surface and subsurface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in **Appendix H**.

Although detected at concentrations consistent with background, arsenic is selected as a COPC in surface and subsurface soils due to the 3 detects above the EPA RBC for residential soils. No other inorganics exceeded EPA RBC values.

Chemicals of Potential Concern

COPC identified during the hazard identification of the LARC 60 site media include the following:

Media	COPC
Surface and Subsurface Soils	Arsenic ~~and Manganese~~
Groundwater	cis 1,2-DCE, MIBK, ~~ethyl benzene, xylenes,~~ toluene, vinyl chloride, ~~PCE, TCE, toluene~~, 2-

	methylnaphthalene, naphthalene, antimony, arsenic, iron, and manganese
Surface Water	Iron and Manganese

Potential risk associated with the COPC will be further evaluated in the exposure assessment section.

6.3.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the surface and subsurface soils, groundwater and surface water COPCs that are present at or migrating from the LARC 60 site.

Potentially Exposed Populations

As part of the exposure assessment, it is important to characterize the potentially exposed populations at or near the site with regard to the current situation and potential future conditions.

Current Situation

The site is currently a heavy equipment maintenance facility with numerous maintenance facilities and outdoor staging areas for heavy equipment. The site is fenced with the two entrance gates locked during off-duty hours (typically 6:00 pm to 6:00 am). Fort Story personnel are present at the site for five days per week. However, because the only surface and subsurface soils COPC~~s~~ identified was~~were~~ arsenic ~~and manganese~~ due to exceedence of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Because the site is fenced, potential exposures to the general public and/or trespassers are not significant. ~~Therefore, there are **no exposed populations to the surface soils at the LARC 60 site under the current situation.**~~ Therefore, exposures to surface and subsurface soils under current conditions should not exceed risk-based limits.

The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located at the site of which water is obtained for nonpotable uses only. The well is screened in a deeper aquifer below the confining unit present at a depth of approximately 40 feet below land surface at the site. No COPC were identified in the two deep monitoring wells at the site which are screened at a depth of 30 to 40 feet below land surface. Based

on a comparison of data from Montgomery-Watson's study in 1990 and data from Malcolm Pirnie's studies in 1995 and 2000, VOC concentrations have decreased substantially due to numerous subsurface mechanisms such as biodegradation, volatilization, and dispersion. ~~Therefore, there are currently no exposed populations to the groundwater at the LARC 60 site.~~ Therefore, exposures to groundwater under current conditions should not exceed risk-based limits since there are no current uses of the groundwater.

Based on vertical elevations established for the two surface water locations in the ditch, the ditch intersects the shallow water table. The elevations were consistent with the groundwater elevations in that area as shown on **Figure 3-6**. Due to shallow water table elevation fluctuations during the dry season, it is expected that at certain times of the year that no surface water will be present in the drainage ditch. No flow or discharge point is present, therefore, no impacts to other surface water bodies or potential receptors have been identified. There are no current personnel exposures to the surface water and no trespassers into this area would be anticipated. The surface water in the ditch when present is not used for drinking water or fish consumption. ~~Therefore, there are currently no exposed populations to the surface water at the LARC 60 site.~~ Therefore, exposures to surface water under current conditions should not exceed risk-based limits.

Future Land Use

Although construction or excavation activities could be conducted in the future, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. Therefore, as for future conditions, potentially exposed populations include residential exposures to the surface and subsurface soils and groundwater at the LARC 60 site.

Although the iron and manganese levels in surface water exceeded the Virginia surface water quality standards for consumption of fish and water, it is not expected that the water or fish (ditch does not support edible fish species) would be consumed even if this drainage area were present after future residential development. EPA Region III recommended that 10 times the residential tap water screening level (i.e., hazard quotient of 1 for non-carcinogens and an increased cancer risk of 1E-05 for carcinogens) be used for screening of surface water when the waters may be used for recreational purposes such as wading or swimming. It is anticipated that this value will allow for sufficient conservatism for the protection of the recreational user of the ditch, if any. Therefore, because the iron (maximum of 1,400 ug/l) and manganese (maximum of 140 ug/l) concentrations are less than the adjusted criteria for recreational exposures (22,000 ug/l for iron and 730 ug/l for manganese), population exposures should be less than risk-based limits and no further analysis is required. Therefore, for the future land use scenario, no potentially exposed populations were

identified for the surface water in this drainage ditch.

Exposure Pathways

The potential exposure pathways for future land use at the LARC 60 site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.

- Residential exposure (adults and children) to **contaminated soil** through ingestion of and dermal contact with chemicals.

Data Limitations and Uncertainties

The limitations and uncertainties associated with the analytical data for the site were reviewed during data validation to ensure that appropriate and reliable data are selected for use in estimating human exposure.

Samples and their duplicates are not considered as separate sampling events. Rather a chemical-specific value representing the maximum value of the sample and its duplicate is used. This may result in a conservative estimate of exposure. However, since relatively few duplicate samples were collected, the overall impact on risk estimates should be minimal.

For purposes of this HHRA, if a COPC was not detected in a sample, it is assumed to be present at 1/2 the practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant Intake

See the text in the "Estimates of Contaminant Intake" section (Section 6.2.2) for the FTA site for a discussion of sample data uses and statistical equations.

~~Evaluation of the exposure pathways described above involves the estimation of several parameters such as skin surface area available for contact; skin permeability factors; exposure time, frequency, and duration; soil-to-skin adherence factors; ingestion rates; as well as the contaminant~~

concentrations in the specific media of concern. **Table 6-5** represents a general equation for calculating chemical intakes (chronic daily intakes or CDI) and defines the intake variables in terms of chemical-related, population-related and evaluation-determined parameters.

The USEPA recommends that estimates of contaminant intake be developed to portray reasonable maximum exposures (RME) which might be expected to occur under current and future site conditions. Accordingly, the highest exposure that might reasonably be expected to occur at the site, one that is well above the average case of exposure but within the range of possibility should be considered.

The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the contaminant concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative" concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence limits, etc. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:

$$UCL = e^{\{x + 0.5s^*s + Sh/\sqrt{(n-1)}\}}$$

where:

UCL = 95th percent upper confidence limit on the mean
e = constant (natural log)
x = the mean of the log transformed data
s = the standard deviation of the log transformed data
H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean
n = sample size

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be

~~conducted for data sets of 5 or greater.~~

~~Therefore, for the groundwater COPCs of arsenic and manganese, the maximum concentration will be used because only 4 dissolved groundwater samples were collected.~~

Because of the sufficient data sets (greater than 5 samples) for groundwater and soil, ~~T~~the 95th percentile UCL concentrations were computed for arsenic ~~and manganese~~ in surface and subsurface soils and the ~~numerous~~ VOCs (cis 1,2-DCE, MIBK, toluene, and vinyl chloride), SVOCs (2-methylnaphthalene and naphthalene), and metals (antimony, arsenic, iron, and manganese) in groundwater to estimate the mean concentration. These UCL calculations are provided in **Appendix I**. The results of the UCL calculations with comparison to the maximum concentration detected are provided in **Table 6-19~~20~~**.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In **Appendix J**, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

Surface and Subsurface Soil

Tables 6-7a and 6-7b present~~s~~ the parameters and assumptions used in assessing potential exposures to chemicals in surface and subsurface soil. Minimal exposures due ~~to dermal contact and~~ inhalation are typically present for metals, and therefore, this ~~these~~ exposure pathways ~~is~~ are not evaluated. The assumptions made for exposure to chemicals through ingestion and dermal contact are the same as those provided in the discussion for the FTA site in Section 6.2.2. ~~In addition, arsenic and manganese did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:~~

- ~~In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).~~

- ~~The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.~~

- ~~The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence.~~

- ~~An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).~~

- ~~The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).~~

- ~~The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:~~

  - ~~When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.~~

  - ~~When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.~~

  ~~This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.~~

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.3.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8 and ~~through~~ **6-9~~10~~** present the parameters and assumptions used in assessing potential exposures to chemicals in ground water through ingestion and dermal contact while **Table 6-20** presents the parameters and assumptions used in assessing inhalation exposures. In the evaluation of exposures resulting from ground water via ingestion of and ~~,~~ dermal contact ~~or inhalation~~, the ~~following~~ factors and assumptions provided in the FTA assessment are used. The evaluation of inhalation exposures utilized the following assumptions and factors:

~~*Ingestion*~~

- ~~For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption~~

(USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in **Appendix I**.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

- ~~The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).~~

- ~~An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).~~

- ~~The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).~~

- ~~The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:~~

  - ~~When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.~~

  - ~~When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.~~

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using the VDEQ shower model as provided in **Appendix I.** The model uses various equations and factors such as the groundwater concentration, molecular weight, Henry's Law Constant among others to calculate the concentration in air of each COPC. In that metals do not have a significant volatilization component and that no Henry's Law Constant is available for them, their concentrations in are not calculated.

- ~~For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be $30m^3$ in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:~~

~~Chemical concentration in air (mg/m^3) = CW x CF x WV x 1/RV~~
~~where:~~

~~CW = chemical concentration in water (ug/l)~~
~~CF = conversion factor (1E-03 mg/ug)~~
~~WV = volume of water (200 liters)~~
~~RV = room volume (30 m^3)~~

~~The concentration in air for the chemicals of potential concern are presented in Table 6-20.~~
~~All concentration-in-air calculations are provided in **Appendix I**.~~

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 24 ~~30~~ years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

    - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

    - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.3.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.3.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves (1) determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and (2) characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used when available. These include verified reference doses (RfDs) for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slopes (CPSs) for the evaluation of cancer risk from lifetime exposure. Each of these are discussed below.

Sources of toxicological guidance information, in order of preference, include: (1) IRIS (Integrated Risk Information System) which is a USEPA database containing current health risk and regulatory information for many chemicals (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

The inherent toxicity of the COPC for the HHRA is briefly summarized in **Appendix J**.

Non-Carcinogenic Effects

The potential for non-cancer health effects associated with chemical exposure is evaluated by comparing an estimated intake (such as chronic daily intake or CDI) over a specified time period with a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that are likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical.

The RfDs for the COPC used for the characterization of chronic non-cancer risk via oral exposure routes are presented in **Table 6-21**, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD and any uncertainty of modifying factors used in the derivation

LARC 60 DPT GROUNDWATER SAMPLES RANGE AND FREQUENCY OF DETECTION BY ORGANIC COMPOUND					
Compound	On-site Analysis		Off-site Analysis		EPA RBC Criteria[3]
	Range	Frequency	Range	Frequency	
Ethylbenzene	NT	N/A	6.6 - **530**	3/21	130
p-Isopropyl toluene	NT	N/A	2.3	1/1	--
Methylene chloride	NT	N/A	2.7	1/21	4.1
MIBK	NT	N/A	**50 - 54**	2/21	14
Tetrachloroethene	**160**	1/21	**12 - 170**	2/21	1.1
Trichloroethene	**47 - 180**	2/21	**62 - 260**	3/21	1.6
1,2,4-Trimethylbenzene	NT	N/A	5.6	1/1	1.2
1,3,5-Trimethylbenzene	NT	N/A	4.3	1/1	1.2
Vinyl Acetate	NT	N/A	**220**	1/21	41
Toluene	NT	N/A	6.4 – **2200**	2/21	75
Xylene	NT	N/A	37 - **2,900**	2/21	1,200
SVOCs *(ug/l)*					
Acenaphthene	NT	N/A	1	1/17	37
Bis(2-ethylhexyl)phthalate	NT	N/A	2	1/17	4.8
m&p Cresol	NT	N/A	12	1/17	--
Di-n-butylphthalate	NT	N/A	2	1/17	370
Fluorene	NT	N/A	1	1/17	24
2 Methyl-naphthalene	NT	N/A	3 - **57**	3/17	12
Naphthalene	NT	N/A	**2.8 - 81**	2/17	0.65
Phenanthrene	NT	N/A	2	1/17	--
TPH *(mg/l)*					
as Gasoline	**8**[2]	1/17	0.18 - **12**[2]	4/17	1.0[5]
as Diesel Fuel	NT	N/A	**21**[2]	1/17	1.0[5]
as Fuel Oil	NT	N/A	**2.3**[2]	1/17	1.0[5]

LARC 60 DPT GROUNDWATER SAMPLES RANGE AND FREQUENCY OF DETECTION BY ORGANIC COMPOUND					
Compound	On-site Analysis		Off-site Analysis		EPA RBC Criteria[3]
	Range	Frequency	Range	Frequency	

Notes: 1. NT = not tested.
2. **Underlined ranges** are concentrations above the EPA Region III RBC Criteria/Virginia Groundwater Standards/Maximum Contaminant Level.
3. EPA Region III Risk-based Concentration Criteria for Tap Water.
4. NA = not available.
   N/A = not applicable.
5. Virginia Groundwater Standard for Petroleum Hydrocarbons.

Several of the detected VOCs (chloroform, cis 1,2-DCE, ethylbenzene, MIBK, PCE, TCE, toluene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, vinyl acetate, vinyl chloride, and xylenes) occurred at concentrations greater than the EPA RBC Criteria for Tap Water. Two SVOCs (2-methylnaphthalene and naphthalene) also exceeded the EPA RBCs in tap water. The concentrations of these VOCs exceeded the comparison criteria by greater than one to two orders of magnitude. The detected TPH compounds (as Gasoline, as Diesel Fuel, and as Heavy Oil) were detected at concentrations greater than the comparison criteria by one order of magnitude. The remaining VOCs and SVOCs were detected at concentrations less than the comparison criteria by one to two orders of magnitude.

Numerous metals were detected in DPT groundwater samples. All inorganic analyses were performed off-site by Savannah Laboratory. The following table provides a summary of the range of detected concentrations of metals and frequency of detection:

LARC 60 DPT GROUNDWATER SAMPLES RANGE AND FREQUENCY OF DETECTION FOR TOTAL METALS			
Compound	Range *(ug/l)*	Frequency	EPA RBC[2] *(ug/l)*
Aluminum	860 – **9,900**	3/3	3,700
Arsenic	**20 - 54** [1]	2/3	0.045
Barium	14 – **330**	3/3	260
Cadmium	**6.8**	1/3	1.8
Calcium	6,400 – 70,000	3/3	NA [4]

LARC 60 DPT GROUNDWATER SAMPLES RANGE AND FREQUENCY OF DETECTION FOR TOTAL METALS			
Compound	Range (ug/l)	Frequency	EPA RBC[2] (ug/l)
Chromium	19 – **200**	3/3	110
Cobalt	30	1/3	73
Copper	63 – **250**	2/3	140
Iron	3,600 – 52,000	3/3	2,200
Lead	**54 – 460** [1]	2/3	15 [3]
Magnesium	1,300 – 1,900	3/3	NA
Manganese	63 – **1,700**	3/3	73
Nickel	52	1/3	73
Potassium	1,500 – 9,800	3/3	NA
Sodium	4,100 – 18,000	3/3	NA
Vanadium	26 - **33**	2/3	26
Zinc	60 – **2,700**	3/3	1,100

Notes:
1. **Underlined ranges are concentrations above the EPA Region III RBC Criteria/Virginia Groundwater Standards/Maximum Contaminant Level.**
2. **EPA Region III Risk-based Concentration Criteria for Tap Water.**
3. **USEPA Action Level for Drinking Water.**
4. **NA = Not Available.**

The detected concentrations of total aluminum, arsenic, chromium, iron, ~~and total~~ lead, manganese, vanadium, and zinc were over the EPA RBCs for tap water~~comparison criteria~~. Their locations and concentrations are presented on Figure 4-4. All other concentrations of total metals detected were lower than the selected comparison criteria.

Temporary Well Point Analytical Results

Three (3) groundwater samples were collected from temporary well points installed at the Former UST Area to assess the nature of VOC and TPH contamination in groundwater in the Former UST Area. The samples were analyzed off-site by Savannah Laboratories. Groundwater samples from WP-1 and WP-2 were analyzed for VOCs, TPH light and TPH heavy while only a TPH heavy sample was collected from WP-3. The following table provides a summary of temporary well point analysis:

Compound	LARC 60 Temporary Well Points			EPA RBC Criteria [2]
	WP-1	WP-2	WP-3	
1,1-DCA	**200 µg/l**	< 5 µg/l	NT	80 µg/l
cis 1,2-DCE	**3,200 µg/l**	**120 µg/l**	NT	6.1 µg/l
Methylene chloride	**130 µg/l**	< 5 µg/l	NT	4.1 µg/l
PCE	**370 µg/l**	**13 µg/l**	NT	1.1 µg/l
TCE	**1,300 µg/l**	**36 µg/l**	NT	1.6 µg/l
Toluene	**2,000 µg/l**	25 µg/l	NT	75 µg/l
Xylenes	250 µg/l	< 5 µg/l	NT	1,200 µg/l
TPH as Diesel	**6.9 mg/l**	< 0.30 mg/l	< 0.30 mg/l	1 mg/l
TPH as Gas	**9.1 mg/l**	0.27 mg/l	< 0.05 mg/l	1 mg/l

Notes:
1. Underlined are concentrations above EPA Region III RBC Criteria/VA GW Criteria.
2. EPA Region III RBC Criteria for Tap Water.
3. NT = not tested.

Numerous VOCs and TPH were detected in samples collected from two of the three temporary well points in the Former UST Area. Several VOCs including 1,1-DCA, cis 1,2-DCE, methylene chloride, PCE, TCE, and toluene and TPH exceeded risk screening criteria in WP-1 which is located in the center of the former UST pit. Several VOCs were also detected in WP-2 which is located approximately 25 feet downgradient of the former UST pit.

As shown below, the concentrations of the chlorinated hydrocarbons are less than the EPA estimate of 1 to 10 percent of the aqueous solubility for determination of the presence of dense non-aqueous phase liquid (DNAPL).

Compound	Maximum Concentration	Aqueous Solubility Limit	% of Aqueous Solubility
PCE	0.37 mg/l	150 mg/l	0.25
TCE	1.3 mg/l	1,100 mg/l	0.12
cis 1,2-DCE	3.2 mg/l	3,500 mg/l	0.09

Nature and Extent of Groundwater Contamination

The nature and extent of groundwater contamination for the three AOCs at the LARC 60 site is described in the following sections. The analytical results listed on Figure 4-4 are for those compounds which exceeded the screening criteria or that were used in evaluating any apparent trends in vertical or lateral distribution of contaminants.

The lateral distribution of chlorinated hydrocarbons and petroleum hydrocarbons extended from the Former UST Area northeastward to the Sandbox Area. For this reason, these compounds are discussed in the following section with respect to all three AOCs.

Former UST Area

Several VOCs were detected at concentrations greater than the EPA RBC Criteria in the Former UST Area. One sampling location (WP-1) within the former pit and five sampling locations downgradient of the Former UST Area contained VOCs including PCE and/or one or more of its degradation products (TCE and 1,2-DCE).

Two of the four sampling locations (DPT #3 and DPT #11) were near the OWS approximately 500 feet downgradient of the Former UST Area. The sampling locations with detections of VOCs including PCE and its degradation products are summarized below:

VOC	AOC No. 1 UST SAMPLE LOCATIONS				AOC No. 2 OWS SAMPLE LOCATIONS		EPA RBC[3] CRITERIA (ug/l)
	MW-117 (ug/l)	DPT-2[2] (ug/l)	WP-1 (ug/l)	WP-2 (ug/l)	DPT-3 (ug/l)	DPT-11 (ug/l)	
PCE	8.5[1] / < 50	<50/25	370	13	170/160	12	1.1
TCE	18 / < 50	<50/47	1,300	36	260/180	62	1.6
Vinyl chloride	**< 10 / 8.6**	BDL	BDL	BDL	BDL	BDL	0.015
cis 1,2-DCE	**20 / 1,900**	<50/150	3,200	120	20/30	<5	6.1

Notes:
1. Underlined text exceeds the screening criteria.
2. Off-site analytical result/On-site analytical result.
3. EPA Risk-based Criteria for Tap Water.
4. 1995 sample result / 2000 sample result

The former UST was used to store waste oil and also contained PCE and other chlorinated solvents (degreasers from maintenance shops) on groundwater samples collected from the center of the UST excavation during this investigation. If the Former UST Area is assumed to be the source of the release of these compounds based on historical use of the former UST and the temporary well point (WP-1) groundwater data which shows elevated levels of VOCs especially chlorinated hydrocarbons in the pit area, then an apparent vertical and lateral distribution of PCE and degradation compounds can be discerned.

Based on the assumption that the Former UST Area was the source of the release, the lateral distribution of PCE, TCE, cis 1,2-DCE, and vinyl chloride implies these compounds have migrated with groundwater from the Former UST Area downgradient to the northeast. The observed distribution of PCE and degradation products implies that the plume has impacted groundwater downgradient from the Former UST Area at DPT #11 and as far downgradient as well 6MW-3S since TCE, cis 1,2-DCE, and vinyl chloride was detected in this well in the 2000 year sampling but not in the original 1995 sampling. VOCs are still present at well MW-117 as shown in the 2000 year sampling. Since PCE and its degradation products were not detected at DPT points #13 and #16 located west and east of the zone of impact, the lateral distribution of these compounds in groundwater is very narrow as delineated by the sampling program. The narrowness of the plume may be the result of the impact of subsurface structures such as utility lines, building footings, or sedimentary variations on groundwater flow and contaminant transport. This implies that the primary direction and method of transport is to the northeast as a dissolved phase in groundwater. Based on the previous discussion concerning the apparent absence of DNAPLs, PCE and its degradation products are present in a dissolved state and are migrating in groundwater along the primary groundwater flow direction toward the northeast.

The vertical extent of contamination was delineated by the sampling program. The DPT points and monitoring wells with detectable concentrations of PCE and its degradation products penetrated to a depth of approximately 14 feet below grade. Wells 6MW-3D and 6MW-2 are screened from 30 to 40 feet below grade. Detectable concentrations of PCE or its degradation products were not present in groundwater samples from these wells indicating that in these areas the vertical extent of contamination is limited to depths above 30 feet. DPT #17, located downgradient of MW-117 and adjacent to DPT #2 (approximately 13 feet below grade), penetrated to 39.5 feet for collection of groundwater samples. TCE and cis 1,2-DCE were detected in DPT #2 but not in the deeper sample collected from DPT #17 indicating that in this area the vertical extent of contamination is limited to above 39.5 feet. However, since no deeper groundwater samples were collected in well 6MW-3D in the 2000 sampling event, it is unclear whether more extensive vertical migration is now occurring.

Several other VOCs were detected at levels less than the EPA RBC Criteria and included ethylbenzene, xylene, and MIBK. Toluene was detected at WP-1 and DPT-2 at concentrations of 2,000 and 2,200 *ug/l*, respectively which are an order of magnitude greater than its screening criteria of 750 *ug/l*. These VOCs along with the detected TPH compounds were used in assessing the presence and distribution of petroleum hydrocarbons.

Six (6) groundwater sampling locations had detections of TPH and petroleum aromatic hydrocarbons. Four (4) of the six (6) locations were downgradient of the OWS Area. A summary of these sampling results is presented below:

COMPOUND	UST SAMPLE LOCATIONS				OWS SAMPLE LOCATIONS				EPA RBC[2] CRITERIA
	MW-117	DPT #2[1]	WP-1	WP-2	DPT #11	6MW-3S	DPT #9	DPT #13	
TPH as Gasoline (*mg/l*)	3.0	12/8	9.1	0.27	0.40	<0.05	0.18	<0.25	1.0[4]
TPH as Diesel Fuel (*mg/l*)	2.7	21	6.9	<0.30	<0.3	2.7	<3.0	<0.3	1.0[4]
TPH as Fuel Oil (*mg/l*)	<1.0	<20.0	BDL	BDL	2.3	<5.0	<1.0	<1.0	1.0[4]
Ethylbenzene (*ug/l*)	66 / 76	530	<5	<5	6.6	<5.0 / <10	<5	9.3	1,300
Naphthalene (*ug/l*)	32	81	NT	NT	< 10	<10	<10	< 10	6.5
Toluene (*ug/l*)	68 / 310	2,200	2,000	25	<5.0	<5.0 / <5	6.4	<5.0	750
Xylene (*ug/l*)	290 / 450	3,100	250	<5	37	<5.0 / < 10	<5	<5	12,000

Notes:
1. Off-site analytical result/On-site analytical result for DPT sample #2
2. EPA Risk-based Criteria for Tap Water.
3. Underlined text exceeds the screening criteria.
4. Virginia Groundwater Standard for Petroleum Hydrocarbons.
5. 1995 sample result / 2000 sample result results reported for ethylbenzene, toluene, and xylene in MW-117 and 6MW-3S

The distribution of the above compounds is similar to that observed for PCE and its degradation products. Based on the Former UST Area as the source of the release of petroleum hydrocarbons to groundwater and including all sampling in the groundwater assessment locations, there is an apparent pattern in the distribution of the TPH compounds and PAHs. The highest concentrations of TPH (as Gasoline) and PAHs occur at DPT #2. The TPH and PAH concentrations decrease laterally from DPT #2 in the upgradient direction (at DPT #11 and DPT #9) and in the downgradient location (in well MW-117). Since DPT #9 and DPT #11 are downgradient of the OWS, the detected TPH compounds may be related to leakage from the OWS and/or migration from the Former UST Area or both. The detected TPH compounds in WP-1 which is located within the former UST pit and WP-2 and in well MW-117 which are downgradient of the Former UST Area appear to delineate the trailing edge of a plume migrating away from the Former UST Area. The TPH and PAH compounds were also detected at DPT #13 west of DPT #2 but not to the east at DPT #16. As noted for the PCE

plume, the TPH and PAH plume is also narrow and migrating in the predominant groundwater flow direction toward the northeast.

With respect to the vertical extent of these compounds, the DPT points and Monitoring Wells MW-117 and 6MW-3S penetrated to a depth of approximately 14 feet. Only Wells 6MW-3D, 6MW-2, and DPT 17 extended to a depth of 30 to 40 feet below grade, but the sample from these wells and DPT point did not contain any detectable concentrations of the TPH or PAH compounds. As was the case for the PCE plume, the vertical extent of the distribution of TPH and PAHs is a minimum of 14 feet below grade but not to 30 feet below grade.

Although the analytical results correlate with the conceptual model for the plume, there are a few sampling locations with non-detects for TPH and PAHs that do not. First, none of the TPH or PAH compounds were detected in DPT #3 which is downgradient of DPT #2 and upgradient of the OWS. The sampling depth for DPT #2 of 13 feet below grade was deeper than that of DPT #3 at 9.5 feet below grade. The non-detects for TPH and PAH at DPT #3 may indicate that the detected compounds in DPT #11 (downgradient of DPT #3) may be related to the OWS and not to migration of a plume from the Former UST Area. DPT #1 and DPT #5 located east and west of the centerline of the area of impact penetrated to 13 and 9 feet below grade, respectively. Neither DPT sample contained detectable concentrations of TPH and PAHs. These two points are beyond the lateral area of impact. DPT #12 also did not contain detectable concentrations of TPH and PAH compounds. This location of DPT #12 may be impacted by groundwater flow influenced by subsurface features such as utility lines, building construction, or sedimentary variations.

Naphthalene was detected at MW-117 and DPT #2 at concentrations greater than the EPA RBC for tap water. All other SVOCs were detected at concentrations that were two orders of magnitude less than the available screening criteria. All other samples were below detection limits for TPH compounds.

The concentration for total and dissolved arsenic, iron, and manganese exceeded the screening criteria at well MW-117 in the 1995 and 2000 year. No other sampling locations in the Former UST Area detected concentrations of total or dissolved metals above the screening criteria.

OWS Area

The presence of VOCs, TPH, and PAHs detected in either DPT or groundwater well samples in the OWS Area are discussed under the Former UST Area.

All SVOCs detected in the OWS Area were below detection or detected at concentrations two orders of magnitude below the screening criteria.

Total arsenic was detected in well 6MW-3S in 1995 at a concentration of 14 *ug/l* which is above the 0.045 *ug/l* EPA RBC Criteria. However, arsenic was not detected in the dissolved metals analysis for 6MW-3S which indicates that arsenic is not dissolved in groundwater at detectable concentrations. Thus, the total arsenic value is not representative of groundwater quality and is

associated with the sediment in the groundwater sample. Neither total nor dissolved arsenic was detected in 6MW-3S during the 2000 year sampling event.

~~Total iron was also detected in well 6MW-3S at a concentration greater than the EPA RBC but the dissolved iron levels were less than the screening criteria indicating the majority of the iron is associated with the sediment in the sample and not in a dissolved state.~~

Various total and dissolved metals including antimony, iron, and manganese were detected through the OWS area above the EPA RBC.

Sandbox Area

The distribution of the VOCs, TPH, and PAHs, with respect to depth and lateral distance, were discussed under the Former UST Area. No SVOCs were detected at concentrations greater than the screening criteria.

Total aluminum, arsenic, barium, cadmium, ~~and~~ chromium, copper, iron, lead, manganese, vanadium, and zinc were detected in DPT samples in the Sandbox area~~at DPT #7 and DPT #9~~ at concentrations greater than the screening criteria. ~~Total manganese was detected in the sample from DPT #9 at a concentration that exceeded the screening criteria.~~ Since no dissolved metals analysis is available for these two locations, no conclusions can be made with regard to whether the detected concentrations are associated with sediments in the groundwater sample or in a dissolved state in groundwater. ~~All concentrations of total and dissolved metals were from two locations; therefore, no trends could be discerned with respect to vertical and lateral distribution.~~

4.5 AUTO CRAFT BUILDING AREA

Soil and groundwater samples were collected at the former Auto Craft Building Area to define the nature and extent of contamination. Surface soil samples were collected by hand auger while subsurface soil and numerous groundwater samples were collected by DPT methods. In addition, groundwater samples were collected from newly installed and existing monitoring wells.

In this section analytical data for all media is compared against EPA risk screening criteria. Groundwater is screened against EPA RBC for tap water while soils data are compared to EPA RBC for industrial and residential soils. This initial screening against these criteria are only used to assign significance to the analytical data and not as an analysis of risk or impacts. A detailed risk assessment which screens the data against ARARs such as MCLs, surface water quality standards, EPA soil screening levels, EPA RBC residential soil criteria, EPA Region III BTAG ecological risk levels, etc. is provided in Sections 6.0 (Human Health Risk Assessment) and 7.0 (Ecological Risk Assessment).

4.5.1 Surface and Subsurface Soils

Soil Analytical Results

Soil samples were collected from six (6) soil borings with samples collected from three depths to assess the lateral and vertical extent of contamination in the vadose zone.

All soil samples were analyzed for VOCs, SVOCs, and TPH heavy and light fractions while one (1) surface and three (3) subsurface soil samples were additionally analyzed for metals and cyanide. Table 4-14 provides the analytical results for the soil samples collected at the site. As shown in Table 4-14, only those contaminants detected are presented. Additionally, the EPA Region III RBC Criteria for Industrial and Residential Soils are presented for comparison purposes. The EPA Region III RBCs for industrial and residential soils for non-carcinogenic compounds presented in Table 4-14 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for soil, the RBCs have been adjusted.

VOCs

Several VOCs including acetone, ethylbenzene, methylene chloride, MEK, styrene, toluene, TCE and xylenes were detected in surface and subsurface soils. Acetone was detected in 1 of 18 soil samples (31 *ug/kg*), ethylbenzene in 1 of 18 samples (1.6 *ug/kg*), methylene chloride in 1 of 18 samples (41 *ug/kg*), MEK in 4 of 18 samples (55 to 100 *ug/kg*), styrene in 1 of 18 samples (6 *ug/kg*), toluene in 10 of 18 samples (7.9 to 34 *ug/kg*), TCE in 1 of 18 samples (33 *ug/kg*) and xylenes in 1 of 18 samples (16 *ug/kg*).

All concentrations were at least 3 orders of magnitude less than the risk screening criteria for industrial and residential soils. Acetone, methylene chloride, and MEK are common laboratory artifacts.

SVOCs

Numerous PAHs were detected from two depths (0 to 1 foot and 5 to 7 feet) in soil boring #1 which is located upgradient of the site and under an asphalt pad. Although concentrations of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene were higher than the risk screening criteria, the PAHs present are probably related to leaching from the asphalt parking lot and not attributable to site influences. Butylbenzylphthalate was detected in 2 of 18 samples at concentrations of 230 and 550 *ug/kg*.

TPH

TPH as Heavy Oils was detected in 6 of 18 samples (72 to 390 *mg/kg*) at the site. Five of these samples had concentrations greater than the 100*mg/kg* screening criteria. The location and concentration of these samples is presented on Figure 4-5. No other TPH compounds were

detected in soils at this site.

Metals

Numerous metals were detected in surface and subsurface soils. Detection frequencies and range of concentrations for each of these metals is provided below:

AUTO CRAFT SOIL SAMPLES
RANGE AND FREQUENCY OF DETECTION OF INORGANIC COMPOUNDS

Compound	Range (mg/kg)	Frequency	EPA RBC (mg/kg)
Aluminum	440 to 5200	4/4	100,000/7,800
Arsenic	1.1 to 1.5	4/4	3.8/0.43
Barium	2.8 to 82	4/4	14,000/550
Beryllium	0.058	1/4	410/16
Cadmium	0.18	1/4	100/3.9
Calcium	84 to 1200	3/4	--
Chromium	2.3 to 8.6	4/4	610/23
Cobalt	0.79 to 4.4	2/4	4,100/160
Copper	5 to 18	2/4	8, 200/310
Iron	1200 to 9100	4/4	120,000/4,700
Lead	1.7 to 95	4/4	1,200/400
Magnesium	96 to 2400	4/4	--
Manganese	10 to 170	4/4	4,100/160
Mercury	0.011 to 0.10	3/4	--
Nickel	1.1 to 4.8	2/4	4,100/160

AUTO CRAFT SOIL SAMPLES RANGE AND FREQUENCY OF DETECTION OF INORGANIC COMPOUNDS			
Compound	**Range (mg/kg)**	**Frequency**	**EPA RBC (mg/kg)**
Potassium	130 to 2700	3/4	--
Sodium	20 to 64	2/4	--
Vanadium	1.8 to 18	4/4	1,400/55
Zinc	4.5 to 64	4/4	61,000/2,300

~~Although the majority of metal concentrations were greater than background levels, all concentrations for the metals detected were less than the EPA risk screening criteria.~~.

The only metals detected above EPA RBCs residential soil were arsenic, iron, and manganese. However, none of these concentrations exceeded EPA RBCs for industrial soils.

Nature and Extent of Soil Contamination

Acetone, methylene chloride, MEK, styrene, toluene and TCE were detected in numerous surface and subsurface soil samples collected at the site. Concentrations of the VOCs varied from surface to deeper depths with no apparent trends (i.e., concentrations decreasing/increasing with depth). The lateral extent of VOC contamination was not defined because VOCs were detected in all of the surface soil samples collected in this area. But as discussed in Section 4.5.1.1, concentrations were several orders of magnitude lower than EPA screening criteria.

As previously discussed, numerous PAHs believed to be the results of asphalt leaching in the upgradient area of the site are present in the shallow soils under the asphalt pad. PAHs were not detected in any other soil locations at the site. Butylbenzylphthalate was detected in the surface soils at a location northeast of the former building adjacent to the intersection of Attu and Cebu Roads.

TPH as Heavy Oils was detected in approximately 50 percent of surface and subsurface soil samples collected at this site. TPH as Heavy Oils concentrations decreased with depth in the borings where TPH was detected. The lateral extent of TPH contamination is limited to the area adjacent to and northeast of the former building which are areas where surface transport of contaminants during heavy precipitation events could occur.

Metals were analyzed from three borings (soil boring #1 - 9 to 11 foot depth sampled, soil boring #4 - 0 to 1 and 2 to 4 foot depths sampled, and soil boring #5 - 2 to 4 foot depth sampled) at the site to determine the presence/absence and significance of detected metal concentrations. All metals listed

in Section 4.5.1.1 were detected in at least one of the four samples collected from the three borings. Metal concentrations typically decreased with depth. The lateral extent of metals was not defined because the objective of the sampling program was to determine the presence/absence of metals through analysis of select samples. The data would then be compared to EPA risk screening criteria. ~~Metal concentrations were less than the EPA screening criteria.~~. Arsenic, iron, and manganese concentrations exceeded the EPA RBCs for residential soils but were less than the EPA RBCs for industrial soils. The one detect of iron and manganese that exceed the EPA RBC for residential soils were from boring SB07-004 (surface soil sample) that is located across Attu Road from the site and not hydraulically connected to the former Auto Craft Building.

4.5.2 Groundwater

Groundwater Analytical Results

Monitoring Well Results

Groundwater samples were collected from four (4) monitoring wells with 10-foot screened intervals as shallow as 2 to 13 feet below grade (9.34 to -0.66 feet MSL) and as deep as 30 to 40 feet below grade (-18.22 to -28.22 feet MSL) at 7 MW-3 to assess the lateral and vertical extent of contamination in the Columbia Aquifer (water table aquifer) at the Auto Craft site. All monitoring well samples were analyzed off-site by Savannah Laboratory.

Groundwater samples were analyzed for VOCs, SVOCs, TPH heavy and light fractions, total and dissolved metals and cyanide. A total of four (4) groundwater samples from the Auto Craft Area monitoring wells were analyzed. Only two (2) of the four (4) samples were analyzed for the total and dissolved inorganics. Table 4-15 provides a summary of the analytical parameters and results for the monitoring well groundwater samples collected at the Auto Craft Area. In Table 4-15, only those compounds detected are presented. In addition, the EPA Region III RBC Criteria for Tap Water are presented for comparison purposes. The EPA Region III RBCs for tap water for non-carcinogenic compounds presented in Table 4-7 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for groundwater, the RBCs have been adjusted. A more detailed risk evaluation which provides a comparative analysis of sample results and ARARs and TBC criteria is provided in the baseline risk assessment in Section 6.0.

For the four (4) samples tested, only one (1) contained a detectable concentration of a compound. The sample from Well 7MW-3 contained chloroform at a concentration of 11 *ug/l*. Chloroform has an EPA RBC Criteria of 0.15 *ug/l*. The detected concentration was two orders of magnitude greater than the screening criteria. However, it should be noted that the USEPA MCL for total trihalomethanes (which includes chloroform) is 100 ug/l. The location and concentration of the detected chloroform is presented on Figure 4-6. With respect to TPH and SVOCs analyses, no samples contained concentrations greater than the method detection limit.

Several metals were detected in monitoring well groundwater samples but no concentrations of total metals were greater than the screening criteria. The following table provides a summary of the range of detected concentrations of metals and frequency of detection:

AUTO CRAFT AREA MONITORING WELL SAMPLES
RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND

Compound	Total Metals		Dissolved Metals		EPA RBC Criteria[1] (ug/l)
	Range (ug/l)	Frequency	Range (ug/l)	Frequency	
Aluminum	240 – 540	2/2	<0.20	0/2	3,700
Barium	12	1/2	<0.01	0/2	260
Calcium	6,400 – 30,000	2/2	5,800 – 31,000	2/2	NA
Iron	790 – 9,700	2/2	110 – 8,100	2/2	2,200
Magnesium	3,700 – 5,200	2/2	3.7 – 4,600	2/2	NA
Manganese	91	1/2	80	1/2	73
Potassium	1,600 – 2,600	2/2	2,100 – 15.000	2/2	NA
Sodium	12,000 – 16,000	2/2	11,000 – 15,000	2/2	NA
Zinc	22	1/2	<2	0/2	1,100

Notes: 1 . EPA Region III Risk-based Concentration Criteria for Tap Water.
2. USEPA Action Level for Drinking Water.

DPT Analytical Results

Six (6) groundwater samples were collected from non-permanent sampling locations using a DPT rig to penetrate to the desired sampling depth. Non-permanent DPT groundwater samples were collected upgradient and downgradient of the former building to assess the lateral and vertical extent of contamination in groundwater. The DPT samples were analyzed on-site by GC (Modified EPA Method 8015 and EPA Method 3810). The GC analytical results were utilized to assist with placement of permanent monitoring wells. Five (5) of the six (6) DPT samples were collected in replicate and sent off-site to Savannah Laboratory for analysis to confirm on-site analytical results for select VOCs and TPH light.

On-site analysis of DPT groundwater samples was for TPH light fractions (TPH as Gasoline) and specific VOCs (Benzene, cis 1,2-DCE, PCE, TCE, and vinyl chloride). Replicate DPT groundwater samples were analyzed off-site for VOCs and TPH light with additional analysis conducted for SVOCs, TPH heavy and Total Metals. A total of six (6) DPT groundwater samples were analyzed. One (1) DPT groundwater sample from DPT #6 was not analyzed on-site. The table below presents the distribution of DPT groundwater samples analyzed by on- or off-site lab and analytical parameter:

AUTO CRAFT AREA DPT GROUNDWATER SAMPLES
DISTRIBUTION OF SAMPLE TESTING BY LAB

Analytical Laboratory	VOCs	TPH Light	TPH Heavy	SVOCs	Total Metals
On-site	5/6	5/6	0/6	0/6	0/3
On-site Only	0/6	0/6	0/6	0/6	0/3
Off-site and On-site	5/6	5/6	0/6	0/6	0/3
Off-site Only	1/6	1/6	6/6	6/6	3/3

Table 4-16 provides a summary of the analytical parameters and results for the DPT groundwater samples collected at the Auto Craft Area. In Table 4-16, only those compounds detected are presented. Additionally, the EPA Region III Risk Screening Criteria for Tap Water are presented for comparison purposes. The analytical results indicate that detectable concentrations of vinyl chloride were quantified only in DPT groundwater samples analyzed on-site for VOCs.

Methylene chloride was detected in one DPT groundwater sample. However, it was also detected in the laboratory blank and its presence in the groundwater sample may be related to lab contamination.

As was the case for the FTA, vinyl chloride was detected in DPT groundwater samples by the on-site GC, but its presence was not confirmed by the duplicate samples analyzed by Savannah Laboratories or the QA split samples analyzed by the USACE NED laboratory which were analyzed by GC/MS. No vinyl chloride was detected in any samples submitted to Savannah Laboratories or the USACE NED laboratory.

Additional samples were collected from monitoring wells at the FTA and LARC 60 sites which were located within areas where on-site GC analysis indicated the presence of a vinyl chloride plume to ascertain its presence/absence. Preserved and unpreserved samples were also collected to assess any effects of hydrochloric acid preservations on vinyl chloride concentrations. All samples were

analyzed by EPA Method 3810 (GC) and Method 8270 (GC/MS). Savannah Laboratories contacted Earth Technologies to determine their procedures and equipment used so that they could duplicate this process in their analysis. No vinyl chloride was detected by either method for the preserved and unpreserved samples. However, there was a detect of an unknown compound in the GC analysis whose retention time was similar to vinyl chloride. This data indicates that the on-site GC analysis was identifying this compound and its concentration as vinyl chloride.

Therefore, based on previous GC/MS analysis of duplicate and QA split samples and the additional analysis conducted, no vinyl chloride is expected to be present at the site in the groundwater.

Two SVOCs, di-n-butylphthalate and bis(2-ethylhexyl)phthalate, were detected at groundwater point DPT #5 at concentrations of 5 and 8 ug/l, respectively. The bis(2-ethylhexyl)phthalate concentration exceeded the EPA RBC for tap water of 4.8 ug/l.

TPH was not detected in any DPT groundwater sample.

Several metals were detected in DPT groundwater samples with one detect of arsenic and one detect of iron above EPA RBCs for tap water. ~~samples but the detected concentrations of total metals were all lower than the comparison criteria~~. All inorganic analyses were performed off-site by Savannah Laboratory. The following table provides a summary of the range of detected concentrations of metals and frequency of detection:

AUTO CRAFT AREA DPT GROUNDWATER SAMPLES
RANGE AND FREQUENCY OF DETECTION FOR TOTAL METALS

Compound	Range *(ug/l)*	Frequency	EPA RBC Criteria[1] *(ug/l)*
Arsenic	56	1/3	0.045
Aluminum	360 – 630	2/3	3,700
Barium	12 - 21	3/3	260
Calcium	17,000 – 36,000	3/3	NA
Iron	1,600 – 3,600	3/3	2,200
Magnesium	2,800 – 7,400	3/3	NA
Manganese	14 - 42	3/3	73
Potassium	1,800 – 8,200	3/3	NA

AUTO CRAFT AREA DPT GROUNDWATER SAMPLES RANGE AND FREQUENCY OF DETECTION FOR TOTAL METALS			
Compound	**Range** *(ug/l)*	**Frequency**	**EPA RBC Criteria[1]** *(ug/l)*
Sodium	9,900 – 12,000	3/3	NA
Zinc	8.4 – 35	2/3	1,100

Note:
1. EPA Region III Risk-based Concentration Criteria for Tap Water.

Nature and Extent of Groundwater Contamination

The nature and extent of groundwater contamination for the Auto Craft Area is described in the following section.

The sample from 7MW-3 contained 11 *ug/l* of chloroform that is two orders of magnitude greater than the EPA RBC Criteria of 0.15 *ug/l*. Well 7MW-3 is located downgradient of the former building. Because one sample only contained a detectable concentration of a compound, there was no discernible pattern of contaminant distribution with respect to depth and lateral distance. As previously stated, the methylene chloride may be the results of lab contamination due to its presence in the lab blank.

SVOCs were only detected at one groundwater location at the site, and therefore, there was no discernible pattern of contaminant distribution with respect to depth and lateral distance

No TPH was detected in any of the groundwater samples.

Several total and dissolved metals were detected in groundwater samples~~. Although total arsenic was detected at one location greater than the EPA RBC, none of the dissolved concentrations exceeded the screening criteria for the monitoring wells.~~ Total arsenic and total iron exceeded the EPA RBCs for tap water in one DPT location each while total and dissolved iron and manganese exceeded the EPA RBCs for tap water in one monitoring well (7MW-3). Most of the detected compounds are related to the composition of the sediment and groundwater at the site which naturally contains calcium, iron, magnesium, manganese, potassium, and sodium. The detected levels of these metals are similar to levels detected in groundwater samples tested during water quality studies of the area (Sindyla, 1981).

For the detected compounds (VOC, SVOCs and metals) no apparent pattern with respect to depth and lateral distance was determined.

Section 5
FATE AND TRANSPORT

This section provides a qualitative evaluation of contaminant fate and transport at the three Fort Story sites. Known and potential contaminant sources, site physical characteristics, physical and chemical properties of the contaminants, and the nature and extent of contamination are discussed.

Section 5.1 provides a general discussion of the mechanisms that influence the various contaminant transport pathways. Section 5.1 also identifies the physical and chemical properties of contaminants that control their environmental fate and transport in the environment.

Section 5.2 discusses the contaminant transport pathways that are applicable to the sites.

Section 5.3 presents conceptual fate and transport models developed for each site.

The discussion of specific transport mechanisms, and pertinent physical and chemical properties of contaminants is expanded in Section 5.4, where applicable, to support the conceptual fate and transport models.

5.1 TRANSPORT MECHANISMS AND CONTAMINANT PROPERTIES

The fate and transport of contaminants in the environment is influenced by the following mechanisms:

- Adsorption/Desorption. The process by which contaminant transport is retarded due to adsorption of contaminants to soil particles. Desorption is the reverse process of adsorption.
- Advection. The physical process by which contaminants are transported in solution at the average linear velocity of groundwater in the direction of groundwater flow.
- Complexation. The chemical process by which dissolved species are formed from two or more simpler dissolved species, each of which can exist in an aqueous solution.
- Diffusion. The chemical process that results in the movement of contaminants in response to concentration gradients.
- Dispersion. The mechanical process of mixing that results from local variations in the average velocity of groundwater.
- Dissolution/Precipitation. The chemical process by which a material is dissolved in a liquid solvent such as water. Precipitation is the reverse process of dissolution.
- Ion Exchange. The chemical process involving the reversible exchange of ions between a liquid and a solid.

- Reduction/Oxidation. A chemical reaction (redox reaction) involving changes in the oxidation states of elements.

- Transformation. The loss or degradation of contaminants from the environment as a result of chemical reactions of microbial activity.

- Volatilization. The transfer of contaminants from the liquid phase to the vapor phase (i.e., soil gas in unsaturated environments or the atmosphere).

The following sections discuss the physical and chemical properties of organic and inorganic contaminants that influence these fate and transport mechanisms.

5.1.1 Organic Contaminants

The primary organic compounds that have been detected at the Fort Story RI project sites are chlorinated hydrocarbons, total petroleum hydrocarbons (TPH), and, to a less extent, polynuclear aromatic hydrocarbons (PAHs).

The potential for a chemical to elicit an adverse human health or ecological effect depends upon the chemical's potential to migrate and persist in an environmental media. Factors that influence chemical mobility include: the physical and chemical properties of a chemical, the physical characteristics of the environmental media, and the site chemistry. This section presents a discussion of the various physical and chemical properties of the types of compounds detected at selected Fort Story sites. The section also covers the fate and transport of the detected chemical types at specific sites.

Table 5-1 presents a summary of the physical and chemical properties associated with organic and inorganic chemicals detected at the Fire Training Area, the LARC Maintenance Area, and the Auto Craft Building Area. The potential for chemical mobility and fate is determined by the chemical's properties and its interaction with the site's physical and chemical properties. Physical and chemical properties of organic compounds that affect mobility include:

- Vapor Pressure
- Water Solubility
- Octanol/Water Partition Coefficient
- Organic Carbon Adsorption Coefficient (Sediment partition)
- Specific Gravity
- Henry's Law Constant
- Mobility Index

Vapor pressure provides an indication of the rate at which a chemical volatilizes. Significant volatilization occurs at interfaces such as surface soil and air or surface water and air, and to a lesser extent, at the water table and shallow soils. Volatilization impacts selection of remedial

technologies for groundwater and subsurface soils. Generally vapor pressure for monocyclic aromatics is higher than that of petroleum aromatic hydrocarbons (PAHs). Chemicals with high vapor pressure such as volatile organic compounds (VOCs) enter the atmosphere more rapidly than those with low vapor pressures such as semivolatile organic compounds (SVOCs).

Water solubility impacts the rate that a compound leaches from soil by infiltrating precipitation. More soluble compounds (e.g., VOCs) leach more readily than less soluble compounds (e.g., inorganics). Water solubility data indicates that VOCs are several-orders-of-magnitude more soluble than PAHs; therefore, highly soluble compounds (e.g., VOCs) migrate more rapidly than less water soluble compounds (e.g., SVOCs or inorganics).

The octanol/water partition coefficient (K_{ow}) is the ratio of a chemical's soluble concentration in octanol divided by the soluble concentration in water. This coefficient correlates well with bioconcentration factors in aquatic organisms and adsorption to soil or sediment. A linear relationship has been demonstrated between the K_{ow} and the uptake of chemicals by fatty tissues in animal and human receptors (the bioconcentration factor - BCF) (Lyman et al., 1982). This coefficient also assists with characterizing the sorption of compounds by organic soils where experimental data does not exit. For example, the discontinuous organic soil encountered at the LARC 60 Maintenance Area would preferentially sorb more hydrocarbons than the quartz sand and gravel deposits that comprise most of sediments underlying site.

The organic carbon adsorption coefficient (K_{oc}) describes the tendency of a chemical to adhere to soil particles high in organic carbon. The solubility of a chemical in water is inversely proportional to the K_{oc}. Compounds with a high soil/sediment adsorption coefficient generally have low water solubilities.

For example, PAHs that are relatively immobile in the environment tend to preferentially sorb to soil/sediments and are less likely to migrate via aqueous transport mechanisms. However, erosional properties of surface soil that sorb PAHs must be considered in determining the potential for migration.

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 specified temperature. Specific gravity primarily assists in determining the potential for a compound to form a non-aqueous phase (NAPL) on top of an aquifer or at the base of an aquifer if the compound concentration exceeds a level of 1 to 10 percent of its corresponding water solubility. Henry's law constant uses vapor pressure and water solubility to determine volatilization rates from surface water and groundwater for a compound. This constant is an estimate of the concentration of a compound at equilibrium in the water phase and in the air directly above the water.

The Mobility Index (MI) assesses quantitatively the mobility of a compound based on its water solubility (S), vapor pressure (VP), and organic carbon coefficient (K_{oc}) as defined by:

$$MI = \log ((S*VP)/K_{oc})$$

Ford and Gurba (1984) presented a relative scale that assists in evaluating MI and Dragun presented a summary that related mobility to the K_{oc} as follows:

Relative MI[1]	Mobility Description	log K_{oc}[2]
>5	extremely mobile (EM)	< 1.7
0 to 5	very mobile (VM)	1.7 to 2
-5 to 0	slightly mobile (SM)	2 to 2.7
-10 to -5	immobile (IM)	2.7 to 3.3
< -10	very immobile (VIM)	> 3.3

Notes:
1. From Ford and Gurba (1984)
2. From Dragun (1988)

A general discussion of the fate and transport of the general category of organic contaminants detected at the Fort Story RI sites is presented below. The information is included in this section but not included in the site-specific conceptual model discussions (Section 5.3) in order to provide a general understanding of these fate and transport processes that may be applicable to a number of the sites.

Chlorinated Hydrocarbons

These compounds can occur as a dense non-aqueous phase liquid (DNAPL) when the concentrations in groundwater of DNAPLs exceed 1 to 10 percent of the compound's aqueous solubility. The concentrations of these compounds at the Fort Story RI sites are roughly 0.25 percent of the aqueous solubility and occur as a dissolved phase. The Former UST Area at the LARC 60 site has been impacted by these compounds.

Petroleum Hydrocarbons

Petroleum hydrocarbons are divided into two classes of compounds; aliphatic (straight chain or cyclic) and aromatic (containing a benzene ring). Aliphatic and aromatic hydrocarbons can be degraded by microbial oxidation in both soil and water. The rate of microbial oxidation is a function of the molecular structure, microbial population, and availability of oxygen and nutrients. Aliphatic hydrocarbons generally degrade more rapidly than aromatic hydrocarbons. The products of aliphatic

transformations are alcohols and carboxylic acids, which can be further degraded to shorter chain alcohols, aldehydes and carboxylic acids. The products of aromatic degradation are aliphatic dihydroxylbenzene compounds, which are then further transformed. Aromatic hydrocarbons can also be transformed by microbes in reducing environments (i.e., anaerobic degradation). The benzene ring is reduced to form a cyclic aliphatic compound, which can further degrade to other products (Dragun, 1988). Fuel hydrocarbons generally do not bioconcentrate in plant and animal species.

Polynuclear Aromatic Hydrocarbons

Polynuclear Aromatic Hydrocarbons (PAHs) tend to strongly sorb to most soils, although lower molecular weight PAHs will leach in soils with low organic carbon content. Lower molecular weight PAHs may volatilize from shallow soils and surface water but higher molecular weight PAHs have limited volatility. Since PAHs have very low solubilities in water, these compounds will be readily sorbed and deposited onto sediment. The major fate process for PAHs in soil and water is biodegradation; although PAHs in surface water may also photodegrade.

5.1.2 Inorganic Contaminants

The reactions and processes that are expected to govern the fate and transport of the inorganic contaminants detected at the Fort Story RI sites are:

- Dissolution/precipitation
- Adsorption/desorption
- Ion exchange
- Reduction-oxidation (redox) reactions
- Complexation

These characteristics and processes are interrelated, which complicates the fate and transport of inorganic species. Furthermore, some inorganic species that influence the reactions occur naturally and are present in background concentrations, while other inorganic species are derived from anthropogenic sources. **Table 5-2** summarizes the potential fate and transport of these inorganic contaminants in soil, sediment, water, air, and biological systems, and identifies the applicable reactions and processes.

5.2 POTENTIAL PATHWAYS OF CONTAMINANT TRANSPORT

This section discusses the potential transport pathways by which groups of contaminants can migrate between and within environmental media (i.e., air, surface water, soil, sediment, and groundwater) at the Fort Story RI sites.

5.2.1 Soil/Surface Water to Air Transport

The primary mechanism of contaminant transport from soil and surface water to air is volatilization. Volatile soil contaminants can migrate up through soil pore spaces and diffuse into the atmosphere. Less volatile contaminants such as PAHs and metals can be transported to air only if adhered to airborne particulate matter.

5.2.2 Surface Water to Sediment Transport

Three important mechanisms that control contaminant migration from surface water to sediment are:

- Seepage: Contaminated storm water can flow through sediment under hydraulic head, potentially transporting dissolved contaminants to sediment.

- Gravity Settling: Gravity settling is a mechanism for separating particles with sorbed metals and organic chemicals from surface water.

- Adsorption: Depending on the chemistry of the surface water and sediment and the physical interactions between surface water and sediments, adsorption can be a mechanism for transporting contaminants in water to sediment.

5.2.3 Sediment to Surface Water Transport

The primary mechanisms for transporting contaminants from sediment to surface water are desorption, dissolution, and ion exchange. However, these mechanisms are considered minor relative to other transport mechanisms.

5.2.4 Soil/Vadose Zone to Groundwater Transport

The primary mechanism of contaminant transport from the soil/vadose zone to groundwater is through dissolution and transport of constituents via infiltration of rainwater. This mechanism can effectively transport soluble contaminants. Because of the large amount of precipitation at Fort Story, infiltration rates can be very high. However, some areas at Fort Story may have reduced potential for infiltration due to localized impermeable features (i.e., pavement and buildings).

5.2.5 Groundwater to Soil/Vadose Zone Transport

There are several mechanisms of contaminant transport from groundwater to the vadose zone. VOCs in groundwater can volatilize into the unsaturated pore space in the vadose zone. At the capillary fringe, groundwater contaminants can be transported to unsaturated soil via precipitation, adsorption, and ion exchange.

5.3 FATE AND TRANSPORT CONCEPTUAL MODELS

The conceptual fate and transport models presented in this section provide a qualitative analysis of the environmental mechanisms, site characteristics, and physical/chemical properties of contaminants that have influenced, or currently influence, contaminant fate and transport at the Fort Story RI sites. An evaluation of the site conditions of the individual RI sites identified the potential contaminant pathways which are presented in **Table 5-3.**

Discharge of compounds from groundwater in the Columbia Aquifer to the Upper Yorktown Aquifer was considered to be unlikely based on the following considerations:

- The Yorktown confining unit is roughly 40 to 50 feet thick and the top of the unit occurs approximately 55 to 65 feet below land surface. The delineated vertical extent of the analyzed compounds was between 14 to 30 feet below land surface.

- The Yorktown confining unit has a very low hydraulic conductivity that has been measured to be approximately 10^{-8} cm/sec by geotechnical studies in the general area of Virginia Beach.

- The delineated distribution of compounds was 14 to 30 feet below land surface which is roughly 25 to 35 feet above the top of the Yorktown confining unit.

- The physical and chemical properties of the identified compounds and identified concentrations indicate that a dense non-aqueous phase liquid does typically does not occur at concentrations less than 1 to 10 percent of aqueous solubility. Thus, a separate DNAPL phase that would tend to migrate to the base of the Columbia Aquifer does not appear to exist.

5.4 SITE-SPECIFIC FATE AND TRANSPORT

This section discusses the fate and transport for each of the Ft Story sites. **Table 5-2** presents the transport mechanisms applicable to the individual transport pathways while the transport pathways identified for each site are presented in **Table 5-3**. Based on the fate and transport properties of the general type of chemical(s) present at each site and the site conditions, a conceptual model for each site is presented. A graphical presentation of the conceptual model for each site is presented in **Figures 5-1, 5-2 and 5-3** for the Firefighter Training Area (FTA), the LARC 60 Maintenance Area, and the Auto Craft Area, respectively.

5.4.1 Firefighter Training Area

The possible transport pathways identified for the FTA included the following:

- Volatilization of TPH as Gasoline and, to a lesser extent, chlorinated hydrocarbons from shallow groundwater to the atmosphere.

- Migration of TPH as Heavy Oils adsorbed to sediments by storm water runoff into the drainage ditch at the southwest corner of the site and then movement of the sediment by surface water in the drainage ditch.

- Migration, enhanced by infiltrating rainwater, of TPH as Gasoline, Diesel Fuel and Heavy Oils (to a lesser extent) through the vadose zone to groundwater.

- Migration of dissolved phase of chlorinated hydrocarbons and undissolved TPH as Gasoline and Diesel Fuel as advective flow, diffusion and dispersion in groundwater.

- Adsorption of TPH as Gasoline, Diesel Fuel and Heavy Oils onto soil particles as a result of lowering of the water table.

Northern Area

PCE was detected at one DPT point in the Northern Area of the site. PCE degrades by reduction of one chlorine atom to TCE. However, because the PCE concentration (6.4 µg/l) was only slightly above the detection, reduction in conjunction with dispersion and diffusion will ultimately result in chlorinated hydrocarbon concentrations, especially PCE concentrations, less than the detection limits.

Although total lead concentrations were above screening criteria in several DPT points, all concentrations of dissolved lead were below the screening criteria by several orders of magnitude indicating that the lead primarily is associated with sediment and not dissolved in groundwater. For this reason, the fate and transport of lead is not addressed because only dissolved lead would be available for migration with flowing groundwater.

Former FTP Area

The nondetection of TPH compounds at the Former Fire Training Pit (FTP) at the FTA site indicates that the majority of the contaminated soils were removed and treated and residual soil contamination should not result in any additional impacts to groundwater quality. The concentrations detected in groundwater are an order of magnitude lower than those detected during the PA/SI roughly 5 years ago. This further supports the decreased impact to groundwater as a result of the excavation of the contaminated soils. Also, the lowered concentrations in groundwater indicate that the compounds are biodegrading and dispersing.

The low concentration of total arsenic detected in groundwater at Well 4MW-2S was adsorbed onto sediments contained in the sample. Arsenic strongly sorbs onto soils and sediments at normal pH especially when in the presence of iron, manganese, and aluminum oxides. Arsenic is soluble in

water but the nondetection of it in the dissolved arsenic analysis confirms that it is not dissolved in groundwater at the Former FTP. For this reason, the fate and transport of arsenic is not addressed because only dissolved arsenic would be available for migration with flowing groundwater.

Solvent Plume Area

As discussed in Section 4.3.1.2, TPH as Heavy Oils was detected in the southwest corner of the FTA and in the drainage ditch south of the site. Because TPH as Heavy Oils adsorbs very strongly onto soil and has a low aqueous solubility, the adsorbed compounds move with the sediments during storm runoff into the drainage ditch. TPH as Heavy Oils has a low volatility and does not readily volatilize into the atmosphere. These compounds are subject to biodegradation.

Chlorinated hydrocarbons were detected in two DPT points at the southwest corner of the site. PCE is a chlorinated hydrocarbon with four chlorine atoms incorporated into its complex molecule. PCE degrades by reduction of one chlorine atom to TCE. Further reduction, elimination and hydrolysis of its degradation products ultimately produces vinyl chloride. If degradation is occurring through time then groundwater analysis should indicate a decrease in the PCE concentration and increase in the concentrations of degradation products. Through natural attenuation, PCE and its degradation products have shown to decrease over time. Since these compounds migrate in groundwater as a result of advective flow, dispersion and diffusion, depending on the concentrations present, the decreased concentrations of PCE and degradation products can be found at some lateral distance away from the source.

PCE, 1,1,1-TCA and 1,1-DCA were detected in two DPT points that are upgradient of MW-112 based on the water table elevations measured in May 1995. The groundwater sample collected from MW-112 during the RI did not contain any detectable concentrations of PCE nor its degradation products. The concentrations of these compounds were three orders of magnitude greater in the sample from MW-112 collected during the PA/SI.

5.4.2 LARC 60 Maintenance Area

The possible transport pathways identified for the LARC 60 Maintenance Area included the following:

- Volatilization of chlorinated hydrocarbons, PAHs and TPH as Gasoline from shallow groundwater to shallow soils.

- Volatilization of chlorinated hydrocarbons, PAHs and TPH as Gasoline from shallow soils to the atmosphere.

- Migration of TPH as Heavy Oils adsorbed to soil/sediments by storm runoff into the drainage ditch north of the Sandbox Area. Since there are no outlets from the drainage ditch, no subsequent movement beyond the ditch of the sediment is expected.

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- Migration, enhanced by infiltrating rainwater, PAHs, and TPH as Gasoline, Diesel Fuel and Heavy Oils (to a lesser extent) through the vadose zone to groundwater.

- Migration of chlorinated hydrocarbons as advective flow, diffusion and dispersion in and along with (TPHs) groundwater.

- Adsorption of TPH as Gasoline, Diesel Fuel and Heavy Oils onto soil particles as a result of changes in the water table.

Former UST Area

TPH as Heavy Oils was present in the surface soil in the vicinity of the former UST. The soils excavated during removal of the UST were placed alongside the former excavation. Since TPH was not present in the subsurface soils, the presence of TPH in the surface soils is probably due to transport of sediment from the soil pile or from deposition of soil in the area during the excavation activities. TPH as Heavy Oils would be expected to be very persistent in the soil system due to their resistance to hydrolysis, oxidation and biodegradation. Also, due to its low vapor pressure, volatilization to the atmosphere would be a secondary pathway. Adsorption to the soil particles and within interstitial pores would be the predominant fate of these compounds. In the groundwater system, due to its low solubility, TPH as Heavy Oils can be transported as a dissolved phase but may also be transported on top of the water table since it is less dense than water.

In comparison to the detected concentrations of TPH as Heavy Oils in surface soils in the UST area during the PA/SI, the concentrations detected of TPH as Heavy Oils during the RI, almost five years later, are significantly lower. In the UST area, the PA/SI analytical results indicated surface soils had concentrations of 1,900 mg/kg of TPH - Heavy Ends in surface soils in the vicinity of the UST. The UST was removed in the interim between the PA/SI and RI although the soils were placed alongside the excavation. Thus, the concentrations detected during the RI in the surface soils only represent residual levels that remain as a result of the excavation activities. All of the subsurface soils collected and analyzed during the RI for TPH as Heavy Oils had no detectable concentrations. The two surface soil samples collected and analyzed during the RI for TPH as Heavy Oils had detectable concentrations of 100 mg/kg and 42 mg/kg.

TPH as Gasoline, PAHs, and chlorinated hydrocarbons were present in groundwater samples collected from the Former UST Area and hydraulically downgradient of it. Individual gasoline constituents which are less sorbed in the soil systems will dissolve in the presence of percolating water in accordance with their individual aqueous solubility. The TPH as Gasoline and PAHs, due to their low density and low aqueous solubility, would tend to migrate to the top of the water table and migrate as a dissolved phase as long as groundwater concentrations do not exceed each compound's aqueous solubility. These compounds can be moderately persistent in the soil system; however, volatilization and biodegradation are significant fate processes. Constituents of Gasoline such as ethylbenzene, toluene, and xylenes were also detected in groundwater samples from well MW-117 downgradient of the Former UST Area and several downgradient DPT points. The

concentrations of ethylbenzene, toluene, and xylenes detected in groundwater samples are three orders of magnitude lower than the aqueous solubility of these compounds. Since these compounds are present in groundwater at concentrations significantly lower than their individual solubility, they are in a dissolved phase rather than as a separate phase. The presence of these compounds in groundwater is the result of the original release from the Former UST Area as well as leaching from the soil pile adjacent to the former UST excavation. Since the surface and subsurface soils contaminated with TPHs have been removed during the excavation, leaching of these compounds to groundwater has been significantly reduced by removal of the source. Since only surface soils contain low concentrations of TPH compounds, the potential for leaching of these compounds to groundwater has been significantly reduced.

The chlorinated hydrocarbons detected in groundwater are also associated with the release from the Former UST Area and the soil pile. PCE was present in groundwater at roughly 0.25 percent of its aqueous solubility. PCE was detected in only 3 of 49 soil samples. Although PCE was detected in groundwater, soil results indicate that the majority of the PCE has already volatilized and/or leached out due to a high percolation rate because medium to fine grained sands (moderate pore spaces for water migration) are present at the LARC 60 site. Two DPT groundwater points were sampled adjacent to SB-20 where the highest PCE concentration (71 ug/kg) in soils was detected with no PCE detected in groundwater. Additional impacts to groundwater quality through further leaching of PCE would not be anticipated.

Degradation products (TCE and cis 1,2-DCE) were also present which indicates that degradation of PCE is occurring. Although vinyl chloride was not detected during the RI, there is a potential for continued degradation of PCE, TCE and cis 1,2-DCE to vinyl chloride. However, it should be noted that chloroethane, not vinyl chloride, is the primary degradation compound of cis 1,2-DCE. Vinyl chloride is the primary degradation compound of trans 1,2-DCE and 1,1-DCE neither of which were detected during the RI sampling. **Figure 5-4** presents the transformation pathways for chlorinated hydrocarbons.

In comparison to concentrations established for these compounds in groundwater during the PA/SI, the concentrations of degradation products have increased. The increased concentrations of degradation products indicates that degradation of PCE is occurring as expected and also may indicate leaching of these compounds from the soil pile. Since no samples were collected downgradient of the UST and upgradient of the oil/water separator during the PA/SI, no comparison to the RI sampling points in these locations can be made.

Oil/Water Separator and Sandbox Area

Surface and shallow subsurface soils up and downgradient of the oil/water separator and within the Sandbox Area contained TPH as Heavy Oils. Since the presence of TPH as Heavy Oils in these two areas is related, both areas will be addressed in this section.

As discussed in the previous section, these compounds are very persistent in the soil system. The area impacted by TPH as Heavy Oils extended from the oil/water separator northward to the drainage ditch north of the site (hydraulically downgradient). TPH as Heavy Oils would be expected to be transported along with the sediment to which it is adsorbed. This is probably occurring as storm runoff as well as by runoff during equipment maintenance activities at the wash rack immediately north of the oil/water separator. No groundwater samples contained TPH as Heavy Oils as expected since the aqueous solubility of the compound is very low. TPH as Heavy Oils may migrate to the surface of the water table and spread on top of the water table. The water table is intersected by the base of the drainage ditch during the high water table season. During extended dry periods, the water table is generally lower and this reduces the groundwater contribution to the water elevation in the drainage ditch. Thus for some periods of the year the drainage ditch may be dry. During these dry periods, any TPH as Heavy Oils which is transported on top of the water table to the drainage ditch would be adsorbed to soil/sediment in the ditch as the water table is lowered. Methylene chloride was detected in numerous soil samples with concentrations above the EPA soil screening levels for transfer from soils to groundwater. The majority of the methylene chloride was detected in subsurface soils rather than in surface soils indicating the volatilization and leaching has impacted the surface concentration of methylene chloride. The majority of the subsurface soil samples were collected at a depth of 4 to 5 feet below land surface which is a the water table interface. However, even with the methylene chloride detected in this zone, methylene chloride was detected (below the quantitation limit) in only one groundwater sample indicating the it has not significantly impacted groundwater quality. Equilibrium partitioning models (Mackay, 1982) indicate that approximately 56 percent of the methylene chloride will sorbed onto soil particles while 33 percent will be available for transport with percolating water in the unsaturated zone. The portion of the methylene chloride available for transport has probably already leached over time but due to low concentrations and processes such as dilution and dispersion, no impact on groundwater quality occurred and levels were below detection limits. Therefore, it is unlikely that the residual methylene chloride present in the subsurface soils will further leach and significantly degrade groundwater quality.

As discussed in the previous section the presence of TPH - Light Ends and chlorinated hydrocarbons in groundwater underlying the oil/water separator and sandbox areas is most likely the result of migration of these compounds from the Former UST Area. It is possible that the concentrations in groundwater in the vicinity of the oil/water separator are amplified by a release from the oil/water separator, but this can not be confirmed. Regardless, the fate and transport of the compounds would be the same as discussed under the Former UST Area.

5.4.3 Auto Craft Area

The possible transport pathways identified for the Auto Craft included the following:

- Migration of TPH as Heavy Oils adsorbed to sediments by storm runoff into the depressed grassy area north of the former building location.

As discussed in Section 4.5.1.2, TPH as Heavy Oils was detected in the shallow (1 to 4 feet) soils in the drainage swale north of the site. Because TPH as Heavy Oils adsorbs very strongly onto soil and has a low aqueous solubility, the adsorbed compounds move with the soil/sediments during storm runoff into the drainage swale. TPH as Heavy Oils have a low volatility and do not readily volatilize into the atmosphere. TPH as Heavy Oils was also detected in the subsurface soils (5 to 7 feet below grade) under the paved parking lot south of the auto craft building. Since TPH as Heavy Oils is persistent in soils and has a low solubility it would not be expected to readily leach or dissolve in groundwater. This is further supported because TPH as Heavy Oils was not detected in any downgradient monitoring wells.

In comparison to soil analytical results for this site during the PA/SI, the concentration of TPH as Heavy Oils during the PA/SI in the drainage swale ranged from 160 mg/kg at 9.5 feet below ground to 470 mg/kg in the surface soils. The RI analytical results for TPH as Heavy Oils in the surface soil in the same area ranged from 220 mg/kg to 390 mg/kg. The RI results indicate that the concentration of TPH as Heavy Oils decreased with depth. In the groundwater system, the PA/SI detected TPH as Heavy Oils in well MW-119 at 0.7 *mg/L* but the RI sample for MW-119 did not contain detectable concentrations of any TPH compounds. While TPH as Heavy Oils persists in the soils, it does appear to be leaching to groundwater.

Chloroform was detected in the deep well (7MW-3) of the shallow/deep cluster downgradient of the former building location. Chloroform has a high aqueous solubility (8,220 *mg/L*, see **Table 5-1**) and the concentration detected was 0.011*mg/*L which is well below the aqueous solubility. Thus the chloroform is in a dissolved state. Since chloroform was detected in only one downgradient well, no conclusions could be made with respect to transport in groundwater. Since the compound is in a dissolved state, it would be expected to migrate with groundwater.

6.1 INTRODUCTION

This risk assessment presents an assessment of potential human health risk associated with contaminants detected at the three RI sites at Fort Story, Virginia. The objectives of the human health risk assessment (HHRA) are to (1) provide an analysis of baseline risks, currently and in the future, in the absence of any major action to control or mitigate site contamination, and (2) to assist in determining the need for and extent of remediation. It provides a basis for comparing a variety of remedial alternatives, and determining which will be the most protective of human health. The HHRA presents an assessment of potential human health risks associated with exposure to contaminants detected at or migrating from each of the three RI sites.

The baseline risk assessment will follow guidance provided in the following documents:

- *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Parts A and B)*, EPA, 1989a and 1989b
- *Risk Assessment Guidance for Superfund, Volume I: Human Health. Supplemental Guidance. "Standard Default Exposure Factors"*, EPA, 1991a
- *Selecting Exposure Routes and Contaminants of Concern by Risk-based Screening*, EPA Region III, 1993a
- *Risk-Based Concentration Table*, EPA Region III, January - June 1995, 1995a
- *Exposure Factors Handbook*, EPA, 1989c
- *Guidance for Data Useability in Risk Assessment, Part 2*, EPA, 1992a
- *Dermal Exposure Assessment: Principles and Applications*, Interim Report, EPA, 1992b

Objectives

The goal of the HHRA is to provide a framework for developing the risk information necessary to assist decision-making at the three RI sites. A site-by-site risk assessment will be conducted that includes the components of hazard identification, exposure assessment, toxicity assessment and risk characterization. Preliminary screening may reduce the level of effort for this human health evaluation at some of the sites. Specific objectives of the process are to:

- Provide an analysis of baseline risks (human health) and help determine the need for remedial action at the three sites.
- Provide a basis for determining levels of chemicals that can remain at each of the sites and still be adequately protective of public and Fort Story personnel health.

- Provide a basis for comparing potential health impacts of various remedial alternatives at the sites.

- Provide a consistent process for evaluating and documenting public health threats at the sites.

HHRA Components

The HHRA process is site-specific. Therefore it may vary in both detail and the extent to which qualitative and quantitative analyses are used, depending on the complexity and particular circumstances of the site, as well as the availability of ARARs and other criteria, advisories and guidance. There are four components to the HHRA: (1) hazard identification; (2) exposure assessment; (3) toxicity assessment; and (4) risk characterization. Each step is described briefly as follows:

- **Hazard identification** involves gathering and analyzing the site data relevant to the human health evaluation and identifying the chemicals of potential concern (COPC) at each site that are the focus of the risk assessment process. The selection of such chemicals is based on a number of parameters, including the frequency of detection and concentration in each environmental medium, environmental fate and transport characteristics, intrinsic toxicity and the likelihood of human exposure via significant exposure routes.

- **Exposure assessments** are conducted to estimate the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures, and the pathways by which humans are exposed. In the exposure assessment, reasonable maximum estimates of exposure are developed for both current and future land-use assumptions. Conducting an exposure assessment involves analyzing contaminant releases, identifying exposed populations, identifying all potential pathways of exposure, estimating exposure point concentrations for specific pathways and estimating contaminant intakes for specific pathways. The results of this assessment are pathway-specific intakes for current and future exposures to individual substances.

- **Toxicity assessments** consider the types of adverse health effects associated with chemical exposures, the relationship between magnitude of exposure and adverse effects and related uncertainties such as the weight of evidence of a particular chemical's carcinogenicity in humans. Qualitative and quantitative toxicity data for each COPC are summarized, and appropriate guidance levels with which to characterize risks are identified.

- **Risk characterization** summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk, both in quantitative expressions and qualitative statements. The likelihood and magnitude of adverse health risks are estimated in this step, in the form of noncancer hazard quotients and cancer risks.

6.2 FIREFIGHTER TRAINING AREA

6.2.1 Hazard Identification

Numerous groundwater, surface soil and sediment samples were collected from the Firefighter Training Area (FTA) and analyzed for various chemical contaminants. **Figures 2-5 and 2-6** provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in **Tables 6-1 through 6-4** to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select COPCs for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

The EPA Region III RBC for industrial soils, residential soils and tap water for non-carcinogenic compounds have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for each matrix (surface water, groundwater, soil and sediment), the RBCs have been adjusted.

Emphasis is given in the ensuing evaluation to chemical contamination in the surface and subsurface soil throughout the site, sediment near the site and groundwater underlying the site as these environmental media are regarded as having the greatest potential for human contact. ~~Chemical contamination in the subsurface soils are discussed in the context of the potential for exposure from future excavation of these soils and continued or further degradation of groundwater from leaching.~~

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III Risk-based Concentration (RBC) Criteria and Virginia Petroleum Program Criteria are included in **Table 6-1** as TBC criteria for purposes of comparison. A total of 28 surface soil samples were collected during the initial field investigations in 1995 with analysis for VOCs, SVOCs, TPH, and metals while eight surface soil

samples were collected in 2000 for pesticide and PCB analysis only to address data gaps in the VDEQ comment letter, dated February 6, 1996.

VOCs and SVOCs

All concentrations of VOCs and SVOCs were less than EPA RBC criteria, and therefore, are not selected as COPCs.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in only 1 of 28 surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethylbenzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA RBC criteria.

PCBs

PCBs were not detected in any of the eight surface soil samples, and therefore, are not selected as COPCs.

Pesticides

Five pesticides (alpha and gamma chlordane, DDE, DDT, and heptachlor epoxide) were detected in the soil samples collected at the FTA site. However, as shown in Table 6-1, concentrations did not exceed EPA RBC criteria, and therefore, pesticides are not selected as COPCs.

Inorganics

Arsenic and iron exceeded the carcinogenic RBC value for residential soils but did not exceed the industrial soils criteria. Arsenic concentrations in surface soils ranged from 1.2 to 1.6 mg/kg with a mean concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. A copy of the Montgomery Watson background data (text discussion and tables) from the *Fort Story PA/SI, January 1992,* is provided in **Appendix H**.

Therefore, the arsenic levels detected in the surface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in **Appendix H**. Iron was not analyzed as part of the background study but its maximum concentration of 5,400 mg/kg is consistent with regional background as shown in the table in **Appendix H**.

Although consistent with background levels, for the purposes of risk analysis, arsenic and iron are ~~is~~ selected as ~~a~~ COPCs based on their ~~its~~ exceedance of the residential soils criteria ~~for carcinogens~~.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in **Table 6-2** along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC criteria. Only the dissolved inorganic data is presented in Table 6-2. Total inorganic data are influenced by percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment typically is not available for transport with flowing groundwater and would also be filtered out before use if drinking water wells were installed in this area.

Thirty-four (34) groundwater samples (24 DPT and 10 monitoring well samples) were collected from the upper aquifer during the 1995 field investigation and analyzed for VOCs, SVOCs, TPH, and total and dissolved metals while four wells were resampled in 2000 with analysis for VOCs, pesticides, PCBs, and total and dissolved metals. The number of results for each chemical may vary due to the analysis of different compounds at different locations. However, in that DPT data is typically used for screening purposes, only the groundwater data collected from the permanent monitoring wells will be included in the risk analysis. The 2000 sampling event data will be utilized in place of the 1995 data when the same constituents were analyzed (i.e., VOCs and dissolved metals).

#4

VOCs

~~Although numerous VOCs were detected during groundwater sampling, only tetrachloroethene (PCE) (6.4 and 78 ug/l) and benzene (10 ug/l) were detected in excess of the screening criteria. However, benzene was only detected in 1 of 34 samples (3 percent detection frequency), and therefore due to infrequent detection, it is not selected as a COPC. Although PCE was detected in only 2 of 34 samples, it is selected as a COPC.~~

No VOCs were detected in monitoring well samples above screening criteria, and therefore, VOCs are not selected as COPCs.

#6

SVOCs

SVOCs were not detected in any of the groundwater samples in excess of screening criteria, and therefore, are not selected as COPC.

TPH

Although TPH exceeded the Virginia Groundwater Standard of 1 mg/l in 3 of 34 groundwater

samples, low concentrations of BTEX and PAHs were present and below their respective risk screening criteria.

Pesticides/PCBs

No pesticides or PCBs were detected in the four monitoring wells sampled in 2000.

Inorganics

Several dissolved inorganics (aluminum, iron, and zinc) were detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, these standards were established for aesthetic qualities only for drinking water supplies. Because the concentrations of these dissolved inorganics were significantly lower than the EPA RBC criteria for human health risks, they are not selected as COPC. However, dissolved antimony and manganese exceeded the EPA RBC for tap water ~~in one sample~~, and therefore, are ~~is~~ selected as ~~a~~ COPCs.

Sediment

Sediment sampling was conducted to evaluate the nature and extent of contamination in the sediment in the drainage area south of the site. Sediment samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for sediment cleanup, EPA Region III RBC Criteria and Virginia Petroleum Program Criteria are included in **Table 6-3** as TBC criteria for purposes of comparison. A total of four sediment samples were collected during the field investigation.

VOCs and SVOCs

All concentrations of VOCs and SVOCs were less than EPA RBC criteria, and therefore, are not selected as COPC.

TPH

TPH exceeded the 100 mg/kg TBC criterion in three of four sediment samples. Because TPH is typically used as an indicator of contamination, it will not be used during this quantitative risk assessment. BTEX and PAH concentrations, as previously discussed, were lower than risk screening criteria.

Inorganics

Arsenic, iron, and thallium exceeded the ~~non-carcinogenic and carcinogenic~~ RBC values for residential soils but did not exceed the industrial soils criteria ~~while, although only detected in one sample, thallium exceeded the RBC value for thallium compounds (e.g., thallium sulfate) for residential soils~~.

Arsenic was only detected in one sediment sample at a concentration of 2.5 mg/kg with a mean concentration of 1.1 mg/kg for all sediment values. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the sediment are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in **Appendix H**. Sediment values for inorganics were compared against soils data because the samples were collected from lowlying area near the site and not from a stream. The sediment in that area of the site are more consistent with soils rather than typical sediments.

Although consistent with background levels, for the purposes of risk analysis, arsenic is selected as a COPC based on its exceedence of the residential soils criteria for carcinogens. Thallium and iron ~~is~~ are also selected as ~~a~~ COPCs.

Combined Surface and Subsurface Soils ~~and Soil Leachability~~

To evaluate the potential exposures to surface and subsurface soils (i.e., future excavation activities and residential development) ~~and for the potential leaching of contaminants form soil to groundwater~~, as shown in **Table 6-4**, soil analytical data was compared against EPA RBC for industrial and residential soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria are included in Table 6-4 as TBC criteria for purposes of comparison. A total of 72 soil samples were collected during the field investigation.

VOCs and SVOCs

All concentrations of VOCs and SVOCs were less than EPA RBC criteria, and therefore, are not selected as COPCs.

~~All concentrations of VOCs were less than EPA RBC criteria for industrial soils while acetone was the only VOC higher than the EPA SSLs. Acetone exceeded the SSL of 8,000 ug/kg in only 1 of 72 samples, and therefore, VOC contamination in site soils should not further degrade groundwater quality through potential leaching.~~

~~As discussed in Section 2.2.9, the high levels of acetone detected in several soil samples were the result of using isopropyl alcohol as a decontamination solution and not associated with site conditions. Acetone is a primary oxidation product of isopropyl alcohol.~~

~~SVOCs and Inorganics~~

~~All concentrations SVOCs and inorganics were less than EPA RBC criteria for industrial soils and the EPA SSLs, and therefore, are not selected as COPCs and should not further degrade groundwater quality through potential leaching.~~

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 7 of 72 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethyl benzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA RBC criteria. #1

PCBs

PCBs were not detected in any of the eight surface soil samples, and therefore, are not selected as COPCs.

Pesticides

Five pesticides (alpha and gamma chlordane, DDE, DDT, and heptachlor epoxide) were detected in the soil samples collected at the FTA site. However, as shown in Table 6-1, concentrations did not exceed EPA RBC criteria, and therefore, pesticides are not selected as COPCs.

Inorganics

Arsenic and iron exceeded the carcinogenic RBC value for residential soils but did not exceed the industrial soils criteria. Arsenic concentrations in surface soils ranged from 1.2 to 1.6 mg/kg with a mean concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the surface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in **Appendix H**. Iron was not analyzed as part of the background study but its maximum concentration of 5,400 mg/kg is consistent with regional background as shown in the table in **Appendix H**.

Although consistent with background levels, for the purposes of risk analysis, arsenic and iron are selected as COPCs based on their exceedence of the residential soils criteria.

No other inorganics exceeded EPA RBC values.

compounds were detected in FTA soils.

Metals

Numerous metals including aluminum, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, sodium, vanadium and zinc were detected in surface and subsurface soils.

Detection frequencies, range of concentrations, and EPA RBCs for industrial/residential soils for each of these metals is provided below:

FTA SOIL SAMPLES
RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND

Compound	Range (mg/kg)	Frequency	EPA RBC (mg/kg)
Aluminum	250 to 980	14/14	100,000/7,800
Arsenic	0.98 to 1.6	9/14	3.8/0.43
Barium	2.2 to 12	14/14	14,000/550
Calcium	37 to 370	9/14	--
Chromium	1.6 to 6.7	14/14	610/23
Cobalt	0.44	1/14	4,100/160
Copper	0.63 to 13	6/14	8,200/310
Iron	740 to 5400	14/14	120,000/4,700
Lead	1.8 to 33	14/14	1,200/400
Magnesium	44 to 190	9/14	--
Manganese	5.7 to 34	14/14	4,100/160
Mercury	0.011 to 0.20	3/14	--
Nickel	0.57	1/14	4,100,000/160,000
Potassium	27 to 160	3/14	--
Sodium	9.9	1/14	--
Vanadium	1.1 to 3.7	14/14	1,400/55
Zinc	2.3 to 22	14/14	61,000/2,300

Although concentrations for the majority of the soil samples were slightly above background levels, all metals concentrations were lower than the EPA risk screening criteria for industrial soils while concentrations of arsenic were above the residential soil RBC of 0.43 mg/kg in most samples and iron exceeded the residential soil RBC of 4,700 mg/kg in only one sample. Detects above the RBCs

are presented on **Figure 4-1.**

Pesticides/PCBs

No PCBs were detected in any of the eight soil samples collected throughout the site in 2000. Several pesticides including alpha-chlordane (1 detect at 0.36 ug/kg), gamma-chlordane (3 detects at 0.30 to 0.84 ug/kg), DDE (7 detects at 0.37 to 9 ug/kg), DDT (8 detects at 0.90 to 24 ug/kg), and heptachlor epoxide (1 detect at 0.94 ug/kg) were detected in surface soils. These concentrations are well below EPA RBCs for industrial and residential soils and are also below EPA RBCs for residential soils. Pesticide concentrations at this site are consistent with levels seem on military installations from the widespread pesticide application and not from waste disposal or spills.

Nature and Extent of Soil Contamination

The nature and extent of soil contamination for the three AOCs at the FTA is described in the following sections.

Northern Area

Acetone, MEK, and toluene were detected in most surface and subsurface soil samples collected in two sections of the Northern Area of the site. Concentrations of acetone and MEK varied from surface to deeper depths with no apparent trends (i.e., concentrations decreasing/increasing with depth). Toluene concentrations typically decreased with depth with the highest concentrations present in the surface soils. The lateral extent of VOC contamination was not defined because toluene was detected in all but one of the surface soil samples collected in this area. But as discussed in Section 4.3.1.1, concentrations were several orders of magnitude lower than EPA screening criteria.

Metals were analyzed from two borings (soil borings #1 and #5) (3 samples per boring) in the Northern Area of the site to determine the presence/absence and significance of detected metal concentrations. All metals listed in Section 4.3.1.1 except mercury were detected in at least one of the six samples collected from the two borings. Metal concentrations typically decreased with depth. The lateral extent of metals was not defined because the objective of the sampling program was to determine the presence/absence of metals through analysis of select samples. The data would then be compared to EPA risk screening criteria. Metal concentrations were at least one order of magnitude lower than the EPA screening criteria.

DDE and DDT concentrations were detected in two surface soil samples collected in this area at concentrations much lower than the EPA RBCs. Due to past widespread application of these pesticides, their presence at these low concentrations are expected at the site.

Low or non-detect concentrations of contaminants indicate that residual soil contamination should not pose any additional impacts to groundwater quality through leachate generation.

Former FTP Area

Acetone, MEK, and toluene were detected in most surface and subsurface soil samples collected in the Former FTP Area of the site. Concentrations of acetone, MEK and toluene varied from surface to deeper depths with no apparent trends (i.e., concentrations decreasing/increasing with depth). The lateral extent of VOC contamination was not defined because VOCs were detected in all of the surface soil samples collected in this area. The primary objective of the soil sampling in the FTP area was to evaluate the effectiveness of prior soil removal actions. As discussed in Section 4.3.1.1, concentrations were several orders of magnitude lower than EPA screening criteria.

Metals were analyzed from only one boring (soil boring #10) (3 sample depths) from this area of the site to determine the presence/absence and significance of detected metal concentrations. All metals listed in Section 4.3.1.1 were detected in at least one of the sample depths. Metal concentrations typically decreased with depth. The lateral extent of metals was not defined because the objective of the sampling program was to determine the presence/absence of metals through analysis of select samples. The data would then be compared to EPA risk screening criteria. Again, except for arsenic which had concentrations above the EPA RBC for residential soils, metal concentrations were at least one order of magnitude lower than the EPA screening criteria.

Chlordane, DDE, DDT, and heptachlor epoxide concentrations were detected in both surface soil samples collected in this area at concentrations much lower than EPA RBCs. As previously stated, due to past widespread application of these pesticides, their presence at these low concentrations are expected at the site.

Low or non-detect concentrations of contaminants especially TPH compounds indicate that the majority of the contaminated soils were removed and treated, and that residual soil contamination should not pose any additional impacts to groundwater quality through leachate generation.

Solvent Plume Area

Acetone and toluene were detected in most surface and subsurface soil samples collected in the Solvent Plume Area of the site. Concentrations of acetone and toluene varied from surface to deeper depths with no apparent trends (i.e., concentrations decreasing/increasing with depth). Methylene chloride was only detected in one surface soil sample (soil boring #19). The lateral extent of VOC contamination was not defined because VOCs were detected in all of the surface soil samples collected in this area. However, as discussed in Section 4.3.1.1, concentrations were several orders of magnitude lower than EPA screening criteria.

Two SVOCs (polynuclear aromatic hydrocarbons (PAHs) - fluoranthene and pyrene) were detected in all three samples depths of soil boring #22 located in this area. PAHs are typical constituents of petroleum products such as diesel fuel and heavy oils such as motor oil or hydraulic fluid. TPH as Heavy Oils was also detected in the three samples from this soil boring (66 *mg/kg* at 0 to 1 foot, 150 *mg/kg* at 2 to 4 feet and 95 *mg/kg* at 6 to 8 feet). TPH as Heavy Oils was also detected in all three samples from soil boring SB04-019 (5300, 300 and 48 *mg/kg*) and from the surface soils at soil

boring #21 at a concentration of 48 *mg/kg*. TPH and SVOC contamination generally decreased with depth in these soil borings. The lateral extent of TPH and SVOC contamination is limited to the area near Hospital Circle in the southeast corner of the site. SVOC concentrations were lower than EPA risk screening criteria.

Metals were analyzed from two borings (3 samples from soil boring #15 and 2 samples from soil boring #20) to determine the presence/absence and significance of detected metal concentrations. All metals listed in Section 4.3.1.1 except potassium were detected in at least one of the five samples collected from the two borings. Metal concentrations typically decreased with depth. The lateral extent of metals was not defined because the objective of the sampling program was to determine the presence/absence of metals through analysis of select samples. The data would then be compared to EPA risk screening criteria. Except for arsenic and iron (one sample only), m~~M~~etal concentrations were at least one order of magnitude lower than the EPA screening criteria.

Chlordane, DDE, and DDT concentrations were detected in both surface soil samples collected in this area at concentrations much lower than EPA RBCs. As previously stated, due to past widespread application of these pesticides, their presence at these low concentrations are expected at the site.

Low or non-detect concentrations of other contaminants such as metals, SVOCs and VOCs indicate that residual soil contamination should not pose any additional impacts to groundwater quality through leachate generation.

4.3.2 Sediment

Sediment Analytical Results

Sediment samples were collected from four (4) locations within the drainage areas to the south of the site to assess the presence/absence of contamination.

All sediment samples were analyzed for VOCs, SVOCs, TPH heavy and light fractions, metals and cyanide. Table 4-6 provides the analytical results for the sediment samples collected at the FTA. As shown in Table 4-6, only those contaminants detected are presented. Additionally, the EPA Region III RBC Criteria for Industrial and Residential Soils are presented for comparison purposes. The EPA Region III RBCs for industrial and residential soils for non-carcinogenic compounds presented in Table 4-5 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for sediment, the RBCs have been adjusted.

VOCs

Only one VOC (toluene) was detected in the sediment samples. Toluene was detected in all 4 samples at concentrations of 23 to 180 *ug/kg*. These concentrations are less than the EPA RBCs for industrial and residential soils. ~~of 200,000,000 *ug/kg*~~.

SVOCs

No SVOCs were detected in the sediment samples collected at the site.

TPH

TPH as Heavy Oils was detected in 3 of 4 samples (130 to 350 *mg/kg*) at the FTA. These three samples had concentrations greater than the 100 *mg/kg* screening criteria. The locations and concentrations of these samples are presented on **Figure 4-1**. No other TPH compounds were detected in FTA sediment.

Metals

Numerous metals including aluminum, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, sodium, thallium, vanadium and zinc were detected in the sediment. Detection frequencies and range of concentrations for each of these metals is provided below:

FTA SEDIMENT SAMPLES
RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND

Compound	Range (mg/kg)	Frequency	EPA RBC (mg/kg)
Aluminum	160 to 7600	4/4	100,000/7,800
Arsenic	2.5	1/4	3.8/0.43
Barium	2.4 to 110	4/4	14,000/550
Calcium	64 to 120	4/4	--
Chromium	21	1/4	610/23
Cobalt	2.6	1/4	4,100/160
Copper	26	1/4	8,200/310
Iron	230 to 17,000	4/4	120,000/4,700
Lead	4.3 to 210	4/4	1,200/400
Magnesium	960	1/4	--
Manganese	1.7 to 42	3/4	4,100/160
Mercury	0.017 to 0.051	2/4	61/2.3
Potassium	260	1/4	--
Sodium	87 to 180	2/4	--

FTA SEDIMENT SAMPLES RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND			
Compound	**Range (mg/kg)**	**Frequency**	**EPA RBC (mg/kg)**
Thallium	1.4	1/4	14/0.55
Vanadium	2 to 18	2/4	1,400/55
Zinc	6 to 76	2/4	61,000/2,300

Although metal concentrations were typically greater than background levels, and ~~all~~ concentrations ~~for the metals detected lower~~ of arsenic, iron, and thallium were greater than the EPA RBC~~risk screening~~ criteria for residential soils in one sample each.

Nature and Extent of Sediment Contamination

Sample locations, SD04-001 through SD04-003, are located in a distinct drainage pattern with SD04-001 located upgradient of the other two points. SD04-004 is located within a different drainage area from the other sediment locations. Concentrations of toluene, TPH as Heavy Oils, and metals decrease from SD04-001 to SD04-003 indicating that surface transport of contaminants in sediment may be occurring. SD04-001 is located within the drainage pattern of surface runoff from the southeast corner of the FTA site. TPH as Heavy Oils was detected in several surface soil samples collected in the southeast corner of the FTA site indicating that transport of TPH and other compounds from the FTA site to this drainage area may have occurred. Also, a former UST fuel farm was located adjacent to the Solvent Plume Area that through fuel spills may have impacted the sediments in the drainage area. Runoff from the UST area could have entered the drainage area. However, as previously discussed, concentrations of toluene and metals were lower than EPA screening criteria.

4.3.3 Groundwater

Groundwater Analytical Results

Monitoring Well Results

In 1995, groundwater samples were collected from ten (10) monitoring wells with 10-foot screened intervals as shallow as 4 to 14 feet below grade (6.57 to -3.43 feet MSL) and as deep as 30 to 40 feet below grade (-17.12 to -27.12 feet MSL) for two wells (4 MW-2D and 4 MW-5) to assess the lateral and vertical extent of contamination in the Columbia Aquifer (water table aquifer) at the FTA. All monitoring well samples were analyzed off-site by Savannah Laboratory. Groundwater samples were analyzed for VOCs, SVOCs, TPH heavy and light fractions, total and dissolved metals and cyanide. A total of 10 groundwater samples from FTA monitoring wells were analyzed. Only three of the ten samples were analyzed for the total and dissolved inorganics. Table 4-7 provides a summary of the analytical parameters and results for the monitoring well samples collected at the

FTA. In Table 4-7, only those compounds detected are presented. The EPA Region III RBCs for tap water for non-carcinogenic compounds presented in Table 4-7 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for groundwater, the RBCs have been adjusted.

In addition, the EPA Region III RBC Criteria for Tap Water are presented for comparison. A more detailed risk evaluation which provides a comparative analysis of sample results and chemical-specific ARARs and TBC criteria is provided in the baseline risk assessment in Section 6.0.

In 2000, groundwater samples were collected from four existing monitoring wells (4MW-1, MW-111, MW-112, and MW-114A) with analysis for VOCs, pesticides/PCBs, total suspended solids (TSS), and total dissolved solids (TDS), and total and dissolved metals. These samples were collected to track changes in the contaminants of concern (VOCs and metals) identified from the 1995 sampling and to assess the presence/absence of pesticides and PCBs per a request from VDEQ. Sample results are presented in Table 4-7.

For the organic analyses, the following table provides a summary of the range of concentrations detected by analytical parameter and frequency of detection:

FTA MONITORING WELL SAMPLES
RANGE AND FREQUENCY OF DETECTION BY ORGANIC COMPOUND

Compound	Range (1995/2000)	Frequency (1995/2000)	EPA RBC Criteria[1]
VOCs *(ug/l)*			
Acetone	28 / 10 to 15	1 of 10 / 2 of 4	610
Carbon Disulfide	5 to 8.3 / ---	3 of 10 / 0 of 4	1,000
1,1-Dichloroethane	--- / 0.6 to 0.86	0 of 10 / 2 of 4	800
Ethylbenzene	47 / ---	1 of 10 / 0 of 4	1,300
Xylene	25 to 200 / --	2 of 10 / 0 of 4	12,000
SVOCs *(ug/l)*			
Naphthalene	11	1/10	150
TPH *(mg/l)*			
As Gasoline	0.66	1/10	1.0[2]
As Diesel Fuel	**2.0**[3]	1/10	1.0[2]

Notes:
1. EPA Region III Risk-based Concentration Criteria for Tap Water.
2. Virginia Groundwater Standard for Petroleum Hydrocarbons.

FTA MONITORING WELL SAMPLES RANGE AND FREQUENCY OF DETECTION BY ORGANIC COMPOUND			
Compound	Range (1995/2000)	Frequency (1995/2000)	EPA RBC Criteria[1]
VOCs *(ug/l)*			
3. Underlined text are concentrations above the EPA Region III RBC Criteria/Virginia Groundwater Standards/Maximum Contaminant Level.			

Analysis of monitoring well samples detected several VOCs, but none of the concentrations were greater than the comparison criteria. Only one groundwater sample (Monitoring Well 4MW-2D) contained a TPH compound at a concentration greater than the criteria. Figure 4-2 illustrates the location of groundwater sampling points that had analytical data above the screening criteria. Monitoring Well 4MW-2D contained TPH as Diesel Fuel at 2.0 *mg/l*.

With respect to SVOC analytical results, naphthalene was detected in one groundwater sample (Monitoring Well 4MW-2S) at a concentration of 11 *ug/l* which is greater than the EPA RBC for tap water of 6.5 ug/l. The other compounds that are usually associated with petroleum hydrocarbons such as xylene and ethylbenzene were present at concentrations two to three orders of magnitude less than the EPA RBC Criteria for Tap Water.

Although TPH was present at a concentration slightly greater than the Virginia Groundwater Standard, its associated hazardous constituents such as benzene, toluene, ethylbenzene, and xylene (BTEX), and PAHs were detected at low concentrations.

No pesticides or PCBs were detected in the 2000 sampling event in the four groundwater monitoring wells sampled.

Numerous metals were detected in monitoring well samples. The following table provides a summary of the range of detected concentrations of metals and frequency of detection:

FTA MONITORING WELL SAMPLES RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND					
Compound	Total Metals		Dissolved Metals		EPA RBC Criteria[2] *(ug/l)*
	Range *(ug/l)* 1995 / 2000	Frequency 1995 / 2000	Range *(ug/l)* 1995 / 2000	Frequency 1995 / 2000	
Aluminum	Date Rejected / 470 to 920	No data / 3 of 4	120 to 250 / 64 to 590	2 of 3 / 4 of 4	3,700

FTA MONITORING WELL SAMPLES RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND					
Compound	Total Metals		Dissolved Metals		EPA RBC Criteria[2] (ug/l)
	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	
Antimony	--- / ---	0 of 3 / 0 of 4	--- / **3.8 to 5.7**	0 of 3 / 1 of 4	1.5
Arsenic	**10 to 12**[1] / 3.4	2 of 3 / 1 of 4	--- / --	0 of 3 / 0 of 4	0.045
Barium	110 / 6.1 to 18	2 of 3 / 4 of 4	21 to 52 / 6.2 to 18	3 of 3 / 4 of 4	260
Calcium	13,000 to 18,000 / 6,200 to 19,000	3 of 3 / 4 of 4	12,000 to 18,000 / 5,900 to 18.000	3 of 3 / 4 of 4	N/A
Chromium	14 to 30 / 1.2	2 of 3/ 1 of 4	--- / 0.99 to 1.7	0 of 3 / 3 of 4	110
Cobalt	--- / ---	0 of 3 / 0 of 4	--- / 1.2	0 of 3 / 1 of 4	73
Copper	--- / 1.3 to 21	0 of 3 / 4 of 4	25 / 2.6 to 7.9	1 of 3 / 3 of 4	140
Iron	Data rejected / 280 to **4,100**	No data / 4 of 4	280 to 3,600 / 130 to 2,100	2 of 3 / 4 of 4	2,200
Lead	12 to **52**[1] / 2.8 to 4	2 of 3 / 2 of 4	--- / 4.5 to 4.6	0 of 3 / 2 of 4	15[3]
Magnesium	3,000 to 5,900 / 980 to 8,700	3 of 4 / 4 of 4	1,700 to 5,800 / 920 to 8,400	3 of 3 / 4 of 4	NA
Manganese	12 to **150** / 3.7 to 24	3 of 3 / 4 of 4	11 to **81** / 2.5 to 23	2 of 3 / 4 of 4	73
Nickel	--- / 2.2	0 of 3 / 1 of 4	--- / 3	0 of 3 / 1 of 4	73
Potassium	2,100 to 3,600 / 1,300 to 3,000	3 of 3 / 4 of 4	1,700 to 2,900 / 1,300 to 3,000	3 of 3 / 4 of 4	NA
Sodium	3,800 to 7,700 / 5,500 to 36,000	3 of 3 / 4 of 4	4,700 to 8,400 / 5,100 to 36,000	3 of 3 / 4 of 4	NA
Vanadium	16 to **28** / 0.81 to 2.6	2 of 3 / 3 of 4	--- / 1.2 to 1.8	0 of 3 / 4 of 4	26
Zinc	160 / 18 to 83	2 of 3 / 4 of 4	21 to 120 / 13 to 70	3 of 3 / 4 of 4	1,100

FTA MONITORING WELL SAMPLES
RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND

Compound	Total Metals		Dissolved Metals		EPA RBC Criteria[2] (ug/l)
	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	

Notes:
1. Underlined ranges are concentrations above the EPA Region III RBC Criteria/Virginia Groundwater Standards/Maximum Contaminant Level.
2. EPA Region III Risk-based Concentration Criteria for Tap Water.
3. USEPA Action Level for Drinking Water.

The detected concentrations of total lead, ~~and~~ total arsenic, and total vanadium were slightly over the comparison criteria but were below EPA RBCs for the filtered samples. The higher concentrations of total lead and arsenic detected may be attributed to the presence of sediment in the samples. Groundwater samples were very turbid even after well development and purging due to the presence of fine sands in the water table aquifer. Several dissolved concentrations of antimony and one dissolved concentration of manganese were above EPA RBCs for tap water.

These concentrations above the EPA RBCs are presented on Figure 4-2. All other concentrations of total metals and dissolved metals were significantly lower than the comparison criteria.

DPT Analytical Results

Twenty-four (24) groundwater samples were collected from non-permanent sampling locations using a DPT rig to penetrate to the desired sampling depth. Non-permanent DPT groundwater samples were collected in the three AOCs at the site to assess the lateral and vertical extent of contamination in groundwater. One DPT point (GW04-14) was sampled at a depth of 20 to 21 feet to assess the vertical extent of contamination. The DPT samples were analyzed on-site by Gas Chromatograph (GC) (Modified EPA Method 8015 and EPA Method 3810). The GC analytical results were utilized to assist with placement of permanent monitoring wells. Sixteen (16) of the twenty-four (24) DPT samples were collected in replicate and sent off-site to Savannah Laboratory for analysis to confirm on-site analytical results for select VOCs and TPH light.

On-site analysis of DPT groundwater samples was for TPH light fractions (TPH as Gasoline) and specific VOCs (Benzene, cis1,2-dichloroethene (cis1,2-DCE), tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride). Replicate DPT groundwater samples were analyzed off-site for VOCs and TPH light with additional analysis conducted for SVOCs, TPH heavy and total metals. A total of 24 DPT groundwater samples were analyzed. One (1) DPT groundwater sample from DPT #18 was not analyzed on-site.

The table below presents the distribution of DPT groundwater samples analyzed by on- or off-site lab and analytical parameter:

FTA DPT GROUNDWATER SAMPLES
DISTRIBUTION OF SAMPLE TESTING BY LAB

Analytical Laboratory	VOCs	TPH Light	TPH Heavy	SVOCs	Total Metals
On-site	23/24	23/24	0/24	0/24	0/24
On-site (No off-site confirmation)	7/24	7/24	0/24	0/24	0/24
Off-site and On-site (Confirmation)	16/23	16/24	0/24	0/24	0/24
Off-site Only	1/24	1/24	16/24	16/24	4/24

Table 4-8 provides a summary of the analytical parameters and results for the DPT groundwater samples collected at the FTA. In Table 4-8, only those compounds detected are presented. Additionally, the EPA Region III Risk Screening Criteria for Tap Water (adjusted to a HQ of 0.10 as previously discussed for the monitoring well data) are presented for comparison purposes.

The analytical results indicate that detectable concentrations of vinyl chloride were quantified only in DPT groundwater samples analyzed on-site for VOCs. Off-site analysis of DPT groundwater samples detected several VOCs including acetone, benzene, 1,1-dichloroethane (1,1-DCA), PCE, toluene, xylene, and 1,1,1-trichloroethane (1,1,1-TCA).

Although vinyl chloride was detected in numerous DPT groundwater samples by the on-site GC, its presence was not confirmed by the duplicate samples analyzed by Savannah Laboratories or the QA split samples analyzed by the USACE NED laboratory which were analyzed by GC/MS. No vinyl chloride was detected in any samples submitted to Savannah Laboratories or the USACE NED laboratory.

Additional samples were collected from monitoring well 4MW-2S which is located within an area where on-site GC analysis indicated the presence of vinyl chloride to ascertain its presence/absence. Preserved and unpreserved samples were also collected to assess any effects of hydrochloric acid preservations on vinyl chloride concentrations. All samples were analyzed by EPA Method 3810 (GC) and Method 8270 (GC/MS). Savannah Laboratories contacted Earth Technologies to determine their procedures and equipment used so that they could duplicate this process in their analysis. No vinyl chloride was detected by either method for the preserved and unpreserved samples. However, there was a detect of an unknown compound in the GC analysis whose retention

time was similar to vinyl chloride. This data indicates that the on-site GC analysis was identifying this compound and its concentration as vinyl chloride. Therefore, based on previous GC/MS analysis of duplicate and QA split samples and the additional analysis conducted, no vinyl chloride is present at the site in the groundwater.

Of the DPT groundwater samples analyzed for TPH, only two samples contained detectable concentrations of TPH compounds. One sample (DPT #6) located within the former FTP contained concentrations of TPH as Gasoline (2.0 *mg/l* by off-site laboratory analysis and 13.0 *mg/l* by on-site GC analysis) and TPH as Diesel Fuel (7.2 by off-site laboratory analysis). The other sample (DPT #5) located north of the FTP contained TPH as Heavy Oil (1.4 *mg/l*).

For the organic analyses, the following table provides a summary of the range of detected concentrations and frequency of detection:

FTA DPT GROUNDWATER SAMPLES
RANGE AND FREQUENCY OF DETECTION BY COMPOUND

Compound	On-site Analysis		Off-site Analysis		EPA RBC Criteria[3]
	Range	Frequency	Range	Frequency	
VOCs *(ug/l)*					
Acetone	NT[1]	N/A	27	1/17	61
Benzene	BDL	0/23	**10**	1/17	0.32
1,1-DCA	NT	N/A	20	1/17	80
PCE	BDL	0/23	**6.4 - 78**	2/17	1.1
1,1,1-TCA	NT	N/A	9.4 - 31	2/17	320
Toluene	NT	N/A	20	1/17	75
Xylene	NT	N/A	46	1/17	1,200
SVOCs (ug/l)					
Bis(2-EH)phthalate	NT	N/A	1	1/16	4.8
Fluorene	NT	N/A	15	1/16	24
2 Methyl-naphthalene	NT	N/A	**120**	1/16	12
Naphthalene	NT	N/A	**60**	1/16	0.65

FTA DPT GROUNDWATER SAMPLES
RANGE AND FREQUENCY OF DETECTION BY COMPOUND

Compound	On-site Analysis		Off-site Analysis		EPA RBC Criteria[3]
	Range	Frequency	Range	Frequency	
Phenanthrene	NT	N/A	18	1/16	NA
TPH *(mg/l)*					
as Gasoline	**13**[2]	1/23	**2**[2]	1/17	1.0[5]
as Diesel Fuel	NT	N/A	**7.2**[2]	1/16	1.0[5]
as Heavy Oil	NT	N/A	**1.4**[2]	1/16	1.0[5]

Notes:
1. NT = not tested.
2. **Underlined ranges** are concentrations above the EPA Region III RBC Criteria/Virginia Groundwater Standards/Maximum Contaminant Level.
3. EPA Region III Risk-based Concentration Criteria for Tap Water.
4. NA = not available.
5. Virginia Groundwater Standard for Petroleum Hydrocarbons.

Two VOCs (PCE and benzene) and two SVOCs (2-methylnaphthalene and naphthalene) were detected at concentrations greater than the EPA RBC Criteria for Tap Water. The remaining VOCs, SVOCs and TPH compounds were detected at concentrations less than the comparison criteria by 1 to 3 orders of magnitude.

Numerous metals were detected in DPT groundwater samples. All inorganic analyses were performed off-site by Savannah Laboratory. The following table provides a summary of the range of detected concentrations of metals and frequency of detection:

FTA DPT GROUNDWATER SAMPLES
RANGE AND FREQUENCY OF DETECTION FOR TOTAL METALS

Compound	Range *(ug/l)*	Frequency	EPA RBC Criteria[2] *(ug/l)*
Aluminum	**3,600 to 11,000**	4/4	3,700
Barium	24 to 110	4/4	260

FTA DPT GROUNDWATER SAMPLES
RANGE AND FREQUENCY OF DETECTION FOR TOTAL METALS

Compound	Range *(ug/l)*	Frequency	EPA RBC Criteria[2] *(ug/l)*
Calcium	3,200 to 4,200	4/4	N/A
Chromium	13 to 19	4/4	110
Copper	32	4/4	140
Iron	**4,100 to 4,900**	4/4	2,200
Lead	6.1 to **24**[1]	4/4	15[3]
Magnesium	870 to 1,500	4/4	NA
Manganese	50 to 68	4/4	73
Potassium	1,600 to 3,100	4/4	NA
Sodium	2,100 to 3,500	4/4	NA
Zinc	61 to 190	4/4	1,100

Notes:
1. **Underlined ranges are concentrations above the EPA Region III RBC Criteria/Virginia Groundwater Standards/Maximum Contaminant Level.**
2. **EPA Region III Risk-based Concentration Criteria for Tap Water.**
3. **USEPA Action Level for Drinking Water.**

The detected concentrations of total lead (18 to 24 ug/l), total aluminum (3,600 to 11,000 ug/l), and total iron (4,100 to 4,900 ug/l) were greater than the comparison criteria. Total metal concentrations greater than the EPA RBCs for tap water ~~0.015 *mg/l* action level~~ are presented on Figure 4-2. All other concentrations of total metals detected were lower than the selected comparison criteria.

Nature and Extent of Groundwater Contamination

The nature and extent of groundwater contamination for the three AOCs at the FTA is described in the following sections.

Northern Area

Organics

PCE was detected at a concentration greater than the EPA RBC Criteria of 1.1 *ug/l* in only one groundwater sample (DPT #2 at 6.4 *ug/l*) in the Northern Area. All other samples were below detection limits for SVOCs and TPH compounds. Because only one sample only contained measurable concentrations of PCE, no trends with respect to vertical or lateral extent of contamination were evident. Acetone was detected in 2000 at an estimated concentration of 10 ug/l in 4MW-1 which is well below the EPA RBC.

Inorganics

Although the 1995 concentrations (18 to 52 ug/l) for total lead exceeded the EPA action level for lead in drinking water of 15 *ug/l* for all three groundwater samples (DPT points GW-1and GW-2 and well 4MW-1), the dissolved metals analysis for lead for 4MW-1 did not contain detectable levels (less than 5 ug/l) of lead even though the total lead concentration for the 4MW-1 was 52 *ug/l*. The samples collected in 2000 indicated a total lead concentration of 4 ug/l and a dissolved lead concentration of 4.6 ug/l which are below the EPA 15 ug/l action level.

In 1995, total arsenic was detected at a concentration (10 ug/l) above the EPA RBC (0.045 ug/l) at 4MW-1, however, no dissolved arsenic was detected. Neither total nor dissolved arsenic was detected at 4MW-1 during the 2000 sampling event.

Because the dissolved results for lead and arsenic were below the method detection limit, the measured total lead and arsenic values are related to sediment in the groundwater sample. Thus, the total lead and arsenic values are not representative of the concentration of lead and arsenic dissolved in groundwater. Lead and arsenic are not present in groundwater in a dissolved state above the method detection limit nor above the screening criteria.

Former FTP Area

Organics

Most of the VOCs detected in either DPT or monitoring well samples were detected at levels two to three orders of magnitude below the screening criteria. These VOCs included acetone, carbon disulfide, xylene, and ethylbenzene.

Benzene was detected at only location (DPT #12) at the site which is upgradient of the Former FTP.

Only xylene concentrations varied with depth with the highest concentration (200 *ug/l* in Well 4MW-2S) present in shallow wells or DPT points and the lowest concentration (25 *ug/l* in Well 4MW-2D) present in the deepest well in the FTP Area. The vertical trend observed is related to migration of the compounds in groundwater as well as past corrective actions (excavation to remove

contaminated soils).

With respect to lateral distribution of xylene, the highest concentration was detected in well 4MW-2S (200 *ug/l*) and a lower concentration was detected in DPT point #6 (46 *ug/l*) approximately thirty feet west of 4MW-2S. The lateral distribution of xylene is related to the hydraulic conditions at the FTA site.

No VOCs were detected in the one well (MW-111) sampled in this area during the 2000 sampling event.

Groundwater flow was previously reported in the PA/SI to be toward the southwest. However, based on the groundwater elevations measured in May 1995, the groundwater flow direction was to the north. The apparent change in groundwater flow direction is a function of the lateral distribution of monitoring well locations with measured groundwater elevations between the PA/SI and the RI. Due to the additional five monitoring wells installed at the FTA site during the RI, wells are distributed laterally across the site rather than along the southern boundary. This provides a more complete database of groundwater elevations. However, the flat hydraulic gradient at the FTA site may result in temporal (seasonal) changes in flow direction. The apparent trend of lateral distribution of xylene indicates minimal migration in groundwater.

The investigations were limited to the site and adjacent to the site. No evaluation of the suspected groundwater divide discussed in the PA/SI could be made. As shown on Figure 2-3 in the PA/SI and Figure 3-5 in this report, the FTA site is located on a relatively flat groundwater area with minimal gradient. There is insufficient data available to determine the exact location of the groundwater divide. However, because groundwater elevations are greater in wells (4MW-3 and 4MW-4) south of the site than wells on the site, the groundwater divide may be south of 4MW-4.

All SVOCs detected in the FTP Area were one to three orders of magnitude below the screening criteria.

TPH compounds detected in the FTP Area were all greater than the screening criteria. TPH as Gasoline and Diesel Fuel were present in samples from DPT point #6 and well 4MW-2D. In each instance, the DPT groundwater sample from approximately 13 feet below ground contained higher concentrations of these compounds (Gasoline at 2.0 *mg/l* and Diesel Fuel at 7.2 *mg/l*) than well 4MW-2D (Gasoline at 0.66 *mg/l* and Diesel Fuel at 2.0 *mg/l*) which monitors a zone from thirty to forty feet below grade. With respect to lateral distribution, no other shallow or deep groundwater sample from the FTP Area contained measurable concentrations of these compounds so no apparent trends in lateral distribution were discernible. TPH as Heavy Oil was detected in DPT point #5 at 1.4 *mg/l* which is just above the 1.0 *mg/l* Virginia Groundwater Quality Standard. Because the TPH as Heavy Oil was detected in only one sample, no apparent trend in vertical or lateral extent of contamination could be determined. All TPH compounds detected in groundwater were restricted to the FTP Area. The presence of these compounds in groundwater are related to the petroleum hydrocarbon compounds previously used during fire training activities in the former FTP.

Inorganics

Total arsenic was detected in well 4MW-2S at a concentration of 12 *ug/l* which is above the 0.045 *ug/l* EPA RBC Criteria. However, arsenic was not detected in the dissolved metals analysis for 4MW-2S which indicates that arsenic is not dissolved in groundwater at detectable concentrations. Thus, the total arsenic value is not representative of groundwater quality and is associated with the sediment in the groundwater sample. MW-111 was sampled in 2000 and analyzed for total and dissolved metals. No metal concentrations (total or dissolved) were detected in this well above the EPA RBCs for tap water.

Solvent Plume Area

Organics

Only one groundwater sample (DPT #11) contained PCE at a concentration (78 *ug/l*) that exceeded the EPA RBC Criteria. 1,1-DCA and 1,1,1-TCA were detected at DPT points #10 and #11, but none of the concentrations were above the screening criteria. Also, in 1995, acetone was detected in 4MW-4 (at 28 *ug/l*) but the measured value was more than one order of magnitude less than the screening criteria (610 *ug/l*). MW-112 and MW-114A were re-sampled in 2000 to assess any trends in contaminant concentrations. Acetone was detected in MW-114A at 15 ug/l which is well below the EPA RBC of 610 ug/l while 1,1-DCA was detected in MW-112 at 0.60 ug/l and in MW-114A at 0.86 ug/l which are well below the EPA RBC of 800 ug/l. The distribution of the VOCs with respect to depth and lateral distance did not exhibit any trends in concentration values. However the concentrations of all VOCs continue to be well below EPA RBCs and USEPA MCLs.

No SVOCs, pesticides, PCBs, or TPH compounds were detected.

Inorganics

In 1995, total lead was detected at DPT point #8 at 24 *ug/l* which is greater than the 15 *ug/l* USEPA action level for lead in drinking water. There were no dissolved metals analysis for lead conducted that can be compared to the total lead value measured.

In the 2000 sampling event, the only metal detected above the EPA RBC was total arsenic which was detected at 3.4 ug/l at MW-114A. Dissolved arsenic was not detected in this well.

As was the case for total lead in the Northern Area and total arsenic across the site, the value is associated with the sediment in the sample analyzed for the total sample. The dissolved fractions for lead are always below the 15 ug/l action level and non-detect for arsenic.

4.4 LARC 60 MAINTENANCE AREA

Soil, sediment, surface water and groundwater samples were collected at the LARC 60 Maintenance Area (LARC 60) to define the nature and extent of contamination. Surface soil and sediment samples were collected by hand auger while subsurface soil and numerous groundwater samples were collected by DPT methods. In addition, groundwater samples were collected from newly installed and existing monitoring wells. Three AOCs were investigated to determine potential sources and the extent of contamination. These areas include the Former UST Area in the southern end of the site, the Oil/Water Separator (OWS) Area in the central portion of the site and the Sandbox on the northern edge of the site.

In this section analytical data for all media is compared against EPA risk screening criteria. Groundwater and surface water data are screened against EPA RBC for tap water while sediment and soils data are compared to EPA RBC for industrial and residential soils. This initial screening against these criteria are only used to assign significance to the analytical data and not as an analysis of risk or impacts. A detailed risk assessment which screens the data against ARARs such as MCLs, surface water quality standards, EPA soil screening levels, EPA RBC residential soil criteria, EPA Region III BTAG ecological risk levels, etc. is provided in Sections 6.0 (Human Health Risk Assessment) and 7.0 (Ecological Risk Assessment).

4.4.1 Surface and Subsurface Soils

Soil Analytical Results

Soil samples were collected from twenty-three (23) soil borings with samples collected from three depths in the southern end of the site and from two depths in the northern edge of the site to assess the lateral and vertical extent of contamination in the vadose zone.

All soil samples were analyzed for VOCs, SVOCs, and TPH heavy and light fractions while five (5) surface and six (6) subsurface soil samples were additionally analyzed for metals and cyanide. Table 4-9 provides the analytical results for the soil samples collected at the LARC 60 site. As shown in Table 4-9, only those contaminants detected are presented. Additionally, the EPA Region III RBC Criteria for Industrial and Residential Soils are presented for comparison purposes. The EPA Region III RBCs for industrial and residential soils for non-carcinogenic compounds presented in Table 4-5 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for soil, the RBCs have been adjusted.

To address VDEQ concerns over the absence of pesticide and PCB data from soil samples collected in 1995, in 2000, eight (8) surface soil samples were collected throughout the LARC 60 site to assess contamination in surface soils. All eight soil samples were analyzed for pesticides and PCBs. Table 4-9 provides the analytical results for the soil samples collected at the LARC 60 site in 2000.

VOCs

Numerous VOCs including acetone, sec-butyl benzene, ethylbenzene, isopropyl benzene, p-isopropyl toluene, methylene chloride, MEK, n-propyl benzene, styrene, PCE, toluene, 1,2,3-trichlorobenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, TCE and xylenes were detected in surface and subsurface soils.

All concentrations were at least 3 orders of magnitude less than the risk screening criteria for industrial and residential soils. Acetone, methylene chloride, and MEK are common laboratory artifacts.

SVOCs

Several SVOCs (PAHs and phthalates) were detected in only two subsurface soils at the LARC 60 site. Concentrations were several orders of magnitude less than the EPA RBC for industrial and residential soils.

TPH

TPH as Heavy Oils was detected in 31 of 49 samples (42 to 1,500 *mg/kg*) at the site. Twenty-nine (29) of these samples had concentrations greater than the 100 *mg/kg* screening criteria. The location and concentration of these samples is presented on Figure 4-3.

Only those compounds detected at concentrations greater than the risk screening criteria are presented on Figure 4-3. No other TPH compounds were detected in LARC 60 site soils.

Metals

Numerous metals were detected in surface and subsurface soils. Detection frequencies and range of concentrations for each of these metals is provided below:

LARC 60 SOIL SAMPLES
RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUNDS

Compound	Range (mg/kg)	Frequency	EPA RBC (mg/kg)
Aluminum	250 to 2700	11/11	100,000 / 7,800
Arsenic	**0.86 to 1.1**	3/11	3.8 / 0.43
Barium	1.8 to 19	11/11	14,000 / 550

LARC 60 SOIL SAMPLES RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUNDS			
Compound	**Range (mg/kg)**	**Frequency**	**EPA RBC (mg/kg)**
Calcium	43 to 980	8/11	--
Cadmium	0.18	1/11	100 / 39
Chromium	1.5 to 4.3	11/11	610 / 23
Cobalt	0.79	1/11	4,100 / 160
Copper	2.5 to 41	7/11	8,200 / 310
Iron	400 to 1,100	11/11	120,000 / 4,700
Lead	1.3 to 17	11/11	1,200 / 400
Magnesium	56 to 1,400	8/11	--
Manganese	2.4 to 120	11/11	4,100 / 160
Mercury	4.6	1/11	--
Nickel	0.81	1/11	4,100 / 160
Potassium	37 to 1200	2/11	--
Silver	0.51	1/11	1,000 / 39
Vanadium	1.7 to 9.2	10/11	1,400 / 55
Zinc	3 to 33	11/11	61,000 / 2,300

Arsenic exceeded the EPA RBC for residential soils in 3 soil samples. Although greater than background levels, all concentrations for the other metals detected were at least one order of magnitude lower than the EPA risk screening criteria.

Pesticides/PCBs

No PCBs were detected in any of the eight soil samples collected throughout the site in 2000.

Several pesticides including beta-BHC (1 detect at 1.6 ug/kg), alpha-chlordane (1 detect at 0.51 ug/kg), gamma-chlordane (2 detects at 0.49 and 0.63 ug/kg), DDD (4 detects at 1.2 to 4.3 ug/kg), DDE (5 detects at 0.30 to 13 ug/kg), DDT (7 detects at 0.55 to 39 ug/kg), and dieldren (1 detect at 0.47 ug/kg) were detected in surface soils. These concentrations are well below EPA RBCs for industrial soils and are also below EPA RBCs for residential soils. Pesticide concentrations at this site are consistent with levels seem on military installations from the widespread pesticide application and not from waste disposal or spills.

Nature and Extent of Soil Contamination

The nature and extent of soil contamination for the three AOCs at the LARC 60 site is described in the following sections.

Former UST Area

Acetone, PCE, and toluene were detected in several surface and subsurface soil samples collected in the Former UST Area of the site. Concentrations of the VOCs varied from surface to deeper depths with no apparent trends (i.e., concentrations decreasing/increasing with depth). The lateral extent of surficial contamination is limited to a relatively small area around the former UST excavation. As discussed in Section 4.4.1.1, concentrations were several orders of magnitude lower than EPA risk screening criteria.

TPH as Heavy Oils was detected in two surface soil samples collected in the vicinity of the former UST excavation. Excavated soils from the former UST excavation are piled alongside the former excavation. The presence of TPH in the surface soils and not in the subsurface soils in the vicinity of the UST pit is probably due to transport of sediment from the soil pile or from the deposition of some TPH-contaminated soil in this area during excavation activities. The lateral extent of surficial contamination is limited to a small area around the former UST excavation.

Metals were analyzed from soil boring #1) (3 sample depths) from this area of the site to determine the presence/absence and significance of detected metal concentrations. All metals listed in Section 4.4.1.1 except sodium were detected in at least one of the sample depths. Metal concentrations typically decreased with depth. The lateral extent of metals was not defined because the objective of the sampling program was to determine the presence/absence of metals through analysis of select samples. The data would then be compared to EPA risk screening criteria. Except for arsenic concentrations at SB-01 which exceeded the EPA RBC for residential soils, metal concentrations were at least one order of magnitude lower than the EPA screening criteria.

DDT and beta-BHC were detected in 1 of 2 samples collected in the vicinity of the former UST. Concentrations detected were much lower than EPA RBCs and are consistent with expected levels from widespread pesticide application.

Although no soil sampling was conducted from within the former UST excavation, as discussed in Section 1.2.3, previous subsurface soil sampling in this area by ETI indicated the presence of TPH,

toluene, ethylbenzene and xylene.

OWS Area

Numerous VOCs were detected in several surface and subsurface soil samples collected in the OWS area of the site. PCE and TCE were only detected in soil boring #10 located in the concrete pad near the Sandbox Area. For those samples collected underneath the concrete pad located north of the OWS, concentrations of these VOCs were greater in the subsurface soil samples collected from a depth of 4 to 5 feet below land surface (at the water table interface) indicating that the contaminants may be the result of adsorption of groundwater contaminants onto the soil particles due to a fluctuating water table. As discussed in Section 4.3.1.1, concentrations were several orders of magnitude lower than EPA screening criteria.

TPH as Heavy Oils was detected in the majority of surface and subsurface soil samples collected in this area. TPH concentrations decreased with depth in all borings sampled in the OWS Area. TPH as Heavy Oils was also detected at three sample depths in soil boring #4 which is located upgradient of the OWS. The source of the TPH in this area is unknown.

Metals were analyzed from two borings (2 samples from soil boring #5 and soil boring #10) to determine the presence/absence and significance of detected metal concentrations. All metals listed in Section 4.4.1.1 except arsenic, cobalt and potassium were detected in at least one of the four samples collected from the two borings. Metal concentrations typically decreased with depth. The lateral extent of metals was not defined because the objective of the sampling program was to determine the presence/absence of metals through analysis of select samples. The data would then be compared to EPA risk screening criteria. Metal concentrations were at least one order of magnitude lower than the EPA screening criteria.

Dieldren, DDD, DDE, DDT and gamma-chlordane were detected in samples collected in the central portion of the site. Concentrations detected were much lower than EPA RBCs and are consistent with expected levels from widespread pesticide application.

Sandbox

Methylene chloride, MEK, styrene, PCE, toluene and TCE were detected in numerous surface and subsurface soil samples collected in and downgradient of the Sandbox. Concentrations of the VOCs varied from surface to deeper depths with no apparent trends (i.e., concentrations decreasing/increasing with depth). No patterns were indicated in the lateral distribution of VOCs within the Sandbox. As discussed in Section 4.3.1.1, concentrations were several orders of magnitude lower than EPA screening criteria.

TPH as Heavy Oils was detected in the majority of surface and subsurface soil samples collected in this area. TPH as Heavy Oils concentrations increased with depth in all borings (soil borings #11 through #16) sampled in the central and southern portions of the Sandbox while TPH was only detected in surface soils for all borings located along the northern fenceline (soil borings #17 through

#20) of the Sandbox and in the wooded area (soil borings #21 through #23) north of the Sandbox. The area of the Sandbox along the northern fenceline is typically not disturbed while the soil in the central and southern portions of the Sandbox are impacted during LARC vehicle and other heavy equipment (i.e., loaders, dozers, etc.) operations. This area is disturbed when these vehicles are driven and stored on the soil in these areas. This disturbance enhances the transport of contaminants from surface to subsurface soils.

The source of the TPH in this area is probably from past wash rack, operations and maintenance activities in this area and from current LARC vehicle operation and storage activities (i.e., leaks from heavy equipment).

Metals were analyzed from two borings (2 samples from soil borings #15 and #20) to determine the presence/absence and significance of detected metal concentrations. All metals listed in Section 4.4.1.1 except arsenic, cobalt, potassium and sodium were detected in at least one of the four samples collected from the two borings. Metal concentrations increased with depth in soil boring #15 but decreased with depth in soil boring #20. However, except for arsenic at boring #20, their concentrations were at least one order of magnitude lower than the EPA screening criteria. Arsenic was detected at a concentration of 0.86 mg/kg at the 5 to 7 foot interval at soil boring #20 which is greater than the EPA RBC for residential soils of 0.43 mg/kg.

DDD, DDE, DDT and chlordane (alpha and gamma) were detected in samples collected in the sandbox area (and the wooded area downgradient of the sandbox) of the site. Concentrations detected were much lower than EPA RBCs and are consistent with expected levels from widespread pesticide application.

The bioremediation activities conducted by IT Corporation in 1994 significantly reduced the concentration of TPH in the Sandbox soils especially the lighter end hydrocarbons and probably PAH compounds typically associated with petroleum products, however, as confirmed during IT's post-remediation sampling, TPH as Heavy Oils is still present in the majority of the soils within the Sandbox with concentrations ranging from 77 to 1,500 *mg/kg*. However, only low concentrations of VOCs and no PAHs were detected in surface and subsurface soils in the Sandbox indicating that the bioremediation was effective in reducing or eliminating the source of the hazardous constituents typically associated with petroleum hydrocarbons.

4.4.2 Sediment

Sediment Analytical Results

Sediment samples were collected from two (2) locations within the drainage ditch located to the north of the Sandbox to assess the presence/absence of contamination.

All sediment samples were analyzed for VOCs, SVOCs, TPH heavy and light fractions, metals and cyanide. Table 4-10 provides the analytical results for the sediment samples collected at the LARC 60 site. As shown in Table 4-10, only those contaminants detected are presented. Additionally, the

EPA Region III RBC Criteria for Industrial and Residential Soils are presented for comparison purposes.

VOCs/SVOCs

No VOCs or SVOCs were detected in the sediment samples collected at the site.

TPH

TPH as Heavy Oils was detected in both samples (530 and 2,700 *mg/kg*) from the drainage ditch in concentrations greater than the 100 *mg/kg* screening criteria. The locations and concentrations of these samples are presented on Figure 4-3. No other TPH compounds were detected in the sediment.

Metals

Numerous metals including aluminum, barium, calcium, chromium, copper, iron, lead, magnesium, manganese, sodium, vanadium and zinc were detected in the sediment. Detection frequencies and range of concentrations for each of these metals is provided below:

LARC 60 SEDIMENT SAMPLES
RANGE AND FREQUENCY OF DETECTION OF INORGANIC COMPOUNDS

Compound	Range (mg/kg)	Frequency	EPA RBC (mg/kg)
Aluminum	310 and 650	2/2	100,000 / 7,800
Barium	1.4 and 2.7	2/2	14,000 / 550
Calcium	53 and 210	2/2	--
Chromium	1.6 and 2.5	2/2	610 / 23
Copper	3.8 and 9.0	2/2	8,200 / 310
Iron	410 and 940	2/2	120,000 / 4,700
Lead	8.2 and 14	2/2	1,200 / 400
Magnesium	110 and 250	2/2	--
Manganese	3.4 and 6.9	2/2	4,100 / 160
Sodium	70	1/2	--

LARC 60 SEDIMENT SAMPLES RANGE AND FREQUENCY OF DETECTION OF INORGANIC COMPOUNDS			
Compound	**Range (mg/kg)**	**Frequency**	**EPA RBC (mg/kg)**
Vanadium	1.3 and 2.7	2/2	1,400 / 55
Zinc	11 and 30	2/2	61,000 / 2,300

All concentrations for the metals detected were lower than the EPA RBCs for industrial and residential soils ~~risk screening criteria~~.

Nature and Extent of Sediment Contamination

Sample locations, SD06-001 and SD06-002, are located in a drainage ditch adjacent to the northern boundary of the Sandbox. The drainage ditch is a collection basin for stormwater from the Sandbox area, wooded area north of the Sandbox and from the Public Works Center Compound located to the east of the drainage ditch. No flow is present in the ditch and no outfall exists for transport of surface water or sediment from the ditch.

TPH as Heavy Oils is present in the ditch due to surface transport of soil from the Sandbox during heavy precipitation events. Due to stagnant conditions, an accumulation of TPH-contaminated sediment occurs in the ditch with no transport occurring. Metals are present in sediment in the ditch but, as previously discussed, with concentrations lower than EPA screening criteria.

4.4.3 Surface Water

Surface Water Analytical Results

Surface water samples were collected from two (2) locations within the drainage ditch located to the north of the Sandbox to assess the presence/absence of contamination. All surface water samples were analyzed for VOCs, SVOCs, TPH heavy and light fractions, and total metals and cyanide. Table 4-11 provides the analytical results for the surface water samples collected at the LARC 60 site. As shown in Table 4-11, only those contaminants detected are presented. Additionally, the EPA Region III RBC Criteria for Tap Water are presented for comparison purposes.

Acetone was detected in both samples at concentrations of 30 and 35 *ug/l* which is ~~significantly~~ less than EPA RBC for tap water ~~risk screening criteria~~ of 61 ug/l. Acetone is a common laboratory artifact. No SVOCs or TPH compounds were detected in the surface water samples collected at the site. Numerous total metals were detected in the surface water. Detection frequencies and range of concentrations for each of these metals is provided below:

LARC 60 SURFACE WATER SAMPLES RANGE AND FREQUENCY OF DETECTION OF INORGANIC COMPOUNDS			
Compound	**Range (ug/l)**	**Frequency**	**EPA RBC (mg/l)**
Aluminum	0.390 and 420	2/2	3,700
Calcium	11,000 and 12,000	2/2	--
Iron	840 and 1,400	2/2	2,200
Lead	7.8 and 9	2/2	15
Magnesium	15,000 and 17,000	2/2	--
Manganese	**83 and 140**	2/2	73
Potassium	9,100 and 9,400	2/2	--
Sodium	120,000	1/2	--
Zinc	40 and 62	2/2	1,100

~~All concentrations for the metals detected lower than the EPA risk screening criteria.~~

Manganese was the only metal detected above the EPA RBCs for tap water.

Nature and Extent of Surface Water Contamination

Based on vertical elevations established for the two surface water locations in the ditch, the ditch intersects the shallow water table. The elevations were consistent with the groundwater elevations in that area as shown on Figure 3-6. During dry weather conditions, the water (if any) present in the drainage ditch will be groundwater that has seeped into the ditch. Surface water results were also consistent with contaminant concentrations detected in DPT points in the Sandbox and in monitoring well 6MW-3S. Acetone and total metals are present in the ditch but, as previously discussed, except for manganese, with concentrations lower than EPA screening criteria.

4.4.4 Free Floating Product

A Keck Oil/Water Interface Meter was used to determine the presence/absence of FFP in the Former UST area. Three temporary well points were installed in this area and the Keck was used to measure FFP. A Microtip Photoionization Detector (PID) was used to screen soils collected by split

spoon at various intervals during well point installation. A summary of PID readings is provided as follows:

Well Point	Sample Depth (ft)	PID Reading (ppm)	Soil Type
WP-1	4 to 6 9 to 11	1 7	Coarse white sand (pit backfill) Medium tan sand
WP-2	4 to 6 9 to 11	Not detected Not detected	Medium tan sand Medium tan sand
WP-3	4 to 6 9 to 11	Not detected Not detected	Medium tan sand Medium tan sand

No FFP or sheen/discoloration was observed on soil cuttings removed during well point installation. Cuttings from WP-1 had a strong petroleum odor. Upon completion of the well points, the Keck was used to measure any FFP present. The Keck detected no FFP. Three volumes of groundwater were then purged from the well points. No FFP or sheen was present on the purged water. After several hours of well point stabilization, the Keck was used again and the well points purged. Although a petroleum odor is present in WP-1, no FFP or sheen were measured or observed during these investigations.

4.4.5 Groundwater

Groundwater Analytical Results

Monitoring Well Results

Groundwater samples were collected from eight (8) monitoring wells with 10-foot screened intervals as shallow as 2 to 12.5 feet below grade (6.95 to -3.05 feet MSL) and as deep as 30 to 40 feet below grade (-16.98 to -26.98 feet MSL) at two wells (6MW-2 and 6MW-3D) to assess the lateral and vertical extent of contamination in the Columbia Aquifer (water table aquifer). Samples were collected in the three AOCs at the LARC 60 site. All monitoring well samples were analyzed off-site by Savannah Laboratory.

All groundwater samples were analyzed for VOCs, SVOCs, TPH heavy and light fractions, and 20 percent for total and dissolved metals and cyanide. A total of eight groundwater samples from LARC 60 monitoring wells were analyzed. Three of the eight samples were analyzed for the total and dissolved inorganics. Table 4-12 provides a summary of the analytical parameters and results for the monitoring well samples collected at the LARC 60 site. In Table 4-12, only those compounds detected are presented.

In addition, the EPA Region III RBC Criteria for Tap Water are presented for comparison purposes. The EPA Region III RBCs for tap water for non-carcinogenic compounds presented in Table 4-12 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for groundwater, the RBCs have been adjusted.

A more detailed risk evaluation which provides a comparative analysis of sample results and ARARs and TBC criteria is provided in the baseline risk assessment in Section 6.0.

In 2000, groundwater samples were collected from six existing monitoring wells (6MW-1, 6MW-4, 6MW-3S, MW-115, MW-117, and MW-118) with analysis for VOCs, pesticides/PCBs, total suspended solids (TSS), and total dissolved solids (TDS), and total and dissolved metals. These samples were collected to track changes in the contaminants of concern (VOCs and metals) identified from the 1995 sampling and to assess the presence/absence of pesticides and PCBs per a request from VDEQ. Results are presented in Table 4-12.

For the organic analyses, the following table provides a summary of the range of concentrations detected by analytical parameter and frequency of detection:

LARC 60 MONITORING WELL SAMPLES
RANGE AND FREQUENCY OF DETECTION BY ORGANIC COMPOUND

Compound	Range (1995/2000)	Frequency (1995/2000)	EPA RBC Criteria[1]
VOCs *(ug/l)*			
cis 1, 2-Dichloroethene (DCE)	**20 / 2 to 1,900**	1 of 8 / 2 of 6	6.1
Ethylbenzene	66 / 76	1 of 8 / 1 of 6	130
Methyl isobutyl ketone (MIBK)	Not detected / **19 to 50**	0 of 8 / 3 of 6	14
Tetrachloroethene (PCE)	**8.5** / Not detected	1 of 8 / 0 of 6	1.1
Toluene	68 / **310**	1 of 8 / 1 of 6	75
Trichloroethene (TCE)	**18** / 1.3	1 of 8 / 1 of 6	1.6
Vinyl chloride	Not detected / **3.1 to 8.6**	0 of 8 / 2 of 6	0.015
Xylene	290 / 450	1 of 8 / 1 of 6	1,200
SVOCs *(ug/l)*			
2-Methylnaphthalene	**20**	1/8	12
Naphthalene	**32**	1/8	0.65
TPH *(mg/l)*			

LARC 60 MONITORING WELL SAMPLES RANGE AND FREQUENCY OF DETECTION BY ORGANIC COMPOUND			
Compound	**Range (1995/2000)**	**Frequency (1995/2000)**	**EPA RBC Criteria[1]**
as Gasoline	**3.0**	1/8	1.0[2]
as Diesel Fuel	**2.7 - 3.3**	2/8	1.0[2]

Notes:
1. EPA Region III Risk-based Concentration Criteria for Tap Water.
2. Virginia Groundwater Standard for Petroleum Hydrocarbons.

Analysis of monitoring well groundwater samples detected VOCs including cis 1,2-DCE, ethylbenzene, methyl isobutyl ketone (MIBK), tetrachloroethene (PCE), toluene, trichloroethene (TCE), vinyl chloride, and xylene. Based on 1995-year data, only one well (MW-117) had VOCs (cis 1,2-DCE, PCE and TCE) detected at concentrations greater than the EPA RBCs. Based on 2000 year data, four wells had VOC concentrations greater than EPA RBCs for tap water including 6MW-1 (MIBK), 6MW-3S (MIBK and vinyl chloride), 6MW-4 (MIBK), and MW-117 (cis 1,2-DCE, toluene, and vinyl chloride).

Only two groundwater samples (Monitoring Wells 6MW-3S and MW-117) contained TPH compounds at a concentration greater than the criteria. Figure 4-4 illustrates the location of groundwater sampling points that had analytical data above the screening criteria. Monitoring Wells 6MW-3S and MW-117 contained TPH as Diesel Fuel at concentrations of 2.7 and 3.3 *mg/l*, respectively. Monitoring Well MW-117 also contained TPH as gasoline at a concentration of 3 *mg/l*.

With respect to SVOC analytical results, 2-methylnaphthalene (20 *ug/l* from 6MW-3S) and naphthalene (32 *ug/l* from MW-117) were detected at the LARC 60 site. The naphthalene concentration of 32 ug/l was greater than the EPA RBC Criteria of 6.5 ug/l. The other compounds that are usually associated with petroleum hydrocarbons such as xylene and ethylbenzene were present at concentrations two to three orders of magnitude less than the EPA RBC Criteria for Tap Water. Although TPH compounds were present at concentrations greater than the Virginia Groundwater Standard for Petroleum Hydrocarbons, the associated hazardous constituents such as BTEX and PAHs were detected at low concentrations.

No pesticides or PCBs were detected in the 2000 sampling event in the six groundwater monitoring wells sampled.

Numerous metals were detected in monitoring well samples. The following table provides a summary of the range of detected concentrations of metals and frequency of detection:

LARC 60 MONITORING WELL SAMPLES RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND					
Compound	Total Metals		Dissolved Metals		EPA RBC Criteria[1] (ug/l)
	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	
Aluminum	590 to 3,700 / 210 to 260	4 of 4 / 2 of 6	BDL / 14 to 300	0 of 4 / 3 of 6	3,700
Antimony	**BDL / BDL**	0 of 4 / 0 of 6	BDL / 2.8 to 5.4	0 of 4 / 2 of 6	1.5
Arsenic	14 To 91 / 21	2 of 4 / 1 of 6	40 / 14	1 of 4 / 1 of 6	0.045
Barium	14 to 120 / 5.3 to 22	4 of 4 / 6 of 6	21 to 70 / 5 to 21	4 of 4 / 6 of 6	260
Calcium	6,400 to 39,000 / 6,700 to 20,000	4 of 4 / 6 of 6	6,300 to 36,000 / 6,300 to 18,000	4 of 4 / 6 of 6	---
Chromium	**BDL / 1.1 to 2.9**	0 of 4 / 3 of 6	BDL / 0.75 to 2.6	0 of 4 / 5 of 6	110
Copper	**BDL / 1.4 to 14**	0 of 4 / 6 of 6	BDL / 30	0 of 4 / 1 of 6	140
Iron	3,500 to 16,000 / 270 to 17,000	4 of 4 / 6 of 6	5,800 to 9,000 / 70 to 15,000	3 of 4 / 6 of 6	2,200
Lead	6.7 - 8.9 / 2.6 to 4.7	2 of 4 / 4 of 6	BDL / 3.2 to 4.7	0 of 4 / 5 of 6	15[2]
Magnesium	4,200 to 6,400 / 1,500 to 9,100	4 of 4 / 6 of 6	4,000 to 6,300 / 1,400 to 8,700	4 of 4 / 6 of 6	---
Manganese	25 to 640 / 4.2 to 290	4 of 4 / 6 of 6	84 to 530 / 3.8 to 270	3 of 4 / 6 of 6	73
Potassium	4,300 to 12,000 / 2,400 to 6,400	4 of 4 / 6 of 6	1,700 to 11,000 / 2,400 to 6,200	4 of 4 / 6 of 6	---
Sodium	8,100 to 30,000 / 5,300 to 69,000	4 of 4 / 6 of 6	9,800 to 33,000 / 4,800 to 66,000	4 of 4 / 6 of 6	---

LARC 60 MONITORING WELL SAMPLES RANGE AND FREQUENCY OF DETECTION BY INORGANIC COMPOUND					
Compound	Total Metals		Dissolved Metals		EPA RBC Criteria[1] (ug/l)
	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	Range (ug/l) 1995 / 2000	Frequency 1995 / 2000	
Vanadium	11 / 1.5 to 9.5	1 of 4 / 4 of 6	BDL / 1.1 to 9.6	0 of 4 / 4 of 6	26
Zinc	22 to 42 / 3.3 to 29	4 of 4 / 6 of 6	26 / 3.4 to 46	1 of 4 / 6 of 6	1,100

Notes:
1. EPA Region III Risk-based Concentration Criteria for Tap Water.
2. USEPA Action Level for Lead in Drinking Water.

The detected concentrations of total arsenic, iron, and manganese were over the comparison criteria in several wells (arsenic in 6MW-3S and MW-117, ~~and~~ iron in 6MW-1, 6MW-2, 6MW-3S, MW-115, MW-117, and MW-118~~117~~, and manganese in 6MW-2, 6MW-3S, MW-115, and MW-117).

The ~~only~~ dissolved metals detected above the EPA RBCs were~~as~~ as follows:

- Arsenic in well MW-117 as detected during the 1995 and 2000 sampling events. However, it should be noted that the dissolved arsenic levels detected in MW-117 (40 ug/l in 1995 and 14 ug/l in 2000), although above EPA RBCs for tap water, are below the USEPA MCL for drinking water of 50 ug/l.

- Antimony in wells 6MW-3S and 6MW-4 at concentrations of 5.4 and 2.8 ug/l, respectively.

- Iron in most wells on-site at a concentration range of 2,500 to 15,000 ug/l.

- Manganese in most wells on-site at a concentration range of 95 to 530 ug/l.

Their locations and concentrations are presented on Figure 4-4. All other concentrations of total and dissolved metals were lower than the comparison criteria.

DPT Analytical Results

Twenty-five (25) groundwater samples were collected from non-permanent sampling locations using a DPT rig to penetrate to the desired sampling depth. Non-permanent DPT groundwater samples were collected in the three AOCs at the site to assess the lateral and vertical extent of contamination in groundwater. One DPT point (GW06-17) was sampled at a depth of 39 to 40 feet to assess the

vertical extent of contamination. The DPT samples were analyzed on-site by GC by EPA Methods 8015 and 3810. The GC analytical results were utilized to assist with placement of permanent monitoring wells. Twelve (12) of the twenty-five (25) DPT samples were collected in replicate and sent off-site to Savannah Laboratory for analysis to confirm on-site analytical results for select VOCs and TPH light.

DPT groundwater samples were analyzed on-site for TPH light fractions (TPH as Gasoline) and specific VOCs (Benzene, cis 1,2-DCE, PCE, TCE, and vinyl chloride). Replicate DPT groundwater samples were analyzed off-site for VOCs and TPH light with additional analysis conducted for SVOCs, TPH heavy and total metals. A total of twenty-five (25) DPT groundwater samples were analyzed. Nine (9) DPT groundwater samples were not analyzed on-site (DPT Points #4, #11 through #17, and #25). The table below presents the distribution of DPT groundwater samples analyzed by on- or off-site lab and analytical parameter:

LARC 60 DPT GROUNDWATER SAMPLES
DISTRIBUTION OF SAMPLE TESTING BY LAB

Analytical Laboratory	VOCs	TPH Light	TPH Heavy	SVOCs	Total Metals
On-site	16/25	16/24	0/17	0/17	0/3
On-site (No off-site confirmation)	4/24	4/24	0/17	0/17	0/3
Off-site and On-site (Confirmation)	12/25	12/24	0/17	0/17	0/3
Off-site Only	8/24	8/24	17/17	17/17	3/3

Table 4-13 provides a summary of the analytical parameters and results for the DPT groundwater samples collected at the LARC 60 site. In Table 4-13, only those compounds detected are presented. Additionally, the EPA Region III Risk Screening Criteria for Tap Water are presented for comparison purposes. The EPA Region III RBCs for tap water for non-carcinogenic compounds presented in Table 4-12 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for groundwater, the RBCs have been adjusted.

The analytical results indicate that detectable concentrations of vinyl chloride were quantified only in DPT groundwater samples analyzed on-site for VOCs. Off-site analysis of DPT groundwater samples detected several VOCs including acetone, chloroform, isopropyl toluene, methylene chloride, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, cis 1,2-DCE, PCE, TCE, vinyl acetate, ethylbenzene, methyl isobutyl ketone (MIBK), toluene and xylene.

As was the case for the FTA, vinyl chloride was detected in numerous DPT groundwater samples by the on-site GC, but its presence was not confirmed by the duplicate samples analyzed by Savannah Laboratories or the QA split samples analyzed by the USACE NED laboratory which were analyzed by GC/MS. No vinyl chloride was detected in any samples submitted to Savannah Laboratories or the USACE NED laboratory.

Additional samples were collected from monitoring well 6MW-3S which is located within an area where on-site GC analysis indicated the presence of vinyl chloride to ascertain its presence/absence. Preserved and unpreserved samples were also collected to assess any effects of hydrochloric acid preservations on vinyl chloride concentrations. All samples were analyzed by EPA Method 3810 (GC) and Method 8270 (GC/MS). Savannah Laboratories contacted Earth Technologies to determine their procedures and equipment used so that they could duplicate this process in their analysis. No vinyl chloride was detected by either method for the preserved and unpreserved samples. However, there was a detect of an unknown compound in the GC analysis whose retention time was similar to vinyl chloride. This data indicates that the on-site GC analysis was identifying this compound and its concentration as vinyl chloride.

Therefore, based on previous GC/MS analysis of duplicate and QA split samples and the additional analysis conducted, no vinyl chloride is present at the site in the groundwater.

Of the DPT groundwater samples analyzed for TPH, only two samples contained detectable concentrations of TPH compounds. One sample (DPT #2) located hydraulically downgradient of the Former UST Area contained concentrations of TPH as Gasoline (12.0 *mg/l* by off-site laboratory analysis and 8.0 *mg/l* by on-site GC analysis) and TPH as Diesel Fuel (21 *mg/l* by off-site laboratory analysis). The other sample (DPT #9) located in the Sandbox Area contained TPH as Gasoline (0.18 *mg/l*). For the organic analyses, the following table provides a summary of the range of detected concentrations and frequency of detection:

LARC 60 DPT GROUNDWATER SAMPLES
RANGE AND FREQUENCY OF DETECTION BY ORGANIC COMPOUND

Compound	On-site Analysis		Off-site Analysis		EPA RBC Criteria[3]
	Range	Frequency	Range	Frequency	
VOCs *(ug/l)*					
Acetone	NT[1]	N/A	30	1/21	61
Chloroform	NT	N/A	**4.6**	1/21	0.15
cis 1,2-Dichloroethene	**13 - 150**	2/21	**20**	1/21	6.1

prior to collecting groundwater samples. Stabilization of field parameters is defined as less than 10 percent variation for turbidity and conductivity, less than one-half unit variation for pH and less than 1 unit variation for temperature over three well volumes. The volume of standing water in the borehole was calculated using the pre-purge water level, total depth of the well and a known constant for the number of gallons of water per foot of well diameter. Water purged from the well before sampling was disposed of in accordance with procedures outlined in Section 3.9 of the December 1994 FIP.

Sampling protocol was in accordance with the following procedure as described by the Installation, Operation & Maintenance User's Guide for the WELL WIZARD Dedicated Monitoring Systems, by QED Environmental Systems, Inc.:

- Sampling began by obtaining a static groundwater level measurement reading, which was achieved using a portable water level indicator. The water level indicator was inserted through the removable black ½-inch square head hole in the well cap. The purge volume required (3 times the volume of standing water in each well) was determined from static water level measurements, based upon the known depth of each well.

- Well purging was performed prior to obtaining groundwater samples at each well location. Purging of a well was accomplished using the following procedure:

  1. Start the compressor engine.

  2. Connect the short end of the red pump air-supply line to the pump connector on the well cap.

  3. Connect the long end of the red pump air-supply line to the PUMP SUPPLY connector on the Well Wizard controller.

  4. Point the pump discharge line away from the operator.

  5. Set both timers on the Model 3013 controller on setting "C".

  6. Connect the black driver/controller hose to the PUMP PRESSURE INLET connector on the Well Wizard controller. At this stage, there should be a loud hissing and honking noise associated with air releases through the side of the Well Wizard controller. If this sound does not sound as if it is alternating between pressurizing and venting, shorten cycle times by setting the REFILL and DISCHARGE timer knobs to setting "A" on the controller. After the venting noises stop, water flows from the pump discharge line as you begin to purge the well. The time required to actually begin discharge of water depends on the depth to water - it may take several seconds or several minutes.

  7. Check the air pressure on the PRESSURE gage on the controller. The pressure (which controls flow rate) should be between 60 and 120 psi. If necessary, adjust the pressure by using the FLOW THROTTLE control knob. Pull up on the yellow outer ring to unlock the throttle, adjust the setting, then push down to lock the throttle. Turning the FLOW THROTTLE knob clockwise increases pressure; turning it counterclockwise decreases pressure. Flow rate may be maximized by following this procedure:

a. Lift the yellow outer ring of the FLOW THROTTLE control, turn the knob fully clockwise, then push down to lock the control.

b. Turn the DISCHARGE and REFILL timer knobs to setting "D" on the controller.

c. Using a 1,000 mL graduated cylinder, measure the volume of water discharged in one cycle. This is the maximum pump volume should be noted. NOTE: for 1100 series pumps, discharge should be 250 - 350 mL; If the discharge volume is less than this, try increasing the refill cycle time. If this is not effective, try shortening the refill cycle time, especially in deeper wells.

d. To achieve as short a refill time as possible, slightly decrease the REFILL timer setting (turn the knob counterclockwise about a half of a setting). Then measure the volume of water discharged in the next three cycles. Repeat this step until there is a decrease in discharge water volume.

e. Increase the REFILL timer setting (turn the knob clockwise) enough to regain full discharge volume. Refill is now set for maximum flow.

f. To achieve as short a discharge time as possible without losing any discharge volume, slightly decrease the DISCHARGE timer setting (turn the knob counterclockwise). Then measure the volume of water discharged in the next three cycles. Repeat this step until you notice a decrease in discharge water volume.

g. Increase the DISCHARGE timer setting (turn the knob clockwise) enough to regain full discharge volume. Discharge is now set for maximum flow.

h. During humid conditions and very cold conditions, it is especially important to vent the moisture. Press down (and hold for 5 seconds) the silver MOISTURE VENT button on the controller about every 15 minutes. This expels accumulated moisture from the side of the controller.

- Samples were collected once the well has been purged of the required volume. A slow flow rate was used to fill sample bottles. The FLOW THROTTLE knob on the Model 3013 controller was adjusted counterclockwise to slow the flow, as needed. As suggested by the manufacturer, the pressure did not exceed 60 psi to avoid housing or membrane failure, and sample contamination.

- An in-line filter was utilized to collect the dissolved metals samples. The filter was a disposable high capacity in-line cartridge designed for filtering groundwater for dissolved metals analysis. These filter's are 0.45 um polyethersulfone filters that can hold a volume of approximately 150 ml, and have a filtration area of 600 cm^2.

- After collection and transfer to the appropriate sample container (VOCs first followed by pesticides/PCBs, total metals, and finally dissolved metals), the samples were secured in a cooler at 4°C and made ready for shipment to the laboratory.

2.2.8 Water Level Measurements

Water levels were measured all existing and newly constructed monitoring wells on May 17, 1995. Water levels were measured with a Solinst electronic water level indicator. The following procedures were used:

- Equipment operation and accuracy was checked and documented prior to taking measurements.
- All pertinent well data was recorded.
- The water level was recorded to nearest 0.05 foot.
- Weather at time and date of measurement were recorded.

Tidal influence tests were conducted at the FTA, LARC 60, and Auto Craft sites. The purpose of these tests was to assess if there is any influence on the shallow water table aquifer due to the daily tides of the proximate Chesapeake Bay and Atlantic Ocean. For each site, three monitoring wells were chosen at varying distances perpendicular to the Chesapeake Bay or Atlantic Ocean. A Hermit data logger and pressure transducer was installed at each of the three wells. The data logger was programmed to record a reading every fifteen minutes. Prior to the start of the test, groundwater levels were measured with a Solinst water level indicator. A rain gauge was placed in an unobstructed area at each site to record any measurable precipitation over the test period. After tests were completed at the three sites, the data collected from the Hermit data loggers were downloaded to a computer and graphed to assess if there was any tidal influences on groundwater table elevation. Water level data for each well and tidal influence is provided in **Appendix B**.

2.2.9 Equipment Decontamination

Procedures

All non-dedicated sampling equipment and boring materials were cleaned prior to being used and/or reused. All DPT equipment was steam cleaned in a predesignated location prior to use and between locations. All soil, sediment, surface water, and DPT soil and groundwater sampling equipment (i.e., stainless steel augers, scoops and bowls, DPT 0.75 inch teflon bailers, and DPT split spoons) were decontaminated prior to use and between sampling locations using the following procedure:

- Wash and scrub with low phosphate, laboratory-grade detergent
- Rinse with tap water
- Rinse with methanol (use hexane, followed by a methanol rinse, for oil and grease contaminated equipment)
- Rinse with deionized demonstrated analyte free water

- Rinse with tap water
- Rinse with dilute nitric acid if sampling for metals
- Rinse with deionized demonstrated analyte free water
- Air dry

Field instrumentation was cleaned as per manufacturer's instructions. Probes such as those used in pH and conductivity meters and thermometers were rinsed prior to and after each use with deionized water.

Disposable PVC and teflon bailers were used for monitoring well purging and sampling respectively, and therefore, no decontamination was performed on monitoring well sampling equipment.

Decontamination Solutions

Detergent Wash

Alconox was used as the low phosphate, laboratory-grade detergent for the field investigation at the three sites at Fort Story.

Solvent/Acid Rinses

Several different decontamination solutions were used during the RI field investigations at the three sites at Fort Story. Pesticide-grade methanol and 0.1N nitric acid was used for most of the decontamination activities for the investigation. However, the DPT driller did use isopropyl alcohol as their solvent for split spoon decontamination. As reported to Malcolm Pirnie by Savannah Laboratories in the initial stages of the field investigation, analysis of the initial subsurface soil samples collected at the FTA site indicated the presence of high concentrations of acetone (SB04-017 and SB04-022). Acetone is a primary oxidation product of isopropyl alcohol. Therefore, methanol was substituted for isopropyl alcohol for all future decontamination procedures conducted by the DPT driller. Although acetone was detected after the switch to methanol by the DPT driller, concentrations were several orders of magnitude lower than concentrations encountered in samples which isopropyl alcohol-cleaned equipment was used.

Rinse Water

Tap water from Fort Story was used for initial rinses during the decontamination procedure while deionized water was used as the final rinse water. To evaluate the water used during the decontamination procedure for the field investigation, samples were collected and analyzed. Results are discussed in Section 4.2 of the RI report.

2.2.10 Investigation-Derived Waste Management

Drill cuttings generated during monitoring well installation were spread out around the well location unless they were visibly stained. Stained drill cuttings from several borings at the LARC 60 site were containerized in U.S. Department of Transportation (DOT) approved, 55-gallon steel drums with the contents identified and date of collection placed on drum exteriors.

Groundwater from monitoring wells during purging, development and sampling activities was discharged onto the ground at the well location unless it was determined that the water was highly contaminated with a contaminant such as petroleum. Water with a visible sheen or strong petroleum odor from several wells at the LARC 60 site was collected in DOT 55-gallon steel drums with the contents identified and date of collection placed on drum exteriors.

Waste methanol and nitric acid generated from decontamination procedures were also drummed in separate DOT 55-gallon drums for proper disposition.

Malcolm Pirnie maintained a log of the drums and drum contents. The results of the analytical data obtained from the drums were submitted to Fort Eustis personnel for proper disposition. The data indicated that the containerized soil cuttings and purge water from the LARC 60 site was not classified as a hazardous waste. All results were less than TCLP limits. The drums were then handled accordingly as solid waste and disposed of off-post.

2.2.11 Site Surveying

A site survey was completed using horizontal and vertical control to accurately locate RI sampling points at each site. Malcolm Pirnie subcontracted all surveying required for the project site to Sledd, Runey and Associates, a professional land surveyor licensed in the Commonwealth of Virginia. **Table 2-1** provides vertical and horizontal survey data for each site. A copy of the surveyor's report is provided in **Appendix D**.

Vertical control of all groundwater monitoring wells installed during this field investigation and surface water was established using differential and trigonometric leveling to the nearest 0.01 foot. The elevations are referenced to the National Geodetic Vertical Datum of 1929 (NGVD).

The horizontal location of all sampling locations (i.e., monitoring wells, DPT groundwater, DPT soil boring, surface soil, sediment and surface water) was established by using the Virginia State Plan Coordinate System (VSPCS). The horizontal location of sediment and surface water point was estimated by holding the surveying rod slightly above the water at the point where the water or sediment sample was taken. Locations were surveyed to the nearest 0.50 foot.

2.2.12 On-Site GC Analysis

Earth Technology, Inc. provided on-site GC analysis of most groundwater samples collected by DPT. A Hewlett Packard 5890 Series II gas chromatograph equipped with an flame ionization detector

(GC/FID), following modified EPA 8015 methodology, was used to quantify light-end petroleum compounds (TPH light). A Photovac 10S Plus GC equipped with a photoionization detector (GC/PID) was used to identify and quantify select VOCs (vinyl chloride, benzene, 1,1-dichloroethene, cis 1,2-dichloroethene, trichloroethene, and tetrachloroethene) following modified EPA Method 3810.

Groundwater samples collected by DPT were placed in three 40-mL vials with teflon-faced septa, transported to the on-site laboratory trailer and stored at less than or equal to 4°C in a refrigerator prior to analysis. Some samples were analyzed immediately upon receipt.

TPH light analysis included placing an aliquot of 5 mL of water into a clean glass sparging unit (purging chamber) attached to a Tekmar LSC3000 Purge and Trap. Helium was bubbled through the 5 mL sample at ambient temperature for 12 minutes. The TPH light fraction was efficiently transferred from the aqueous phase to the vapor phase. The vapor was swept through a sorbent trap where the organics were trapped. After purging was completed, the trap was heated rapidly to 175°C and backflushed with helium to desorb the organics onto the GC column. The GC was temperature programmed to separate the different constituents of the TPH light fraction which were then detected with the GC/FID. Standards were treated in the same manner as the samples. Methanolic stock solutions purchased from Supelco, Inc. were used to prepare standards.

VOC analysis included placing an aliquot of 30 mL of water into a 40 mL EPA clean vial and then capped with a self-sealing septum. The vial was heated to 80°C for 10 minutes in water bath, in order for an equilibrium to be established between the water sample and the headspace. The chemist used a gas-tight syringe to pierce the septum of the vial and 150 uL of headspace was removed and immediately injected into the GC for analysis. Standards were prepared in the same manner as the samples. Methanolic stock solutions purchased from AccuStandard were used to prepare standards.

All the samples were analyzed on gas chromatographs equipped with capillary columns, thermal ovens, data processors and associated hardware. Each instrument was calibrated at the beginning of the project, as needed during the duration of the project, and the conclusion of the project using standards of known concentrations. Calibration checks were performed at a minimum of twice a day. Retention times of the compounds in each standard solution were used to identify the unknown compounds in field samples. If a field sample contained a compound whose electron volt response fell within the retention time of a known analyte, whose response was greater than the lowest standard and less than the highest standard, then that response was quantified. Samples that had concentrations higher than the standards were diluted until they were within the ranges. Replicate analyses was performed every tenth field sample and matrix spike quality control samples every twentieth.

The results of the analyses were interpreted and reported in a spreadsheet format report including a summary of tabulated analytical results (including QA/QC) which is provided in **Appendix E**.

2.2.13 Off-site Laboratory Analysis

Environmental media samples were submitted to Savannah Laboratories for off-site analysis. Samples were analyzed for a wide variety of chemical compounds. **Table 2-2** provides a summary of the compounds analyzed and the test methods used for each at the Fort Story sites. Laboratory analytical reports are included in the *Quality Control Summary Report/Analytical Results Report (QCSR/ARR), Fort Story, Virginia* submitted as a companion document to this RI Report. Method reporting levels for all compounds discussed in this report can also be found in the *QCSR/ARR*.

With the exception of the TPH analysis, analytical methods are described in *Test Methods for Evaluating Solid Waste, EPA SW-846*. The TPH method is a modified version of EPA Method 8015 and is described in the State of California document *Leaking Underground Fuel Tank Manual - Guidelines for Site Assessment, Cleanup and Underground Storage Tank Closure*.

Data validation of analytical results was performed by URS Consultants, Inc. (subcontractor to Malcolm Pirnie). The results of the detailed validation are provided in the *QCSR/ARR*. The data validation included a review of the following:

- Holding times
- Completeness of deliverables
- 10 percent check per sample fraction for all quantitated values
- Surrogate recoveries for organics
- Duplicate and spike recoveries for organics and inorganics
- Properly analyzed samples (i.e., not over/under diluted)
- Method blank results

2.2.14 Floating Free-Product (FFP) Measurements

Based on the high concentrations of TPH detected in soils and groundwater by ETI at the former UST area at the LARC 60 site, temporary well points were installed so that FFP measurements could be performed. A Keck Oil/Water Interface Meter was used to determine the presence/absence and thickness of FFP in these temporary well points if present.

2.3 SITE-SPECIFIC FIELD INVESTIGATION

The following sections outline the specific RI field activities performed at the Firefighter Training Area, LARC 60 Maintenance Area and Auto Craft Building Area at Fort Story. Initial specific activities, which were conducted in February and April 1995, were based on the Scopes of Services for the project dated 17 August 1994. Additional soil and groundwater analysis was conducted in February and June 2000 to further identify the extent of contamination and to assess any trends in groundwater contamination.

2.3.1 Firefighter Training Area

There were three major areas of concern (AOCs) at the FTA site: (1) Northern Area where 2 locations of stained soils are present, (2) Former Fire Training Pit (FTP) Area in the southwest corner of the site, and (3) Solvent Plume Area located in southeast corner of the site. The layout for the sampling points were centered around these three areas with upgradient, on-site and downgradient soil and groundwater sampling being conducted at each AOC. The FTP and adjacent soils were previously excavated, treated and disposed of off-site. Extensive sampling of soil and groundwater was required in that area to verify clean-up of soils and assess any current groundwater impacts. **Figures 2-5 and 2-6** provide the sampling locations for this site. The locations of the new permanent monitoring wells were established in the field based on the results of the on-site GC and off-site laboratory analysis of DPT groundwater samples, and the location of existing monitoring wells. **Table 2-3** summarizes our field investigations for this site.

Table 2-4 provides a summary of the sample locations and the analyses conducted for each sample. For the 1999 samples, (1) all samples were analyzed for TCL, VOCs, and SVOCs, and TPH Heavy and Light fractions and (2) TAL analysis was conducted on all sediment samples and for approximately 20 percent of soil and groundwater samples because of their infrequent detection in previous investigations. For the 2000 samples, (1) four monitoring wells (4MW-1, MW-111, MW-112, and MW-114A) were sampled for the first time for pesticides and PCBs, (2) the same four wells were sampled for TCL VOCs and TAL metals (total and dissolved fractions), and (3) eight soil samples were analyzed for pesticides and PCBs for the first time.

Although PCBs and pesticides were detected in the PA/SI investigation, they were detected at concentrations less than trigger levels established during that study and were not selected as contaminants of concern for the initial investigations in 1995. ~~Therefore, they were not recommended to be analyzed during future studies including this RI. In addition, the levels detected during the PA/SI are consistent with levels expected due to normal application in industrial areas for pest and weed control, and not from uncontrolled spills or leaks.~~ However, although they were not sampled for during the initial field investigations, soil and groundwater samples were collected in March and June 2000 and analyzed for pesticides and PCBs to assess their presence or absence at the site due to a concern by the Virginia Department of Environmental Quality concerning their omission from the field sampling program.

The soil and groundwater samples for TAL analysis were distributed among upgradient, on-site and downgradient, and at various subsurface soil depths. For those groundwater samples collected from monitoring wells which were analyzed for TAL compounds, both total and dissolved fractions were analyzed. A summary of field activities conducted by media is provided below:

Soils

- Twenty-two soil borings were advanced for the site with samples collected from three depths to assess the vertical and lateral extent of contamination in surface and subsurface soils.

- Eight of these borings were advanced in the vicinity of the former FTP. Six soil borings were advanced in the Northern Area with the final eight soil borings advanced at the Solvent Plume Area in the southeast corner of the site.

- Six surface soil samples were collected at the Northern Area of the site in areas of visible soil staining.

- Eight surface soil samples were collected throughout the site in 2000 to assess the presence/absence of pesticides and PCBs.

Groundwater

- Groundwater samples were collected by DPT from twenty-four (24) locations to assess the nature and extent of contamination in groundwater.

- Groundwater was collected at approximately 10 to 15 feet below land surface for 22 of the points. One DPT location was sampled at a depth of 20 to 21 feet below land surface to assess the vertical extent of contamination at the Solvent Plume Area.

- On-site GC analysis of DPT groundwater samples was conducted for select VOCs and TPH light.

- Six (groundwater monitoring wells were installed and developed as part of this field investigation. Three shallow wells, one shallow/deep well cluster and one deep well located adjacent to an existing shallow well were installed.

- Groundwater samples were collected from four existing and six new monitoring wells. Existing wells were redeveloped prior to sampling.

- Groundwater samples were collected from four monitoring wells in 2000 to assess the presence/absence of pesticides and PCBs and to further define the extent of VOC and metal contamination.

Sediment

- Four sediment samples were collected from within the drainage area located to the south of the site.

2.3.2 LARC 60 Maintenance Area

There were three major AOCs at the LARC site: (1) Former UST Area, (2) Oil/Water Separator (OWS) Area, and (3) Sandbox Area. The layout for the sampling points was centered around these three areas with upgradient, on-site and downgradient soil and groundwater sampling being conducted at each AOC. The Sandbox soils were previously excavated, treated by bioremediation and backfilled into the same area. Extensive sampling of soil and groundwater was required in that

area to verify clean-up of soils and assess any current groundwater impacts. **Figures 2-7, 2-8, and 2-9** provide the sampling locations for this site. The locations of the new monitoring wells were established based on the on-site GC and off-site laboratory analytical results of the DPT groundwater samples, and the location of existing monitoring wells. **Table 2-5** summarizes our field investigations for this site.

Table 2-6 provides a summary of the sample locations and the analyses conducted for each sample. For the 1995 samples, (1) all samples were analyzed for TCL VOCs and SVOCs, and TPH Heavy and Light fractions and (2) TAL analysis was conducted on all surface water and sediment samples and for approximately 20 percent of soil and groundwater samples because of their infrequent detection in previous investigations. For the 2000 samples, (1) four monitoring wells (4MW-1, MW-111, MW-112, and MW-114A) were sampled for the first time for pesticides and PCBs, (2) the same four wells were sampled for TCL VOCs and TAL metals (total and dissolved fractions), and (3) eight soil samples were analyzed for pesticides and PCBs for the first time.

The soil and groundwater samples for TAL analysis were distributed among upgradient, on-site and downgradient, and at various subsurface soil depths. For those groundwater samples collected from monitoring wells which were analyzed for TAL compounds, both total and dissolved fractions were conducted.

A summary of field activities by media is provided below:

Soil

- Twenty-three soil borings were advanced for the site with samples collected from 2 or 3 depths to assess the vertical and lateral extent of contamination in surface and subsurface soils.
- Three of these borings were advanced in the vicinity of the Former UST on the southern end of the site. Seven soil borings were advanced near the OWS in the central section of the site with the final 13 soil borings advanced inside or downgradient of the Sandbox Area.
- Eight surface soil samples were collected throughout the site in 2000 to assess the presence/absence of pesticides and PCBs.

Groundwater

- Groundwater samples were collected by DPT from twenty-five (25) locations to assess the nature and extent of contamination in groundwater.
- Groundwater was collected at approximately 10 to 15 feet below land surface for 24 of the points. One DPT location was sampled at a depth of 39 to 40 feet to assess the vertical extent of contamination downgradient of the UST Area.

- On-site GC analysis of DPT groundwater samples was conducted for select VOCs and TPH light.
- Five groundwater monitoring wells were installed and developed as part of this field investigation. Two shallow wells, one shallow/deep well cluster and one deep well located adjacent to an existing shallow well were installed.
- Groundwater samples were collected from three existing and five new monitoring wells. Existing monitoring wells were redeveloped prior to sampling.
- Groundwater samples were not collected from the production well located on the western edge of the site because it was not functional.
- Three temporary well points were installed at the former UST area to determine the presence/absence of FFP. Groundwater samples for VOC and TPH heavy and light analysis were also collected from these points.
- Groundwater samples were collected from six monitoring wells in 2000 to assess the presence/absence of pesticides and PCBs and to further define the extent of VOC and metal contamination.

Sediment

- Two sediment samples were collected from the drainage ditch located on the northern edge of the Sandbox.

Surface Water

- Two surface water samples were collected from the drainage ditch located on the northern edge of the Sandbox.

2.3.3 Auto Craft Building Area

Potential impacted areas at the site including the former USTs located north of the former building and other downgradient locations. **Figures 2-10 and 2-11** provide the sampling locations for this site. The locations of the new permanent monitoring wells were established based on the on-site GC and off-site analytical results of the DPT groundwater samples, and the location of existing monitoring wells. **Table 2-7** summarizes our field investigations for this site.

Table 2-8 provides a summary of the sample locations and the analyses conducted for each sample. All samples were analyzed for TCL VOCs and SVOCs, and TPH Heavy and Light fractions. TAL analysis was conducted for approximately 20 percent of soil and 50 percent of groundwater samples because of their infrequent detection in previous investigations. The soil and groundwater samples for TAL analysis were distributed among upgradient, on-site and downgradient, and various subsurface soil sampling depths. For those groundwater samples collected from monitoring wells

which were analyzed for TAL compounds, both total and dissolved fractions were conducted. A summary of field activities by media is provided below:

Soil

- Six soil boring locations were installed for the site with samples collected from 3 depths to assess the vertical and lateral extent of contamination in surface and subsurface soils.

Groundwater

- Groundwater samples were collected by DPT from six locations to assess the nature and extent of contamination in groundwater.
- Groundwater was collected at approximately 10 to 15 feet below land surface for the points.
- On-site GC analysis of DPT groundwater samples was conducted for select VOCs and TPH light.
- Three groundwater monitoring wells were installed and developed as part of this field investigation. Two shallow wells and one deep well located adjacent to an existing shallow well were installed.
- Groundwater samples were collected from two existing and two new monitoring wells. Existing monitoring wells were redeveloped prior to sampling.

2.4 FIELD INVESTIGATION CHANGES

A summary of changes made during the field investigations from the Final Work Plan and rationale for those changes is provided on a site-specific basis in the following sections.

2.4.1 Firefighter Training Area

The following changes were made during the field investigations for the site:

- DPT groundwater sampling locations changed and the number of samples collected expanded due to the extent of vinyl chloride detected by the on-site GC analysis.
- Only one deep DPT groundwater sample was collected at the FTA because VOC concentrations decreased significantly in the one deep sample collected. A deep monitoring well was installed and sampled in the area of the former FTP to access the vertical extent of contamination in that area. Because low levels of VOCs were detected in the Northern Area of the site, no assessment of the vertical extent of contamination was required.

- Because no surface water was present in the drainage areas south of the FTA site, no surface water samples were collected.

- Due to the presence of gravel in the former FTP, soil samples could not be collected at this point.

- Dissolved inorganic samples could not be collected from the DPT groundwater samples due to the very high levels of fine suspended solids present in the samples. Attempts were made to settle and filter the samples but high suspended solids prevented this technique. High solids concentrations are present in DPT groundwater sampling because no filter pack is used and no development is conducted. The fines pass through the 0.005 screen.

- Additional groundwater samples were collected from 4MW-2S to further quantify the presence/absence of vinyl chloride in groundwater at the FTA. Preserved/unpreserved samples were collected and analyzed by off-site laboratory for vinyl chloride by EPA Method 3810 (GC) and Method 8240 (GC/MS) to evaluate any method and/or preservation variations on vinyl chloride results in groundwater.

2.4.2 LARC 60 Maintenance Area

The following changes were made during the field investigations for the site:

- DPT groundwater sampling locations changed and the number of samples collected expanded due to the extent of vinyl chloride detected by the on-site GC analysis.

- In the Sandbox Area, due to the shallow water table (about 4 feet below land surface), subsurface soil samples were collected at one depth instead of 2 depths as called for in the Final Work Plan.

- No DPT groundwater samples could be collected in the wooded area north of the Sandbox due to the inaccessibility of the area because of dense vegetation, soft sands and trees.

- Groundwater samples could not be collected from the production well located at the LARC 60 area because it is not functional.

- Dissolved inorganic samples could not be collected from the DPT groundwater samples due to the very high levels of fine suspended solids present in the samples. Attempts were made to settle and filter the samples but high suspended solids prevented this technique. High solids concentrations are present in DPT groundwater sampling because no filter pack is used and no development is conducted. The fines pass through the 0.005 screen.

- Additional groundwater samples were collected from 6MW-3S to further quantify the presence/absence of vinyl chloride in groundwater at the LARC 60 site. Preserved/unpreserved samples were collected and analyzed by off-site laboratory for vinyl chloride by EPA Method 3810 (GC) and Method 8240 (GC/MS) to evaluate any method and/or preservation variations on vinyl

chloride results in groundwater.

- Temporary well points were installed at the former UST area to determine the presence/absence of FFP and sampled for VOCs and TPH to determine groundwater quality.

2.4.3 Auto Craft Building Area

The following changes were made during the field investigations for the site:

- Dissolved inorganic samples could not be collected from the DPT groundwater samples due to the very high levels of fine suspended solids present in the samples. Attempts were made to settle and filter the samples but high suspended solids prevented this technique. High solids concentrations are present in DPT groundwater sampling because no filter pack is used and no development is conducted. The fines pass through the 0.005 screen.

- Two existing monitoring wells were sampled instead of one well as listed in the Final Work Plan.

- One newly installed groundwater monitoring well (7MW-1) was not sampled because a DPT groundwater sample (GW07-001) had previously been collected from the same location.

Section 3.1 discusses the physical characteristics for Fort Story including data on topography, climate, hydrology, geology/hydrogeology, and ecology. A site-specific summary of physical characteristics is provided in **Table 3-1** with detailed descriptions provided in Section 3.2 for the three Remedial Investigation (RI) sites.

3.1 FORT STORY PHYSICAL CHARACTERISTICS

This section provides a summary of the physical characteristics of Fort Story including topography, climate, surface water hydrology, geology, hydrogeology and ecology. A Fort Story map is provided in **Appendix F** which provides general physical characteristics including wetland areas, topography, man-made structures, and surface water bodies.

3.1.1 Topography

Land features encountered at Fort Story consist of linear sand ridges, sand flats and wetland areas. The topography is dominated by a series of prominent linear, well-drained sand ridges that roughly bisect the Fort Story area. The central ridges trend parallel to the coastline and are characterized by maximum elevations in excess of 85 feet, National Geodetic Vertical Datum (NGVD) of 1929. A second series of sand ridges located on Fort Story are comprised of an active dune complex located adjacent to the coastline. The coastal sand ridges attain maximum elevation in excess of 25 feet NGVD. Broad, poorly drained sand flats are located adjacent to the sand ridge areas. Land surface elevations in the sand flat areas typically range between 5 and 10 feet, NGVD. Wetland areas, which are common features of the sand flats, occur locally in closed depressions. South of the central sand ridges, the Fort Story topography consists of an extensive wooded, wetland area, formerly a back-bay, lagoonal feature. Most of the installation's facilities and operations are confined to the sand ridge and sand flat areas.

3.1.2 Climate

Historical climatological data for the Fort Story area is recorded at the Norfolk-Virginia Beach Airport, and is available from the National Atmospheric and Oceanic Administration (NOAA) through the National Climatic Data Center. The Norfolk-Virginia Beach Airport is located approximately 8 miles west of Fort Story. **Table 3-2** summarizes average precipitation and temperature for the Fort Story area from 1941 to 1970.

Fort Story climate is characterized by mild winters and hot summers. Temperatures are affected by air flowing through the area from the Atlantic Ocean. Average relative humidity is high in the area, with an afternoon average humidity of approximately 60 percent, which rises in the nighttime to 80 percent. In Winter, the average temperature is 41°F, with the lowest temperature recorded of 5°F for the period of record. The average Summer temperature is 76°F with a highest recorded temperature of 104°F.

The greatest percentage of precipitation occurs between April and September, which encompasses most of the growing season. The maximum amount of rainfall recorded in the area was 9.95 inches in a one day period.

3.1.3 Surface Water Hydrology

Surface water on Fort Story is conveyed by drainage ditches or storm water lines to the Chesapeake Bay on the northwestern portion of the facility, to the Atlantic Ocean on the northeast portion of the base or to wetland areas adjacent to Broad Bay on the southern portions of the facility. There are no major streams located on Fort Story. Several small ponds are located on Fort Story. Surface water transport is through the many small drainage ditches. Surface water on the southern portion of Fort Story flows into wetland and marshy areas with eventual flow across Route 60 and into Broad Bay south of the facility.

3.1.4 Geology

The geology of the eastern Coastal Plain and sedimentary characteristics in the Fort Story area has been described in a number of reports including Oaks and Coch (1973); Teifke (1973); and Onuschak (1973). Recent geologic studies of the eastern Coastal Plain re-defined the sedimentary units (formations names). These publications include the following: Ward and Blackwelder (1982); Johnson and Peebles (1984); Johnson and Ramsey (1987); Johnson et al., (1987); Laczniak and Meng (1988); Meng and Harsh (1988); and Mixon, et al., (1989). The formation names used for post Yorktown sediments (Windsor and Norfolk Formation) in Johnson (1972) have been revised in subsequent investigations. The more current formation names, which are described in the references listed above, have been used in this report.

Fort Story is located on Cape Henry within the eastern Coastal Plain of Virginia which is characterized by a series of gently sloping, highly dissected terraces bound by seaward-facing, ocean-cut escarpments. The escarpments (scarps) were formed by shoreline erosion during ancient sea level stands. The terraces (plains) are an emergent landform representing stream, estuarine, bay, and marsh deposits (Johnson and others, 1987). The scarp and terrace topography dominates the eastern Coastal Plain except along Cape Henry where recent sand ridges have formed over the older deposits. These recent dune deposits form a series of convex sand ridges with crests ranging in elevation from 20 to 85 feet above Mean Sea Level (MSL) (Oaks and Coch, 1973).

Coastal Plain sediments overlie crystalline rock and form an eastward thickening wedge of predominately unlithified marine, estuarine and riverine deposits. The sediments range in age from Cretaceous to Holocene (recent time). The sediments predominately form layers of unlithified gravel, sand, silt, and clay with variable amounts of shells. Although layers of hard rock are absent, cemented calcareous deposits can form local lithified strata.

Coastal Plain sediments range in thickness from nearly zero along an ancient ocean strandline in the vicinity of Richmond, Virginia to as much as 6,186 feet beneath the Eastern Shore Peninsula at Temperanceville, Virginia (Meng and Harsh, 1988). In the vicinity of Fort Story, the reported

thickness of sediments ranged from 2,600 feet in Norfolk (Teifke, 1973) to approximately 3,500 feet in Virginia Beach (Meng and Harsh, 1988). The uppermost surficial sediments that are significant to this study are approximately 420 feet thick in the vicinity of Fort Story (Meng and Harsh, 1988). These units include the following sedimentary units:

- Columbia Group - roughly the uppermost sediments (comprises the water table aquifer) which ranges from 40 to 60 feet thick.

- Yorktown Confining Unit - Silty clay to clay unit that forms a confining unit between the water table aquifer and the underlying Yorktown-Eastover Aquifer and ranges from 40 to 50 feet thick.

- Yorktown-Eastover Formations- a potable use aquifer, the top of the aquifer occurs at approximately 100 to 142 feet below MSL (Meng and Harsh, 1988)

The upper 40 to 60 feet of surficial sediments belong to the Columbia Group. Although the Columbia Group includes the Holocene age Kennon Formation and the Pleistocene age sediments of the Windsor, Charles City, Chuckatuck, Shirley, and Tabb Formations; only the Kennon and Tabb Formations occur at Fort Story. Underlying the surficial sediments of the Columbia Group are the semi-confining unit and water bearing sediments of the Yorktown Formation. A regional cross-section map is provided as **Figure 3-1**. Since the physical and chemical characteristics of these sediments affect the potential for and rate of migration of fluids, these sediments are described in more detail on the following pages.

Columbia Group

The surficial sediments of the Columbia Group are eolian, estuarine and riverine sediments of Holocene (Kennon Formation) and Pleistocene (Tabb Formation) age.

Kennon Formation - Sediments comprising the Kennon Formation include contiguous marine, estuarine, paludal, fluvial and aeolian sedimentary deposits along and in streams (tidal and unidirectional), bays and nearshore marine environments. Sediments deposited in these environments can contain highly organic deposits that impact the geochemical and hydraulic behavior of fluids. The deposits of this formation vary greatly in thickness, mineral composition and fossil content but intergrade with one another and disconformably overlie Pleistocene deposits (Johnson et al., 1987 and Johnson and Ramsey, 1987). The Kennon Formation is described as a light orange brown quartz sand to silty sand. It is unbedded and has an indistinct lower boundary (Johnson and Ramsey, 1987). The indistinct lower boundary can make it indistinguishable from the underlying Tabb Formation in the Fort Story area.

Tabb Formation - Sediments comprising the Tabb Formation are predominately found east of the Suffolk and Harpersville Scarps; thus the formations occur east of Newport News, in Hampton, Poquoson, eastern York County, Norfolk and in Virginia Beach. These sediments were deposited under fluvial and estuarine conditions in the Late Pleistocene. The Tabb Formation has been divided into three members; the Poquoson Member, Lynnhaven Member, and Sedgefield Member. Based

on the sedimentary descriptions from on-site borehole data, the sediments will not be differentiated by members in this report.

All three members contain a basal deposit of coarse pebbly sand with rare occurrence of cobbles and boulders, which fine upwards to cross-bedded sands, silts, and clayey sands. The cross-bedded sands are commonly capped by a clay to silty clay unit. The clayey-silt layers have been reported to contain as much as 20 percent quartz, 5 to 20 percent feldspar, 0 to 20 percent vermiculite, 0 to 20 percent kaolinite or chlorite, and 0 to 20 percent Illite or Muscovite (Oaks and Coch, 1973). Along the Suffolk and Harpersville Scarps (east of Hampton) the unit is very thin but thickens eastward to more than 50 feet in paleochannels in the vicinity of Fort Story. The paleochannels are recognized by a basal pebbly to cobblely sand grading upward into a crossbedded fine to coarse sand with organic-rich silty clay and peat. Tree stumps in living position and other plant remains are associated with the organic-rich clays. Plant remains were present in soil samples collected from two borings 4MW-2D and 4MW-4 at the FTA.

Background soil samples were collected during the PA/SI from three soil borings, one near the eastern perimeter of Fort Story, one adjacent to the western boundary, and one in the north-central perimeter of Fort Story. Two samples were collected from each boring and analyzed for pesticides/PCBs, volatile organics, semivolatile organics, total metals, and EP toxicity metals. Of the parameters analyzed, only five metals (chromium, copper, zinc, arsenic, and lead) were detected. An upper 95 percent confidence limit value was calculated for each. A summary of the background soils analysis is provided as follows:

PARAMETER	BACKGROUND 95% UCL (mg/kg)
Arsenic	2.1
Barium	Not Detected
Cadmium	Not Detected
Chromium	2.8
Copper	1.4
Lead	7.1
Mercury	Not Detected
Nickel	Not Detected
Zinc	5.7

Chesapeake Group

Yorktown Formation - Although no boreholes penetrated the Yorktown Formation, the formation is described in detail due to its significance as a confining unit (Morgarts Beach Member) overlying a potable aquifer comprised in part by sediments of the Yorktown Formation. The Rushmere and Sunken Meadow Members along with The Cobham Bay Member of the Eastover Formation form the Yorktown-Eastover Aquifer.

The current definition of the Yorktown Formation is described in the USGS Bulletin 1482-D, Stratigraphic Revision of Upper Miocene and Lower Pliocene Beds of the Chesapeake Group, Middle Atlantic Coastal Plain (Ward and Blackwelder, 1980). The Yorktown Formation consists of shallow marine deposits of Pliocene age which unconformably overlie Late Miocene sediments of the Eastover Formation. Based on lithologic and faunal assemblage changes, the Yorktown Formation has been subdivided into four members:

- Moore House Member - an upper sandy shell hash.
- Morgarts Beach Member - a very fine-grained sandy clay unit (forms a confining unit.
- Rushmere Member - a shelly fine-grained sand unit.
- Sunken Meadow Member - a basal, pebbly coarse-grained sand unit.

The uppermost unit of the Yorktown, the Moore House Member, typically consists of quartz sand shell beds, cross-bedded shell hash and bioclastic sands. The sediments range from an orange, fragmental shell hash, with some fine quartz sand and bryozoan and mollusc fragments to a tan, clayey, phosphatic, glauconitic, poorly-sorted, sand, with abundant molluscs (Crepidula, oysters, and pectens), foraminifers, and ostracodes. In some areas the shell hash is moderately cemented, such as along the bluffs of the York River near Yorktown, Virginia. Areal extent of this member is more restricted than the other members, and is confined to an area east of the Suffolk Scarp, extending to the west as far as Williamsburg, Virginia, extending as far north as the southern third of Gloucester County, Virginia. and as far south as the northern third of Currituck County, North Carolina. From this point, the Moore House sediments tend to thicken to the east and northeast. Maximum thickness of this member is approximately 18 feet. The Moore House Member conformably overlies the Morgarts Beach Member with a sharp contact that can be gradational in some localities (Ward and Blackwelder, 1990).

The Morgarts Beach Member consists of gray (unweathered) or tan (weathered), very fine-grained, sandy to silty clay with a few silty, very fine sand beds. Abundant mollusks (Mulinia) occur; however, mollusks are less abundant than in the underlying Rushmere and Sunken Meadow Members. The Morgarts Beach Member is distinguishable by its fine, clayey lithology and abundance of small molluscs (Mulinia congesta). This Member of the Yorktown Formation represents the confining layer for the Yorktown Aquifer. The Morgarts Beach Member conformably overlies the Rushmere Member and the contact is sharp but can be gradational in some localities (Ward and Blackwelder, 1980).

The Rushmere Member is a blue-gray, fine, well-sorted, shelly sand. It commonly contains phosphatic and glauconitic sands in amounts of less then 10 percent. The unit can contain some medium-grained well-rounded quartz sands. The Rushmere Member is distinguished from the overlying Morgarts Beach Member based on the higher content of sand and mollusks. The basal contact with the Sunken Meadow Member is sharp and may have some coarse sand and pebbles

at the contact (Ward and Blackwelder, 1980).

The Sunken Meadow Member is described as a coarse to medium, poorly sorted sand with abundant shells. In the vicinity of Fort Story, the basal contact with the Eastover Formation typically is recognized by the occurrence of a glauconitic and phosphatic fine sand with abundant shells. The Rushmere and Sunken Meadow Members, along with the Cobham Bay Member of the Eastover Formation, comprise the Yorktown Aquifer (Ward and Blackwelder, 1980).

3.1.5 Hydrogeology

The Virginia Coastal Plain sediments underlying Fort Story are comprised of interlayered gravel, sand, silt, and clay with varying amounts of shells. The permeable and non-permeable sedimentary units were delineated into a hydrogeologic system of eight aquifers and eight intervening confining units by Meng and Harsh (1988). A description of the sedimentary sequence is presented in Section 3.1.4. This discussion of the regional hydrogeology focuses on the hydrogeology of the eastern portion of the Virginia Coastal Plain in the vicinity of Fort Story.

Sources of current hydrogeologic information for the eastern Coastal Plain include Siudyla (1981), Laczniak and Meng (1988); and Meng and Harsh (1988). Based on well data from the Virginia Coastal Plain, Meng and Harsh (1988) delineated the hydrogeologic framework for the Virginia Coastal Plain. In the Fort Story area, Meng and Harsh (1988) delineated four aquifer units separated by intervening confining units. One of these aquifers (the Yorktown-Eastover) consists of three major water-bearing sand units (roughly 5 to 20 feet thick each) which are referred to as the Upper, Middle, and Lower Yorktown Aquifer. Each of the water-bearing sand units are separated by intervening confining units. In order of increasing age and depth from ground surface, these aquifers include:

- The Columbia Aquifer - This is the water table aquifer and is comprised of Holocene age sediments (Kennon Formation) and Pleistocene age sediments (Tabb Formation). Thickness is approximately 40 to 60 feet in the Fort Story area (Meng and Harsh, 1988).

- The Yorktown-Eastover Aquifer - This aquifer occurs within the water bearing strata of the Yorktown and Eastover Formations of Pliocene and Miocene age, respectively. The Yorktown - Eastover Aquifer is divided into three water bearing units (Upper, Middle, and Lower Yorktown) and intervening confining units. The aquifer attains a thickness of 240 feet in the vicinity of Fort Story, however, it generally ranges from 100 to 200 feet thick.

- The Chickahominy-Piney Point Aquifer - This aquifer occurs within the Old Church Formation of Oligocene Age, where present, and the Chickahominy and Piney Point Formations of Eocene Age. The aquifer ranges in thickness from 50 to 100 feet throughout the Virginia Coastal Plain.

- The Upper, Middle, and Lower Potomac Aquifers - These aquifers occur within the Potomac Group of Early Cretaceous age. In Virginia, the sediments of these aquifers have not been

studied extensively, however, based on the known well data these aquifers can attain thicknesses of over 100, 900, and 3,000 feet respectively.

The Columbia, Yorktown-Eastover, and Chickahominy-Piney Point aquifers and intervening confining units are approximately 858 feet thick and comprise approximately the upper 28 percent of the total thickness of approximately 3,500 feet of coastal plain sediments in the Fort Story area. The remaining sediment thickness (approximately 2300 feet), in turn, consists of the Nanjemoy-Marlboro confining unit which overlies the Upper, Middle and Lower Potomac aquifers. The Upper, Middle, and Lower Potomac aquifers are separated by intervening confining units that comprise the Potomac Group of Cretaceous age. In consideration of the nature and distribution of the compounds of concern, the hydraulic characteristics of the sediments and thickness (40 to 50 feet) of the Yorktown confining unit; the following discussion of the conditions of the hydrogeologic units will be restricted to the Columbia Aquifer, the Upper Yorktown Aquifer and intervening confining unit. These hydrogeologic units are comprised by roughly the upper 150 feet of sediments which does not include the water bearing units of the middle and lower water bearing strata of the Yorktown-Eastover aquifer.

Columbia Aquifer

Based on studies of the Virginia Coastal Plain which incorporated the general area of Fort Story (Meng and Harsh, 1988; Siudyla, 1981; Teifke, 1973; Oaks and Coch, 1973) and boreholes drilled at Fort Story, the thickness of the Columbia Aquifer in the Fort Story area is approximately 40 to 60 feet. It is separated from the underlying Yorktown-Eastover Aquifer by the Yorktown confining unit which is roughly 40 to 50 feet thick. The Columbia aquifer is mostly unconfined; however, clayey sediments can produce locally confined or semi-confined conditions. No confined or semi-confined conditions have been delineated by subsurface investigations at Fort Story. The Columbia Aquifer occurs approximately 6 to 8 feet below land surface (BLS) and extends approximately to a depth of 40 to 60 feet BLS in the area of Fort Story.

The Columbia Aquifer is comprised of a sequence of several geologic formations deposited during marine transgressions; thus, each formation exhibits a coarse-grained basal deposit which grades upward to fine-grained sediments. The Columbia Aquifer is predominately sand with interbedded coarse gravel lag deposits which grade upward into silts and clays. Previous subsurface investigations at Fort Story included slug tests on 28 wells. Based on these aquifer tests, the estimated average hydraulic conductivity was 8.21×10^{-3} centimeters per second (cm/sec). Based on studies of the Columbia Aquifer, reported transmissivity values range from 300 to 8,000 square feet per day (ft^2/day) and specific capacity values range from 1.7 to 35 gallons per minute per foot (gpm/ft) in the vicinity of Fort Story (Hamilton and Larson, 1988).

Based on records of water levels of wells located in northern Virginia Beach, the potentiometric surface of the Columbia Aquifer has fluctuated approximately 1 to 12 feet BLS (Siudyla, 1981). Precipitation is the primary source of recharge to the Columbia Aquifer and averages about 44

inches per year (Siudyla, 1981). In 1981 Siudyla estimated that approximately 30 to 50 percent was available to recharge the aquifer. Although the Virginia Beach area has developed rapidly since Siudyla's 1981 study, there has been only limited construction of paved areas and other impermeable structures at Fort Story so the estimated recharge amount would still be adequate.

Groundwater flow in the Columbia Aquifer moves under the influence of gravity to areas of discharge, such as streams, lakes or other surface water bodies. A portion of the groundwater flows vertically downward through the underlying Yorktown confining unit and is a recharge source for the Upper Yorktown Aquifer (Siudyla, 1981). Siudyla (1981) noted that water levels in wells constructed in the Upper Yorktown Aquifer were approximately 3 feet lower than water levels of wells constructed in the Columbia Aquifer for the same area. Due to the variations within the sediments which comprise the two aquifers, Siudyla (1981) noted that hydraulic recharge from the Columbia Aquifer through the Yorktown confining unit to the Upper Yorktown Aquifer varied greatly throughout the southeastern Virginia Coastal Plain.

Based on water level measurements obtained from monitoring wells installed for the PA/SI, other studies in the general area, and for the current study, the water table occurs at roughly 4 to 10 feet BLS feet in the Fort Story area. **Table 3-3** presents a summary of the water elevations and well construction details for all existing wells at the site. The PA/SI concluded that a local groundwater divide in the vicinity of the central sand ridge complex existed; however, this could not be confirmed based on the available data. In consideration of available data, the PA/SI concluded that the general ambient groundwater flow directions are northward toward the coastline and southward toward the wooded wetland, from the central sand ridge area.

Limited water quality data exists for the Columbia Aquifer because most hydrogeologic studies of the area have focused on the potable use aquifers. Some of water quality data for the water table aquifer as reported by Siudyla (1981) is covered in the following discussion.

Water quality of the water table aquifer is highly variable. Local features can affect the concentration of certain water quality parameters such as chloride. Chloride concentration is generally low except in areas adjacent to tidal waters where the levels ranged from 221 to 450 mg/L. Groundwater of the Columbia Aquifer ranges from hard (121 to 180 mg/L) to moderately hard (61 to 120 mg/L). The most prevalent water quality concern for the water table aquifer is low pH and high iron content. The low pH (acidic) water is very corrosive to metal that may be used for well construction, plumbing or other industrial uses. Iron content in the Columbia Aquifer commonly exceeds 5 mg/l. At this level, staining can occur when the water comes into contact with air thus initiating precipitation of iron as iron hydroxide. Dissolved solids range from 200 to 300 mg/l.

Due to the variable water quality (e.g., high chlorides, low pH, and high iron content) of the Columbia Aquifer at Fort Story, it is not currently used as a drinking water source. However, there are currently several housing communities located within 1 mile west of Fort Story that are developing shallow drinking water wells in the water table aquifer due to the City of Virginia Beach's restrictions on new

hook-ups to their distribution system because of their water shortfall. Because their have been no pumping or slug tests conducted on the RI wells at each of the sites, the development of the groundwater in the Columbia Aquifer at each site for drinking water purposes is unknown.

Although no background groundwater samples were collected during the PA/SI and RI, several groundwater samples were collected at upgradient locations of the sites where no site impacts to groundwater quality were anticipated. Groundwater samples were collected upgradient of the FTA site (monitoring well 4 MW-4), LARC 60 site (monitoring well MW-118) and Auto Craft site (DPT point GW07-001). Other than the acetone detect (28 µg/l) at 4 MW-4 probably as a result of laboratory contamination, no other volatile organics, semivolatile organics, or total petroleum hydrocarbons were detected in the three upgradient wells.

Based on the estimated groundwater flow direction stated in the PA/SI, monitoring well 4MW-1 was installed as the upgradient location with all parameters including inorganics analyzed. However, based upon our evaluation as described in Section 3.2.1, the groundwater flow direction was determined to be towards the Chesapeake Bay to the north. This change in direction makes 4MW-1 a downgradient well and 4MW-4 the upgradient well, however, inorganics were not analyzed at 4MW-4.

Comment #6

Total and dissolved metals analysis was conducted at MW-118 in years 1995 and 2000 while only total metals were analyzed for samples collected at GW07-001. A summary of the metals analysis is provided as follows:

PARAMETER	MW-118		GW07-001	
	TOTAL 1995/2000 (ug/l)	DISSOLVED 1995/2000 (ug/l)	TOTAL (ug/l)	DISSOLVED (6g/l)
Aluminum	3,700 / < 6	< 200 / < 6	360	-
Antimony	NS / < 2.7	NS / < 2.7	-	-
Arsenic	< 10 / < 3	< 10 / < 3	< 10	-
Barium	35 / 5.3	39 / 5	14	-
Beryllium	NS / < 0.1	NS / < 0.1	-	-
Calcium	15,000 / 9,100	17,000 / 8,400	37,000	-
Chromium	NS / < 0. 7	NS / < 0.7	-	-
Cobalt	NS / < 0.9	NS / < 0.9	-	-
Copper	NS / 2.4	NS / < 0.9	-	-
Iron	3,500 / 270	< 50 / 70	1,800	-
Lead	6.7 / < 2.4	< 5	< 5	-
Mercury	< 0.5 / < 0.1	< 0.5 / < 0.1	< 0.5	-

Comment #7 units? Was response in mg/l and table in ug/l (.01 mg/l = 10 ug/l)

PARAMETER	MW-118		GW07-001	
	TOTAL 1995/2000 (ug/l)	DISSOLVED 1995/2000 (ug/l)	TOTAL (ug/l)	DISSOLVED (6g/l)
Magnesium	6,400 / 2,800	6,300 / 2,600	3,000	-
Manganese	25 / 4.2	< 10 / 3.8	42	-
Nickel	NS / < 1.1	NS / < 1.1	-	-
Potassium	6,600 / 3,600	6,400 / 3,500	1,800	-
Selenium	NS / < 3.4	NS / < 3.4	-	-
Silver	NS / < 0.5	NS / < 0.5	-	-
Sodium	9,300 / 5,300	9,800 / 4,800	9,900	-
Thallium	NS / < 4.3	NS / < 4.3	-	-
Vanadium	< 10 / < 0.7	< 10 / < 0.7	< 10	-
Zinc	24 / 3.6	26 / 4.3	35	-

A summary of the metals analysis for the upgradient groundwater samples is provided as follows:

- Antimony, arsenic, beryllium, chromium, cobalt, mercury, nickel, selenium, silver, thallium, and vanadium were not detected in either total or dissolved samples.

- No significant reduction was detected from total to dissolved samples for barium, calcium, magnesium, potassium, sodium, and zinc indicating that these inorganics are primarily in the dissolved state.

- Aluminum and lead were detected in total samples but not in dissolved samples indicating that these inorganics are associated with sediment and are not in a dissolved state.

Yorktown Confining Unit

The Morgarts Beach Member of the Yorktown Formation forms the underlying Yorktown semi-confining unit. This unit is comprised of marine silt with occasional interbeds of fine sand and coquina. It is characterized by blue-gray to green-gray clay interbedded with massive silty clay, fine sand, and calcareous shell fragments. The Yorktown confining unit extends from approximately 50 to 60 feet BLS and is estimated to be approximately 40 to 50 feet thick (Meng and Harsh, 1988). Vertical hydraulic conductivity for the Yorktown confining unit has been reported to range from 5.9 x 10^{-4} to 3.9 x 10^{-3} ft/day based on laboratory tests (Harsh and Laczniak, 1990). The leakance for the confining unit has been reported to range from 0.00013 to 0.00018 per day (Harsh and Laczniak, 1990).

Upper Yorktown Aquifer

The Yorktown - Eastover Aquifer underlies the Yorktown confining unit and is encountered between the depths of roughly 140 and 200 feet below ground surface. The sediments of the Upper Yorktown Aquifer are comprised of thick, massively-bedded shelly sands (Meng and Harsh, 1988). Groundwater in the Yorktown-Eastover Aquifer generally flow to the east. Within the Upper Yorktown, Siudyla (1981) noted that in some areas the groundwater flow was influenced by local conditions such as topography, streams, lakes, and pumping from the Columbia Aquifer. Siudyla (1981) reported that this was a localized condition which varied with the sedimentary features of the Columbia Aquifer, Yorktown Confining Unit and Upper Yorktown Aquifer. Hydraulic parameters reported for the Upper Yorktown Aquifer include: transmissivity which ranged from approximately 1,200 to 36,000 gallons per day (gpd/day), specific capacity which ranged from 0.8 to 9.5 gpm/ft, and storage coefficient which ranged from 0.0035 to 0.00008 (Siudyla, 1981). The potentiometric surface of the Upper Yorktown Aquifer has fluctuated from approximately 7 to 16 feet BLS (Siudyla, 1981).

Local recharge to the Upper Yorktown Aquifer is from vertical flow of groundwater through the overlying Yorktown Confining Unit from the Columbia Aquifer (Siudyla, 1981). Recharge from precipitation occurs in the western portion of the Coast Plain where past erosion has exposed the Yorktown Formation and the Yorktown Aquifer is unconfined. The exposed portions of the Yorktown Formation are approximately 80 miles west of Fort Story.

Water quality of the Yorktown Aquifer is suitable for potable water use as well as many other uses. Water quality is variable - even within the same well field. Variation of water quality parameters is as follows: hardness ranges from 1 to 1430 mg/L, iron from 0.1 to 48 mg/L, chloride from 6 to 2000 mg/l, and total dissolved solids from 77 to 4110 mg/L. In comparison to the Columbia Aquifer, corrosion and high iron levels are less severe in the Yorktown Aquifer. However, due to the variation with the aquifer, some public supply water systems treat for high iron levels. Brackish water (more than 250 mg/L of chloride) in the Yorktown Aquifer can be a problem in some areas. For example, in the Fort Story area the water-salt water interface of the Yorktown Aquifer occurs approximately along the shoreline of the Atlantic Ocean and Chesapeake Bay and turns inward along tidal estuaries or bays such as the Lynnhaven River, the Elizabeth River, and Back Bay. The water-saltwater interface occurs approximately 100 to 120 feet BLS in inland areas but can be as shallow as 50 to 60 feet BLS in coastal areas. In these areas, the presence of brackish water may affect the chemical behavior of the affected sediments.

3.1.6 Ecology

Flora

Most of Fort Story is covered by the southeastern evergreen forest community. This forest type is the northernmost extension of a vegetation type in which long-needled pines dominate. This forest type extends along the Gulf and Atlantic coastal plains from eastern Texas to the James River. The

southeastern evergreen forest south of the James River is characterized by Loblolly Pine (*Pinus taeda*) interspersed with various oaks and other hardwoods (Braun, 1950). This forest community is a mosaic of plant assemblages controlled largely by soils and drainage patterns. The indicator species of the southeastern evergreen forest was historically Longleaf Pine (*Pinus palustris*). Loblolly Pine now predominates in this area since it rapidly colonizes old fields, outcompetes Longleaf Pine and has been extensively planted.

Due to fire suppression, many portions of the region are now populated with hardwoods such as White Oak (*Quercus alba*), Southern Red Oak (*Quercus falcata*), Post Oak (*Quercus stellata*), Swamp Chestnut Oak (*Quercus michauxii*), Water Oak (*Quercus nigra*), hickories, gums, maples, and ash (Mitchell, 1994). On the heavier alluvial deposits, swamp forests dominate, characterized by Baldcypress (*Taxodium distichum*), Tupelo (*Nyssa aquatica*), Green Ash (*Fraxinus pensylvanica*), Black Gum (*Nyssa sylvatica*), Red Maple (*Acer rubrum*), and Sweet Gum (*Liquidambar styraciflua*).

A portion of Fort Story contains maritime forests which are characterized by Live Oak (*Quercus virginiana*), hollies, Red Bay (*Persea borbonia*), and Loblolly Pine interspersed with dense thickets of Wax Myrtle (*Myrica cerifera*), Eastern Redcedar (*Juniperus virginiana*), Poison Ivy (*Rhus toxicodendron*), Virginia Creeper (*Parthenocissus quinquefolia*), and Greenbrier (*Smilax rotundifolia*). These forests typically contain stunted trees influenced by salt spray from the Atlantic Ocean, though they are somewhat protected by sand dunes (Mitchell, 1994).

Fort Story also contains old field communities which are dominated by Broomsedge (*Andropogon virginicus*), Eastern Redcedar, ragweeds, asters and young Loblolly Pine. These fields experience higher thermal extremes, greater diurnal and seasonal fluctuations in temperature, and lower moisture regimes than the forested areas on the facility. However, they are an important component of the natural ecosystem of the facility and support a wide variety of animals.

Fauna

Wildlife found at Fort Story is typical of that found in the Virginia Beach and Seashore State Park area. Common mammal species found at the installation include Muskrat (Ondontra zibethicus), Eastern Cottontail (Sylvilagus floridanus), Raccoon (Procyon lotor), Opossum (Didelphis virginiana), and Squirrel (Scuirus spp.). Some White-tailed Deer (Odocoileus virginianus) may take temporary residence in and around the cypress swamp.

Common species of birds include seagulls (Larus spp.), European Starling (Sturnus vulgaris), Robin (Turdus migratorius), American Crow (Corvus brachyrhynchos), and Bluejay (Cyanocitta cristata).

Typical species of amphibians and reptiles found within the installation include common species of frogs, turtles, and snakes, such as the Green Frog (Hyla cinerea), Eastern Box Turtle (Terrapene carolina carolina), and Copperhead Snake (Agkistrodon contorix contorix). (Horne Engineering and Environmental Services, 1995)

comment #8

The four freshwater lakes have been stocked and managed through an agreement with the U.S. Fish and Wildlife Service (USFWS). Species stocked include a variety of bass (Micropterus spp.) and sunfish (Lepomis spp.). Fish populations within the lakes are monitored and stocked by the USFWS as needed.

According to the Virginia Department of Conservation and Recreation, Division of Natural Heritage, in a study conducted for Virginia Beach, several threatened and endangered species may occur in the vicinity of Fort Story where suitable habitat exists. These species are the Federal threatened Bald Eagle (Haliaeetus leucocephalus) the Federal threatened Dismal Swamp Shrew (Sorex longirostris fisheri), the State Endangered Chicken Turtle (Deirochelys reticularia), and the State threatened Eastern Glass Lizard (Ophisaurus ventralis).

An ongoing study by Old Dominion University on the Chicken Turtle at Seashore State Park and a portion of Fort Story has recorded no incidence of the turtle on the installation. Occurrences of the other species also need to be confirmed. (Horne Engineering and Environmental Services, 1995)

3.2 SITE SPECIFIC PHYSICAL CHARACTERISTICS

This section provides a detailed description of each of the three RI sites at Fort Story; Firefighter Training Area, LARC 60 Maintenance Area and the Auto Craft Building Area.

3.2.1 Firefighter Training Area (FTSTY-04)

The Firefighter Training Area (FTA) is located in the southwest area of Fort Story south of Hospital Road and bounded by Hospital Circle. A former fuel tank farm is located adjacent to the site on the southeast end. The FTA site map is provided on **Figure 3-2**.

Topography

The FTA is located in a sandy flat area with little or no topographic elevation relief which is situated adjacent to the northern flank of the central sand ridge in the southwestern section of Fort Story.

Surface Hydrology

Surface runoff on the majority of the site within the bounds of Hospital Circle does not drain outside of this area. The elevation of Hospital Circle is 1 to 3 feet higher than the area inside of the road. A low point is located in the northeast corner of the site where runoff from areas within and outside of the site ponds during high rain events. As observed during field investigations, seepage is slow in this area with several days required for the standing water to percolate into the soils.

Surface runoff from the southeast corner and the area immediately south of the site adjacent to the road drains into a lowland area south of the site. A berm is located along the perimeter of the southwest boundary of the site preventing any runoff from that area to enter the lowland area.

Geology/Hydrogeology

Geology and hydrogeology data was obtained through current drilling activities and from previous investigations. Six permanent monitoring wells and two piezocone borings from the current investigation along with three permanent monitoring wells and nine soil borings from the previous investigations were reviewed to evaluate the site geology. The site is underlain by sand deposits of the Kennon Formation and Columbia Group of Holocene and Pleistocene in age respectively. The upper forty feet of sediments were described with respect to lithology and sedimentary features during drilling activities. Based on lithology, the sediments can be separated into four layers as follows:

DEPTH (BLS)	USCS SOIL TYPE	DESCRIPTION
0 - 2	SM	Sand to silty sand.
2 - 18	SP	Medium sand, rounded to subrounded, moderately well sorted, with trace amounts heavy minerals, grading to coarse to very coarse sand at approximately 18 feet BLS.
18 - 40	SW	Interlayers of coarse to very coarse sand and gravel, heavy minerals, well sorted within layers, rounded to subrounded.
40 - 46	SM	Sharp contact with overlying unit. Fine sand to silty sand, some shell fragments, non-cohesive, non-plastic.

Previous investigations described a silty sand present from 0 to 2 feet BLS across the site which extended to a depth of 4 feet in the eastern area of the site. The sand was subrounded to subangular, usually poorly graded and medium to coarse grained at depths greater than 4 feet which corresponds to the sand layers encountered 2 to 18 ft BLS in the current investigations. **Figures 3-3 and 3-4** present the traverses and the cross-section views of the site. The cross-section incorporates borehole data from the PA/SI with data from the current investigation.

Previous investigations reported that the water table elevations ranged from 8.5 feet NGVD in the northern portion of the site to less than 8.3 feet NGVD in the southern portion. The water table was

encountered approximately six (6) feet BLS during drilling activities. Based on water elevations measured in the on-site wells, the water table occurs at 7.5 to 7.8 feet National Geodetic Vertical Datum (NGVD) of 1929.

Based on measured water levels, groundwater flows from the southwest to the northeast, as opposed to the groundwater flow direction reported in the PA/SI which was from the north to the south. The change in the groundwater flow direction is based on groundwater level data collected from existing and newly installed wells. The flow direction estimated during the PA/SI was based on data collected from monitoring wells (MW-110 (destroyed), MW-111, and MW-112) that were located along a line perpendicular to the direction of groundwater flow. There were no wells located outside of this general line. New monitoring wells were installed upgradient and downgradient of the site with water level data used to better estimate groundwater flow direction. The additional well data along with water level data from other wells indicate groundwater flow direction to be to the northeast. However, it should be noted that there is minimal gradient in the southern end of the site where data indicates only a 0.02-foot gradient over a 200-foot horizontal distance (4 MW-4 to MW-112). Previously reported estimated hydraulic conductivity values at the site ranged from 1.17×10^{-2} to 1.37×10^{-2} centimeters per second (cm/sec) with an average value of 1.24×10^{-2} cm/sec. **Figure 3-5** presents a water table elevations and flow direction.

To evaluate possible tidal influence on water table elevations, water levels for monitoring wells 4MW-1, 4MW-4, and MW-112 were recorded by a data logger from May 19 through May 22, 1995. No measurable amount of precipitation was recorded by the rain gauge, though the inside of the gauge was moist. Over the test period, groundwater levels varied no more than 0.08 feet. Data indicate a generally lowering water table, but do not suggest any changes in groundwater elevation that are attributable to tidal influence. A graphical presentation of the water levels measured in the three wells during the monitoring period are presented on three graphs in **Appendix B**.

3.2.2 LARC 60 Maintenance Area (FTSTY-06)

The Lighter Amphibious Resupply Cargo (LARC) 60 maintenance area, which is the maintenance and wash rack area for LARC vehicles includes Buildings 1081, 1082, 1083 and 1084 as shown on **Figure 3-6**. The LARC 60 area is bounded on the southwest by the Crane Motor Park, on the northwest by the Public Works compound, on the east by a go-kart track and on the northwest and west by wooded areas.

Topography

The LARC 60 area is located in the sand flat area that lies between the coastal dune complex to the north and the central sand ridge to the south. The majority of the site is a paved maintenance area with no significant topographic relief.

Surface Hydrology

Surface runoff and wash water from the majority of the site is controlled by a storm drain system. A system of 39 catch basins and an oil/water separator is used to collect storm and wash water from the site. The water flows into a drainage outfall line and then into the Chesapeake Bay at Outfall 001 as shown on **Figure 3-6**. This point is monitored through a National Pollution Discharge Elimination System (NPDES) permit by the Virginia Department of Environmental Quality (DEQ), Water Division. Surface runoff from the Sandbox Area drains into a drainage ditch located along the northern boundary of the Sandbox. The ditch is a storm water collection area with no discharge point.

Geology/Hydrogeology

The site lithology was established based on borings conducted during the current and PA/SI field activities. Borehole logs provided lithologic data for five permanent monitoring wells and two piezocone borings from the current investigation. The sediments underlying the LARC area consist of sand deposits of the Kennon and Columbia Group that are of Holocene and Pleistocene Age respectfully. Drilling penetrated the upper forty feet of sediments and these were described with respect to lithology and sedimentary features by the site geologist. The following table provides a summary of the lithologic units:

DEPTH (BLS)	USCS SOIL TYPE	DESCRIPTION
0 – 2	SP	Asphalt. Fine sand, well sorted, with heavy minerals, moderately sorted.
2 – 18	SM	Medium to fine sand, with heavy minerals, moderately sorted.
18 – 35	SW	Coarse to medium sand, subrounded, with lenses of gravel and medium sand of heavy minerals; with layers of fine to medium sand and sand of heavy minerals.
35 – 46	SC	Fine sand, with heavy minerals, with lenses of cohesive, plastic clay.

Borings during the PA/SI encountered similar deposits that consisted of fine to medium sand, poorly graded, subrounded and occasionally slightly silty. **Figures 3-7 and 3-8** present the traverses and the cross-section views of the site. The cross-section incorporates borehole data from the PA/SI. At one location within the site area, a borehole penetrated a peat lens less than 1 foot in thickness at a relatively shallow depth. The soil boring converted into well 6MW-3D penetrated a 3- to 4-inch thick buried soil horizon (A1) at approximately 8 to 10 feet below land surface. The horizon was very

organic rich but did not contain any visible vascular plant material. This type of buried soil horizon in coastal plain sediments is typically laterally discontinuous.

The significance of such a horizon is that an organic-rich soil has a high cation exchange capacity that can influence the fate and transport of inorganic compounds and a high total organic carbon content that can influence organic compounds similarly. At this borehole location, the water table occurs approximately four to six feet below land surface which is approximately two feet more shallow than for other borings at the site.

The measured depth to groundwater at the site ranged from 2.80 to 9.91 feet BLS. This is similar to the levels of 5.07 to 7.47 feet below ground surface measured during the PA/SI. Water level data from on-site wells indicates that the water table elevation ranges from approximately 4.81 to 6.33 NGVD. These elevations are similar to the PA/SI levels of 8 feet NGVD in the southern portion of the site to less than 5 feet NGVD in the unpaved, wash rack area. **Figure 3-9** presents the water table elevations and flow direction.

The PA/SI reported that an evaluation of the water level data suggest a possible cone of depression in the vicinity of the wash rack supply well located at the southwestern corner of the wash rack area. The minimum groundwater level elevation within the cone of depression was approximately 4 feet NGVD. However, this well is not currently in use. Though locally variable in magnitude and direction, the prevailing hydraulic gradient for the site is in a northward direction toward the coastline as established by the PA/SI. Estimated hydraulic conductivity values range from 1.99×10^{-3} to 1.84×10^{-2} centimeters per second (cm/sec) with an average value of 7.42×10^{-2} cm/sec as established by the PA/SI.

To evaluate possible tidal influence on water table elevations, water levels for monitoring wells 6MW-3S, 6MW-4, and MW-118 were recorded by a data logger from May 17 through May 19, 1995. No measurable amount of precipitation was recorded by the rain gauge, though the inside of the gauge was moist. Over the test period, groundwater levels varied no more than 0.19 feet. Data indicate a generally lowering water table, but do not indicate any trends in groundwater elevation that are attributable to tidal influence. A graphical presentation of the water levels measured in the three wells during the monitoring period are presented on three graphs in **Appendix B**.

3.2.3 Auto Craft Building Area (FTSTY-07)

The Auto Craft Building Area is located near the intersection of Atlantic Avenue and Cebu Road in the east-central portion of Fort Story as shown on **Figure 3-10**. The Fort Story car wash is located south of the site.

Topography

The Auto Craft Building Area is located in the sand flat area south of the coastal dune complex at the junction of Atlantic Avenue and Cebu Road. Approximately 2 to 3 feet of topographic relief is present on the site. The area of the former building and the parking lot south of the building are located on an area of about 15 feet MSL while the grassy areas north and northwest of the building have an elevation of about 12 to 13 feet MSL.

Surface Hydrology

Surface runoff from the paved area around the former building drains into either storm drains located in the grassy area north of the building or into a small drainage ditch between Cebu Road and the paved area. This ditch drains into the grassy area and storm drains previously mentioned.

Geology/Hydrogeology

Most of the site's upper surface is covered by asphalt pavement that is constructed on top of the native sediments. Data was obtained during drilling activities of the current investigation and during previous investigations. Boring logs for three permanent monitoring wells and two piezocone borings from the current investigation and two monitoring wells and eight soil borings from the previous investigations were reviewed to evaluate the site geology.

The site is underlain by Holocene and Pleistocene Age sand deposits of the Kennon Formation and the Columbia Group. During drilling activities, the upper forty-two feet of sediments were described with respect to lithology and sedimentary features. Based on lithology, the sediments can be separated into four layers as follows:

DEPTH (BLS)	USCS SOIL TYPE	DESCRIPTION
0 - 2		Asphalt and black sand.
2 - 18	SM	Fine sand with heavy minerals.
18 - 34	SP	Medium sand, with fine sand and heavy minerals; grades into layers of coarse to very coarse sand and fine sand or very coarse sand with gravel.
34 - 44	SP	Interlayers of coarse to very coarse sand and fine sand and very coarse sand and gravel.

Previous investigations encountered fine to medium grained sand that was subrounded and poorly graded. The PA/SI reported penetrations of clay and silt layers approximately 2 feet thick and horizontally discontinuous in the northern part of the site at depths of 5 feet. **Figures 3-11 and 3-12** present the traverses and the cross-section views of the site. The cross-section incorporates borehole data from the PA/SI.

Depths to groundwater at the site varied from 7.8 to 10.9 feet below surface which is similar to the range from 7.8 feet to 10.3 feet below ground surface encountered during the PA/SI. Water table elevations at the site ranged from 4.4 to 4.7 NGVD whereas the PA/SI established that water table elevations ranged from 5.3 feet NGVD near the building to 5.1 feet NGVD. **Figure 3-13** presents a contoured water table elevation map. The PA/SI established that the lateral hydraulic gradient at the site is directed to the northeast. This direction was confirmed during the current study based on water table elevations measured on May 17, 1995. During the PA/SI, in-situ aquifer tests established estimated, hydraulic conductivity values which range d from 3.23×10^{-3} to 7.11×10^{-3} centimeters per second (cm/sec) with an average value of 5.17×10^{-3} cm/sec.

To evaluate possible tidal influence on water table elevations, water levels for monitoring wells 7MW-1, 7MW-2, and MW-119 were recorded by a data logger from May 22 through May 23, 1995. No precipitation occurred during the specified time period over which water levels were recorded. Over the study, water table elevations varied no more than 0.08 feet. Data indicate a generally lowering water table over the monitored time period, but do not indicate any trends in groundwater elevation that are attributable to tidal influence. The initially higher water table elevation recorded of 7.5 feet MSL decreased to 7.4 feet MSL at the end of the monitored period. The initial water levels reflect a series of precipitation events that preceded the tidal study. The decrease in water elevations reflect the infiltration of precipitation and the return of the water table to equilibrium. A graphical presentation of the water levels measured in the three wells during the monitoring period are presented on three graphs in **Appendix B**.

This section provides a preliminary identification of the applicable or relevant and appropriate requirements (ARARs), the results of the field water used during decontamination of equipment, the environmental media analytical results and an assessment of the nature and extent of contamination for the three sites. As previously noted in Section 2, the majority of the field investigations and sampling was conducted in 1995 while some additional sampling for trends analysis and data gap address was conducted in 2000.

The quality of the 1995 analytical data is presented in the *Quality Control Summary/Analytical Results Report (QCS/ARR)* submitted separately. The results of the data validation as conducted by our subcontractor, URS Consultants, Inc. are provided in Appendix E of the *QCS/ARR*. Split samples were submitted to the U.S. Army Corps of Engineers (USACE) New England Division (NED) Laboratory for quality assurance checks. Results from the field samples were submitted to the USACE NED Laboratory for their review. Their Chemical Quality Assurance Report for the QA sampling is provided in Appendix D of the *QCS/ARR*.

The quality of the 2000 analytical data is presented in an addendum to the QCS/ARR which includes URS' data validation report.

comment #9

Based on the data validation results and the USACE NED laboratory QA sampling (1995 sampling only), the 1995 and 2000 analytical data were considered acceptable and valid for use in determining the nature and extent of contamination and in performance of the baseline risk assessment provided in Sections 6.0 and 7.0 of this report. Qualifiers are provided for those results that are considered deficient based on the data validation.

The data reported in the summary tables in this section include the highest concentration detected for a contaminant whether in the original, dilution, re-extraction, duplicate or QA sample so that the maximum concentration is shown and evaluated especially in the subsequent risk assessment.

4.1 IDENTIFICATION OF ARARS

4.1.1 Definition of ARARs

The National Contingency Plan (NCP) and Section 121 of the Comprehensive Environmental Response, Compensation and Liabilities Act (CERCLA) require that CERCLA remedial actions attain Federal and State ARARs unless specific waivers are granted. State ARARs must be attained under Section 121(d) of CERCLA, if they are legally enforceable and consistently enforced statewide. ARARs may be classified as either applicable or relevant and appropriate. In addition to ARARs, other guidance and regulations may be classified as guidance "to be considered" (TBC). Potential ARARs and TBCs are identified in this section to aid in development of remedial actions and in establishment of required cleanup levels. Additionally, ARARs and TBCs are used to scope and formulate remedial action alternatives and to govern implementation and operation of the selected remedial alternatives.

Discussions of ARARs and TBC criteria are provided as follows:

- **Applicable Requirements**. Applicable requirements refer to those Federal or State requirements that would be legally enforceable. An example of an applicable requirement would be the Safe Drinking Water Act's Maximum Contaminant Levels (MCLs) for a site that contaminates a public drinking water supply.

- **Relevant and Appropriate Requirements**. Relevant and appropriate requirements are Federal or State standards, criteria or guidelines that are not legally enforceable at a site, but where application is appropriate because they address problems similar to those on-site. Relevant and appropriate requirements have the same weight and consideration as applicable requirements. An example of Relevant and Appropriate Requirements might be state groundwater protection levels established for other regulatory programs such as UST or RCRA Subtitle D.

- **To Be Considered (TBC).** Other Federal and State recommended standards or criteria applicable to a specific site which are not generally enforceable but are advisory are categorized as TBC. For example, where no specific ARAR exists for a chemical or situation, or where such an ARAR is not sufficient to be protective of human health or the environment, Federal and/or State guidance or advisories may be considered in determining the necessary level of cleanup for protection of public health and the environment. An example of a TBC would be use of EPA risk screening criteria or EPA Health Advisories for specific chemicals in determining action or cleanup levels.

4.1.2 Development of ARARs and TBCs

The development of ARARs and TBCs is conducted on a site-specific basis. ARARs and TBCs are further categorized as either chemical-specific, location-specific or action-specific. CERCLA actions may have to comply with them as follows:

- **Chemical-Specific**. Chemical-specific requirements define acceptable exposure levels for specific hazardous substances and therefore may be used as a basis for establishing preliminary remediation goals and cleanup levels for chemicals of concern in the designated media. Chemical-specific ARARs and TBCs are also used to determine treatment and disposal requirements for remedial actions. In the event a chemical has more than one requirement, the more stringent of the two requirements will be used.

- **Location-Specific**. Location-specific requirements set restrictions on the types of remedial actions that can be performed based on site-specific characteristics or location. Alternative remedial actions may be restricted or precluded based on Federal and State laws for hazardous waste facilities, proximity to wetlands or floodplains, or to man-made features such as existing landfills, disposal areas and local historic landmarks or buildings.

- **Action-Specific**. Action-specific requirements set controls or restrictions on the design, implementation and performance of remedial actions. They are triggered by the particular types of treatment or remedial actions that are selected to accomplish the cleanup. After remedial alternatives are developed, action-specific ARARs and TBCs which specify remedial action performance levels as well as specific contaminant levels for discharge of media or residual chemical levels for media left in place, are used as a basis for assessing the feasibility and effectiveness of the remedial action.

4.1.3 Identification of ARARs and TBCs

Chemical-Specific ARARs and TBCs

As a basis for comparison of the contaminant concentrations discussed in this section, lists of chemical-specific ARARs and TBC criteria has been developed for the Fort Story sites. These chemical-specific ARARs and TBCs have been identified for soil, sediment, surface and groundwater in Tables 4-1 through 4-4, respectively. Chemical-specific ARARs and TBCs that have been identified from the following regulations and standards:

ARARs

- Virginia Groundwater and Surface Water Quality Standards
- EPA Ambient Water Quality Criteria (40 CFR 131)
- Safe Drinking Water Act Maximum Contaminant Levels (40 CFR 141 and 143)
- Virginia Groundwater Protection Levels from DEQ Solid Waste Regulations

TBC Criteria

- Virginia DEQ Petroleum Program Manual (March 1995)
- EPA Region III Risk-based Concentration Tables (October 2000)
- EPA Region III BTAG Screening Levels
- Virginia Groundwater Quality Criteria

Location-Specific ARARs and TBC

Identification of potential location-specific ARARs and TBC include the following:

- Virginia Stormwater Management Regulations
- Virginia Pollution Abatement (VPA) Permits
- Virginia Water Protection Permit Regulations
- Virginia Hazardous Waste Management Regulations
- Virginia Solid Waste Management Regulations
- Virginia Regulations for Transportation of Hazardous Materials
- Resource Conservation and Recovery Act (RCRA) Regulations (40 CFR 261-270)

- DOT Transportation Regulations (49 CFR 107, 171)
- Virginia Regulations for the Control and Abatement of Air Pollution
- Clean Air Act Regulations
- Virginia Erosion and Sediment Control Regulations

Action-Specific ARARs and TBC

Identification of potential action-specific ARARs and TBC may include the following based on the required remedial action:

- National (40 CFR 122) and Virginia Pollutant Discharge Elimination System permits
- Virginia and Federal Endangered Species Act
- Virginia Wetlands Regulations
- Federal Water Pollution Control Act Regulations (Clean Water Act)(33 CFR 323)
- Federal Wetlands Executive Order 11990
- Chesapeake Bay Preservation Regulations
- Virginia Beach Coastal Management Plan
- Virginia Historic Resources Law and Antiquities Act
- Federal Floodplain Executive Order 11988
- Local Noise Statutes

The applicability and refinement of these chemical, location and action-specific ARARs and TBC to future remedial actions will be evaluated in detail on a more site-specific basis in the feasibility study process, if required.

4.2 FIELD WATER SAMPLING RESULTS

As discussed in Section 2.1.9, field water used for equipment decontamination consisted of tap water from Fort Story and deionized (DI) water obtained from Savannah Laboratories. A more detailed discussion of the quality of the field water and any impacts to sampling and analysis is provided in the *QCSR/ARR*.

Samples of the tap water and DI water were submitted to Savannah Laboratories for analysis for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), total petroleum hydrocarbon (TPH) light and heavy fractions and total metals and cyanide.

No VOCs, SVOCs, TPH compounds, metals or cyanide were detected in the DI water samples.

Chloroform and bromodichloromethane were detected in the Fort Story tap water sample in concentrations of 68 and 15 micrograms per liter (*ug/l*), respectively. The total concentration (83 *ug/l*) of trihalomethanes (chloroform, bromodichloromethane, bromoform and dibromochloromethane) detected is less than the 100 *ug/l* MCL. No SVOC or TPH compounds were

detected in the tap water sample. Several metals including barium (0.024 *mg/l*) , calcium (24 *mg/l*), iron (0.32 *mg/l*), magnesium (2.7 *mg/l*), manganese (0.029 *mg/l*), potassium (2.8 *mg/l*), sodium (13 *mg/l*) and zinc (0.79 *mg/l*) were detected in the tap water sample.

Because tap water was only used as an initial rinse with subsequent methanol, and/or nitric acid and DI water rinses occurring, no impacts to analysis of field samples were identified.

4.3 FIREFIGHTER TRAINING AREA

Soil, sediment and groundwater samples were collected at the Firefighter Training Area (FTA) to define the nature and extent of contamination. Surface soil and sediment samples were collected by hand auger while subsurface soil and numerous groundwater samples were collected by direct push technology (DPT) methods. In addition, groundwater samples were collected from newly installed and existing monitoring wells.

Three areas of concern (AOCs) were investigated to determine potential sources and the extent of contamination. These areas include several stained areas in the Northern Area of the FTA, the Former Fire Training Pit (FTP) located in the southwest corner of the FTA and the Solvent Plume Area located in the southeast corner of the site.

In this section analytical data for all media is compared against EPA risk screening criteria. Groundwater data is screened against EPA RBC for tap water while sediment and soils data are compared to EPA RBC for industrial and residential soils. This initial screening against these criteria are only used to assign significance to the analytical data and not as an analysis of risk or impacts. A detailed risk assessment which screens the data against ARARs such as MCLs, surface water quality standards, EPA soil screening levels, EPA RBC residential soil criteria, EPA Region III BTAG ecological risk levels, etc. is provided in Sections 6.0 (Human Health Risk Assessment) and 7.0 (Ecological Risk Assessment).

4.3.1 Surface and Subsurface Soils

Soil Analytical Results

In 1995, soil samples were collected from twenty-two (22) soil borings with samples collected from three depths to assess the lateral and vertical extent of contamination in the vadose zone and to assess the effectiveness of IT Corporation's removal action which included excavation and treatment of contaminated soil from the Former FTP Area. In addition, six surface soil samples were collected from two areas in the Northern Area of the FTA to assess contamination in surface soils in several stained areas. All soil samples were analyzed for VOCs, SVOCs, and TPH heavy and light fractions while five (5) surface and nine (9) subsurface soil samples were additionally analyzed for metals and cyanide. Table 4-5 provides the analytical results for the soil samples collected at the FTA. As shown in Table 4-5, only those contaminants detected are presented. Additionally, the EPA Region III Risk-based Concentration (RBC) Criteria for Industrial and Residential Soils are presented for

comparison purposes. The EPA Region III RBCs for industrial and residential soils for non-carcinogenic compounds presented in Table 4-5 have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for soil, the RBCs have been adjusted.

The risk assessment provided in Section 6.0 of this report will provide a more detailed risk screening against all chemical-specific ARARs and TBC criteria.

To address VDEQ concerns over the absence of pesticide and PCB data from soil samples collected in 1995, in 2000, eight (8) surface soil samples were collected throughout the FTA site to assess contamination in surface soils. All eight soil samples were analyzed for pesticides and PCBs. Table 4-5 provides the analytical results for the soil samples collected at the FTA in 2000.

VOCs

Several VOCs including acetone, methylene chloride, methyl ethyl ketone (MEK), styrene, toluene and xylenes were detected in surface and subsurface soils. No other VOCs were detected in the soils at the FTA.

Acetone was detected in 34 of 72 soil samples (27 to 1,700 micrograms per kilogram (*ug/kg*)), methylene chloride in only 1 of 72 samples (6.4 *ug/kg*), MEK in 9 of 72 samples (28 to 93 *ug/kg*), styrene in only 2 of 72 samples (2 and 3 ug/kg), toluene in 55 of 72 samples (5.8 to 140 *ug/kg*) and xylenes in only 1 of 72 samples (7 ug/kg).

All concentrations were at least two 4 orders of magnitude less than the risk screening criteria for industrial and residential soils. As reported in the EPA Region III Modifications to the National Functional Guidelines for Organic Review, methylene chloride, MEK and acetone are typical laboratory artifacts.

SVOCs

Numerous SVOCs including benzo(b)fluoranthene, benzo(k)fluoranthene, bis(2-ethyhexyl)phthalate, chrysene, di-n-butylphthalate, fluoranthene, naphthalene and pyrene were detected in soils at the FTA. Concentrations for all SVOCs detected were lower than the risk screening criteria for industrial and residential soils.

TPH

TPH as Heavy Oils was detected in 7 of 72 samples (48 to 5,300 milligrams per kilogram (mg/kg)) at the FTA. Three of these samples had concentrations greater than the 100 mg/kg screening criteria. The location and concentration of these samples is presented on **Figure 4-1**. Only those compounds detected above risk screening criteria are presented on **Figure 4-1**. No other TPH

FINAL REPORT (REDLINE/STRIKEOUT VERSION)
REMEDIAL INVESTIGATION

VOLUME I OF II (TEXT, TABLES, AND FIGURES)

FIREFIGHTER TRAINING AREA (FTSTY-04)
LARC 60 MAINTENANCE AREA (FTSTY-06)
AUTO CRAFT BUILDING AREA (FTSTY-07)

FORT STORY, VIRGINIA

PREPARED FOR:

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT
BALTIMORE, MARYLAND

AND

U.S. ARMY TRANSPORTATION CENTER
FORT EUSTIS, VIRGINIA

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Malcolm Pirnie, Inc. was contracted by the U.S. Army Corps of Engineers (USACE), Baltimore District to conduct Remedial Investigations (RI) at three below-listed sites at Fort Story, Virginia under Contract DACA31-94-D-0017.

- Firefighter Training Area (FTA)
- LARC 60 Maintenance Area
- Auto Craft Building Area

The three sites were recommended for further study in the Final Preliminary Assessment/Site Investigation (PA/SI) Report submitted in January 1992. A RI is considered to be the first attempt at characterization of the sites.

ES.1 BACKGROUND

All work was conducted in accordance with the Scopes of Services developed by the USACE with field investigation procedures further developed in the Final Work Plan, dated December 1994 and approved by the USACE which included the Field Investigation Plan (FIP), Chemical Data Acquisition Plan (CDAP) and Site Safety and Health Plan (SSHP). The specific objectives of the RI were:

- Delineation of the nature and extent of contamination at each site.
- Evaluation of potential migration of contaminants.
- Assessment of risks to human health and the environment posed by each site.
- Development of recommendations for future action at each site based on the findings.

The following sections summarize the site description, nature and extent of contamination, fate and transport, risk assessment and recommendations for each site.

ES.2 FIREFIGHTER TRAINING AREA

An extensive field investigation program was conducted to acquire sufficient data quality to assess the nature and extent of contamination. A summary of the site description, nature and extent, fate and transport, risk assessment and recommendations for this site are provided as follows.

Site Description

- The Firefighter Training Area (FTA) is located in a sandy flat area in the southwestern section of Fort Story along Hospital Road and Hospital Circle.

- Past site use includes a temporary hospital, a fire training area and an unauthorized dumping site. The northern section of the site is currently used as a heavy equipment (i.e., front end loaders, trucks) operation training area.

- Previous investigations included a PA/SI by James M. Montgomery which indicated the presence of several contaminants including metals, petroleum hydrocarbons and chlorinated solvents. IT Corporation conducted a removal action which included excavation, treatment and disposal of

the former fire training pit and associated petroleum-contaminated soils.

- Three areas of concern (AOCs) were identified at this site requiring investigation including the Northern Area of the site, the Former Fire Training Pit (FTP), and the Solvent Plume Area.

Nature and Extent

- Volatile organics (VOCs) such as toluene, acetone, and MEK, TPH as Heavy Oils and metals were detected in surface and subsurface soils collected throughout the FTA while semivolatile organics (SVOCs) were only detected in several soil samples located in the Solvent Plume Area of the site. Except for arsenic and iron in one sample, concentrations in soils were less than EPA screening criteria.

- Although total metals were detected in groundwater samples, dissolved metals were not detected which indicates that metals are associated with the sediment and not in a dissolved state.

- TPH as Heavy Oils were detected in most of the sediment samples located in the drainage area south of the site. The TPH contamination may be the result of surface transport from the Solvent Plume Area or former adjacent UST tank farm during heavy precipitation events.

- PCE, total lead, and total arsenic were the only compounds detected in groundwater above EPA risk screening criteria. No compounds were detected in soils or sediment above EPA risk screening criteria, however, TPH as Heavy Oils were detected above the Virginia UST Program action level of 100 milligrams per kilogram.

Fate and Transport

- The concentrations detected in groundwater are an order of magnitude lower than those detected during the PA/SI, which suggests that the compounds are biodegrading. The excavation of the contaminated soils in this area has decreased the potential for impact to groundwater quality through leachate generation.

- TPH as Heavy Oils were detected in the southwest corner of the FTA and in the drainage ditch south of the site. Because TPH as Heavy Oils adsorb very strongly onto soil and has a low aqueous solubility, the adsorbed compounds move with the sediments during storm runoff into the drainage ditch.

Baseline Risk Assessment

- ~~No chemicals of potential concern (COPCs) were identified for soil and sediment at the FTA while no exposure pathways or exposed populations were identified for contaminated groundwater located at the site. Therefore, no potential human health risk was identified due to contaminants present at the FTA site.~~

- Because arsenic was detected in site soils at concentrations consistent with the background soils, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Therefore, upon removal of arsenic as a COPC, the risk levels for site soils, sediment, and groundwater become less than the criterion of 1.0 and 10^{-6}, and no further action

related to this site (based on human health risk) is warranted.

- No exposure pathways or exposed populations were identified for contaminated media at the site. Therefore, no potential ecological risk was identified due to contaminants present at the FTA site.

Recommendations

No Further Action is recommended for the FTA site based on the limited contamination detected in the three AOCs, the trends which indicate that the TPH and VOC concentrations in soil and groundwater are decreasing due to numerous fate mechanisms and the results of the baseline risk assessment which did not identify receptors and potentially exposed populations.

ES.3 LARC 60 MAINTENANCE AREA

An extensive field investigation program was conducted to acquire sufficient data quality to assess the nature and extent of contamination. A summary of the site description, nature and extent, fate and transport, risk assessment and recommendations for this site are provided as follows.

Site Description

- The Lighter Amphibious Resupply Cargo (LARC) 60 Maintenance Area, which is the maintenance and wash rack area for LARC 60 vehicles, is located in a sand flat area in the north central portion of Fort Story.

- Past use of the area includes use as the barge amphibious resupply cargo (BARC) motor pool and maintenance facility and the LARC 60 vehicle maintenance area.

- A former 10,000-gallon underground storage tank (UST) was located at the north gate of the LARC 60 vehicle motor pool.

- Previous investigations included a PA/SI by James M. Montgomery, which indicated the presence of several contaminants including metals, petroleum hydrocarbons and chlorinated solvents. IT Corporation conducted a removal action, which included excavation and biotreatment of petroleum-contaminated soils from within the sandbox area. Treated soils were placed back into the sandbox area.

- Three areas of concern (AOCs) were identified at this site requiring investigation including the Former UST Area, the Oil/Water Separator (OWS) Area, and the Sandbox Area.

Nature and Extent

- Acetone, methylene chloride, MEK, PCE, TCE, styrene, and toluene were detected in several surface and subsurface soil samples collected at the site, however, at concentrations less than EPA screening criteria. Concentrations of the VOCs varied from surface to deeper depths with

no apparent trends.

- TPH as Heavy Oils were detected in the majority of surface and subsurface soil samples collected at the site with concentrations greater than 100 mg/kg in approximately 50 percent of the samples.

- Numerous metals were detected in soils at this site with concentrations typically decreased with depth. The lateral extent of metals was not defined. Although typically above background levels, except for arsenic at two soil sample locations (SB-1 and SB-20), metal concentrations were at least one order of magnitude lower than the EPA screening criteria.

- PCE, trichloroethene (TCE), Cis 1,2-dichloroethene, toluene, total lead, total and dissolved manganese, and total and dissolved arsenic were detected in groundwater above EPA risk screening criteria. No compounds were detected in soils or sediment above EPA risk screening criteria, however, TPH as Heavy Oils were detected above the Virginia UST Program action level of 100 milligrams per kilogram.

Fate and Transport

- Because of the persistence of TPH as Heavy Oils, its concentrations will only slow decrease over time in surface soils and groundwater although some migration in groundwater would be expected.

- The chlorinated hydrocarbons detected in groundwater are also associated with the release from the former UST. PCE was present in groundwater at roughly 0.25 percent of its aqueous solubility. Degradation products were also present which indicates that degradation of PCE is occurring. In comparison to concentrations established for these compounds in groundwater during the PA/SI, the concentrations of degradation products have increased. The increased concentrations of degradation products indicates that degradation of PCE is occurring as expected.

Baseline Risk Assessment

- ~~No COPC were identified for soil and sediment at the LARC 60 site while no exposure pathways or exposed populations were identified for contaminated groundwater and surface water located at the site. Therefore, no potential human health risk was identified due to contaminants present at the LARC 60 site.~~

- Because arsenic was detected in site soils at concentrations consistent with the background soils, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Therefore, upon removal of arsenic as a COPC, the risk levels become less than the criterion of 1.0 and 10^{-6}, and no further action related to the soils at this site (based on human health risk) is warranted. Additional studies in the form of a feasibility study are warranted for the groundwater risk associated with the site.

- No exposure pathways or exposed populations were identified for contaminated media at the site. Therefore, no potential ecological risk was identified due to contaminants present at the LARC 60 site.

Recommendations

~~***No Further Action*** is recommended for the LARC 60 site based on the limited contamination detected in the three AOCs, the trends which indicate that the TPH and VOC concentrations in soil and groundwater are decreasing due to numerous fate mechanisms and the results of the baseline risk assessment which did not identify receptors and potentially exposed populations.~~

Additional studies in the form of a feasibility study are warranted for the site due to the potential groundwater risk associated with the site due to the presence of various chlorinated organics at concentrations greater than the EPA RBCs and USEPA MCLs.

ES.4 AUTO CRAFT BUILDING AREA

An extensive field investigation program was conducted to acquire sufficient data quality to assess the nature and extent of contamination. A summary of the site description, nature and extent, fate and transport, risk assessment and recommendations for this site are provided as follows.

Site Description

- The Auto Craft Building is located in the sand flat area at the junction of Atlantic Avenue and Cebu Road.

- Two solvent dip tanks were used for the storage of spent degreasing solvents and waste oils when the building was in use. Previously, waste oil generated at the site was piped out of the building and into an adjacent UST. Prior to its use as the Auto Craft Building, the site was used as a motor pool for wheeled vehicles. The site is currently used as a vehicle impoundment area.

- Previous investigations included a PA/SI by James M. Montgomery which indicated the presence of several contaminants including metals and petroleum hydrocarbons.

Nature and Extent

- Acetone, methylene chloride, MEK, styrene, toluene and TCE were detected in numerous surface and subsurface soil samples collected at the site, however, at concentrations less than EPA screening criteria.

- TPH as Heavy Oils were detected in soils with concentrations decreasing with depth in the borings where TPH were detected. The lateral extent of TPH contamination is limited to the area adjacent to and northeast of the former building which are areas where surface transport of

contaminants during heavy precipitation events could occur.

- Chloroform was the only compound detected in groundwater above EPA risk screening criteria. No compounds were detected in soils above EPA risk screening criteria, however, TPH as Heavy Oils were detected above the Virginia UST Program action level of 100 milligrams per kilogram. Total arsenic and total iron exceeded the EPA RBCs for tap water in one DPT location each while total and dissolved iron and manganese exceeded the EPA RBCs for tap water in one monitoring well (7MW-3).

- Numerous metals were detected in soils with concentrations typically decreasing with depth. Arsenic, iron, and manganese concentrations exceeded the EPA RBCs for residential soils but were less than the EPA RBCs for industrial soils.

Fate and Transport

- TPH as Heavy Oils were detected in the shallow (1 to 4 feet) soils in the drainage swale north of the site. Because TPH as Heavy Oils adsorb very strongly onto soil and has a low aqueous solubility, the adsorbed compounds move with the soil/sediments during storm runoff into the drainage swale.

- In the groundwater system, the PA/SI detected TPH as Heavy Ends in well MW-119 at 0.7 *mg/l* but the RI sample for MW-119 did not contain detectable concentrations of any TPH compounds. Thus TPH as Heavy Oils persist in the soils, but is not leaching to groundwater.

- Chloroform was detected in the deep well (7MW-3) of the shallow/deep cluster downgradient of the former building location.

Baseline Risk Assessment

- ~~No COPC were identified for soil at the Auto Craft site while no exposure pathways or exposed populations were identified for contaminated groundwater located at the site. Therefore, no potential human health risk was identified due to contaminants present at the Auto Craft site.~~

- Because arsenic was detected in site soils at concentrations consistent with the background soils, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Chloroform was only detected in one groundwater sample at the site and in a concentration (11 ug/L) below the USEPA MCL for total trihalomethanes. Therefore, upon removal of arsenic and chloroform as COPCs, the risk levels become less than the criterion of 1.0 and 10^{-6}, and no further action related to this site (based on human health risk) is warranted.

- No exposure pathways or exposed populations were identified for contaminated media at the site. Therefore, no potential ecological risk was identified due to contaminants present at the Auto Craft site.

Recommendations

No Further Action is recommended for the Auto Craft site based on the limited contamination detected, the trends which indicate that the TPH concentrations in soil and groundwater are decreasing due to numerous fate mechanisms, that the chloroform concentrations although greater than the EPA RBC for tap water is less than the USEPA MCL, and the results of the baseline risk assessment which did not identify receptors and potentially exposed populations.

Malcolm Pirnie, Inc. was contracted by the U.S. Army Corps of Engineers (USACE), Baltimore District to conduct Remedial Investigations (RI) at three sites at Fort Story, Virginia under Contract DACA31-94-D-0017 including the Firefighter Training Area, the LARC 60 Maintenance Area, and the Auto Craft Building Area.

1.1 PURPOSE OF REPORT

The work was conducted under the requirements of the Department of Defense (DOD) Installation Restoration Program (IRP) which are consistent with the U.S. Environmental Protection Agency (EPA) guidelines. The EPA guidelines followed during the RI are set forth in "Guidance on Remedial Investigations and Feasibility Studies under CERCLA" (EPA, 1988a). All work was conducted in accordance with the Scopes of Services developed by the USACE with field investigation procedures further developed in the Final Work Plan, dated December 1994 and approved by the USACE.

The activities in the RI are geared towards collecting the information necessary to evaluate the type and magnitude of contamination as well as the transport mechanisms and impacts of contamination on various media such as surface water, groundwater, soil and sediment. The specific objectives of the RI were:

- Delineation of the nature and extent of contamination at each site.
- Evaluation of potential migration of contaminants.
- Assessment of risks to human health and the environment posed by each site.
- Development of recommendations for future action at each site based on the findings.

1.2 BACKGROUND

1.2.1 Facility Description and History

Fort Story is located in southeastern Virginia within the city of Virginia Beach, Virginia. Fort Story occupies an area of approximately 1,451 acres and is situated on Cape Henry which roughly divides the waters of the Chesapeake Bay to the north and the Atlantic Ocean to the east. **Figure 1-1** provides the location of Fort Story.

On 10 March 1914, the Virginia General Assembly ceded 343.1 acres, located at Cape Henry in Princess Anne County, to the U.S. Government "to erect fortifications and for other military purposes." On 14 June 1914, the U.S. District Court acquired title for the land by condemnation proceedings against the Cape Henry Syndicate and other landowners in the Cape Henry subdivision. War Department General Order No. 31, dated 24 July 1916, named this newly acquired tract of land Fort Story in honor of Major General John Patton Story.

Construction of powder magazines and projectile rooms was initiated during the latter part of 1916 and by February 1917, construction of the 16-inch howitzer fortifications had begun. Also, during February 1917, the 2nd and 5th Coast Artillery Companies established the military garrison at Fort Story. From 1917 through 1925, the installation continued to develop as a small coastal artillery garrison consisting of little more than its armament. The only land expansion which occurred during the period was the acquisition of 9.38 acres from the Norfolk and Southern Railway Company in March 1917.

During World War I, Fort Story was integrated into the Coast Defenses of Chesapeake Bay which included Fort Monroe (Headquarters) and Fort Wool (located at the east entrance of the Hampton Roads Bridge Tunnel). On 9 June 1925, Fort Story was designated a Harbor Defense Command by War Department General Order No. 13, but the change in designation added little to the dwindling post-war activity of the garrison.

As World War II approached, Fort Story began an extensive development. Many of the facilities which exist at Fort Story today were constructed at that time, and the installation increased in size to 1,439 acres. An additional 11.82 acres were acquired in 1963 which increased its size to its present 1,451 acres. In the 1940s, the construction included temporary artillery batteries, theater, chapel, fire station, mess halls, barracks, Officer and NCO clubs, shops, additional powder magazines and projectile rooms, six underground storage bunkers and 19 seacoast searchlights.

In December 1941, the Headquarters of the Harbor Defense Command was moved from Fort Monroe to Fort Story. Two harbor defense installations were added to the network in 1941; Fort John Curtis and a mine base. On March 1, 1944, the Chesapeake Bay sector of the Harbor Defenses was inactivated, and control passed to Headquarters, Southeastern Sector, Eastern Defense Command, Raleigh, North Carolina.

By September 1944, Fort Story began a transition from a heavily fortified coast artillery garrison to a convalescent hospital. At the time of its closing on 15 March 1946, the hospital had accommodated over 13,472 patients. At the closing of World War II, Fort Story again changed missions. It assumed the role which it still has today, to train units and individuals for amphibious operations. Fort Story was officially transferred to the Transportation Corps in July 1948 as a subpost of the Transportation Training Command, Fort Eustis, Virginia.

Fort Story trains army personnel in amphibious and Logistics Over-the-Shore (LOTS) operations. Fort Story is the only available facility which has the necessary natural terrain features and beaches, sand, surf, variable tide conditions (bay and ocean) and hinterlands, all of which are normally experienced by amphibious and LOTS operations. In addition, Fort Story contains beach training areas, tactical training areas and a series of trails throughout the installation. The deep water ship anchorage, off-road driving areas and soil of sufficient bearing strength for the heavy vehicles are indispensable in amphibious training, LOTS training and the testing of new equipment, doctrines and techniques.

1.2.2 Site Descriptions and History

Firefighter Training Area (FTSTY-04)

The Firefighter Training Area (FTA) is located in a sandy flat area situated adjacent to the northern flank of the central sand ridge in the southwestern section of Fort Story along Hospital Road and Hospital Circle. A former underground storage tank fuel farm was located adjacent to the southeast corner of the site. **Figure 1-2** provides the location of the site.

A temporary hospital facility was located on the site until 1960 when its operations were relocated and the structure demolished. From 1960 through 1978, the area adjacent to the southern boundary along U.S. Route 60 was used as a wildlife game preserve. The site was cleared and used for fire training exercises in the latter part of 1978. Prior to 1980, these exercises consisted of extinguishing JP-4 aviation fuel, which was released and ignited directly to the surface soils of the site. The releases were reportedly extinguished by a mixture of firefighting foam and water.

A concrete pit was constructed in 1980 and used for firefighting training exercises. The 40 foot square by 2 foot deep pit was used on a monthly basis. Procedures included:

- Filling the pit with several inches of water and 75 to 400 gallons of ignitable materials (i.e., JP-4, contaminated fuels and hydraulic fluid).
- Igniting the mixture and allowing it to burn.
- Extinguishing the fire with 50 to 150 gallons of firefighting foam.
- Allowing the residues of the fuel and extinguishing mixtures to evaporate naturally.

Additionally, during 1980 through 1986, many installation personnel reportedly used the area as an unauthorized dumping site. In June 1988, firefighting training activities were discontinued at this site. The site is currently free of any surface debris or surficial evidence of buried debris. The northern section of the site is currently used as a heavy equipment (i.e., front end loaders, trucks) operation training area while a ramp located in the southeast corner of the site is used for equipment loading and unloading.

LARC 60 Maintenance Area (FTSTY-06)

The Lighter Amphibious Resupply Cargo (LARC) 60 Maintenance Area, which is the maintenance and wash rack area for LARC 60 vehicles, is located in the sand flat area that lies between the coastal dune complex to the north and the central sand ridge to the south. The LARC 60 area includes Buildings 1081, 1082, 1083 and 1084. The location of the site is provided on **Figure 1-2**.

During the 1950s, the wash rack area was first used as the barge amphibious resupply cargo (BARC) motor pool and maintenance facility. In 1964, the BARC vehicle was phased out and the LARC 60 vehicle was prototyped. Presently, Fort Story is the only base on the East Coast available to the Army Transportation Corps for amphibious training.

In 1982, the LARC 60 facility was modified with the construction of a concrete wash rack pad. Approximately 39 catch basins are located through the LARC 60 site which are used for collection of storm and wash water. In 1987, the U.S. Army Environmental Hygiene Agency (USAEHA, 1987) conducted a study at the site and concluded that the soil north of the wash rack (Sandbox Area) was contaminated with grease, oil, lead and chromium but that this contaminated material did not pose a significant health hazard. Heavy equipment are currently stored awaiting maintenance and operated on the concrete wash rack and Sandbox Area.

A former 10,000-gallon underground storage tank (UST) was located at the north gate of the LARC 60 vehicle motor pool approximately 600 feet south of the wash rack area. This UST was installed in 1983 and used for waste oil and degreaser storage. Although James M. Montgomery, Inc.'s (JMM) April 1990 field visits to this area identified soil-stained zones around the UST, no reports of tank failing or leaking have been documented. These soil-stained areas may have been caused by overfilling or spillage during use. In 1987, the USAEHA sampled the UST and found it contained oil, water, 1,1,1-trichloroethane and chromium.

Auto Craft Building Area (FTSTY-07)

The Auto Craft Building is located in the sand flat area south of the coastal dune complex at the junction of Atlantic Avenue and Cebu Road. The location of the site is provided on **Figure 1-2**.

Two solvent dip tanks were used for the storage of spent degreasing solvents and waste oils when the building was in use. Previously, waste oil generated at the site was piped out of the building and into the adjacent UST. The UST has subsequently been removed.

Prior to its use as the Auto Craft Building, the site was used as a motor pool for wheeled vehicles. During the winter of 1989 and 1990, a portion of the building was destroyed by fire. A portion of the building's concrete foundation and some debris remain in the area. A previous investigation indicated that waste solvents were poured directly on the ground to control weed growth along the fence surrounding the site. A visual inspection by JMM in 1990 verified the presence of an apparent petroleum-based product around the area and distinctive petroleum odor at the site. The site is currently used as a vehicle impoundment area.

1.2.3 Previous Investigations

A summary of previous investigations conducted at the three sites is provided below.

JMM Preliminary Assessment/Site Investigation

Preliminary assessment/site investigation (PA/SI) activities were conducted in 1991 and 1992 by James M. Montgomery, Inc. (JMM, 1992). JMM conducted the PA/SI to determine the presence of significant contamination at eight sites including the following:

- Landfill 1
- Landfill 2
- Firefighter Training Area
- Underground Fuel Storage Tank Farm
- LARC 60 Maintenance Area
- Auto Craft Building Area
- Drainage Outfall Line
- NIKE Facility

For the eight sites investigated by JMM, three were recommended for no further action: Landfill 1, Drainage Youthful Line and the NIKE Facility. Further confirmatory investigation was recommended at Landfill 2. A remedial investigation/feasibility study (RI/FS) was recommended at the remaining four sites: FTA, Underground Fuel Storage Tanks, LARC 60 area and Auto Craft Building. The Underground Fuel Storage Tanks were removed in October 1994.

A summary of site-specific investigations and findings are provided as follows:

Firefighter Training Area

Soil gas samples were collected at the intersections of a 100-foot by 100-foot grid having seven rows and six columns. Results of the survey indicate that potentially contaminated areas of the site include the north central site location, as indicated by detectable levels of benzene, and the extreme southeastern corner of the site, as indicated by elevated levels of benzene, 1,1,1-trichloroethane (1,1,1-TCA) and total hydrocarbons.

Several analytes were detected in soil samples at levels above the trigger levels. Media-specific trigger levels were developed for each of the analytes detected. The trigger levels were based on statistically significant site background data and regulatory standards promulgated by the U.S. EPA or the Commonwealth of Virginia for the chemicals of concern. The highest concentration was associated with the area adjacent to the fire training pit (FTP), as well as an area located in the southeast corner of the site. Total fuel hydrocarbons, copper, and lead were detected above trigger levels at the site. Numerous analytes without trigger levels were detected at the site including xylenes and numerous semivolatiles.

As with soil samples, numerous analytes were detected in groundwater above trigger levels with the major areas of contamination associated with the FTP and the southeast corner of the site. Benzene, total fuel hydrocarbons, phenol, 1,2-dichloroethane (1,2-DCA), 1,1,1-TCA and 1,1-

dichloroethene (1,1-DCE) were detected above trigger levels.

LARC 60 Maintenance Area

Several analytes were detected in soil at levels above the trigger levels. The site has two main areas of possible environmental concern: the wash rack area where the LARCs are parked which has an oil/water separator and the former UST area. Total fuel hydrocarbons, copper, zinc, and lead were detected above trigger levels at the site.

As with soil samples, numerous analytes were detected in groundwater above trigger levels at the wash rack and UST areas. Benzene, vinyl chloride, total fuel hydrocarbons, and 1,1-DCE were detected above trigger levels.

Auto Craft Building Area

Several analytes were detected in soil at levels above the trigger levels. Total fuel hydrocarbons, zinc, and lead were detected above trigger levels at the site. Total fuel hydrocarbons was the only analyte detected above trigger levels in groundwater.

IT Removal Actions

IT Corporation (IT, 1994) conducted several rapid response removal actions at several sites at Fort Story in 1994. Their removal actions consisted of the following:

Firefighter Training Area

- Removal and disposal of water contained in the Fire Training Pit (FTP). This water was removed by a vacuum truck and disposed of by PetroChem, Inc. of Norfolk, Virginia. Approximately 6,800 gallons of water was removed and disposed of as oil-contaminated.

- Removal and containerization of FTP materials including concrete, electrical parts and miscellaneous debris. The concrete FTP was approximately 40 feet by 40 feet with a 20-foot square gravel pit on the interior. The interior pit was approximately 4 feet deep with 2 feet of gravel at the surface of the pit. The gravel was removed and placed on the concrete apron and then pressure washed to remove any residual fuel or petroleum contamination. The wash water was collected with a vacuum truck and disposed of by PetroChem. The concrete, gravel and miscellaneous material was loaded into five rolloffs (approximately 100 cubic yards) and transported to the BFI landfill in Chesapeake, Virginia.

- Excavation of the contaminated soil surrounding the concrete pad of the FTP until a Total Petroleum Hydrocarbon (TPH) action level of 50 parts per million (ppm) was met. Approximately 550 tons of soil was excavated and staged at the site in three bermed holding cells on 6 mil polyethylene.

- Transportation of the excavated soils to the LARC 60 area for treatment.

- Backfilling of the excavation with clean gravel. A total of 547 tons of stone was placed as backfill in the excavated pit and the area was regraded. An additional area approximately 40 feet long by 5 feet wide was excavated on the eastern edge of the area due to high TPH concentrations detected during confirmation sampling. This soil was transported to the LARC 60 for treatment.

LARC 60 Area

- Disposal off-site of two piles of soil previously stockpiled adjacent to the LARC 60 area which were believed to contain F-listed solvents.

- Design and installation of an in-situ bioremediation system for the treatment of TPH-contaminated soils. A portable holding pool was constructed to contain the inoculant prepared by Solutions Laboratory of Chesapeake, Virginia to be used in the bioremediation process. The pool was 40 foot by 100 foot consisting of a steel frame and a plastic liner to contain approximately 120,000 gallons of water.

- Excavation and treatment of the soil within the LARC 60 Sandbox and the soils from the FTP to a TPH level of less than 50 ppm. The soils were transferred to the pool for treatment. The soil was mixed and aerated using a slurry pump. After sufficient mixing and retention, the slurry was pumped from the pool into holding pits. However, this process was abandoned when mixing and pumping of the soil in the pool became too difficult due to debris passing through the screening operation. Pits were then excavated with the inoculant transferred to the pits through trenches from the holding pool. The contaminated soils were then placed in the pits and mixed with the inoculant by an excavator and the slurry pumps. The slurry was then pumped from the pit to a stockpile area to drain. The soil was transported to another stockpile to be analyzed prior to being placed in an excavated area.

- Placement of the "clean" soils back in the excavated areas. However, due to the presence of heavy oils and greases in the soils, the 50 ppm treatment goal could not be reached with the bioremediation process. TPH concentrations remaining in treated soils ranged from non-detect to 4,800 ppm with an average concentration of 229 ppm (by Method 8015) and 751 ppm (by EPA Method 418.1) remaining in soils.

USACE, Norfolk District UST Investigation

In February 1995, Environmental Technology of North America, through a USACE, Norfolk District contract, collected soil and groundwater samples by direct push technology (DPT) from the former UST pit at the southern end of the LARC 60 site to determine groundwater quality in that location. A copy of the report is provided in Appendix G. TPH, toluene, ethylbenzene and xylene were detected in soils from the pit and from stockpiled soils. Numerous chlorinated organics were detected in the groundwater sample including TPH (180 mg/l), tetrachloroethene (2,700 *ug/l*),

trichloroethene (8,800 *ug/l*), and cis 1,2-dichloroethene (5,200 *ug/l*).

1.3 REPORT ORGANIZATION

A summary of the organizational format of the RI report is provided as follows:

Volume I

- **Section 1.0** addresses the **Introduction** to the report, provides background information including site descriptions and history and provides a discussion of previous investigations and provides the report organization.
- **Section 2.0** summarizes the **Field Investigation Procedures** at the three sites including a discussion of soil boring and monitoring well installations, direct push technology (DPT) sampling of soil and groundwater, environmental sampling, site surveying, tidal influence testing, and on-site analytical services.
- **Section 3.0** describes the **Physical Characteristics** of Fort Story and each site including geology/hydrogeology, climatology, ecology, and topography.
- **Section 4.0** discusses the **Nature and Extent of Contamination** detected at each site. A discussion of potential applicable or relevant and appropriate requirements (ARARs) is also provided.
- **Section 5.0** discusses the **Fate and Transport** mechanisms for contaminants at each site. Potential routes of transport, contaminant persistence and contaminant migration is discussed.
- **Section 6.0** presents the methodologies and results of the **Human Health Risk Assessment**.
- **Section 7.0** presents the methodologies and results of the **Ecological Risk Assessment**.
- **Section 8.0** presents the **Summary and Conclusions** of the investigation including the nature and extent of contamination and the assessment of human health and environmental risk.
- **Section 9.0** presents the **Recommendations** for each site.

Volume II

Appendices are provided with this report and include the following:

- Appendix A – References
- Appendix B - Geologic and Well Data
- Appendix C - Sampling Forms
- Appendix D - Site Surveying Report
- Appendix E - On-site GC Analysis Data

- Appendix F - Fort Story Map
- Appendix G - ETI Report
- Appendix H - Background Soils Data
- Appendix I – Human Health Risk Calculations
- Appendix J – Toxicity Profiles: Human Health Risk Assessment
- Appendix K – Toxicity Profiles: Ecological Risk Assessment
- Appendix L – Wildlife Species of the Fort Story/Cape Henry Region
- Appendix M – Ecological Risk Assessment Exposure Calculations

This section documents specific field investigation program for the Remedial Investigation (RI) at three sites at Fort Story. Field investigation procedures, sampling locations, analytical requirements, field documentation requirements, data quality objectives, and health and safety procedures were presented in the following USACE-approved documents: The initial investigations were conducted in 1995 while the re-sampling of select monitoring wells and additional surface soil sample collections were conducted in 2000.

- *Final Field Investigation Plan, Remedial Investigation for Fort Story, Virginia* (FIP), (Malcolm Pirnie, 1994a).

- *Final Chemical Data Acquisition Plan, Remedial Investigation for Fort Story, Virginia* (CDAP), (Malcolm Pirnie, 1994b).

- *Final Site Safety and Health Plan, Remedial Investigation for Fort Story, Virginia* (SSHP), (Malcolm Pirnie, 1994c).

An overview of the field program including data gaps and needs is presented in Section 2.1, detailed field investigation procedures are described in Section 2.2, a summary of field investigations performed at each site is provided in Section 2.3, and a summary of changes to the field investigation program and rationale is provided in Section 2.4.

2.1 FIELD INVESTIGATION OVERVIEW

To better define data gaps and establish a comprehensive field investigation approach, an assessment of the existing database as it relates to the nature and extent of contamination and support of the risk assessment was necessary. The identification of data needs based on the uses and decisions we made were critical in establishing the field investigation approach for the project. These data needs focused on the following:

- Establishing background data.

- Determining the extent of surficial/subsurface soil contamination on-site.

- Evaluating the potential migration of contaminants from source soils to groundwater on-site and downgradient of the site.

- Evaluating the potential migration of contaminants from source soils to surface water and sediment to on-site and downgradient receptors.

Based on a review of existing data and the data quality objectives for the project, the data gaps identified for the field investigation are summarized as follows:

Firefighter Training Area

- The vertical and lateral extent of contamination in soils and groundwater at the Fire Training Pit, solvent plume area and northern area of the site has not been established.
- The vertical and lateral extent of contamination in groundwater downgradient of the site has not been established.
- Presence/absence of contamination in other media such as sediments and surface water has not been determined.
- Impacts to human health and the environment through exposure to contaminants has not been evaluated.

LARC 60 Maintenance Area

- The vertical and lateral extent of contamination in soils and groundwater at the UST, oil/water separator and sand box areas has not been established.
- The vertical and lateral extent of contamination in groundwater downgradient of each area at the site has not been established.
- Presence/absence of contamination in other media such as sediments and surface water has not been determined.
- Presence/absence of free-product and DNAPL in the area of the former UST.
- Impacts to human health and the environment through exposure to contaminants has not been evaluated.

Auto Craft Building Area

- The vertical and lateral extent of contamination in soils and groundwater at the site has not been established.
- The vertical and lateral extent of contamination in groundwater downgradient of the site has not been established.
- Impacts to human health and the environment through exposure to contaminants has not been evaluated.

Based on a review of the data gaps listed above, the data needs that were identified for the field investigation are summarized as follows:

- Vertical extent of soil contamination at each site will be addressed by the installation of soil borings with samples collected at three depths.

- Vertical and lateral extent of on-site and downgradient groundwater contamination at each site will be addressed by the collection of groundwater samples from DPT points, DPT temporary well points and permanent monitoring wells.

- Presence/absence of contamination in other media such as sediment and surface water at the FTA and LARC sites will be addressed with the collection of numerous samples for these media.

- Impacts to human health and the environment through exposure to contaminants will be evaluated through the performance of a baseline risk assessment at each site.

2.2 FIELD INVESTIGATION PROCEDURES

2.2.1 Soil Borings

Piezocone

A direct push technology (DPT) rig equipped with a piezocone was used to provide real-time geotechnical data. A schematic of the piezocone is provided on **Figure 2-1**. The DPT rig used hydraulic pressure to push the piezocone into the formation to be investigated. No cuttings were generated and no foreign substances were permanently introduced into the sampling zone during the procedure. Use of the DPT and piezocone was governed by ASTM Standard 3441. The data from the piezocone was continuously fed into the on-board computer, and a standardized soil type was generated for the formation through which the piezocone passed. This information was viewed on the computer's monitor in real-time and documented on a computer-generated piezocone data form. The geotechnical information (depth, tip resistance, tip friction, pore pressure and inclination) generated on site by the piezocone was calibrated to provide stratigraphic information for each site by collecting a continuous core sample adjacent to one of the piezocone soundings and adjusting the standardized soil type descriptions to match the log from the core sample. Sounding data from the piezocones are provided in **Appendix B.**

The soils recovered from borings for calibration to piezocone logs were logged in accordance with the Unified Soil Classification System (USCS) in accordance with the USACE Borehole Logging Requirements. Information generated during the boring process were recorded on field boring logs. These boring logs are provided in **Appendix B**.

Soil Sampling

Surface Soil Samples

Hand augers were used to collect the surface sample from the soil borings. Surface soil samples were collected to a depth of twelve inches below ground surface. The samples were collected with a stainless steel hand auger. Aliquots for volatile organic compound (VOC) and TPH light analysis were taken directly from the hand auger, packed tightly into 125 ml amber glass containers, and immediately stored at 4°C. With the exception of VOC and TPH light samples, soil samples were homogenized by first removing rocks, twigs, leaves and other debris. The soil was then removed from the sampling device, placed in a decontaminated stainless steel bowl, and thoroughly mixed using a stainless steel spoon. The samples were collected in the following order: VOCs, TPH light, semivolatile organics (SVOCs), TPH heavy and inorganics. After mixing, a portion of the sample was placed in each sample container. The sample containers were then labeled, added to the chain-of-custody and stored at 4°C for shipping to the laboratory. Sampling forms for all sampling tasks are provided in **Appendix C**.

Subsurface Soil Samples

A DPT rig equipped with a soil sampler was used to collect soil samples from deeper subsurface depths. For collecting discrete soil samples, the tip was advanced to the top of the interval to be sampled. The tip was retracted and the sampler (2 foot split spoon) was pushed through the desired interval to collect the sample. **Figure 2-2** provides a schematic of the DPT soil sampler. The sampler was withdrawn from the push rods. The soil samples obtained from each split spoon were screened with a photoionization detector (PID) for VOCs.

For any boreholes in which refusal occurred, samples were obtained by relocating the DPT rig approximately two feet from the original location. The DPT rig was relocated up to three times to obtain a sample. If the sample was not retrieved an alternate boring location was selected typically within 10 feet of the original point.

Aliquots for VOCs and TPH light analysis were taken directly from the soil sampler, packed tightly into 125 ml amber glass containers and stored at 4°C. Prior to placement into the sample jars, all soil not requiring VOC or TPH light analysis were homogenized as described above.

Upon completion of the soil sampling, each borehole was allowed to cave in on itself due to the sandy soils present.

2.2.2 Surface Water Sampling

Field information (e.g., pH, conductivity, temperature) was recorded for the surface water. Surface water samples were collected by immersion of a dipper jar which was decontaminated prior to collecting each sample. The surface water was then poured into the sample containers starting with the VOC and TPH light containers. The sample containers were then labeled, added to the chain-of-

custody and stored at 4°C for shipping to the laboratory.

2.2.3 Sediment Sampling

Sediment samples were collected using a decontaminated stainless steel auger or scoop following surface water sampling. Sampling was conducted in a downstream-to-upstream order to limit disturbance of sediments upstream of a sample location. The transfer of sediment, sample container management and container storage is the same as described for surface soils in Section 2.1.1.2.

2.2.4 DPT Groundwater Sampling

Following completion of the soil boring to the desired depth by the DPT rig, groundwater samples were collected for on-site GC analysis and/or off-site laboratory analysis. Sampling of groundwater at each location did not require well development. For collecting discrete groundwater samples, the tip was advanced below the water table to the bottom of the interval to be sampled. The push rod was retracted exposing a 0.005 inch slotted stainless steel screen. **Figure 2-3** provides a schematic of the DPT groundwater screen. After exposing the screen and allowing the water table to rise to a stable level based on water level indicator readings, VOC and TPH light samples were collected from the push rod using a 0.75-inch outside diameter (O.D.) bailer while a peristaltic pump with dedicated flexible tygon tubing was used to collect all other parameter groups.

Field pH, conductivity, and temperature readings were measured. Groundwater samples for VOC and TPH light analyses were then collected, followed by SVOC, TPH heavy and then inorganic analytes. VOC and TPH light samples were placed in three hydrochloric acid-preserved 40-ml vials filled completely to the top with no air gaps or bubbles present. SVOC and TPH heavy samples were placed in unpreserved 1-liter amber glass bottles while cyanide samples were placed in sodium hydroxide-preserved 500-ml polyethylene containers, mercury samples were placed in nitric acid-preserved 130-ml glass bottles, and other metals were placed in nitric acid-preserved 500-ml polyethylene bottles. All samples were placed in a cooler at 4°C and made ready for shipment to the laboratory. For most DPT groundwater samples, on-site GC analysis was conducted for select VOCs and TPH light.

2.2.5 Monitoring Well Installation

Monitoring wells were installed using a 4 1/4-inch inside diameter (I.D.) hollow stem augers. The augers were advanced either by a truck-mounted or all-terrain vehicle (ATV) drilling rig depending upon the ground surface conditions. Each monitoring well was constructed in accordance with the RCRA Groundwater Monitoring Technical Enforcement Guidance Document (TEGD) and the U.S. Army Corps of Engineers Engineering and Design, Monitoring Well Installation at Hazardous and Toxic Waste Sites, EM MO-7-XX (FR).

Each monitoring well was installed through the hollow stem augers and was constructed of 2-inch I.D., flush-threaded PVC well screen and riser. A 10-foot screen was used for the monitoring wells. The well screen was constructed of 0.010 inch slot size to minimize the intrusion of finer materials.

A Morie Number 1 Filter Sand was placed in the annulus around the well screen as the sandpack to provide a filter zone. The sandpack was placed 2 feet above the top of the well screen. A minimum of 1 foot of bentonite seal was then placed above the sandpack while the remainder of the annular space was cement grouted to the surface. Each well was flush mounted and constructed with a protective manhole. **Figure 2-4** provides a schematic of the flush-mounted well design used at Fort Story. Well construction data for each well are provided in **Appendix D**.

A more detailed description of the installation procedure is provided as follows:

- The hollow stem auger was slowly advanced to the desired depth.

- The screen and riser pipe was assembled and lowered within the hollow stem augers. The well was suspended several inches off the bottom of the boring to ensure that the casing is not bowed during installation.

- After the screen and riser pipe were in place, a sandpack was placed in the annular space to 2 feet above the top of the screen. As the sandpack was being poured into the annular space, the hollow stem augers in the borehole were simultaneously withdrawn, to prevent the sandpack from becoming jammed (bridged) between the well casing and hollow stem augers.

- A bentonite seal with a minimum thickness of 1 foot was then placed above the top of the screen (on top of the sandpack) to maintain a discrete sampling interval. It is important to seal the annulus to prevent water flow along a higher permeability zone in this space. This flow could alter the measured contamination.

- A bentonite/cement seal was then placed on top of the bentonite seal and extended to within about 12 inches of the ground surface.

- A flush-mounted meter box assembly was installed over the well. The flush mount construction consisted of a concrete pad sloping in all directions away from the well casing to prevent standing water from entering the well. The well casing was truncated just below ground level and enclosed in a steel meter box equipped with a steel flush-mounted manhole cover.

Temporary well points were installed at the LARC 60 site to assess the presence of free-product/DNAPL at the former UST area. Their installation was similar to the monitoring well installation except a bentonite seal was placed from 1 foot above the top of the screen to the surface. No cement seal or concrete pad/protective casing was used for final construction. A locking cap was placed on the top of the casing.

2.2.6 Monitoring Well Development

Well development included the overpumping and backwashing method. Overpumping was accomplished by using a submersible pump or by hand bailing. Surging was accomplished by using a surge block and backwashing by air-lift technologies. These methods of development consisted of alternately pumping the well at a high rate to draw the water level down and then "backwashing," reversing the flow direction so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack served to remove fines from the formation while preventing bridging (wedging) of sand grains. Backwashing was accomplished by starting and stopping the equipment intermittently to cause the water level to fluctuate. Wells were considered developed when turbidity, pH, specific conductance and temperature stabilized for a minimum of three readings and all were within 10 percent of the previous two readings. Well development data are provided in **Appendix B**.

2.2.7 Monitoring Well Sampling

1995 Sampling Event - Monitoring Well Sampling Protocol

Following monitoring well installation and development, groundwater samples were collected from monitoring wells for off-site laboratory analysis. Sampling of groundwater at each well location began no sooner than 14 days following well development. Each well was purged of at least three to five well volumes prior to collecting groundwater samples. The volume of standing water in the borehole was calculated using the pre-purge water level, total depth of the well and a constant for the number of gallons of water per foot of well diameter.

After purging, groundwater samples were collected when the water level in the well had sufficiently recovered to a minimum of 75 percent of the pre-purge level. Field pH, conductivity, temperature, and turbidity was measured for each well volume during purging in order to obtain a representative sample from the aquifer, where field parameters reached equilibrium as discussed above, samples were collected. Purging of the monitoring wells was conducted using a disposable PVC bailer. Samples were then collected using a disposable teflon bailer. Following collection of the VOC and TPH light samples first, followed by the SVOC, TPH heavy, and total inorganic samples (where required), the groundwater samples were filtered through a disposable filtration system equipped with a 45-micron size filter to obtain dissolved inorganic samples. After collection and transfer to the appropriate sample container, the samples were secured in a cooler at 4°C and made ready for shipment to the laboratory.

2000 Sampling Event - Monitoring Well Sampling Protocol

Dedicated QED well pumps were installed in select wells at the three sites for the 2000 sampling event. These well pumps were installed so that more representative groundwater samples (free of excess solids) could be collected and the data analyzed.

Each well was purged of three well volumes (or more if required for stabilization of field parameters)

contaminants from the site to the ecosystems of concern are discussed, and potential ecological effects are summarized.

7.2.1 Ecosystems of Concern

Firefighter Training Area

Site Description

The FTA site has been highly disturbed by past activities such as the existence of a hospital, firefighting activities, and current activities such as heavy equipment operation training. The woods adjacent to the site are used for infantry training and several small burned areas are evident. Additionally, since 1995, approximately 12,000 square feet of the site has been used for land farming of contaminated soil from an adjacent UST excavation. These soils are contaminated with several VOCs and the contaminants are being allowed to volatilize naturally. An impermeable liner was placed underneath and around the soil so that contaminants could not migrate from the land farming area.

Flora and Fauna

In April 1996, Malcolm Pirnie biologists conducted an inventory of vegetative species occurring within and adjacent to the site. The former Fire Training Pit has been dismantled and is currently covered by gravel. A few weed species grow through the gravel. The remaining southern end of the site is covered with low-growing vegetative species thriving in a sandy soil environment. The northern end of the site has sandy soil and is primarily unvegetated. Pine forests border the site on the west and south, with a road and a vegetated berm separating the forest from the site. A low area occurs in the forest to the south of the site, but standing water does not usually collect in the area. The woods contain several tall-vegetated sand dunes and run south and west to Shore Drive. Dominant vegetation at the former FTA site is listed in Table 7-1.

Indicators and observations of wildlife usage in the FTA site included the following: Eastern Cottontail (*Sylvilagus floridanus*), Eastern Bluebird (*Sialis sialis*), and the European Starling (*Sturnus vulgaris*). Greater Yellowlegs (*Tringa melanoleuca*) were observed foraging in a temporary pool immediately adjacent to the land farming area. Observations of wildlife usage in the wooded area adjacent to the site included the following: Raccoon (*Procyon lotor*), Common Mole (*Condylura cristata*), Gray Squirrel (*Sciurus carolinensis*), Blue-gray Gnatcatcher (*Polioptila coerulea*), Killdeer (*Charadrius vociferus*), Pine Warbler (*Dendroica discolor*), and Cardinal (*Richmondena cardinalis*). A detailed list of wildlife species expected to occur in the vicinity of Fort Story is included as Appendix L.

LARC 60 Maintenance Area

Site Description

The LARC 60 site is an active heavy equipment maintenance and operation area which includes three subsites: the Sandbox and adjacent wash rack, an oil/water separator, and a former UST area. Because the majority of the site is covered with asphalt, concrete, or has little to no vegetative cover, there are limited habitats for wildlife. The Sandbox is an unvegetated sandy area that is used as a heavy equipment operating area. A small wooded island occurs within the western end of the Sandbox. A chain link fence borders the northern end of the Sandbox, and a mixed pine/deciduous forest is located beyond the fence. There is a drainage ditch immediately north of the fence which collects storm water runoff from the Sandbox, the adjacent wash rack, and the wooded area. The oil/water separator is located at the west end of Building 1083 and is surrounded by asphalt paving. This area would not be attractive to wildlife. The former UST area is covered with gravel and sand and a few weedy species. The remaining area between the subsites is covered with buildings, asphalt, or concrete pavement. Wildlife species most frequently associated with the site would probably nest in the wooded area to the north of the Sandbox or to the west of the former UST site. Because of the proximity of the sites and similar lack of vegetation, the three subsites were assessed together.

Flora and Fauna

In April 1996, Malcolm Pirnie biologists conducted an inventory of vegetative species occurring within and immediately adjacent to the LARC 60 site. A few weedy species grow on the sand and gravel surface of the former UST area. These species are listed in Table 7-2. Similar vegetative species occur in the woodlands surrounding the site and in the wooded island in the Sandbox. The areas are predominantly covered by pines, Live Oak, and Water Oak. The dominant vegetative species are also included in Table 7-2.

Indicators and observations of wildlife usage of the LARC 60 site, adjacent wooded area, and adjacent drainage ditch include the following: Bobwhite (*Colinus virginianus*), Green-backed Heron (*Butorides virescens*), Cardinal (*Richmondena cardinalis*), American Crow (*Corvus brachyrhynchos*), Mallard (*Anas platyrhynchos*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), Common Grackle (*Quiscalus quiscula*), House Finch (*Carpodacus mexicanus*), and Brown-headed Nuthatch (*Sitta pusilla*).

Auto Craft Building Area

Site Description

The Auto Craft Site contains a small building and an asphalt parking lot completely enclosed by a chain link fence. A small weeded area now marks a former building, which was partially

destroyed by fire, then dismantled. Downgradient of the site, between the site and Atlantic Avenue, lies a small grassy area. No wetlands or streams are located in the vicinity of the site.

Flora and Fauna

In April 1996, Malcolm Pirnie biologists conducted a vegetative inventory of the species occurring within the area. The few vegetative species occurring within the fenced area and the dominant grassy species occurring downgradient of the site are listed in Table 7-3. In addition, the species in the wooded area to the east of the site are listed. Because of the lack of vegetative species within the site itself, it is likely that wildlife will forage and nest within the adjacent wooded area.

Indicators and observations of wildlife within and adjacent to the site include the following: Common Grackle (*Quiscalus quiscula*), Mourning Dove (*Zenaidura macroura*), Killdeer (*Charadrius vociferus*), House Wren (*Troglodytes aedon*), Blue-grey Gnatcatcher (*Polioptila coerulea*), American Crow (*Corvus brachyrhynchos*), White-throated Sparrow (*Zonotrichia albicollis*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), and Common Mole (*Condylura cristata*).

7.2.2 Threatened and Endangered Species

According to the Natural Heritage Listing, dated May 1995, three endangered species are known to occur in Virginia Beach (Horne Engineering Services, 1995). They are the Bald Eagle (*Haliaeetus leucocephalus*), Dismal Swamp Shrew (*Sorex longirostris fisheri*), and the Loggerhead Sea Turtle (*Caretta caretta*).

There is no suitable habitat or nesting area for these three species in or adjacent to the three sites. The Bald Eagle nests along inland waters and the Chesapeake Bay in relatively secluded areas. It requires large snags for perching and roosting, which do not occur within or near the sites. The Dismal Swamp Shrew is found in swampy forests near the interior waters of Virginia Beach and closer to the Dismal Swamp area of the City of Chesapeake, Virginia. The sandy coastal areas of the FTA site are not suitable habitat for the Dismal Swamp Shrew. The Loggerhead Turtle is known to nest along the beach areas of Virginia Beach. Each site is in developed areas, at least 1,200 feet from the Chesapeake Bay. Therefore, the turtle would not nest in any of the sites.

7.3 POTENTIAL STRESSORS, EXPOSURE PATHWAYS AND ECOLOGICAL EFFECTS

The next step in problem formulation involves the identification of the interrelationships between potential stressors, exposure pathways, and ecological effects for the identified ecosystems of concern. Chemical and/or physical stressors are identified, potential pathways for migration of contaminants from the site to the ecosystems of concern are discussed, and potential ecological effects are summarized.

Contaminants in surface soil and sediment samples were compared to USEPA Region III Biological Technical Assistance Group (BTAG) Screening Levels for Ecological Risks (USEPA, 1995) (Table 7-4). Contaminants detected in sediments were also compared to current Federal regional guidelines. Contaminants detected in surface water were compared with available Federal and Virginia standards to determine which chemicals may be of concern with respect to target wildlife receptors. Virginia State Surface Water (Freshwater) Quality Standards, USEPA Region III BTAG Screening Levels for Aquatics in Surface Water (USEPA, 1995), and USEPA Ambient Water Quality Criteria for chronic effects in fresh water (USEPA, 1991) were utilized (Table 7-5).

The range, mean and maximum soil and sediment concentrations of metals at the sites were also compared with the 95th UCL background concentrations analyzed at Fort Story and the observed range and mean USGS regional background concentrations. Site-specific and regional background values are presented in Table 7-6 and in Appendix H. VOCs, SVOCs, Pesticides, and TPHs were chosen as contaminants of potential concern (COPC) if EPA Region III BTAG screening criteria (screening criteria) were exceeded or lacking. Inorganics were chosen as contamints of potential concern if EPA Region III BTAG screening criteria and site-specific and regional background values (background) were exceeded. Some metals exceeded screening criteria but were lower than measured background levels. These contaminants were not selected as contaminants of potential concern. Minerals detected, such as calcium, sodium, potassium, and magnesium are naturally occurring components of soil, sediment and water. Therefore, they are not considered to be potentially of concern. Sample results for the three sites compared to applicable screening criteria and background concentrations are presented in Tables 7-7 through 7-12.

7.3.1 Potential Stressors

FTA Site

Both physical and chemical stressors do exist at the FTA site and in the surrounding wooded area. Physical stress is caused by the training activities in the area and former use of the site. These activities have prevented the revegetation of the northern end of the site and caused small burned areas in the woods. However, the physical disturbance occurs in a small area and chances of the physical stressor adversely effecting the surrounding areas and wildlife is minimal and is not considered long-term. Therefore, the physical stressors will not be addressed further in this assessment.

A detailed description of the extent of sampling conducted at the Site and full results are provided in Sections 2 and 4 of this report, respectively. Soil samples were taken in the northern area where stained soils were present, in the Former Fire Training Pit area, and in the Solvent Plume Area associated with the adjacent UST site. Sediment samples were taken within the drainage area in the woods located south of the site. No surface water was associated with the site.

Surface Soils

A total of 28 soil samples were analyzed for VOC, SVOC and TPH contamination. Sampling locations are depicted in Figure 2-6. Toluene was detected in 25 of the 28 samples and was found to exceed the EPA Region III BTAG screening criteria in 1 of the samples. This sample was taken from the southeastern end of the site near the former UST area. Therefore, toluene was retained as a COPC. Acetone, methyl ethyl ketone, and xylenes were also detected in the samples, and lacked screening criteria. These compounds, except for acetone, were found at low frequency (i.e., < 5% frequency) and at low levels and were therefore, not considered to be of concern. Acetone lacks EPA Region III BTAG screening criteria and was retained as a COPC.

Of the SVOCs detected in the samples, fluoranthene and pyrene values exceeded screening criteria. Each was detected in 2 samples and exceeded screening criteria in 1. This sample was taken from the southeastern edge of the site, adjacent to the road. These contaminants were retained as COPCs. Bis(2-EH)phthalate and di-n-butylphthalate lacked screening criteria but were detected at low frequency. Therefore, they were not considered of concern. Total Petroleum Hydrocarbons (TPH) as heavy oils was detected in 3 samples; the highest being from the southeastern edge of the site, immediately north of the road. Polycyclic Aromatic Hydrocarbons (PAHs), more toxic components of TPH, were not detected at levels which exceeded screening criteria in samples which contained TPH. Therefore, due to the low frequency of detection and absence of detection of its components, TPH as heavy oils was not retained as a COPC.

A total of 5 soil samples were analyzed for contamination of metals. Minerals detected, such as calcium, sodium, potassium, and magnesium are naturally occurring components of soil, sediment and water. Therefore, they were not considered to be potentially of concern. Several metals were detected with high frequency at levels that exceeded screening criteria. These metals included chromium, iron, and lead. Aluminum, arsenic, copper, and zinc lacked screening criteria. Concentrations of aluminum, arsenic, and iron detected were consistent with measured site-specific and/or USGS regional background concentrations. Concentrations of chromium detected were within USGS regional background concentrations but exceeded site specific background concentrations. Contaminants that exceeded or lacked criteria values and background concentrations were retained as contaminants of potential concern. Therefore, chromium, copper, lead and zinc were considered a COPC in surface soils at the FTA site.

The compounds chosen as contaminants of potential concern for surface soils for the FTA Ecological Risk Assessment are shown in Table 7-13.

Sediment

Sediment samples were taken from 4 locations in the adjacent woodland. All samples were analyzed for VOC, SVOC, TPH, and metal concentrations. Toluene was detected in all 4 samples and exceeded screening criteria in 1 sample. This sample was taken closest to the former UST

site. TPH as heavy oils was detected in 3 samples, but no PAHs were found above the detection limits. Metals were detected in several samples that exceeded or lacked USEPA Region III screening criteria. Site-specific and regional background concentrations were not available for sediment. Therefore, aluminum, barium, cobalt, iron, lead, manganese, thallium, and vanadium were retained as COPCs for sediment because they were detected at concentrations that either exceeded or lacked screening criteria.

The compounds chosen as chemicals of potential concern for sediment for the FTA Ecological Risk Assessment are shown in Table 7-14.

LARC 60 Site

Both physical and chemical stressors exist at the LARC 60 site and in the surrounding wooded area. Physical stress is caused by the training activities in the area which include driving the LARCs and other heavy equipment in the Sandbox. These activities prevent vegetation from becoming established in the Sandbox and have caused some stress on the vegetation in the small wooded island. However, the physical disturbance occurs in a small area and chances of the physical stressor adversely effecting the surrounding areas and wildlife is minimal and is not considered long-term. Therefore, the physical stressors will not be addressed further within the scope of this assessment.

Soil samples were taken from the Sandbox, adjacent wooded area, the wash rack, the oil/water separator, and the former UST site. Sediment and surface water samples were taken within the drainage ditch in the woods north of the Sandbox.

Surface Soils

A total of 22 soil samples were analyzed for VOCs, SVOCs, and TPH concentrations. Five soil samples were also analyzed for metal concentrations. Sampling locations are depicted in Figure 2-9. Although VOCs were detected in some of the surface soil samples, none of the concentrations exceed EPA Region III BTAG screening criteria. Acetone was detected in 1 sample and lacked screening criteria. However, due to the low frequency and the low level at which it was detected, it was not considered to be of concern. Total TPH was detected in 19 of the 22 samples. These samples were taken from the former UST area, the wash rack, the Sandbox and the adjacent wooded area. However, no PAHs were measured above detection limits. Total TPH was not retained as a COPC, since the more toxic components of TPHs were not detected.

Several metals were detected with high frequency at concentrations that exceeded EPA Region III BTAG screening criteria. Metals that exceeded criteria included chromium, iron, and lead. In addition, aluminum, arsenic, copper, and zinc lacked faunal screening criteria. Of these compounds, aluminum, arsenic, iron and vanadium concentrations fell within site specific and USGS regional background concentrations. Therefore, these compounds were not considered to

be potentially of concern. Chromium, lead, and zinc concentrations fell within regional background but exceeded measured site-specific concentrations. Therefore, these compounds were retained as COPCs for surface soils. Copper concentrations exceeded both site-specific and regional background concentrations and was retained as a COPC.

The compounds chosen as contaminants of potential concern for surface soil and the LARC 60 Site Ecological Risk Assessment are presented in Table 7-15.

Sediment

A total of 2 sediment samples were taken from the small drainage ditch adjacent to the site and analyzed for VOCs, SVOCs, TPH and metal concentrations. VOC and SVOCs were not detected in the samples. Total TPH was detected in both samples. Because PAHs were not detected in the samples, TPH was not considered to be of potential concern. No metals detected exceeded EPA Region III BTAG screening criteria. Several metals detected lacked screening criteria. No background values were available for sediment. All contaminants that lacked screening criteria were retained as COPCs.

Compounds selected as contaminants of potential concern for sediment for the LARC 60 site Ecological Risk Assessment are presented in Table 7-16.

Surface Water

Two surface water samples were taken from the adjacent drainage ditch. Acetone was detected in both samples at levels below screening criteria. SVOCs and TPHs were not detected in either sample. No metals were detected at levels which exceeded available screening criteria. Calcium, magnesium, manganese, potassium, and sodium do not have screening criteria. These constituents are naturally occurring in water and were found at low levels in the samples taken. Therefore, they were not considered to be of concern. No COPCs were selected for surface water at the LARC 60 Site.

Auto Craft Site

Very little physical disturbance occurs at the site. Since the site is currently used as a vehicle impoundment lot, there is little human activity. Therefore, impacts from physical disturbance will not be considered for this site.

A total of 6 surface soil samples were taken from within the fenced area, downgradient of the site, and in the grassy areas to the west of the site. All samples were tested for VOC, SVOC and TPH concentrations. One sample was further tested for metal concentrations. The VOCs detected were found to be at levels below EPA Region III BTAG screening criteria. Methyl ethyl ketone

lacks screening criteria. However, because it was detected in only 1 sample at a low level and has a low toxicity, it was not considered to be of concern.

Several SVOCs that were detected from the soil sample taken from within the fenced area were found to be above screening criteria. These were retained as COPCs. SVOCs were not detected in any other sample. Total TPH was detected in three of the samples, all of which were sampled in the grassy area downgradient from the fenced auto craft area. Because several PAHs were considered of concern due to their detected level in the auto craft area and their lack of detection in the grassy areas, the less toxic TPH was not considered of potential concern.

Several metals were detected in the sample analyzed at levels which exceeded available screening criteria. Several metals lacked screening criteria. The majority of these metals which exceeded or lacked criteria were detected at concentrations that fell below measured site-specific or USGS regional background levels. These compounds included chromium, cobalt, and nickel. Although the level of iron detected fell below regional background levels, it was retained as a COPC because its detection level far exceeded the levels detected at the FTA and LARC 60 sites. The level of copper detected in 1 sample fell within regional background concentrations but far exceeded the Fort Story background concentrations. Therefore, copper was retained as a COPC. Lead and zinc were selected as COPCs because the levels detected exceeded screening criteria, site-specific background concentrations, and regional background concentrations. Neither sediment nor surface water existed at the site.

The compounds chosen as contaminants of potential concern for the Auto Craft Ecological Risk Assessment are shown in Table 7-17.

7.3.2 Exposure Pathways

Several ecologically relevant migration pathways for contaminants exist at the Site. Wildlife may have incidental contact with or ingestion of contaminants while foraging, nesting, or engaging in other activities in the site. Chemical contaminants can also adversely affect plants and animals in surrounding habitats via the food chain.

Upon their release, some site contaminants are persistent and may be transformed to more bioavailable forms and mobilized in the food chain. Mobilization of contaminants in the terrestrial food chain could occur through the following pathways:

- Root uptake from contaminated soil by herbaceous plants,
- Bioaccumulation from vegetation or animal prey at the base of the food chain by wildlife.
- Contact and absorption, incidental ingestion, and feeding on contaminated food by invertebrates, and

- Drinking of contaminated surface water by wildlife

Based on these pathways, the following general classes of ecological receptors potentially might be exposed to contaminants at the Fort Story sites.

- Terrestrial plants growing within and adjacent to the sites,
- Terrestrial invertebrates likely to occur in surface soils and benthic invertebrates occurring within the sediments,
- Birds that forage or nest within the areas,
- Small mammals that reside and/or feed in the vicinity of the areas, and
- Other higher trophic level wildlife species (e.g., carnivores) that feed within the vicinity of the sites.

7.3.3 Ecological Effects

As discussed earlier, several site contaminants are present in soil, sediment, and surface water and exceed ecological concern levels and therefore, may have adverse effects on biota in the vicinity of the sites.

FTA Site

The COPCs for the FTA site include the following:

- **Surface Soil** - acetone, toluene, fluoranthene, pyrene, chromium, copper, lead, and zinc
- **Sediment** - toluene, aluminum, barium, cobalt, iron, lead, manganese, thallium, and vanadium

LARC 60 Site

The COPCs for the LARC 60 site include the following:

- **Surface Soil** - chromium, copper, lead, and zinc
- **Sediment** - aluminum, barium, iron, manganese, and vanadium
- **Surface Water** - none

Auto Craft Site

The COPCs for the Auto Craft site include the following:

- **Surface Soil** - acenaphthene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, butylbenzylphthalate, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, chromium, copper, iron, lead, nickel, and zinc

Descriptions of the environmental fate and transport of these chemicals, as well as bioaccumulation potential and toxicity, with regard to various aquatic and terrestrial organisms, are included as Appendix K of this document.

7.4 ECOLOGICAL ENDPOINTS

Based on the potential pathways and receptors identified and described in Section 7.3, detrimental effects (i.e., reduced vigor or population decline) in vegetation, invertebrates, small mammals, birds, and carnivores were selected as the assessment endpoints for the Sites.

Endpoint species considered representative of the local wildlife populations that would use and frequent each Site are presented below. The species were selected based on their potential exposure (i.e., site usage, food habitats, home range size) and susceptibility to adverse effects of the site contaminants.

7.4.1 FTA Site

Following is a brief description of the habitat requirements and diet of the terrestrial endpoint species selected for the FTA Site. In addition, the reasons for selection of these species are discussed.

- **Herbaceous Vegetation.** Plants that occur in pine/oak woodland and disturbed areas of the northeastern United States are likely to occur at the Site. These plants include herbaceous species that serve as an important food source for songbirds, small mammals, and larger herbivores. The measurement endpoints for terrestrial vegetation are published phytotoxicity reference values for each contaminant.

- **Soil/Sediment Invertebrates.** Invertebrates that are common in sandy soils in Southeastern Virginia are likely to occur within and adjacent to the site. In addition, sediment invertebrates that favor intermittent streams and pools or damp soils are likely to occur within the drainage area adjacent to the site. These invertebrates are an important food source for ground gleaning birds and small mammals. The measurement endpoints for soil/sediment invertebrates are published toxicity reference values for each contaminant.

- **Killdeer (*Charadrius vociferus*).** The Killdeer is common in Virginia, migrating out of the area in winter months. A typical density measured during the breeding season is 3.9 pairs per 100 acres, yielding an approximate home range of 25.6 acres per pair (10.36 hectares). Breeding Killdeer prefer open meadows, edges of pasture, and dry uplands. In all areas, sparse or

closely cropped vegetation is required. Preferred food items include insects (especially beetles and grasshoppers), centipedes, spiders, worms, and seeds (Degraaf and Rudis, 1986).

The Killdeer has been selected to represent the ground-gleaning insectivorous bird community at the FTA site. Although the Killdeer is considered an insectivorous bird and may not represent other avian species that concentrate on seeds and worms, it represents avian food-chain exposure most likely at the site. The FTA site does not provide suitable forage habitat for avian species that prefer worms. Insectivorous birds such as the Killdeer are more likely to frequent the site.

Measurement endpoints for the Killdeer are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **White-footed Mouse (*Peromyscus leucopus*).** This common small mammal occurs throughout Virginia and occupies home ranges from 0.054 to 0.072 hectares. It is found in a variety of habitats including interiors and edges of deciduous and coniferous forests, scrub areas, clearings, pastures, stream-side thickets, and buildings. The White-footed Mouse consumes arthropods, seeds, and other vegetation. It is active throughout the year and usually nests off the ground. (USEPA, 1993).

  The White-footed Mouse has been selected to represent the small mammal community at the FTA site. As a receptor with an omnivorous diet, the mouse is representative of herbivorous and insectivorous small mammals present within the boundaries of the site. Due to the scarcity of vegetation on the site itself, larger herbivores such as rabbits are unlikely to make significant use of the area.

  Measurement endpoints for the White-footed Mouse are derived from rodent toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Gray Fox (*Urocyon cinereoargenteus*).** Gray Foxes are present throughout the United States, except in the northwest and northern prairies. Foxes are secretive and nocturnal, and will often climb trees to evade predators. Gray foxes prey on small mammals but will also eat insects, fruits, acorns, birds, and eggs. The home range of this species varies from 57 and 855 hectares (USEPA, 1993). This species is similar in size and habits of the Red Fox (*Vulpes vulpes*).

  The Gray Fox has been selected to represent the terrestrial carnivore community at the Site. Although the Merlin and Red-tailed Hawk may also represent other potential endpoint species in the carnivore category, their home ranges are typically much larger than that of the fox, and their use of the FTA site is likely to be restricted.

  Measurement endpoints for the fox are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

7.4.2 LARC 60 Site

Following is a brief description of the habitat requirements and diet of the terrestrial endpoint species selected for the LARC 60 Site. In addition, the reasons for selection of these species are discussed. Because the drainage ditch is so small in relation to the entire site, a semi-aquatic endpoint species was not selected. Selected species already described in Section 7.4.1 are not repeated here.

- **Herbaceous Vegetation**

- **Soil/Sediment Invertebrates**

- **White-footed Mouse**. Representative of the small mammal community.

- **Northern Bobwhite (*Coilnus virginianus*).** Bobwhite Quail are ground-dwelling birds that occupy a number of habitats in Virginia. They are poor fliers, seldom leave the ground and do not migrate. Their range may encompass several hectares and they prefer grasslands, idle fields and pastures during breeding season while concentrating in wooded areas with an understory adjacent to open fields during winter seasons. Bobwhites forage in areas with open vegetation, some bare ground and light litter. Nearby dry powdery soils are important for dust bathing. Seeds from weeds, woody plants, insects and invertebrates and grasses comprise the majority of the bobwhite's diet throughout the year. In the winter, green vegetation can dominate the diet. Quail consume little grit (USEPA, 1993).

  The Northern Bobwhite was selected to represent the ground-gleaning avian community at the site. Their habit of dustbathing make them a more likely candidate for exposure to contaminants in the Sandbox, in addition to exposure realized through habits such as foraging and nesting.

  Measurement endpoints for the Northern Bobwhite are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Gray Fox**. Representative of the terrestrial carnivores which use the site.

7.4.3 Auto Craft Site

Following is a list of the terrestrial endpoint species selected for the Auto Craft Site. Since the species selected are similar to those selected for the FTA and LARC sites, their habitat descriptions are not repeated here.

- **Herbaceous Vegetation**

- **Soil Invertebrates**

- **Killdeer**
- **White-footed Mouse**
- **Gray Fox**

7.5 ECOLOGICAL CONCEPTUAL SITE MODEL

Following current USEPA guidance (USEPA, 1992), a conceptual model was developed to evaluate how chemical stressors from the Site may affect ecological components of the natural environment (Figure 7-1). This model illustrates the relationship between the ecosystem at risk, including the assessment endpoint species, and the chemical stressors. In addition, the contaminated media, exposure routes, and environmental transport are identified in the conceptual site model.

Ecological receptors evaluated in this risk assessment include representative species of terrestrial habitats (herbaceous plants, soil and sediment invertebrates, small mammals, small birds, and carnivores). Effects evaluated are based on published scientific studies and include the estimated/calculated, or predicted effects of the contaminants of concern on the survival, growth, and reproduction of these receptors.

7.6 EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION

This section includes site-specific information pertinent to the assessment of potential ecological exposures to contaminants at the Site. General discussions of ecosystems of concern, pathways and COPCs are provided in Sections 7.2 and 7.3.

7.6.1 Exposure Point Concentrations

Exposure media of ecological concern at the sites include surface soils and sediment. Surface water only exists at the LARC 60 site. Groundwater is not considered because the potential for exposure to groundwater is minimal. The maximum exposure case is considered for terrestrial vegetation, because it is immobile and for soil/sediment invertebrates because they have low mobility. In these cases, the maximum value best represents the most exposure received and therefore is a conservative estimate of the exposure experienced by the population. The average exposure case is considered for terrestrial wildlife receptors, since they are mobile and are not likely to be exposed to only the maximum concentrations of contaminants. Exposure point concentrations (EPCs) calculated for the average exposure case are the 95 percent upper-confidence limit (95% UCL) of the arithmetic mean of COPC concentrations in surface soil and

sediment. When the 95% UCL concentrations of surface soil and sediment data could not be calculated due to the small sample size for each subsite (5 samples or fewer), the maximum concentrations of COPC in these media were used. When the same contaminant occurred in surface soil and sediment and wildlife receptors would be exposed to both media, the largest concentration was selected for exposure calculations. Exposure point concentrations for the COPC used in exposure calculations are highlighted in Tables 7-13 through 7-17.

7.6.2 Exposure Scenarios and Pathways

As explained previously, three wildlife scenarios were selected for the quantitative risk assessment at each site: a small mammal, an omnivorous bird, and a terrestrial carnivore. The exposure parameters used to estimate exposure through incidental ingestion of soil and sediment, and exposure through food-chain receptors, are provided in Table 7-18.

The exposure parameters were derived or obtained from published sources (primarily the USEPA's Wildlife Exposure Factors Handbook, USEPA, 1993). Average body weights and minimum home ranges were used to project a conservative estimate of exposure. The rate of incidental ingestion of sediment was assumed to be the same as the rate of ingestion of soil. Soil ingestion for the Northern Bobwhite is unknown. Since the Bobwhite is a ground-gleaning bird and it frequently dustbathes, the ingestion rate for soil was assumed to be equal to the American Woodcock, an insectivorous species with a high soil consumption rate. An exposure duration rate was included to allow for the Killdeer, a migratory species, which may not be exposed to a site for an entire year.

To estimate exposure through the terrestrial and wetland food chains, bioaccumulation factors (BAFs) for plants (plant uptake factors or PUFs) and soil/sediment invertebrates (IUFs) were derived from published sources. Using these BAFs, tissue levels in potential food items of the endpoint species were calculated. When soil and sediment invertebrate uptake values were not available, it was assumed that the uptake rate of contaminants was similar to that of earthworms. Where no BAFs were available, the plant and/or invertebrate tissue concentrations were assumed to be equal to the soil or sediment concentration. Concentrations in the prey of Gray Fox (small mammals) were assumed to be equal to the concentrations in their food source. Plant uptake factors and invertebrate uptake factors are provided in Table 7-19.

7.6.3 Exposure Estimates

The estimated exposures for terrestrial herbaceous vegetation and terrestrial invertebrates were derived from maximum surface soil and sediment concentrations of COPCs, as shown in Table 7-20.

Estimates of exposure to contaminants in soil/sediment via ingestion were made for the receptors by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$EE_{soil/sediment} = (C \times FS \times IR_{total}(\text{dry weight}) \times FR) / BW$

Where:

$EE_{soil/sediment}$	=	Estimated exposure through ingestion of soil/sediment (mg/kg BW-day)
C	=	Contaminant concentration in soil/sediment in the area of concern (mg/kg dry weight)
FS	=	Fraction of soil/sediment in diet (as percentage of diet on a dry-weight basis divided by 100; unitless)
IR_{total}	=	Food ingestion rate on a dry-weight basis (kg/day)
FR	=	Fraction of total food intake from the area of concern (unitless)
BW	=	Body weight (kg)

The food ingestion rate on a dry-weight basis was estimated based on body weight (USEPA, 1993):

Birds:	IR_{total} (kg/day) = 0.0582 $BW^{0.651}$ (kg)
Mammals:	IR_{total} (kg/day) = 0.0687 $BW^{0.822}$ (kg)

Estimates of exposure to contaminants via dietary sources were made for the receptors by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$$EE_{diet} = \sum_{k=1}^{m} (C_k \times FR_k \times NIR_k)$$

Where:

EE_{diet}	=	Estimated exposure through diet (e.g., in mg/kg BW-day)
C_k	=	Average contaminant concentration in the kth type of food (e.g., in mg/kg wet weight).
FR_k	=	Fraction of intake of the kth food type that is contaminated (unitless).
NIR	=	Normalized ingestion rate of the kth food type on a wet weight basis (e.g., in g/g-day).
m	=	Number of contaminated food types

The estimated exposure through ingestion of soil/sediment and food for each of the wildlife receptors is given in Tables 7-21 through 7-29. Full exposure calculations are presented in Appendix M.

7.7 ECOLOGICAL EFFECTS ASSESSMENT

7.7.1 Ecological Effects Summaries

Toxicity profiles summarizing the potential adverse ecological effects of each COPC were derived from the literature, and are included as Appendix K. The profiles provide discussions of the acute and chronic toxicity of the COPCs to plants and animals. Effects on growth, reproduction, and survival of terrestrial species are given, where available. Also included are significant fate and transport characteristics of the chemicals. These summaries, in addition to established criteria, were used to identify the critical effects of COPCs.

7.7.2 Toxicity Reference Values

Toxicity reference values (TRVs) were derived for plants, soil/sediment invertebrates and other wildlife as described below.

Terrestrial Plants and Invertebrates - The TRVs used to evaluate the toxicity of a given COPC to terrestrial plants and soil invertebrates were derived from the available literature. Values were applied to both soil and sediment since toxicity values for sediment were unavailable. Phytotoxic values represent the lowest values from toxicity studies conducted in the field or in greenhouse and growth chamber settings (Will and Suter, 1994a). Soil TRVs based on microbial heterotroph and earthworm toxicity represent data provided by toxicity studies in the field or in laboratory settings (Will and Suter, 1994b).

Wildlife - TRVs for mammals and birds chosen as receptor species were derived based on methodology presented by Opresko et al. (1994). This general method is based on USEPA methodology for deriving human toxicity values from animal data. In this method, experimentally derived No Observed Adverse Effect Levels (NOAELs) or Lowest Observed Adverse Effect Levels (LOAELs) are used to estimate NOAELs for wildlife by adjusting the dose according to differences in body size. NOAELs for laboratory species, obtained from the literature, were converted to receptor species NOAELs as follows (Opresko et al., 1994):

$$NOAEL_r = NOAEL_t\ (bw_t / bw_r)-$$

Where: $NOAEL_r$ = receptor species NOAEL

$NOAEL_t$ = test species NOAEL

bw_r = receptor body weight

bw_t = test species body weight

The test species and receptor species NOAELs are provided for each of the COPC in Table 7-30.

7.8 RISK CHARACTERIZATION

In this section, the ecological risks posed by COPC at the sites are identified and summarized. Risk characterization involves two major steps: risk estimation and risk description (USEPA, 1992). The risks are estimated in Section 7.8.1 using general comparisons and hazard quotients (HQs) calculated with estimated exposure and toxicity reference values for each endpoint species. The ratios are summarized, and the principal uncertainties of the assessment are discussed in Section 7.8.2. The ecological significance of the findings and recommendations for further study are discussed in Section 7.9.

7.8.1 Hazard Quotients

FTA Site

The levels of chromium in the soil and aluminum, lead, thallium, and vanadium in sediment were found to exceed phytotoxicity values. The levels of iron in the soil and aluminum and iron in the sediment were found to exceed invertebrate toxicity values. Phytotoxicity and invertebrate toxicity values were not available for acetone, flouranthene or pyrene. Phytotoxicity values were not available for iron. Invertebrate toxicity values were not available for toluene.

The hazard quotients (HQs) for the maximum exposure case are summarized in Table 7-31. These HQs indicate if the maximum concentrations of the COPCs are likely to pose a risk to Killdeer, White-footed Mouse, or Gray Fox at the FTA site. HQs greater than 1 were calculated for aluminum, barium, lead, thallium, and vanadium for the White-footed Mouse. HQs greater than 1 were calculated for aluminum for the Gray Fox. No HQs were greater than 1 for the Killdeer. An HQ greater than 1 means that the total estimated exposure exceeds the species toxicity reference values. These results indicate that there is a potential for risk of exposure for the White-footed Mouse and the Gray Fox to the maximum concentrations of the contaminants whose HQs exceeded 1. Avian toxicity values were not available for toluene, fluoranthene, pyrene or thallium. Therefore, the potential risks of these COPCs to the Killdeer were not evaluated.

LARC 60 Site

The levels of chromium in the soil and aluminum and vanadium in sediment were found to exceed phytotoxicity values. The levels of aluminum and iron in the sediment were found to exceed invertebrate toxicity values. Phytotoxicity values were not available for iron.

The HQs for the maximum exposure case are summarized in Table 7-32. Results of the exposure calculations show that the levels of zinc resulted in an HQ of 1 for the Northern Bobwhite. The levels of aluminum resulted in HQs greater than 1 for the White-footed Mouse and the Gray Fox. These contaminants detected at the site may pose a risk to the species examined. The other contaminants are unlikely to pose a risk to the species examined. Avian and mammalian toxicity values were unavailable for iron. Therefore, the potential risk of this contaminant could not be estimated.

Auto Craft Site

The levels of chromium, lead and zinc in the soil were found to exceed the phytotoxicity values. The levels of iron in the soil were found to exceed invertebrate toxicity values. Phytotoxicity and invertebrate toxicity values were not available for PAHs. Phytotoxicity values were unavailable for iron.

The HQs for the average exposure case for the SVOCs and the maximum exposure case for metals are summarized in Table 7-33. The levels of zinc were found to exceed both Killdeer and White-footed Mouse toxicity values (HQ>1). Therefore, there is a potential for risk to the maximum concentrations of zinc to the White-footed Mouse and the Killdeer at the Auto Craft Site. The wildlife HQs were less than 1 for all other compounds where TRVs were available. These results indicate that the mean concentrations of the SVOCs and the maximum concentrations of metals (except zinc) are unlikely to pose a risk to the Killdeer, White-footed Mouse, or Gray Fox at the Auto Craft Site. Avian toxicity values were not available for PAHs or iron. Mammalian toxicity values were not available for iron. Therefore, the potential risks of these COPCs were not evaluated.

7.8.2 Summary of Risks and Uncertainties

FTA Site

At the FTA site, potential risks of exposure to aluminum, barium, lead and thallium in sediment was identified for small mammals. The potential risk of exposure to aluminum in sediment was identified for terrestrial carnivores. In addition, potential risks of exposure to chromium in the soil and aluminum, lead, thallium, and vanadium in sediment were identified for plants. The potential risks of exposure to iron in the soil and sediment and aluminum in the sediment were found for soil/sediment invertebrates. These risks of adverse effects were identified for the maximum exposure scenario.

LARC 60 Site

At the LARC 60 site, the potential risks of exposure to zinc for avian species and aluminum for small mammals and terrestrial carnivores were identified. The potential risk of exposure to chromium in the soil and aluminum and vanadium in sediment were identified for plants. Lastly, potential risks of exposure to aluminum and iron in the sediment were identified for sediment invertebrates. These risks of adverse effects were identified for the maximum exposure scenario.

Auto Craft Site

At the Auto Craft site, potential risks of exposure to zinc were identified for ground-gleaning birds and small mammals. Potential risks of exposure to chromium, lead and zinc were identified for plants growing in the area. Potential risks of exposure to iron were identified for soil invertebrates. These risks of adverse effects were identified based on the maximum exposure scenario for all contaminants to plants and invertebrates and metals to wildlife. The risks of adverse effects were identified for average exposure conditions for semi-volatile organic compounds to wildlife.

Summary of Uncertainties

Uncertainty in the risk estimates may arise during any stage in the ecological risk assessment process. Incorrect assumptions may be made regarding the potential effects of a stressor, the ecosystems of concern, or the species residing within those ecosystems. Generally, care was taken to fully assess and incorporate field observations into the decision process during problem formulation to minimize these uncertainties.

Uncertainty associated with environmental sampling is generally related to the limitations of the sampling program in terms of the number and distribution of samples, while uncertainty associated with the analysis of the samples is generally related to systematic or random errors. The limited number of samples collected at the sites, and the limited testing of those samples, particularly for the metals at these sites add uncertainty to the contaminant values used for the exposure assessment.

The principal uncertainties in the exposure assessment have to do with quantitative estimates of exposure parameters such as BAFs. These parameters typically are chemical, species, and site specific. Exposure parameters for COPCs were taken from the literature or calculated from literature data. Data on contaminants in wild animals, as opposed to domestic or laboratory animals, were used when available. Generally, the reasonable worst case was assumed to provide a conservative estimate.

Another point of uncertainty lies in the assumption that each of the wildlife receptor species feeds only upon food items found in the study areas. For species with very small home ranges, this

assumption is likely to be true. However, several of the receptors may consume food sources other than those considered in the assessment, the exclusion which could either over-or underestimate the potential risk. It is also possible, particularly due to the lack of forage within the sites, that the receptors may not feed entirely within the study areas. In addition, the average weights and daily intakes used for the receptor species do not take into account smaller and larger individuals, and young of the species, which may be more or less sensitive to contaminants than average-sized adults.

The assumption that soil and sediment invertebrate uptake of compounds would be equal to published Earthworm Uptake Factors may also result in an over- or underestimation of potential risk. The amount of a contaminant which is taken up by earthworms from soil or sediment depends, in part, on site-specific soil and sediment conditions such as organic content, contaminant concentration, and presence of other chemicals in the soil or sediment. Uptake of contaminants by soil and sediment invertebrates may occur at different rates or under different conditions than earthworms. Microbial heterotroph toxicity data were used to the extent possible. Similarly, uptake of chemicals by vegetation is very dependent on the type of chemical, soil type, plant species, and other environmental factors.

Uncertainty arises when using any published toxicity results as TRVs. These uncertainties include extrapolating from acute or subchronic exposures to chronic exposure durations and extrapolating across different species, genera, orders, and families. The lack of published toxicity data adds uncertainty to the assessment.

In general, the risk assessment is likely to overestimate rather than underestimate the risks of adverse ecological effects at the sites, because of the conservative nature of the assumptions used. Overall, a generally conservative approach was taken in the evaluation to minimize the possibility of actual risk being greater than that predicted. Conservative steps taken include:

- The selection of COPC based on exceedence or lack of EPA Region III BTAG criteria and exceedence of site-specific and regional background data.
- The comparison of maximum chemical concentrations in site media with maximum background concentrations
- The use of maximum chemical concentrations, where appropriate.
- The use of average body weights and feeding rates and minumum home ranges for the endpoint species.

7.8.3 Ecological Significance

The FTA, LARC, and Auto Craft sites are potential sources of environmental contamination in soil and sediments. These potential effects are considered to have minimal ecological significance for the following reasons:

- In many cases, wildlife risks were identified for the maximum exposure case. The average concentrations are more representative of exposure for mobile species of wildlife, such as the White-footed Mouse.

- The sites are currently disturbed by military activities occurring on the base, particularly the FTA and LARC 60 sites. In addition, the Auto Craft site is paved and fenced. Therefore, the sites can support only a few individuals, and the potential impacts to plant or animal populations as a whole are minimal.

- The ecosystems in the general vicinity of the site do not appear to be impacted or stressed due to chemical contamination.

- Apex predators and wildlife with large home ranges are not likely to be adversely affected due to the comparatively limited extent of contamination.

7.9 CONCLUSIONS AND RECOMMENDATIONS

No further investigation is recommended for any of the sites examined at Fort Story. Very few chemicals were selected as COPCs and the environmental evaluation is likely to have overestimated the potential risk.

Results show that under certain scenarios, the potential does exist for risk to terrestrial vegetation, invertebrates, and mammals in the drainage ditch adjacent to the FTA site. The small sample size in this drainage area adds uncertainty and probably overestimates risk when extrapolating the maximum detections over the entire site. Because of the size of the drainage ditch compared to the home range of mammals and the lack of current visible impacts on vegetation and invertebrates, this risk is considered very low.

At the LARC site, there is a potential for risk to contaminants in sediment from the drainage ditch to mammals. In addition, zinc in the soil and sediment at the site may pose a risk to avian species. However, the estimated exposure of zinc under worst case conditions were equal to Killdeer toxicity levels. Under average conditions, zinc levels would probably not pose a risk to avian species. Ecologically, much of the site provides little value to wildlife for foraging or nesting habitat. Most of the wildlife activity would occur in the adjacent woodland area, or possibly at the former UST

area. Therefore, the risks to wildlife associated with the ongoing activities at the LARC 60 site are considered low.

Assessment results at the Auto Craft site show that potential risk of exposure to metals does exist for terrestrial vegetation, invertebrates, ground-gleaning birds, and small mammals. One sample downgradient of the site was tested for metals. This small sample size adds uncertainty to the analysis through the possibility of under- or overestimation of risk. Because of the size of the site, minimal habitat value, and the lack of current visible impacts on vegetation; the risk of exposure to metals is considered low.

7.10 REFERENCES

Baes, C.F., R.D. Sharp, A.L. Sjoreen and R.W. Shor. 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture. ORNL-5786. Oak Ridge National Laboratory. Oak Ridge, TN.

Beyer, W.N., E. Conner, and S. Gerould. 1992. Soil Ingestion by Wildlife. SETAC 13th Annual Meeting, Cincinnati, Ohio.

Beyer, W.N. 1990. Evaluating Soil Contamination. U.S. Fish Wildl. Serv., Biol. Rep. 90(2). 25 pp.

Beyer, W.N., R.L. Chaney, and B.M. Mulhern. 1982. Heavy Metal Concentrations in Earthworms from Soil Amended with Sewage Sludge. J. Environ. Qual. 11:381-385.

Comor, J.J. and H.T. Shacklette. 1975. Background Geochemistry of Some Rocks, Soils, Plants,and Vegetables in the Counterminous United States. Unites States Government Printing Office, Washington, D.C.

DeGraaf , R.M. and D.D. Rudis. 1986. New England Wildlife: Habitat, Natural History and Distribution. U.S. Department of Agriculture, General Technical Report NE-108. Amhearst, Massachusetts.

Dumming Jr., J.B.. 1993. CRC Handbook of Avian Body Masses. CRC Press, Inc. Boca Raton, Florida.

Gish, C.D. and R.E. Christensen. 1973. Cadmium, Nickel, Lead, and Zinc in Earthworms from Roadside Soil. Environ. Sci. & Technol. 7:1060-1062.

Heaton, S.N. 1992. Effects on Reproduction of Ranch Mink Fed Carp from Saginaw Bay, Michigan. A thesis submitted to Michigan State University, Department of Animal Science.

Horne Engineering Services, Inc. 1995. Draft Fort Story Integrated Natural Resource Management Plan. Submitted to U.S. Army Corps of Engineers, Norfolk District. June, 1995.

James M. Montgomery, Inc. 1992. Fort Story Preliminary Assessment/Site Investigation and Fort Story NIKE Preliminary Assessment/Site Investigation. U.S. Army Corps of Engineers, Missouri River Division, Omaha District. January, 1992.

Ma, W.C. 1982. The influence of soil properties and worm-related factors on the concentration of heavy metals in earthworms. Pedobiologia 24:109-119.

Martin, A.C., H.S. Zim, and A.L. Nelson. 1961. American Wildlife and Plants, A Guide to Wildlife Food Habits. Dover Publications, Inc. New York, New York.

Opresko, D.M., B.E. Sample and G.W. Suter. 1995. Toxicological Benchmarks for Wildlife: 1995 Revision. ES/ER/TM-86/R1. Oak Ridge National Laboratory. Oak Ridge, TN.

Opresko, D.M., B.E. Sample and G.W. Suter. 1994. Toxicological Benchmarks for Wildlife: 1994 Revision. ES/ER/TM-86/R1. Oak Ridge National Laboratory. Oak Ridge, TN.

Travis, C.C. and H.A. Hattemer-Frey. 1988. Uptake of Organics by Aerial Plant Parts: A Call for Research. Risk Analysis Office, Health and Safety Research Division, Oak Ridge National Laboratory. Oak Ridge, TN. Chemosphere, Vol.17, No.2, pp 277-283.

U.S. Environmental Protection Agency. 1995. Region III Biological Technical Assistance Group Screening Levels - Draft. August 9, 1995.

U.S. Environmental Protection Agency. 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/187a. Office of Research and Development. Washington, D.C.

U.S. Environmental Protection Agency. 1992. Framework for Ecological Risk Assessment. EPA/630/R-92/001. Risk Assessment Forum. February 1992.

U.S. Environmental Protection Agency. 1989. Risk Assessment Guidance for Superfund Volume II: Environmental Evaluation Manual. Interim Final. EPA/540/1-89/001. Washington, D.C.: Office of Emergency and Remedial Response.

Wentsel, R.S., R.T. Checkai, T.W. LaPoint, M. Simini, D. Ludwig, and L. Brewer. 1994. Procedural Guidelines for Ecological Risk Assessments at U.S. Army Sites Volume I. ERDEC-TR-221. Edgewood Research, Development and Engineering Center, U.S. Army Chemical and Biological Defense Command. December 1994.

Will, M.E. and G.W. Suter II. 1994a. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants: 1994 Revision. ES/ER/TM-85/R1. Environmental Sciences Division, Oak Ridge National Laboratory. Oak Ridge, TN.

Will, M.E. and G.W. Suter II. 1994b. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process. ES/ER/TM-126. Environmental Sciences Division, Oak Ridge National Laboratory. Oak Ridge, TN.

8.1 FIREFIGHTER TRAINING AREA

A summary of the nature and extent of contamination, fate and transport characteristics and the baseline risk assessment for the Firefighter Training Area (FTA) is provided in the following sections.

8.1.1 Nature and Extent of Contamination

Soil

A summary of the nature and extent of soil contamination is provided as follows:

- Volatile organics (VOCs) such as toluene, acetone, and MEK and metals were detected in most surface and subsurface soils collected at the FTA while SVOCs were only detected in several soil samples located in the Solvent Plume Area of the site.

- TPH as Heavy Oils was detected in some of the surface and subsurface soil samples located in the Solvent Plume Area of the site.

- However, except for arsenic and iron in one soil sample, all contaminants were detected at levels lower than the EPA Region III risk-based screening criteria.

Groundwater

A summary of the nature and extent of groundwater contamination is provided as follows:

Northern Area

- PCE was detected in only one groundwater sample (DPT #2 at 6.4 *ug/l*) in the Northern Area.

- Although detected in total samples above the EPA action level and EPA RBC, dissolved lead and arsenic were ~~was not~~ detected at concentrations less than the action level and RBC that indicates that lead and arsenic are ~~is~~ associated with the sediment in the groundwater sample.

Former FTP Area

- VOCs detected in the Former FTP Area included acetone, carbon disulfide, xylene, and ethylbenzene. The apparent trend of lateral distribution of xylene indicates minimal migration in groundwater. However, no VOCs were detected in the one well (MW-111) sampled in this area during the 2000 sampling event.

- TPH as Gasoline and Diesel Fuel were present in samples from several locations in this area higher concentrations present in the samples collected at shallow depths. No other shallow or deep groundwater sample from the FTP Area contained measurable concentrations of these

compounds so no apparent trends in lateral distribution were discernible.

- Although detected in total samples, dissolved arsenic was not detected which indicates that arsenic is associated with the sediment in the groundwater sample. MW-111 was sampled in 2000 and analyzed for totald dissolved metals. No metal concentrations (total or dissolved) were detected in this well above EPA RBCs for tap water or the EPA action level for lead.

Solvent Plume Area

- PCE was detected in only one groundwater sample (DPT #11) in the Solvent Plume Area. Degradation products (1,1-DCA and 1,1,1-TCA) of PCE were detected at several locations. The distribution of the VOCs with respect to depth and lateral distance did not exhibit any trends in concentration values.

- In the 2000 sampling event, total arsenic was detected at 3.4 ug/l at MW-114A, which is above the EPA RBC for tap water, but dissolved arsenic was not detected in the well.

Sediment

A summary of the nature and extent of sediment contamination is provided as follows:

- TPH as Heavy Oils was detected in most of the sediment samples located in the drainage area south of the site. The TPH contamination may be the result of surface transport from the Solvent Plume Area or former UST fuel farm during precipitation events. The only expected hazardous constituent of TPH compounds detected was toluene but at concentrations lower than risk screening criteria.

8.1.2 Fate and Transport

A summary of the fate and transport for compounds at the FTA is provided below:

Former FTP Area

- The concentrations detected in groundwater are an order of magnitude lower than those detected during the PA/SI roughly five years ago. The excavation of the contaminated soils in this area has decreased the potential for impact to groundwater quality through leachate generation. Also, the lowered concentrations in groundwater indicate that the compounds are biodegrading or otherwise attenuating.

- The low concentration of total arsenic detected in groundwater at Well 4MW-2S was adsorbed onto sediments contained in the sample. Arsenic strongly sorbs onto soils and sediments at normal pH especially when in the presence of iron, manganese, and aluminum oxides. Arsenic is soluble in water but the nondetection of it in the dissolved arsenic analysis confirms that it is not dissolved in groundwater at the Former FTP.

Solvent Plume Area

- As discussed in Section 4.3.1.2, TPH as Heavy Oils was detected in the southwest corner of the FTA and in the drainage ditch south of the site. Because TPH as Heavy Oils adsorbs very strongly onto soil and has a low aqueous solubility, the adsorbed compounds likely move with the sediments during storm runoff into the drainage ditch. TPH as Heavy Oils have a low volatility and do not readily volatilize into the atmosphere. These compounds are subject to biodegradation, but at a low rate.

- Chlorinated solvent concentrations have decreased greatly since the PA/SI sampling in 1990 and this decrease should continue.

- No PAHs were detected in the sediment samples indicating that these compounds along with most BTEX constituents are not present in areas with TPH compounds detected due to various fate mechanisms such as volatilization, dispersion, and biodegradation.

8.1.3 Baseline Risk Assessment

A summary of the human health and ecological risk assessments are provided below.

Human Health Evaluation Summary

~~No COPCs were identified for soil and sediment at the FTA while no exposure pathways or exposed populations were identified for contaminated groundwater located at the site. Therefore, no potential human health risk was identified due to contaminants present at the FTA site.~~

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized below.

A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

- The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is less than the criterion of 1.0 for adults and children.

A summary of the **Carcinogenic Risk** for future residential land use is provided below:

- The estimated cancer risk for exposure to chemicals in soils and groundwater is about 1.5 in 1 million for adults and 2.7 in 1 million for children. The greatest component for adults and children exposures is ingestion of and dermal contact with arsenic in soils which accounts for 100 percent of the cancer risk. However, arsenic concentrations are consistent with background.

Because arsenic was detected in site soils at concentrations consistent with the background soils as previously discussed, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Therefore, upon removal of arsenic as a COPC, the risk levels

become less than the criterion of 1.0 and 10^{-6}, and no further action related to this site (based on human health risk) is warranted.

Ecological Risk Assessment Summary

No exposure pathways or exposed populations were identified for contaminated media at the site. Therefore, no potential ecological risk was identified due to contaminants present at the FTA site.

8.2 LARC 60 MAINTENANCE AREA

A summary of the nature and extent of contamination, fate and transport characteristics and the baseline risk assessment for the LARC 60 Maintenance Area site is provided in the following sections.

8.2.1 Nature and Extent of Contamination

Soil

A summary of the nature and extent of soil contamination is provided as follows:

Former UST Area

- Acetone, PCE, and toluene were detected in several surface and subsurface soil samples collected in the Former UST Area of the site. Concentrations of the VOCs varied from surface to deeper depths with no apparent trends. The lateral extent of surficial VOC contamination is limited to a relatively small area around the former UST excavation.

- TPH as Heavy Oils was detected in two surface soil samples collected in the vicinity of the former UST pit. The presence of TPH in the surface soils and not in the subsurface soils in the vicinity of the UST pit is probably due to transport of sediment from the soil pile or from the deposition of some TPH-contaminated soil in this area during excavation activities. The lateral extent of surficial contamination is limited to a small area around the former UST excavation.

- Numerous metals were detected in soils in this area with concentrations typically decreased with depth. The lateral extent of metal contamination was not defined, however, metal concentrations, except for arsenic at SB-01, were at least one order of magnitude lower than the EPA screening criteria.

OWS Area

- Acetone, methylene chloride, MEK, and toluene were detected in several surface and subsurface soil samples collected in the OWS area of the site. PCE and TCE were only detected in one soil boring located in the concrete pad near the Sandbox Area.

- TPH as Heavy Oils was detected in the majority of surface and subsurface soil samples collected in this area. TPH concentrations decreased with depth in all borings sampled in the OWS Area. TPH as Heavy Oils was also detected at three sample depths in soil boring #4 which is located upgradient of the OWS. The source of the TPH in this area is unknown.

- Various metals were detected in at least one of the four samples collected from the two borings. Metal concentrations typically decreased with depth. The lateral extent of metal contamination was not defined. Their concentrations were lower than the risk screening criteria.

Sandbox

- Methylene chloride, MEK, styrene, PCE, toluene and TCE were detected in numerous surface and subsurface soil samples collected in and downgradient of the Sandbox. Concentrations of the VOCs varied from surface to deeper depths with no apparent trends. No patterns were indicated in the lateral distribution of VOCs within the Sandbox.

- Numerous metals were detected in soil samples collected. However, their concentrations were at least one order of magnitude lower than the EPA screening criteria.

- TPH as Heavy Oils was detected in the majority of surface and subsurface soil samples collected in this area. The source of the TPH in this area is probably from past wash rack, operations and maintenance activities in this area and from current LARC vehicle operation and storage activities (i.e., leaks from heavy equipment).

- Numerous metals were detected in soil samples collected. However, except for arsenic at SB-20, their concentrations were at least one order of magnitude lower than the EPA screening criteria.

- The bioremediation activities conducted by IT Corporation in 1994 significantly reduced the concentration of TPH in the Sandbox soils especially the lighter end hydrocarbons and probably PAH compounds typically associated with petroleum products, however, as confirmed during IT's post-remediation sampling, TPH as Heavy Oils is still present in the majority of the soils within the Sandbox with concentrations ranging from 77 to 1,500 *mg/kg*. However, only low concentrations of VOCs and no PAHs were detected in surface and subsurface soils in the Sandbox indicating that the bioremediation was effective in reducing or eliminating the source of the hazardous constituents typically associated with petroleum hydrocarbons.

Groundwater

A summary of the nature and extent of groundwater contamination is provided as follows:

Former UST Area

- Numerous sampling locations within and downgradient of the former UST contained TPH, BTEX, PCE and/or one or more of its degradation products (TCE and cis 1,2-DCE).

- Based on the assumption that the former UST was the source of the release, the lateral distribution of these contaminants implies these compounds have migrated with groundwater from the former UST location downgradient to the northeast with the leading edge located at DPT #11 and trailing edge at the former UST pit.

- No FFP was detected in the groundwater in the Former UST Area.

- The concentration of PCE (0.370 *mg/l*) is at approximately 0.25 percent of PCE's aqueous solubility of 150 *mg/l*. EPA estimates that PCE may occur as a dense non-aqueous phase liquid (DNAPL) at concentrations that range from 1 to 10 percent of its aqueous solubility. Thus, PCE and its degradation products are believed to be present only in a dissolved state.

- The vertical extent of contamination was delineated through the collection of samples from one deep DPT point (DPT #17) and several deep wells (6MW-3D and 6MW-2 which are screened from 30 to 40 feet below grade. The vertical extent of contamination is limited to above 39.5 feet.

- The concentration for total and dissolved arsenic, iron, and manganese exceeded the EPA RBCs for tap water ~~screening criteria of 0.011 *mg/l*~~ at Well MW-117. No other sampling locations in the Former UST Area detected concentrations of total or dissolved metals above the screening criteria.

OWS Area

- Although detected in total samples in 1995, dissolved arsenic was not detected which indicates that arsenic is associated with the sediment in the groundwater sample. Neither total nor dissolved arsenic was detected in 6MW-3S from the 2000 sampling event.

- Various total and dissolved metals including aluminum, iron, and manganese were detected throughout the OWS area above the EPA RBCs for tap water.

- ~~Total and dissolved manganese was detected in 6MW-3S at 0.64 and 0.53 *ug/l*, respectively. Both of these values for total and dissolved manganese were above the screening criteria.~~

Sandbox Area

- ~~Total arsenic and lead were detected at DPT #7 and DPT #9 at concentrations greater than the screening criteria. Total manganese was detected in the sample from DPT #9 at a concentration that exceeded the screening criteria.~~ Total aluminum, arsenic, barium, cadmium, chromium,

copper, iron, lead, manganese, vanadium, and zinc were detected in DPT samples in the Sandbox area at concentrations greater than EPA RBCs for tap water. Since no dissolved metals analysis is available for these two locations, no conclusions can be made with regard to whether the detected concentrations are associated with sediments in the groundwater sample or in a dissolved state in groundwater. All concentrations of total and dissolved metals were from two locations; therefore, no trends could be discerned with respect to vertical and lateral distribution.

Sediment

A summary of the nature and extent of sediment contamination is provided as follows:

- TPH as Heavy Oils is present in the ditch north of the Sandbox due to surface transport of soil from the Sandbox during heavy precipitation events. Due to stagnant conditions, an accumulation of TPH-contaminated sediment occurs in the ditch with no transport occurring.

- Metals are present in sediment in the ditch but as previously discussed, with concentrations lower than EPA screening criteria.

Surface Water

A summary of the nature and extent of surface water contamination is provided as follows:

- Based on vertical elevations established for the two surface water locations in the ditch, the ditch intersects the shallow water table. The elevations were consistent with the groundwater elevations in that area as shown on Figure 3-6.

- During dry weather conditions, the water (if any) present in the drainage ditch will be groundwater that has seeped into the ditch. Surface water results were also consistent with contaminant concentrations detected in DPT points in the Sandbox and in monitoring well 6MW-3S. Acetone and total metals are present in the ditch but, as previously discussed, with the exception of manganese which was greater than the EPA RBC for tap water, with concentrations lower than EPA screening criteria.

8.2.2 Fate and Transport

A summary of the fate and transport for compounds at the LARC 60 site is provided below:

Former UST Area

- Because of the persistence of TPH as Heavy Oils, its concentrations will only slowly decrease over time in surface soils and groundwater although some migration in groundwater could occur but would be very limited.

- The chlorinated hydrocarbons detected in groundwater are believed to be also associated with a release from the former UST as confirmed by groundwater sampling in February 1995 by Environmental Technology and Malcolm Pirnie during the current investigation. PCE was present in groundwater at roughly 0.25 percent of its aqueous solubility. Degradation products were also present which indicates that degradation of PCE is occurring. In comparison to concentrations established for these compounds in groundwater during the PA/SI, the concentrations of degradation products have increased.

Oil/Water Separator and Sandbox Area

- TPH as Heavy Oils would be expected to be transported along with the soil/sediment to which it is adsorbed. This is probably occurring as storm runoff as well as by runoff during equipment maintenance activities at the wash rack immediately north of the oil/water separator.

- No groundwater samples contained TPH as Heavy Oils as expected since the aqueous solubility of the compound is very low and concentrations in soils were not significant.

- The presence of TPH - Light Ends and chlorinated hydrocarbons in groundwater underlying the oil/water separator and sandbox areas is most likely the result of migration of these compounds from the former UST area. It is possible that the concentrations in groundwater in the vicinity of the oil/water separator are amplified by a release from the oil/water separator, but this can not be confirmed. Regardless, the fate and transport of the compounds would be the same as discussed under the Former UST Area.

8.2.3 Baseline Risk Assessment

A summary of the human health and ecological risk assessments are provided below.

Human Health Evaluation Summary

~~No COPC were identified for soil and sediment at the LARC 60 site while no exposure pathways or exposed populations were identified for contaminated groundwater and surface water located at the site. Therefore, no potential human health risk was identified due to contaminants present at the LARC 60 site.~~

A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

- The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for adults and children with the majority (approximately 99.9 percent) of this risk associated with exposure to COPCs in groundwater. The noncancer risk associated with the COPC (arsenic only) in soil is less than the criterion of 1.0 for both adults and children.

A summary of the **Carcinogenic Risk** for future residential land use is provided below:

- The estimated cancer risk for exposure to chemicals in soils and groundwater is about 3 in 10 thousand for adults and 2 in 10 thousand for children. The greatest component for adultand children exposures is ingestion of arsenic in groundwater (98 percent of total risk). In addition, the risk associated with exposure to contaminated groundwater from arsenic and vinyl chloride is greater than the USEPA remediation goal.

Because arsenic was detected in site soils at concentrations consistent with the background soils as previously discussed, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Therefore, upon removal of arsenic as a COPC, the risk levels become less than the criterion of 1.0 and 10^{-6}, and no further action related to the soils at this site (based on human health risk) is warranted. Additional studies in the form of a feasibility study are warranted for the groundwater risk associated with the site.

Ecological Risk Assessment Summary

No exposure pathways or exposed populations were identified for contaminated media at the site. Therefore, no potential ecological risk was identified due to contaminants present at the LARC 60 site.

8.3 AUTO CRAFT BUILDING AREA

A summary of the nature and extent of contamination, fate and transport characteristics and the baseline risk assessment for the Auto Craft Building Area site is provided in the following sections.

8.3.1 Nature and Extent of Contamination

Soil

A summary of the nature and extent of soil contamination is provided as follows:

- Acetone, methylene chloride, MEK, styrene, toluene and TCE were detected in surface and subsurface soil samples collected at the site. Concentrations of the VOCs varied from surface to deeper depths with no apparent trends. The lateral extent of VOC contamination was not defined because VOCs were detected in all of the surface soil samples collected in this area, but below risk screening criteria.

- Numerous PAHs believed to be the results of asphalt leaching in the upgradient area of the site are present in the shallow soils under the asphalt pad. PAHs were not detected in any other soil locations at the site.

- TPH as Heavy Oils was detected in soils with concentrations decreasing with depth in the borings where TPH was detected. The lateral extent of TPH contamination is limited to the area adjacent to and northeast of the former building which are areas where surface transport of contaminants during heavy precipitation events could occur.

- Numerous metals were detected in soils with concentrations typically decreasing with depth. ~~Metal concentrations were less than the EPA screening criteria.~~ Arsenic, iron, and manganese concentrations exceeded the EPA RBCs for residential soils but were less than the EPA RBCs for industrial soils.

Groundwater

A summary of the nature and extent of groundwater contamination is provided as follows:

- Chloroform was the only VOC detected at the Auto Craft Area. The sample from 7MW-3 contained 11 *ug/l*. Because one sample only contained a detectable concentration of a compound, there was no discernible pattern of contaminant distribution with respect to depth and lateral distance.

- Several total and dissolved metals were detected in groundwater samples. ~~None of the concentrations exceeded the screening criteria.~~ Total arsenic and total iron exceeded the EPA RBCs for tap water in one DPT location each while total and dissolved iron and manganese exceeded the EPA RBCs for tap water in one monitoring well (7MW-3).

8.3.2 Fate and Transport

A summary of the fate and transport for compounds at the Auto Craft site is provided below:

- TPH as Heavy Oils was detected in the shallow (1 to 4 feet) soils in the drainage swale north of the site. Because TPH as Heavy Oils adsorbs very strongly onto soil and has a low aqueous solubility, the adsorbed compounds move with the soil/sediments during storm runoff into the drainage swale.

- Since TPH as Heavy Oils has a low solubility it would not be expected to leach or dissolve in groundwater. This is further supported because TPH as Heavy Oils was not detected in any downgradient monitoring wells.

- In the groundwater system, the PA/SI detected TPH as Heavy Ends in well MW-119 at 0.7 *mg/l* but the RI sample for MW-119 did not contain detectable concentrations of any TPH compounds. Although TPH as Heavy Oils still persist in the soils, it is not leaching to groundwater.

- Chloroform was detected in the deep well (7MW-3) of the shallow/deep cluster downgradient of the former building location. Chloroform has a high aqueous solubility (8,220 *mg/l*, see Table 5-

1) and the concentration detected was 0.011 *mg/l* which is well below the aqueous solubility. Thus the chloroform is in a dissolved state. Since chloroform was detected in only one downgradient well, no conclusions could be made with respect to transport in groundwater. Since the compound is in a dissolved state, it would be expected to migrate with groundwater.

8.3.3 Baseline Risk Assessment

A summary of the human health and ecological risk assessments are provided below.

Human Health Evaluation Summary

~~No COPC were identified for soil at the Auto Craft site while no exposure pathways or exposed populations were identified for contaminated groundwater located at the site. Therefore, no potential human health risk was identified due to contaminants present at the Auto Craft site.~~

A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

- The total exposure hazard index for adults and children was greater than the criterion of 1.0 with inhalation of chloroform exceeding the criterion for adults and children with ingestion of iron exceeding the criterion for children as well.

A summary of the **Carcinogenic Risk** for future residential land use is provided below:

- The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 6 in 100,000 for adults. The greatest component for adults exposures is inhalation of chloroform in groundwater (92 percent of total risk) which was within the USEPA remediation goal.

- The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 5 in 100,000 for children. The greatest components for child exposures are ingestion of arsenic (although levels are consistent with background) in soils (5 percent of total risk) and inhalation of chloroform (86 percent of total risk) in groundwater.

Because arsenic was detected in site soils at concentrations consistent with the background soils as previously discussed, the risk associated with it is not related to site-specific activities such as spills, leaks, or industrial activities. Chloroform was only detected in one groundwater sample at the site and in a concentration (11 ug/L) below the USEPA MCL for total trihalomethanes. Therefore, upon removal of arsenic and chloroform as COPCs, the risk levels become less than the criterion of 1.0 and 10^{-6}, and no further action related to this site (based on human health risk) is warranted.

Ecological Risk Assessment Summary

No exposure pathways or exposed populations were identified for contaminated media at the site. Therefore, no potential ecological risk was identified due to contaminants present at the Auto Craft site.

This section provides the recommendations for the three sites based on the nature and extent of contamination, fate and transport characteristics and the results of the human health and ecological risk assessments.

9.1 FIREFIGHTER TRAINING AREA

No Further Action is recommended for the Firefighter Training Area (FTA) site based on the limited contamination detected in the three AOCs, the trends which indicate that the TPH and VOC concentrations in soil and groundwater are decreasing due to numerous fate mechanisms and the results of the baseline risk assessment which did not identify receptors and potentially exposed populations.

9.2 LARC 60 MAINTENANCE AREA

~~**No Further Action** is recommended for the LARC 60 site based on the results of the baseline risk assessment which did not identify receptors and potentially exposed populations.~~

Additional studies in the form of a feasibility study are warranted for the site due to the potential groundwater risk associated with the site due to the presence of various chlorinated organics at concentrations greater than the EPA RBCs and USEPA MCLs.

9.3 AUTO CRAFT BUILDING AREA

No Further Action is recommended for the Auto Craft site based on the limited contamination detected, the trends which indicate that the TPH concentrations in soil and groundwater are decreasing due to numerous fate mechanisms and the chloroform detect is less than the USEPA MCL and the results of the baseline risk assessment which did not identify receptors and potentially exposed populations.

FIGURES

Remedial Investigation Report
FTA, LARC 60, and Auto Craft Sites
Fort Story, Virginia

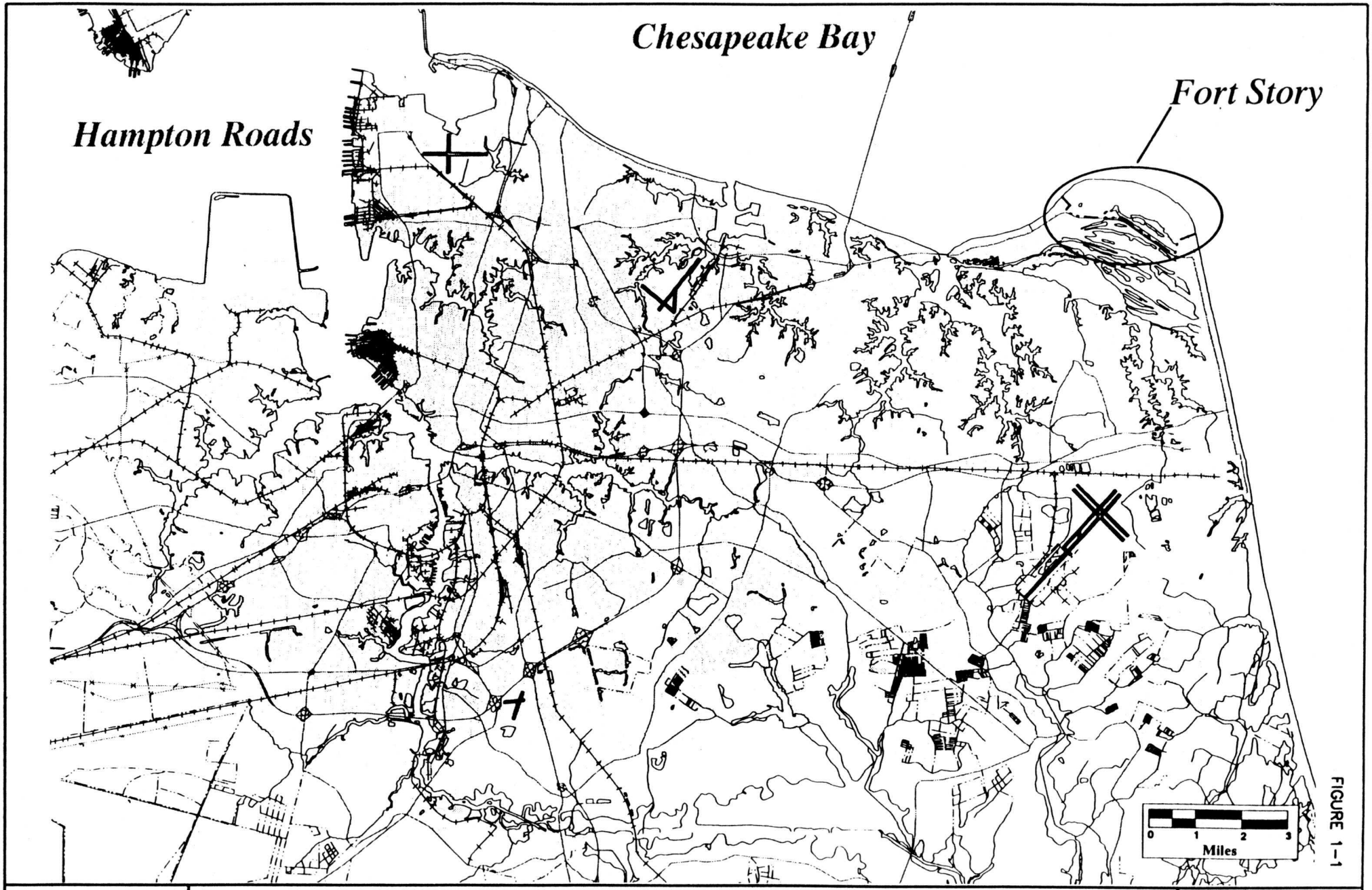


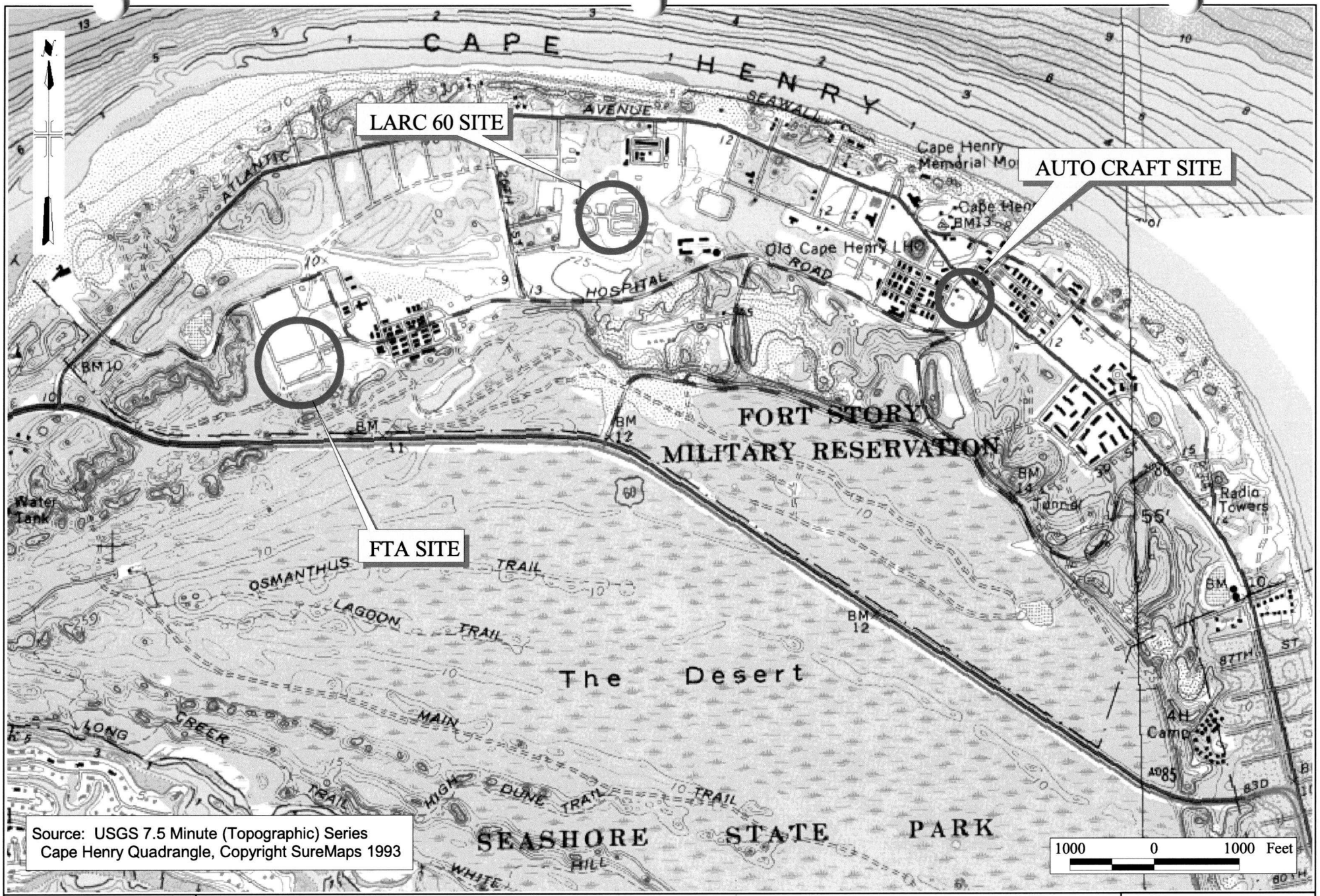
FIGURE 1-1

MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
FORT STORY LOCATION MAP

MALCOLM PIRNIE, INC.

DECEMBER 1995



Source: USGS 7.5 Minute (Topographic) Series
Cape Henry Quadrangle, Copyright SureMaps 1993

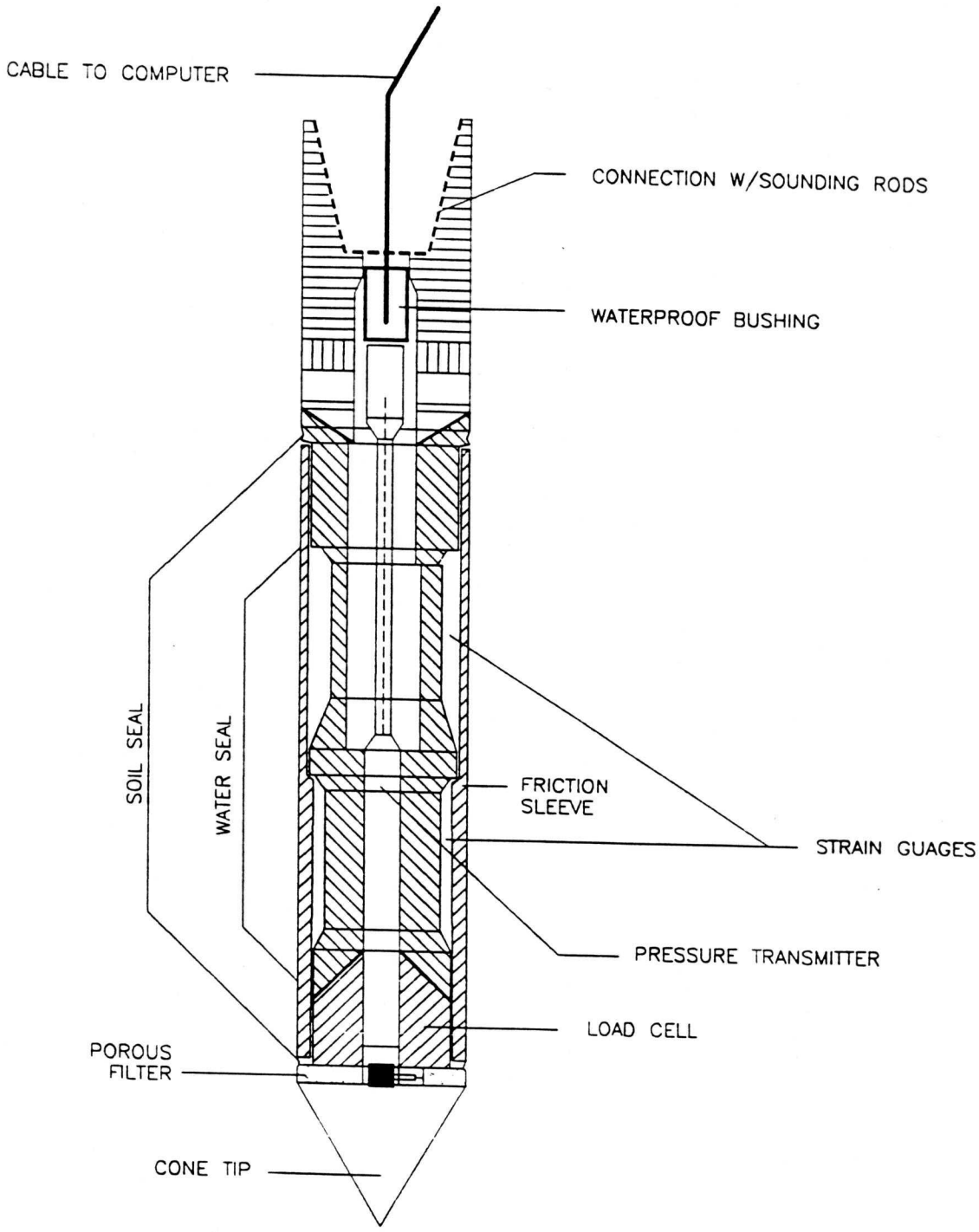
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
SITE LOCATION MAP

May 2002

Figure 1-2

FIGURE 2-1

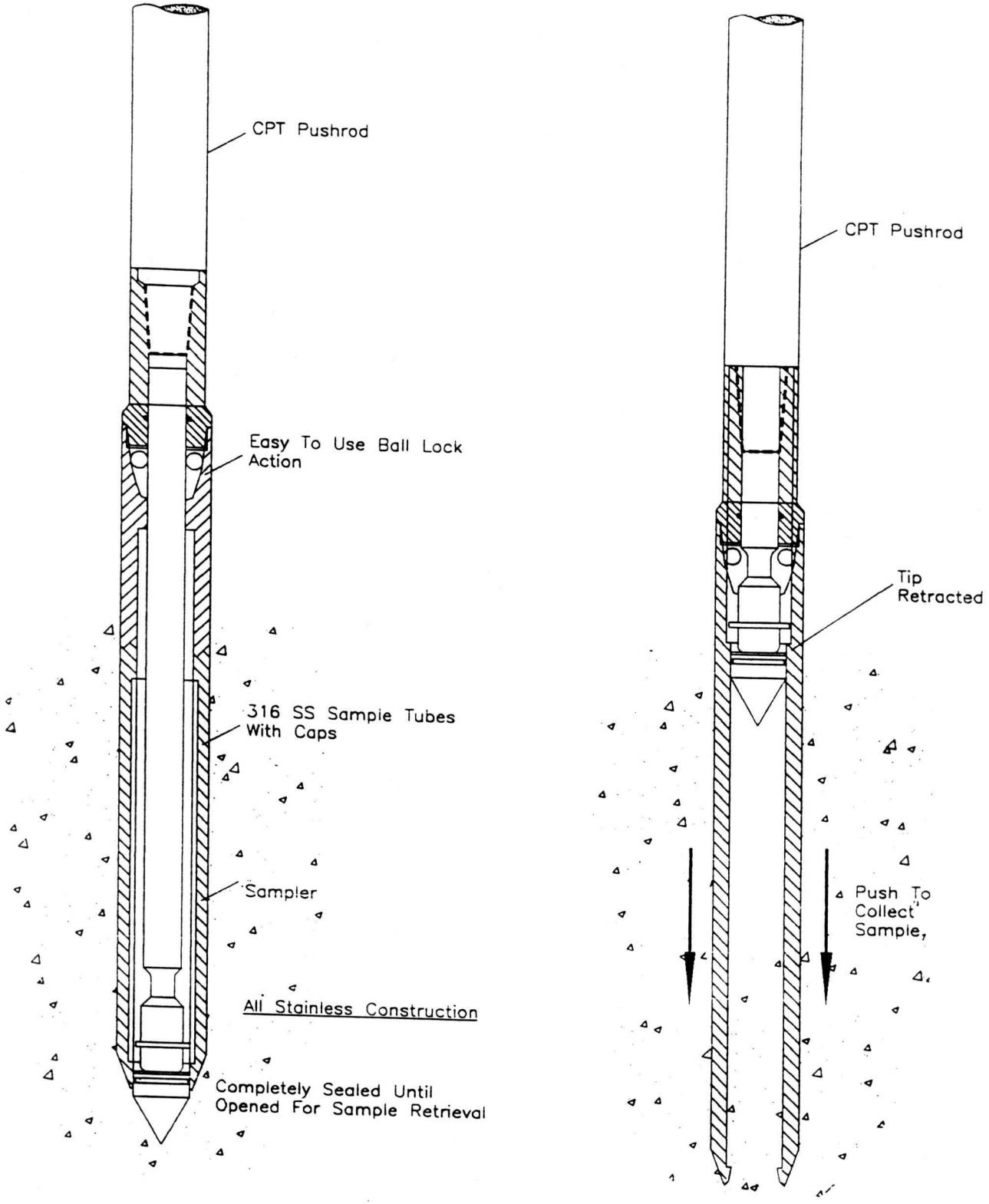


SOURCE: EARTH TECH REMEDIATION SERVICES

NOT TO SCALE

MALCOLM PIRNIE	FORT STORY, VIRGINIA REMEDIAL INVESTIGATION REPORT PIEZOCONE SCHEMATIC	MALCOLM PIRNIE, INC. DECEMBER 1995

FIGURE 2-2



SOURCE: EARTH TECH REMEDIATION SERVICES

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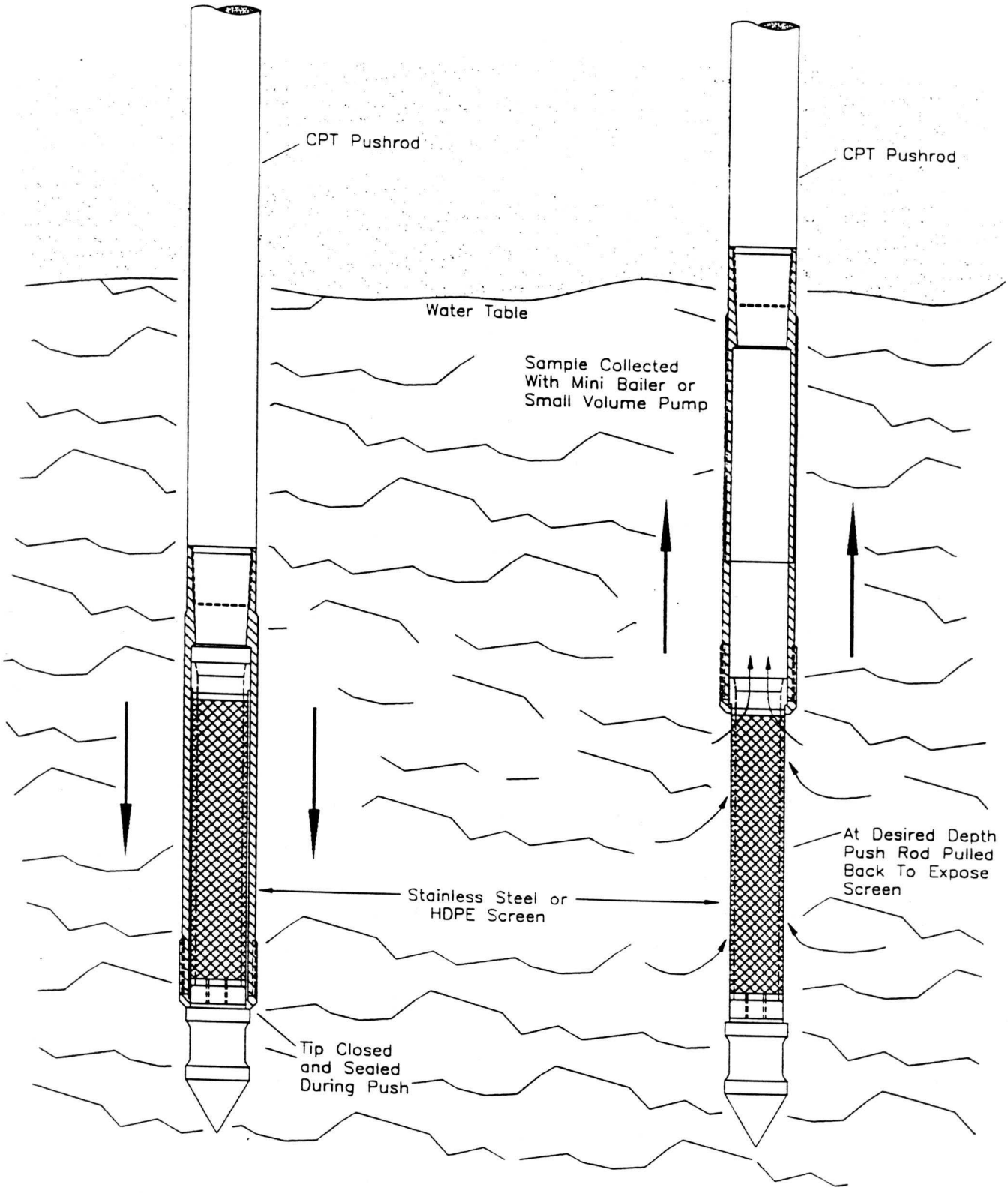
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
SOIL SAMPLER

MALCOLM PIRNIE, INC.

DECEMBER 1995

FIGURE 2-3



SOURCE: EARTH TECH REMEDIATION SERVICES

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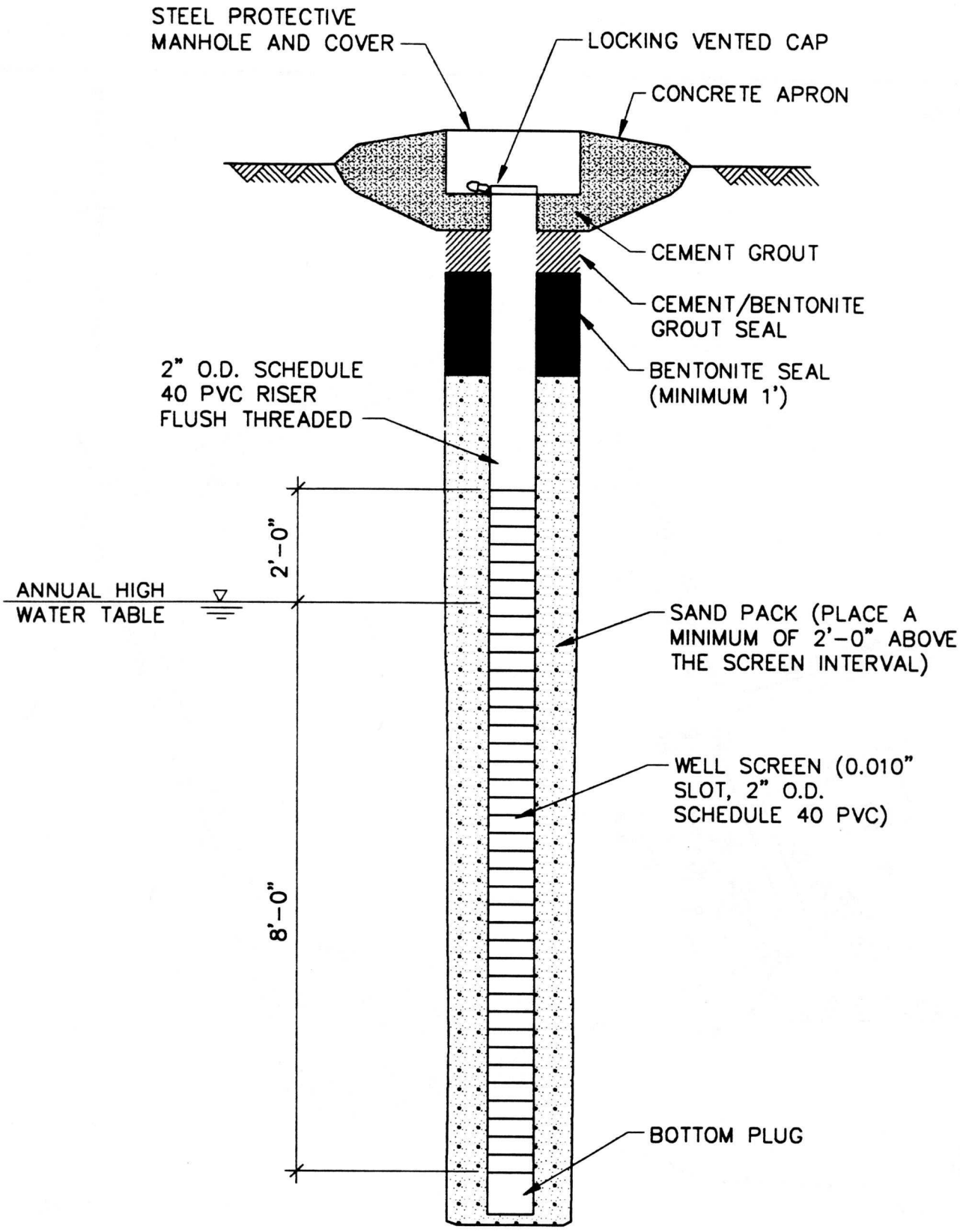
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
GROUNDWATER SAMPLER

MALCOLM PIRNIE, INC.

DECEMBER 1995

FIGURE 2-4

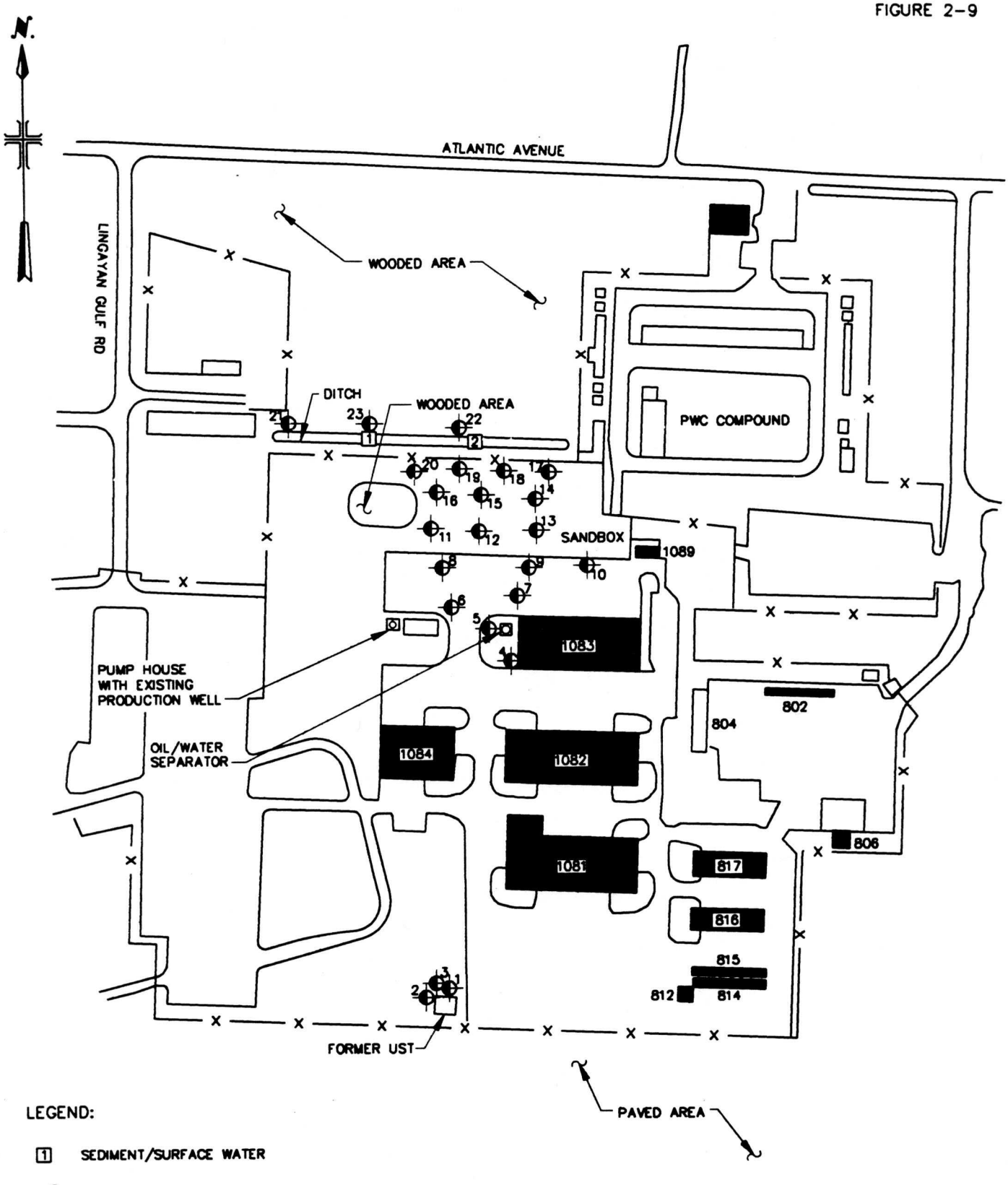


NOT TO SCALE

MALCOLM PIRNIE	FORT STORY, VIRGINIA REMEDIAL INVESTIGATION REPORT TYPICAL FLUSH-MOUNTED WELL DESIGN	MALCOLM PIRNIE, INC. DECEMBER 1995

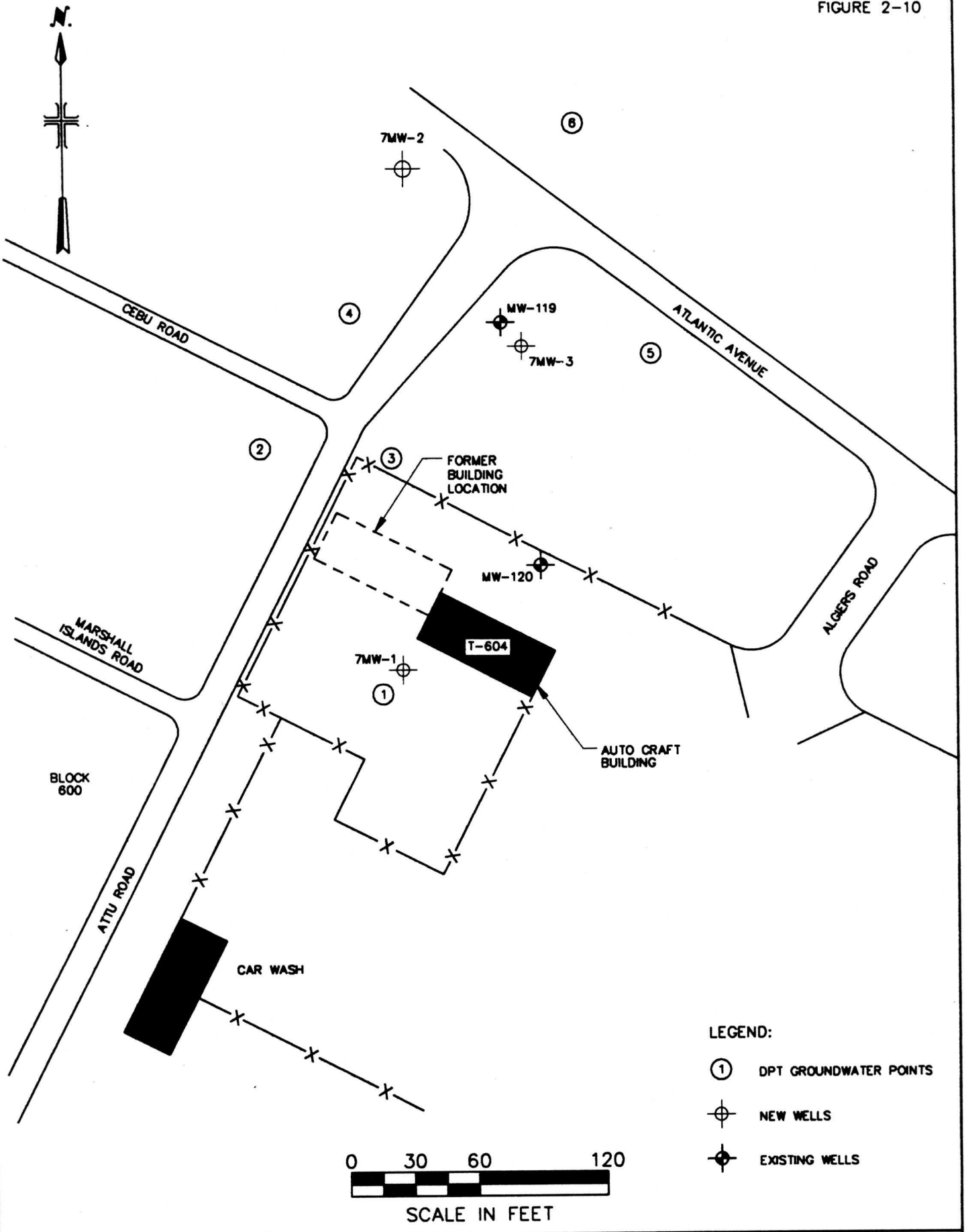
4995 : 0285588320\I:\ACAD\PROJ\0285588\F1F2BDR SCALE: 1:1i 11/30, 1995 at 10:58

FIGURE 2-9



MALCOLM PIRNIE	FORT STORY, VIRGINIA REMEDIAL INVESTIGATION REPORT LARC 60 SOIL, SEDIMENT AND SURFACE WATER SAMPLING LOCATIONS	MALCOLM PIRNIE, INC. DECEMBER 1995

FIGURE 2-10



MALCOLM PIRNIE

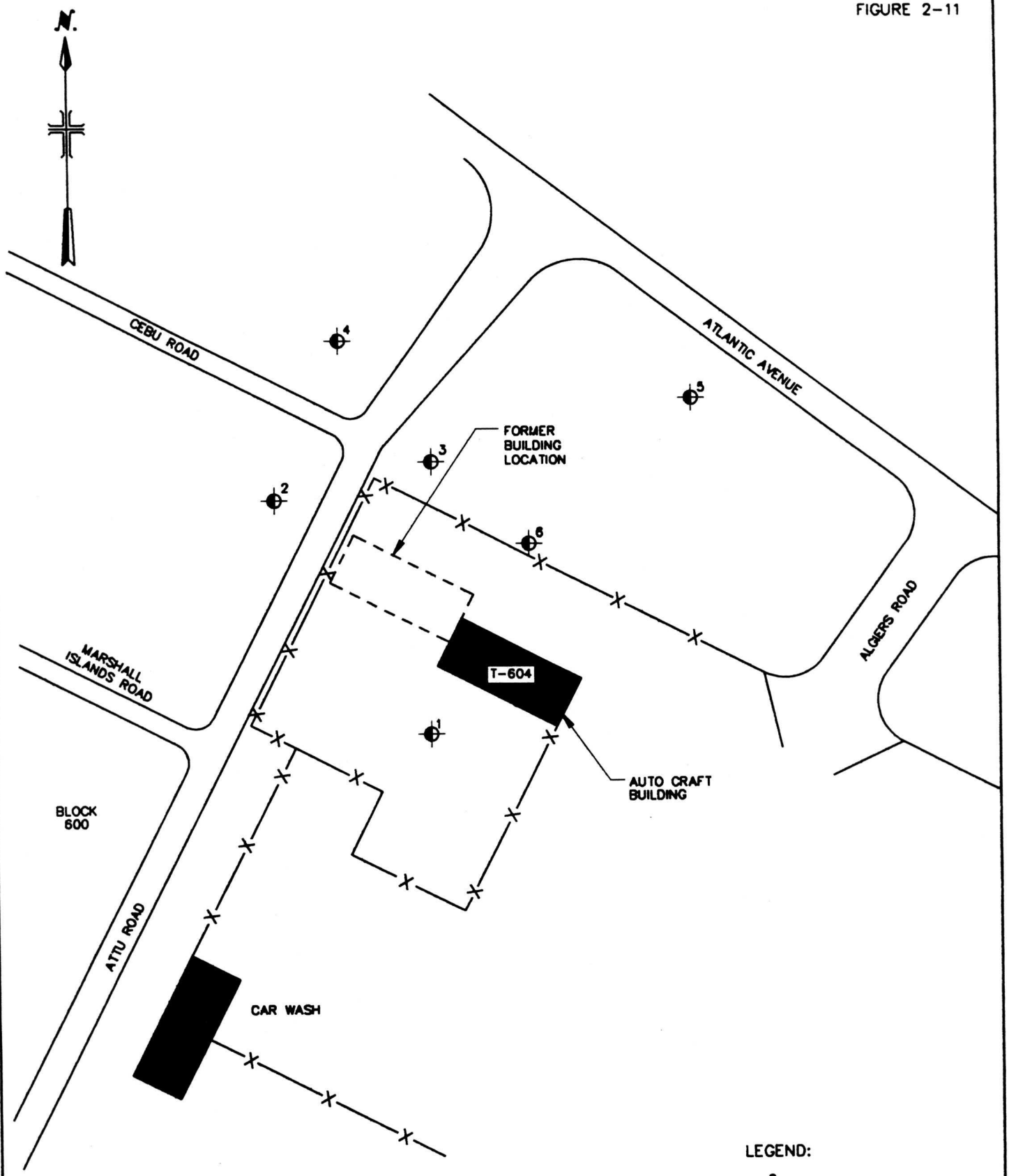
FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
AUTO CRAFT GROUNDWATER SAMPLING LOCATIONS

MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\F2-9-10 SCALE: 1:720i 11/30, 1995 at 13:45

FIGURE 2-11



MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
AUTO CRAFT SOIL SAMPLING LOCATIONS

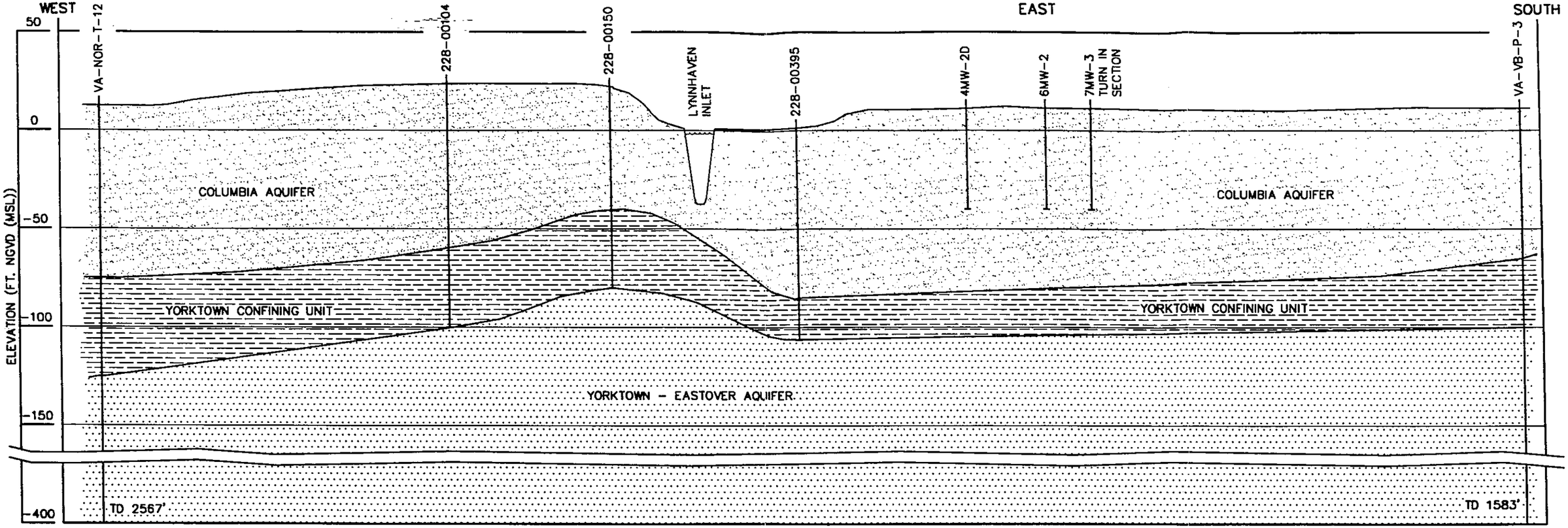
MALCOLM PIRNIE, INC.

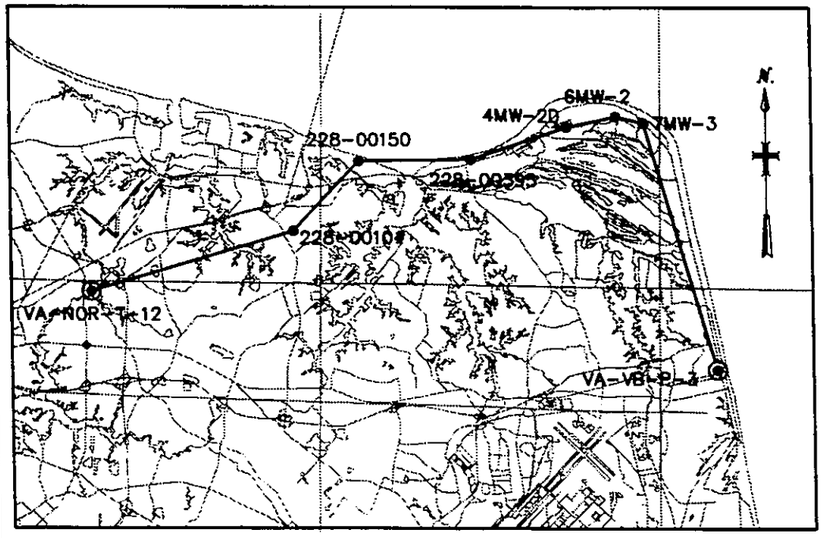
DECEMBER 1995

NORFOLK — CITY OF VIRGINIA BEACH — FORT STORY

WEST — EAST — SOUTH

FIGURE 3-1





SITE PLAN
SCALE: 1" = 5000'

0 1000 2000 4000

SCALE IN FEET

0 2500 5000 10000

SCALE IN FEET

LEGEND

- SILTY SAND
- CLAY
- SAND
- SOIL BORING (FROM PA/SI)
- DEQ REGISTERED WELLS
- CORE HOLE DESCRIBED BY BROWN AND OTHERS (1972)
- TD TOTAL DEPTH

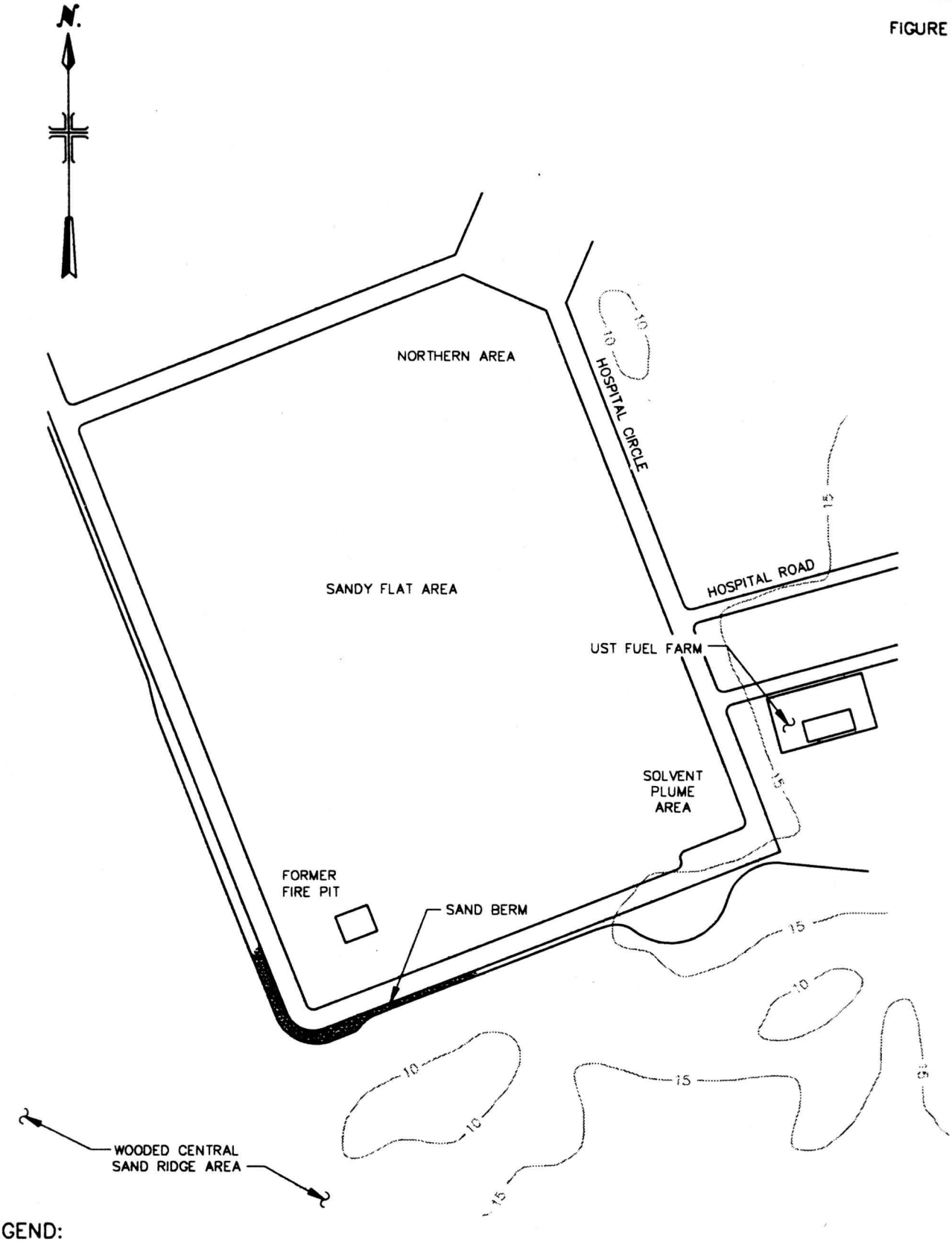
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
REGIONAL CROSS SECTION

MALCOLM PIRNIE, INC.

DECEMBER 1995

FIGURE 3-2



MALCOLM PIRNIE

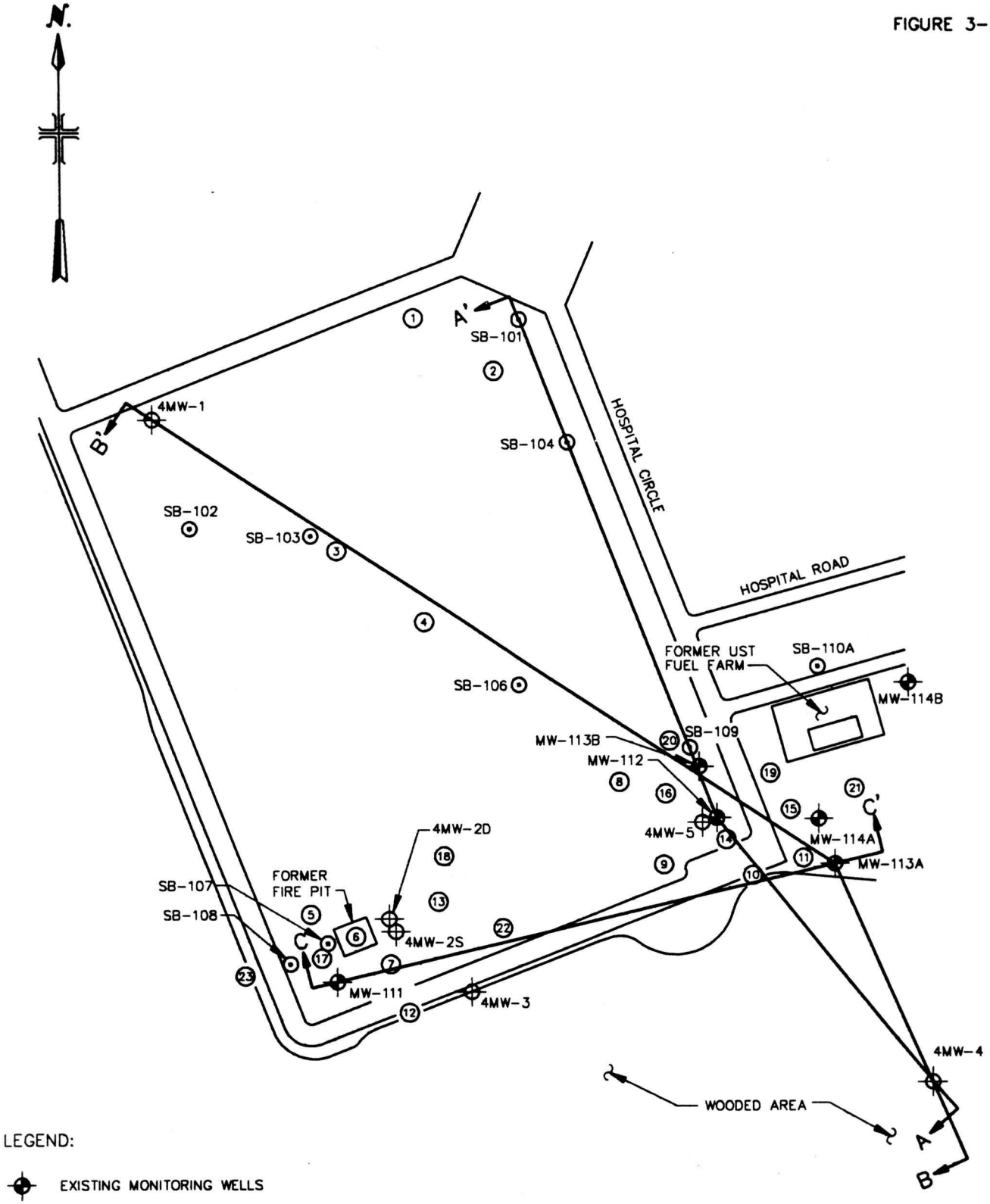
FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
FTA SITE MAP

MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-2 SCALE: 1:1200i 11/30, 1995 at 13:06

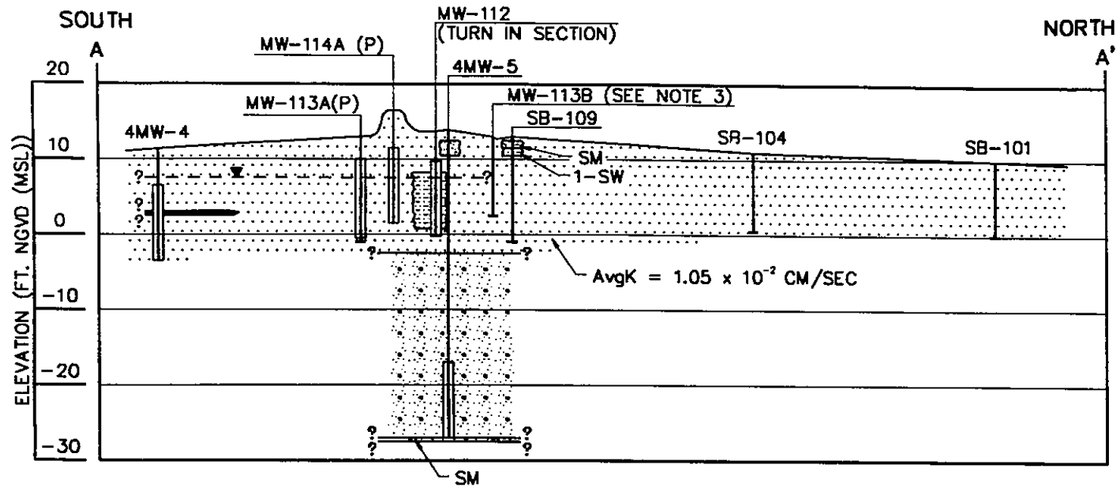
FIGURE 3-3

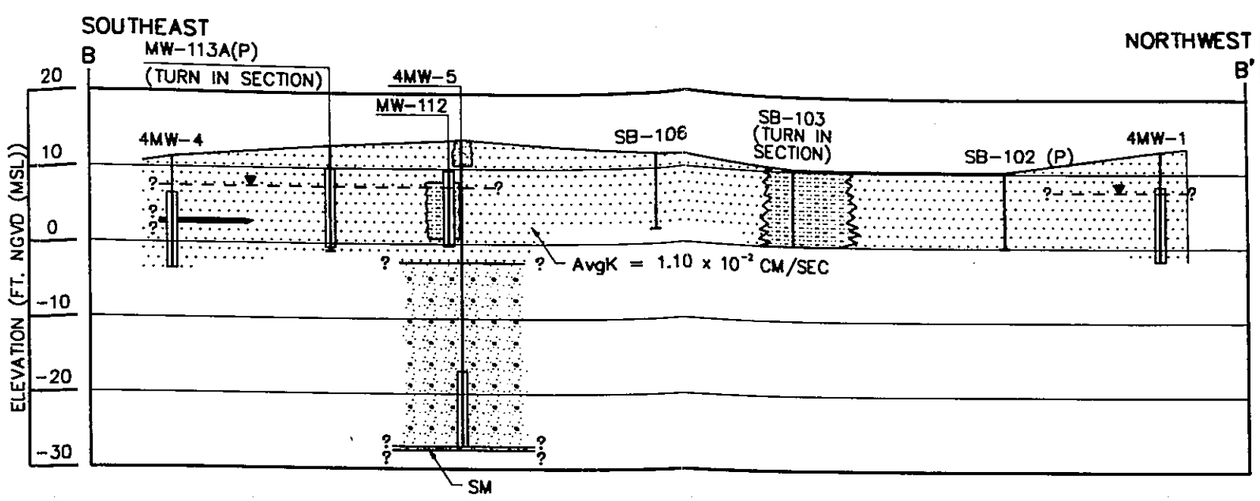


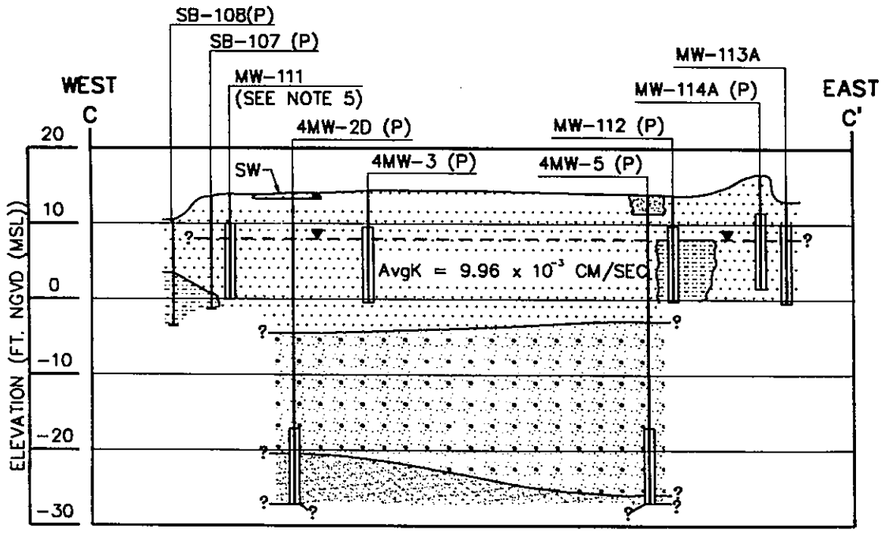
MALCOLM PIRNIE	FORT STORY, VIRGINIA REMEDIAL INVESTIGATION REPORT FTA CROSS SECTION TRAVERSES	MALCOLM PIRNIE, INC. DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-3 SCALE: 1:1200i 11/30, 1995 at 13:57

FIGURE 3-4







NOTES:

1. MONITORING WELL ELEVATION IS FROM TOP OF CASING AS MEASURED ON 5/11/95.
2. SOIL BORING ELEVATION FROM TABLE 2-1 OF PA/SI.
3. WATER TABLE ELEVATION FOR MW-113B IS NOT NOT AVAILABLE FOR 5/17/94.
4. HYDRAULIC CONDUCTIVITY (K) VALUES ARE NOT AVAILABLE FOR OL, SM, AND SW UNITS.
5. MW-111 LITHOLOGY INFERRED BASED UPON LITHOLOGY OF NEARBY BORINGS/WELLS.

LEGEND

- SM/SILTY SAND
- SP/SAND MEDIUM GRAINED
- 1-SW/SAND FINE WITH GRAVEL
- 2-SW/SAND COARSE WITH GRAVEL
- OL/ORGANIC SILT AND SILTY CLAY
- ?- ▼ -? WATER TABLE (5/17/95)
- (P) PROJECTED
- SCREENED INTERVAL
- SOIL BORING (FROM PA/SI)

0 75 150 300

SCALE IN FEET

MALCOLM PIRNIE

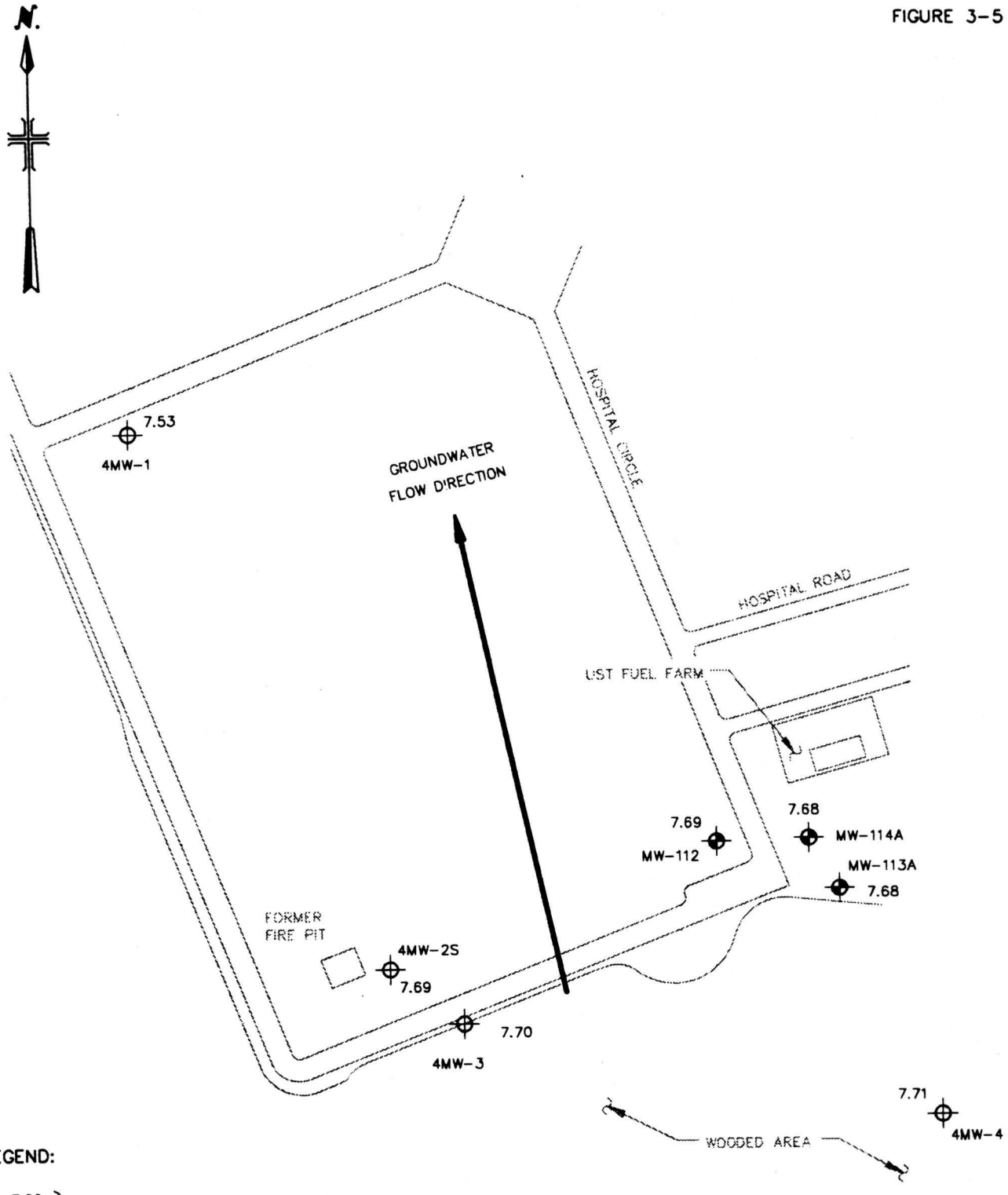
FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
FTA CROSS SECTIONS

MALCOLM PIRNIE, INC.

DECEMBER 1995

1995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-4 SCALE: 1:1800i 11/30, 1995 at 13:08

FIGURE 3-5



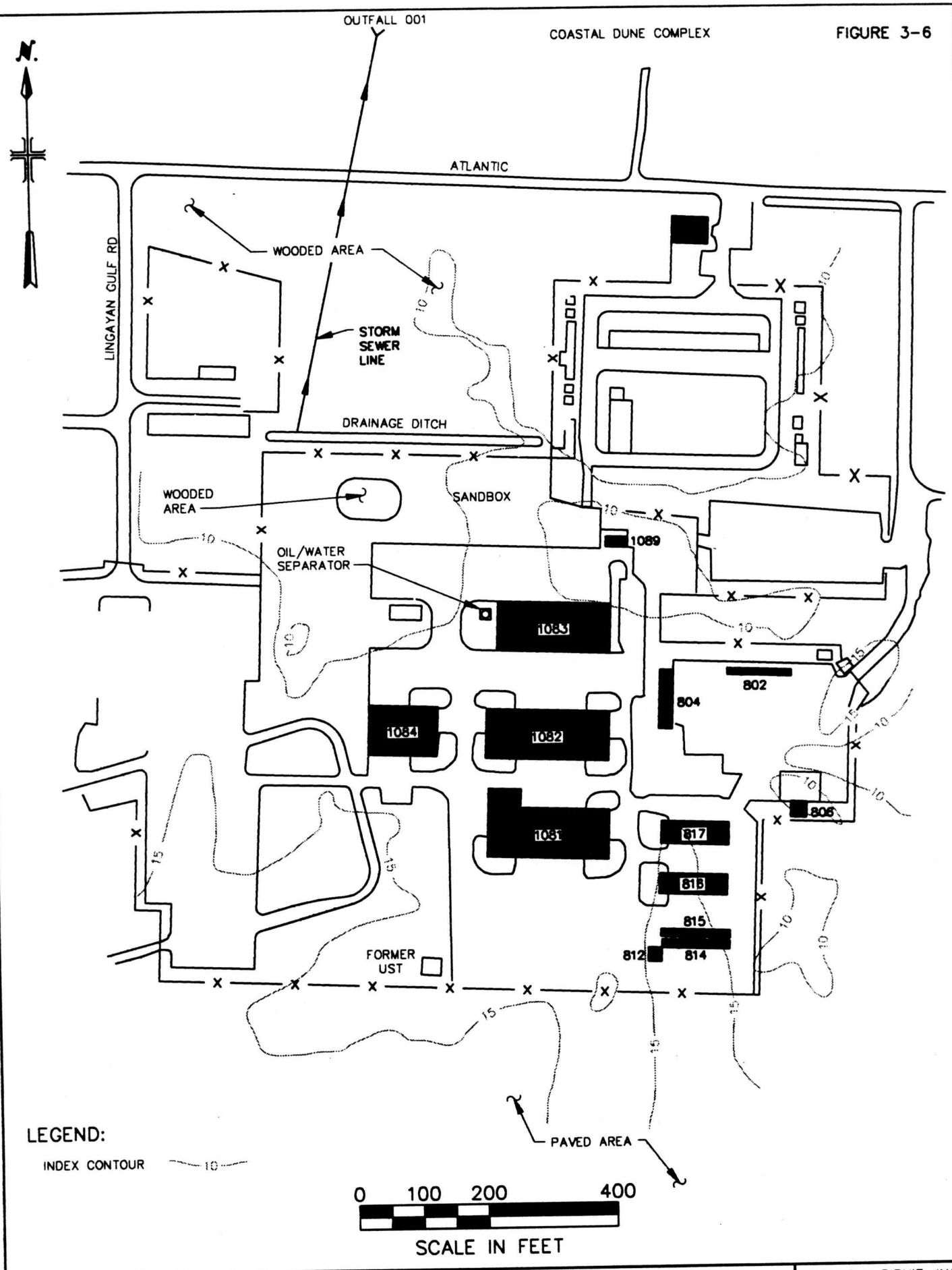
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
FTA SITE WATER TABLE ELEVATIONS

MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-5 SCALE: 1:1200i 11/30, 1995 at 14:31



MALCOLM PIRNIE

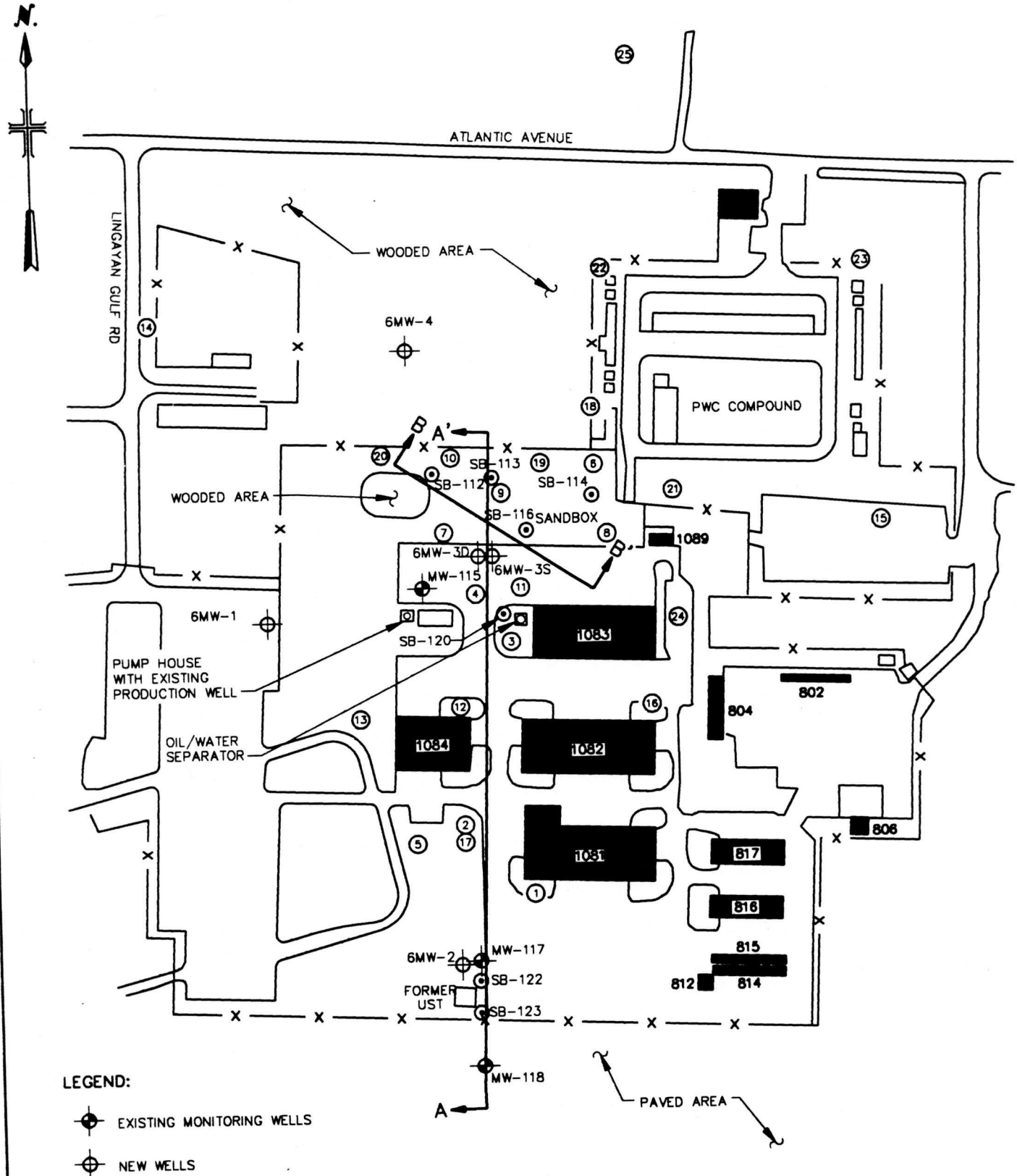
FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
LARC 60 SITE MAP

MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\V:\ACAD\PROJ\0285588\FIG3-6 SCALE: 1:2400i 11/30, 1995 at 14:38

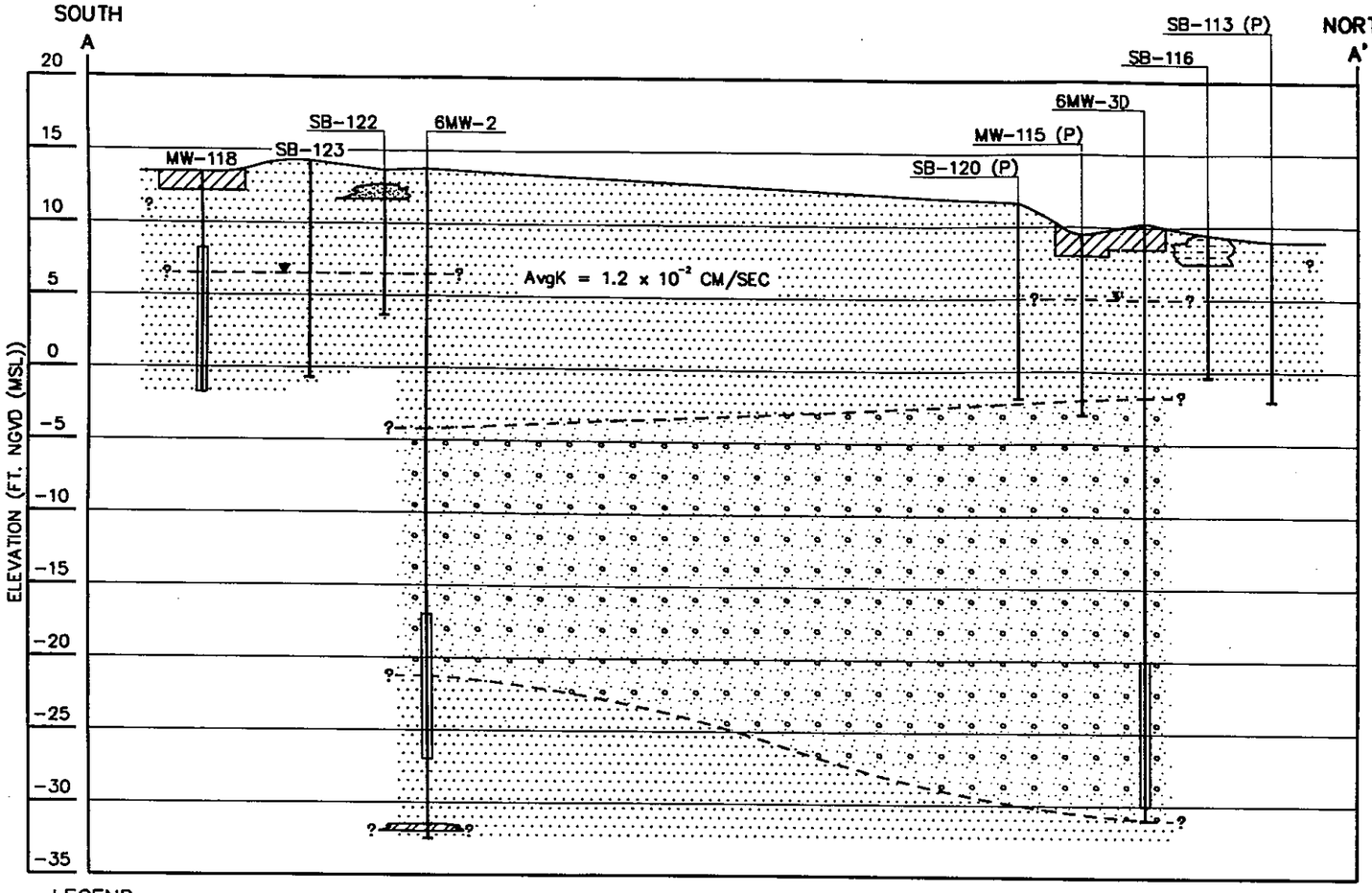
FIGURE 3-7

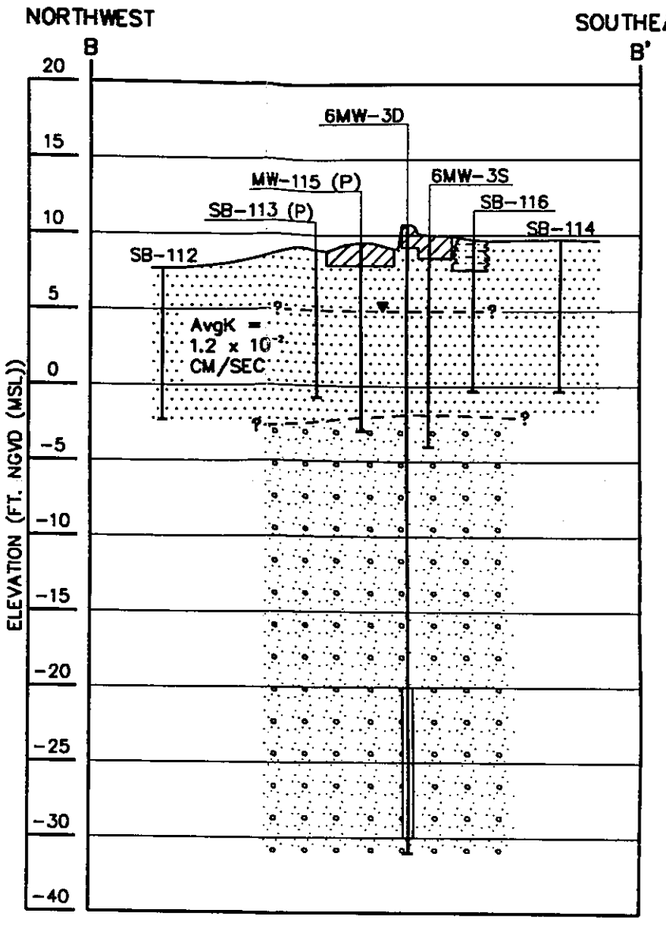


MALCOLM PIRNIE	FORT STORY, VIRGINIA REMEDIAL INVESTIGATION REPORT LARC 60 CROSS SECTION TRAVERSES	MALCOLM PIRNIE, INC. DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-7 SCALE: 1:2400i 11/30, 1995 at 14:39

FIGURE 3-8





LEGEND

- SM/SILTY SAND
- SP/SAND MEDIUM GRAINED
- 1-SW/SAND FINE WITH GRAVEL
- 2-SW/SAND COARSE WITH GRAVEL
- OL/ORGANIC SILT AND SILTY CLAY
- SC/INORGANIC CLAY
- CONCRETE/ASPHALT WITH SAND/GRAVEL
- ?- ▼ -? WATER TABLE (5/17/95)
- (P) PROJECTED
- SCREENED INTERVAL
- SOIL BORING (FROM PA/SI)

0 50 100 200

SCALE IN FEET

NOTES:

1. MONITORING WELL ELEVATION IS FROM TOP OF CASING AS MEASURED ON 5/11/95.
2. SOIL BORING ELEVATION FROM TABLE 2-1 OF PA/SI.
3. HYDRAULIC CONDUCTIVITY (K) VALUES ARE NOT AVAILABLE FOR SM, 1-SW, 2-SW AND SC UNITS. HYDRAULIC CONDUCTIVITY VALUES FROM TABLE 2-1 OF PA/SI.
4. LITHOLOGY FOR MW-115 INFERRED BASED ON ADJACENT BORING LOGS.

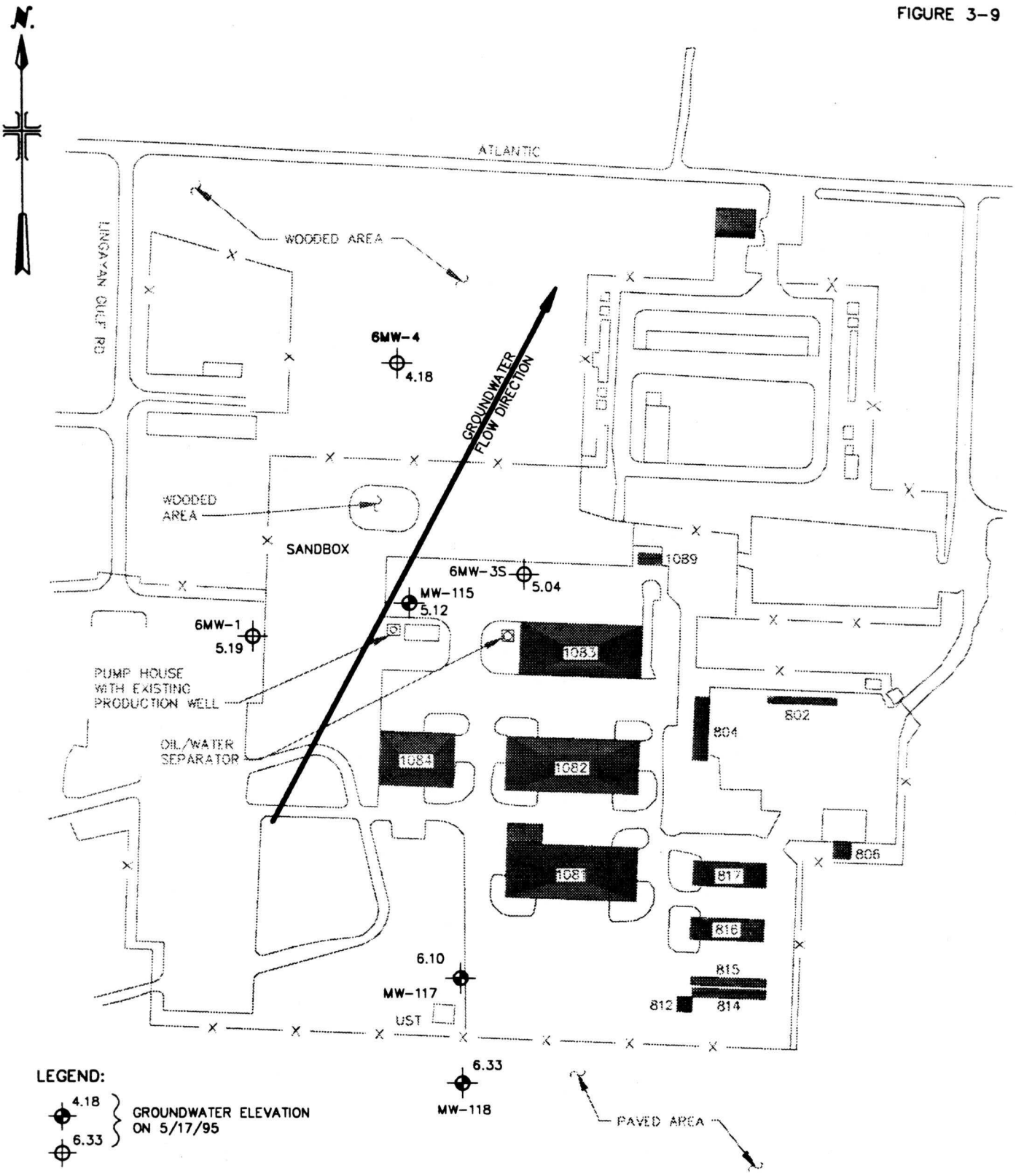
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
LARC 60 CROSS SECTIONS

MALCOLM PIRNIE, INC.

DECEMBER 1995

FIGURE 3-9



MALCOLM PIRNIE

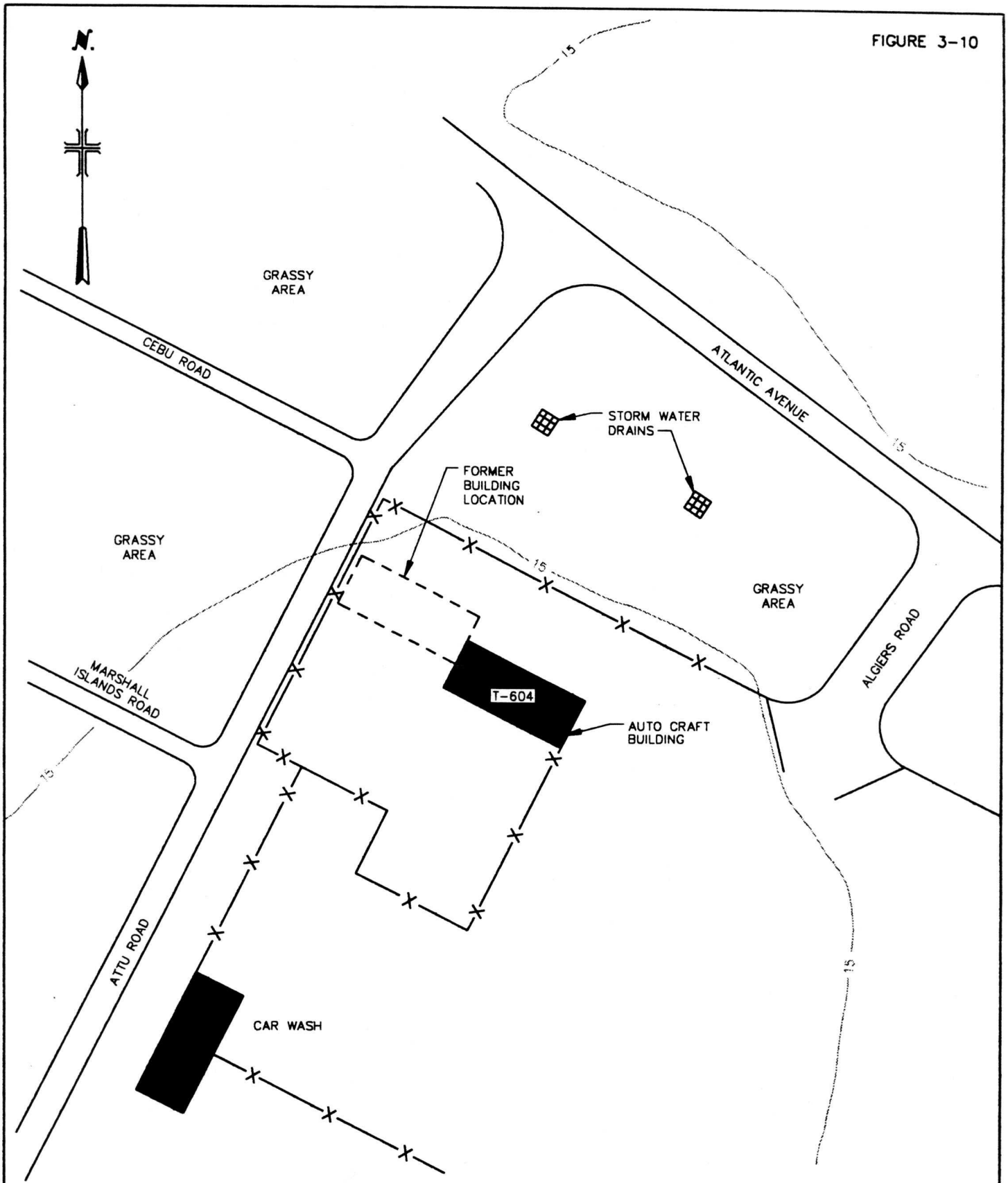
FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
LARC 60 MAINTENANCE AREA
WATER TABLE ELEVATIONS

MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-9 SCALE: 1:2400i 11/30, 1995 at 14:41

FIGURE 3-10



MALCOLM PIRNIE

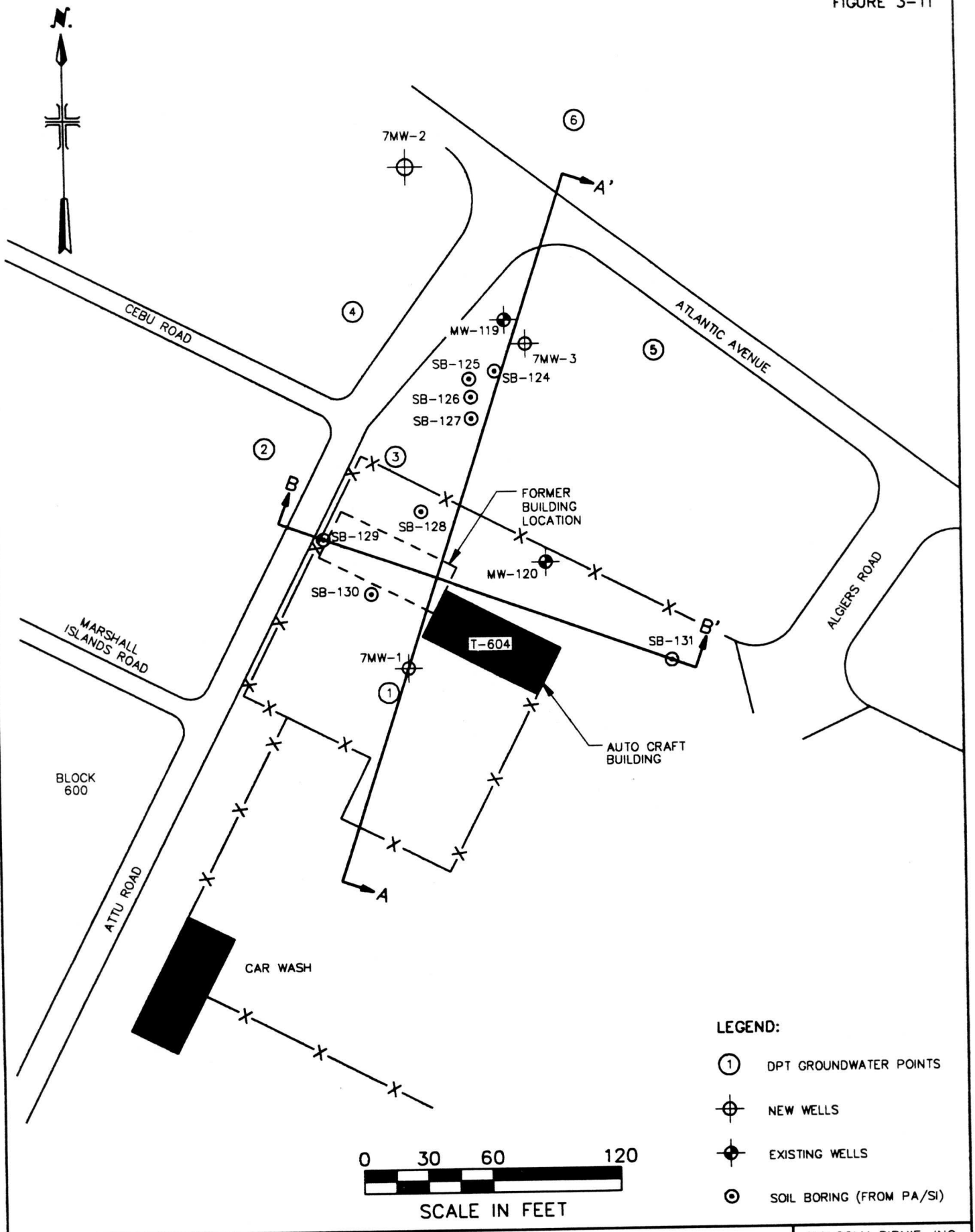
FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
AUTO CRAFT SITE MAP

MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\V:\ACAD\PROJ\0285588\FIG3-10 SCALE: 1:720i 11/30, 1995 at 13:18

FIGURE 3-11



MALCOLM PIRNIE

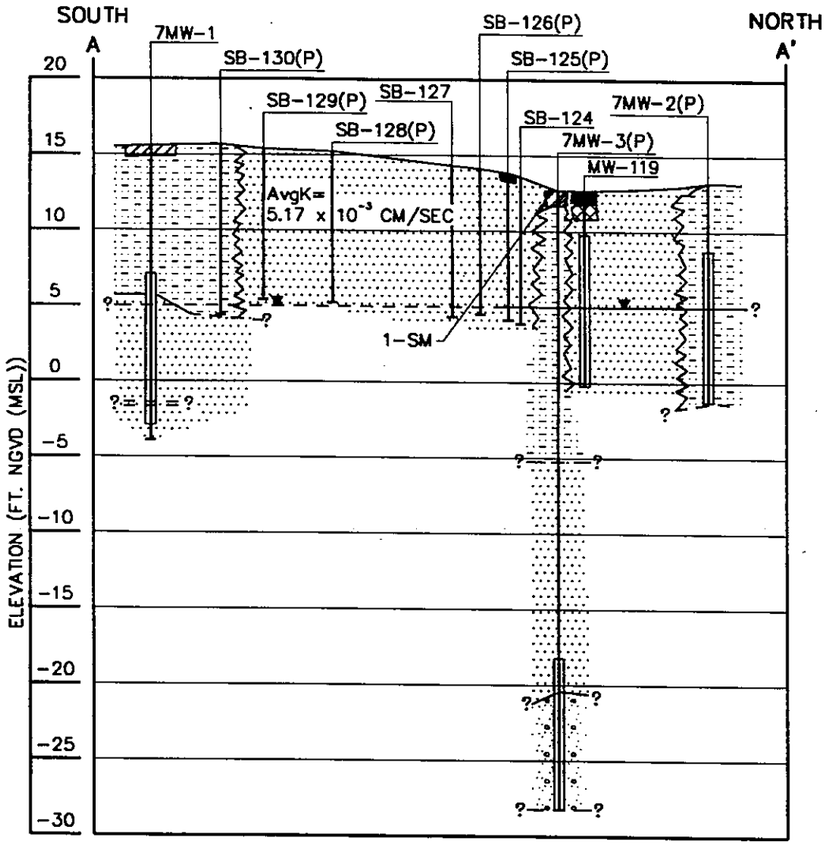
FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
AUTO CRAFT CROSS SECTION TRAVERSES

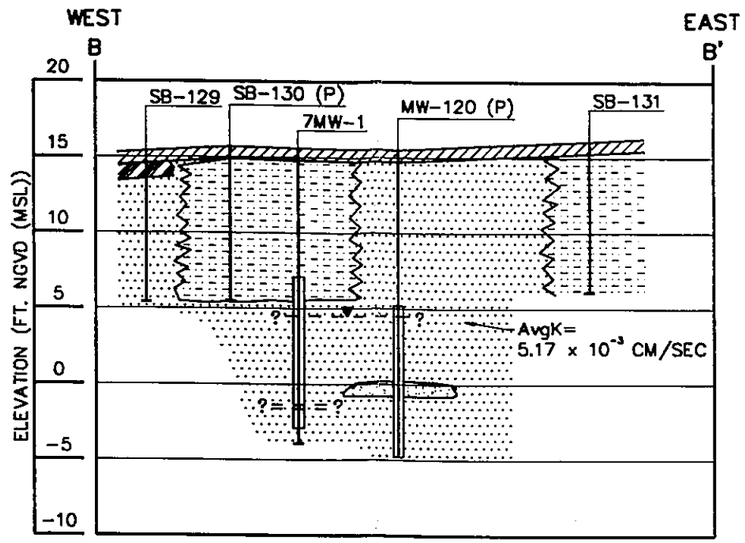
MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-11 SCALE: 1:720i 11/30, 1995 at 13:55

FIGURE 3-12





LEGEND

- SM/SILTY SAND
- 1-SM/SILTY SAND WITH ORGANIC FINES
- SP/SAND MEDIUM GRAINED
- 1-SW/SAND FINE WITH GRAVEL
- 2-SW/SAND COARSE WITH GRAVEL
- ML/SILT
- OL/ORGANIC SILT AND SILTY CLAY
- CONCRETE/ASPHAULT WITH SAND/GRAVEL

?- ⧗ -? WATER TABLE (5/17/95)

?= = =? SOIL HORIZON

(P) PROJECTED

SCREENED INTERVAL

SOIL BORING (FROM PA/SI)

0 30 60 120

SCALE IN FEET

NOTES:

1. MONITORING WELL ELEVATION IS FROM TOP OF CASING AS MEASURED ON 5/11/95.
2. SOIL BORING ELEVATION FROM TABLE 2-1 OF PA/SI.
3. HYDRAULIC CONDUCTIVITY (K) VALUES ARE NOT AVAILBLE FOR 1-SM, ML, OL, 1-SW AND 2-SW. HYDRAULIC CONDUCTIVITY VALUES FROM TABLE 2-10 OF PA/SI.

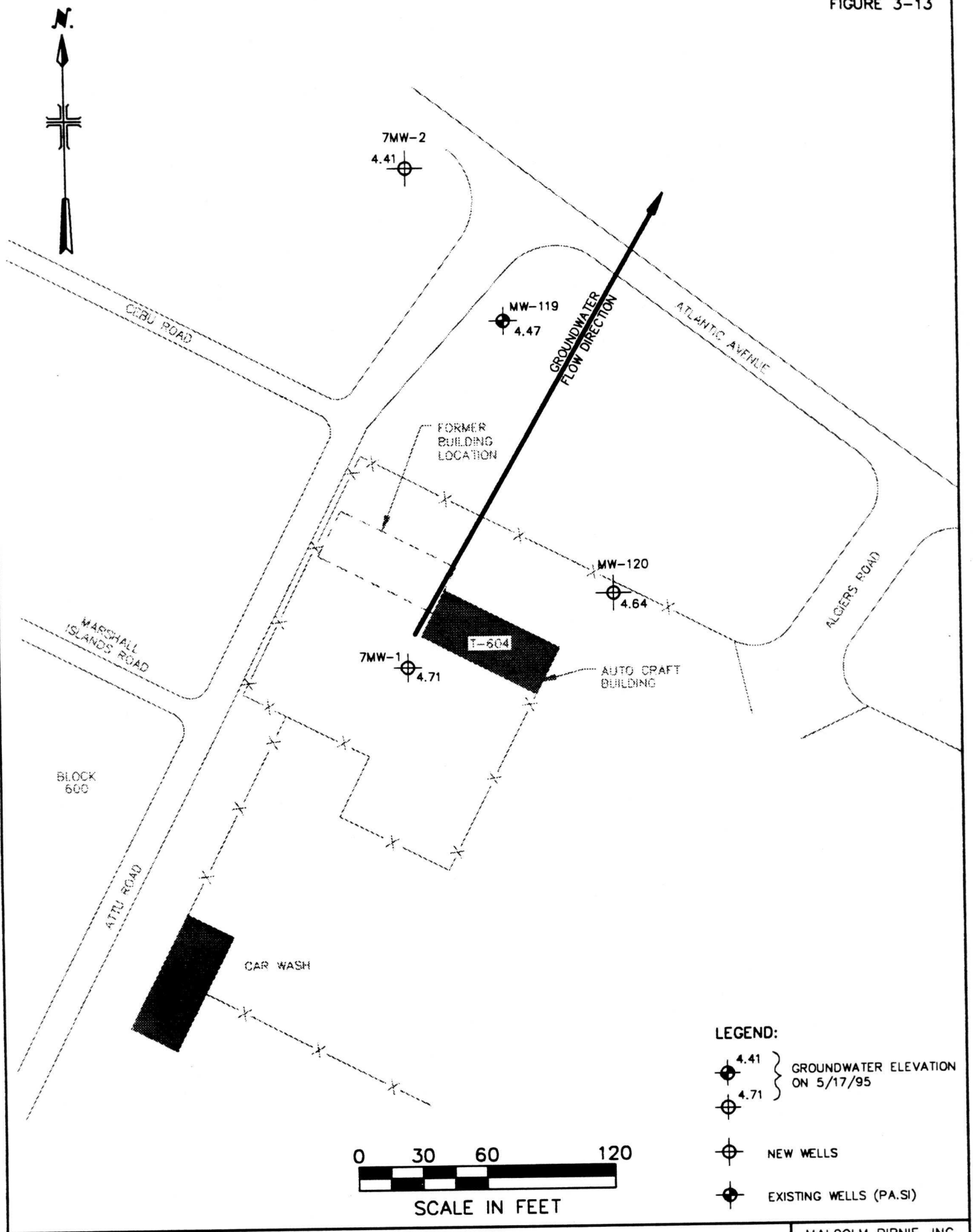
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
AUTO CRAFT SITE CROSS SECTIONS

MALCOLM PIRNIE, INC.

DECEMBER 1995

FIGURE 3-13



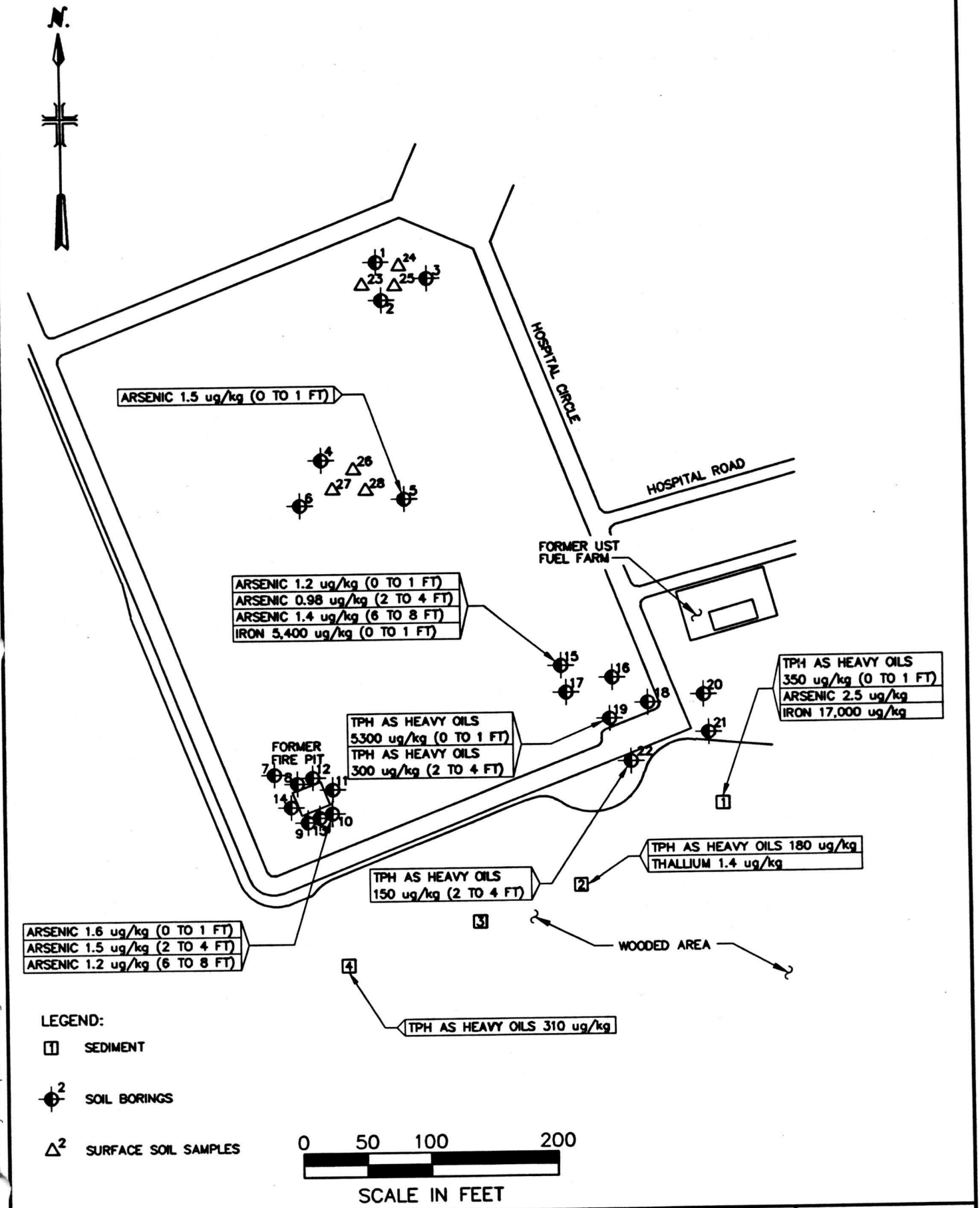
MALCOLM PIRNIE

FORT STORY, VIRGINIA
REMEDIAL INVESTIGATION REPORT
AUTO CRAFT SITE WATER TABLE ELEVATION MAP

MALCOLM PIRNIE, INC.

DECEMBER 1995

4995 : 0285588320\I:\ACAD\PROJ\0285588\FIG3-13 SCALE: 1:720i 11/30, 1995 at 13:56



MALCOLM PIRNIE

FORT STORY, VIRGINIA

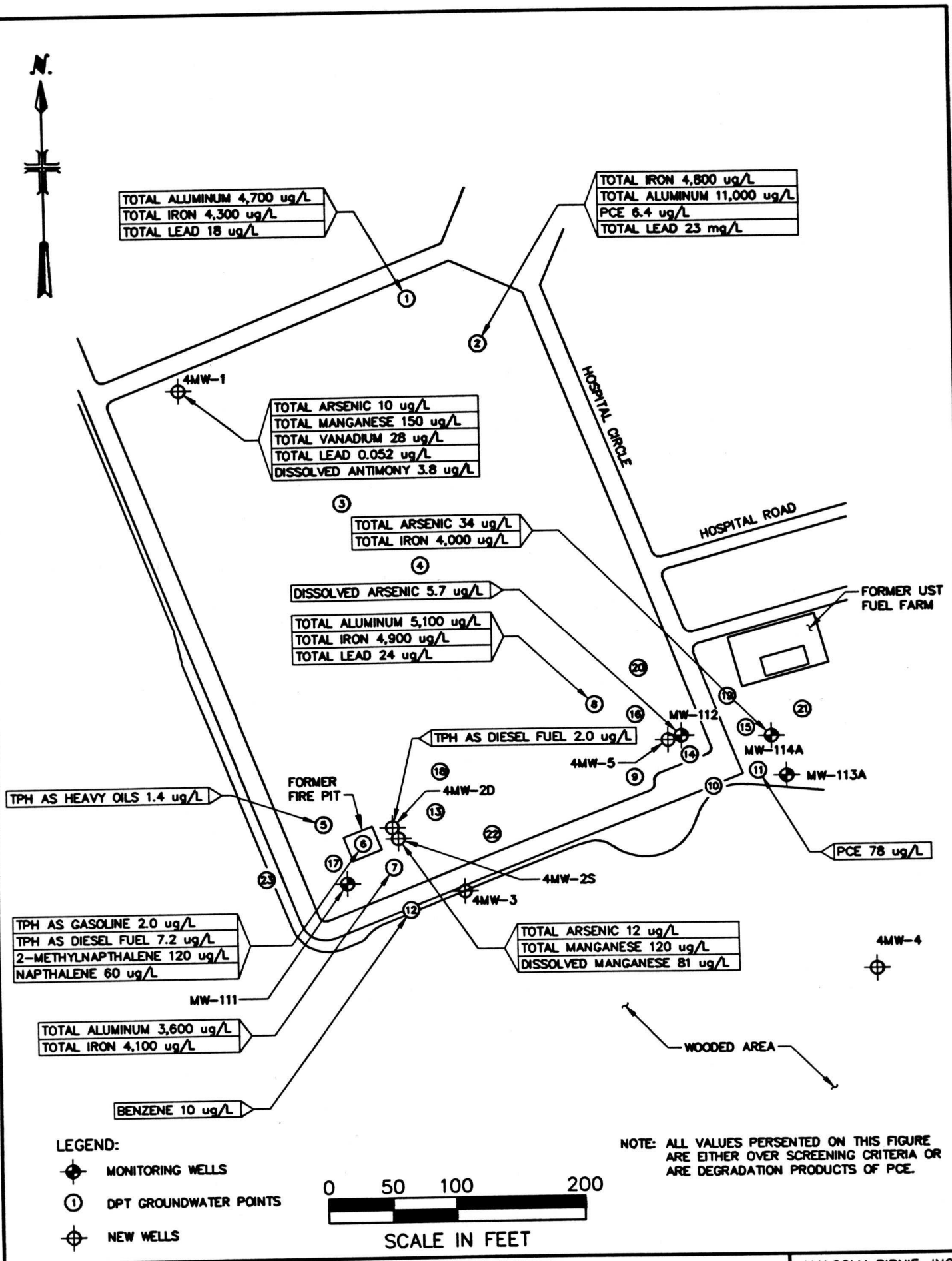
REMEDIAL INVESTIGATION REPORT
FTA SOIL AND SEDIMENT CONCENTRATIONS ABOVE EPA/VDEQ SCREENING CRITERIA

MALCOLM PIRNIE, INC.

APRIL 2002

FIGURE 4-1

File: L:\0285 \$ Army Corps of Engineers\589 - Ft Story LARC RI\Cadd\Apr 02\FIG4-1.DWG Scale: 1:1 Date: 04/08/2002 Time: 13:23 Layout1



MALCOLM PIRNIE

FORT STORY, VIRGINIA

REMEDIAL INVESTIGATION REPORT
FTA GROUNDWATER CONCENTRATIONS ABOVE EPA/VDEQ SCREENING CRITERIA

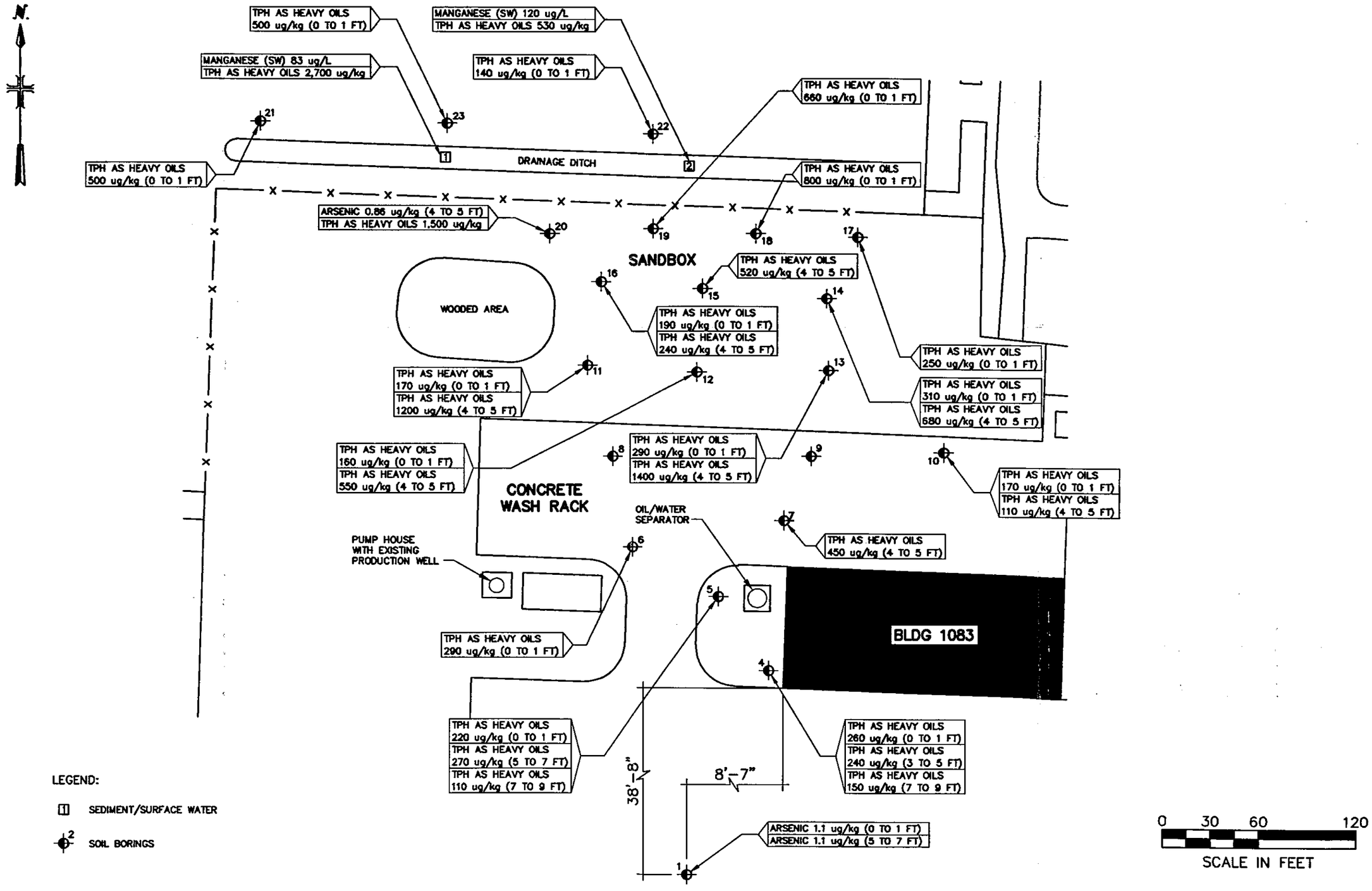
MALCOLM PIRNIE, INC.

APRIL 2002

FIGURE 4-2

File:L:\0285 US Army Corps of Engineers\589 - Ft Story LARC RI\Cadd\Apr 02\FIG4-2.DWG Scale:1:1 Date:04/05/2002 Time:09:60 Layo Layout1

File: L:\0285 — US Army Corps of Engineers\589 — Ft Story LARC RI\Cadd\April—2002\FIG4—3.DWG Scale:1:1 Date:04/09/2002 Time:09:32 Layout:Layout1



FORT STORY, VIRGINIA

REMEDIAL INVESTIGATION REPORT

LARC 60 SOIL, SEDIMENT AND SURFACE WATER CONCENTRATIONS ABOVE EPA SCREENING CRITERIA

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.

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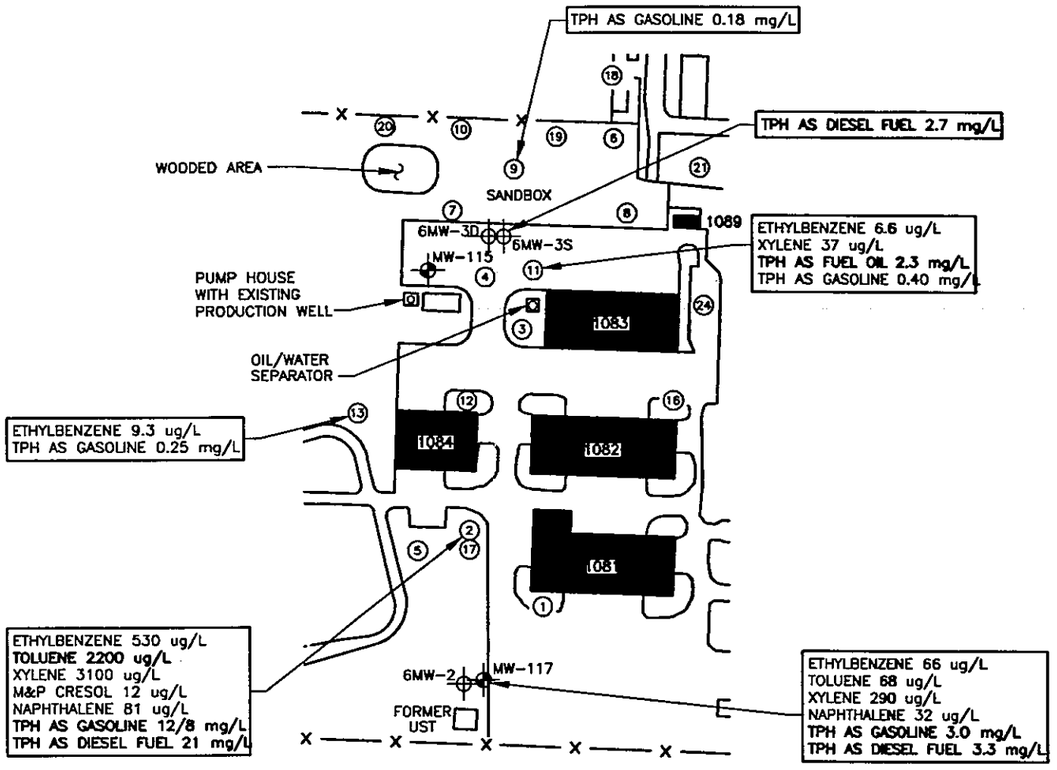
FIGURE 4—3

File:L:\0285 - US Army Corps of Engineers\589 - Ft Story LARC RI\Cadd\April 2002\FIG4-4.DWG Scale:1:1 Date:04/09/2002 Time:09:36 Layout:Layout1



LEGEND:

- EXISTING MONITORING WELLS
- NEW WELLS
- (1) DPT GROUNDWATER POINTS

0 100 200 400

SCALE IN FEET

MALCOLM PIRNIE

FORT STORY, VIRGINIA

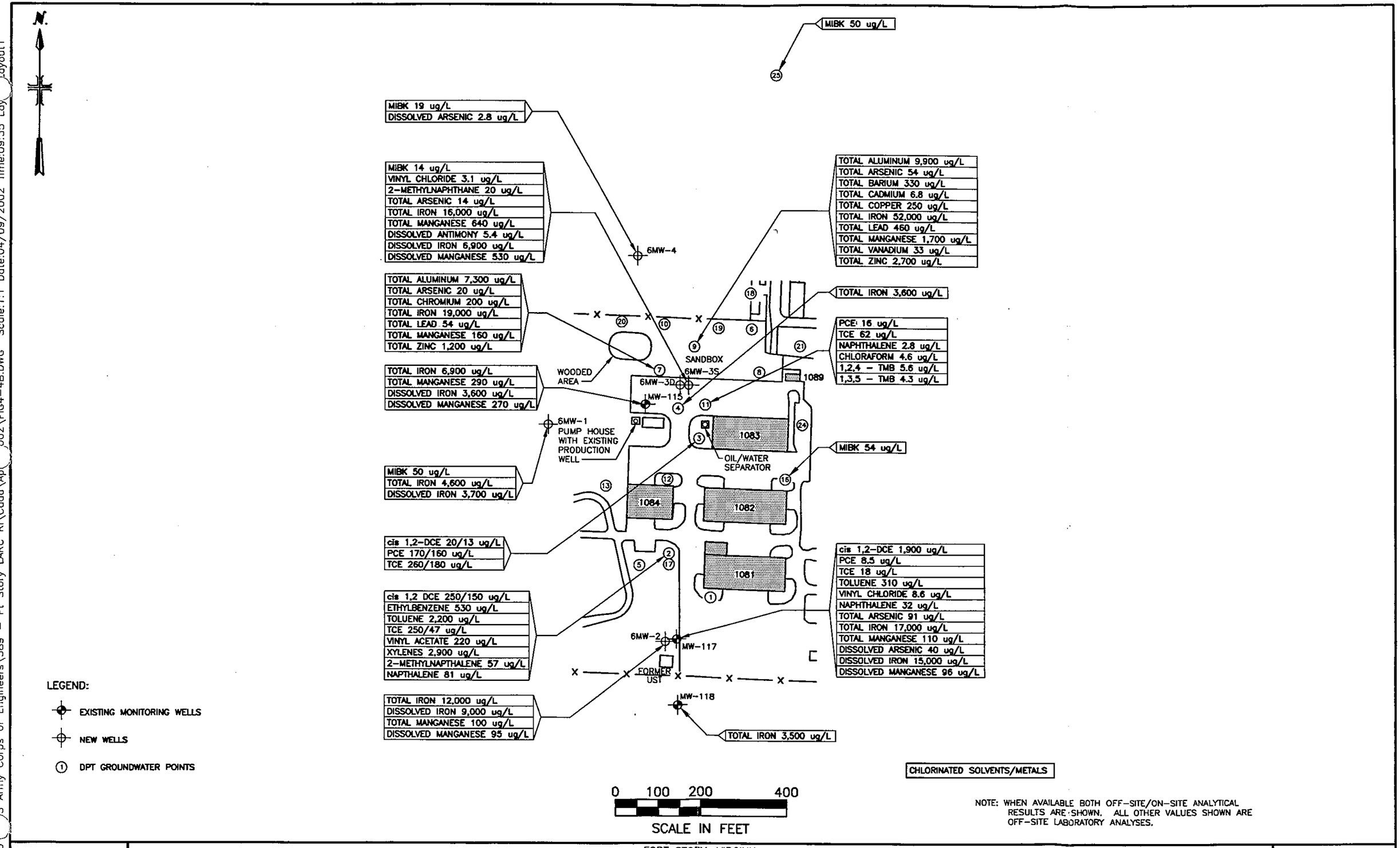
REMEDIAL INVESTIGATION REPORT

LARC 60 GROUNDWATER CONCENTRATIONS ABOVE EPA SCREENING CRITERIA

MALCOLM PIRNIE, INC.

APRIL 2002

FIGURE 4-4



NOTE: WHEN AVAILABLE BOTH OFF-SITE/ON-SITE ANALYTICAL RESULTS ARE SHOWN, ALL OTHER VALUES SHOWN ARE OFF-SITE LABORATORY ANALYSES.

MALCOLM PIRNIE

FORT STORY, VIRGINIA

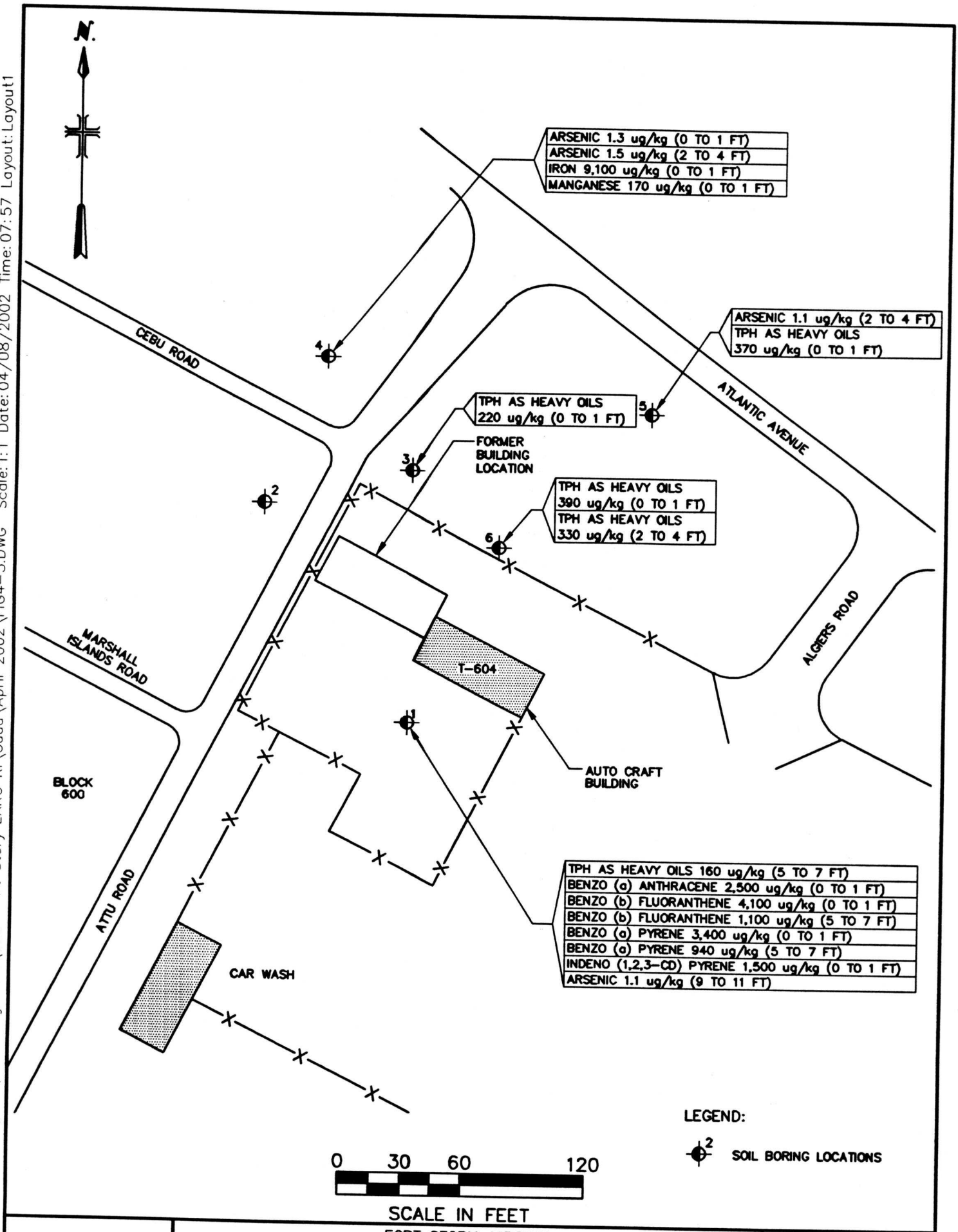
REMEDIAL INVESTIGATION REPORT
LARC 60 GROUNDWATER CONCENTRATIONS ABOVE EPA SCREENING CRITERIA

MALCOLM PIRNIE, INC.

APRIL 2002

FIGURE 4-4B

File:L:\0285\US Army Corps of Engineers\589 - Ft Story LARC RI\Cadd\Ap002\FIG4-4B.DWG Scale:1:1 Date:04/09/2002 Time:09:35 Layout:Layout1



File: L:\0285 - US Army Corps of Engineers\589 - Ft Story LARC RI\Cadd\April 2002\FIG4-5.DWG Scale: 1:1 Date: 04/08/2002 Time: 07:57 Layout: Layout1

MALCOLM PIRNIE

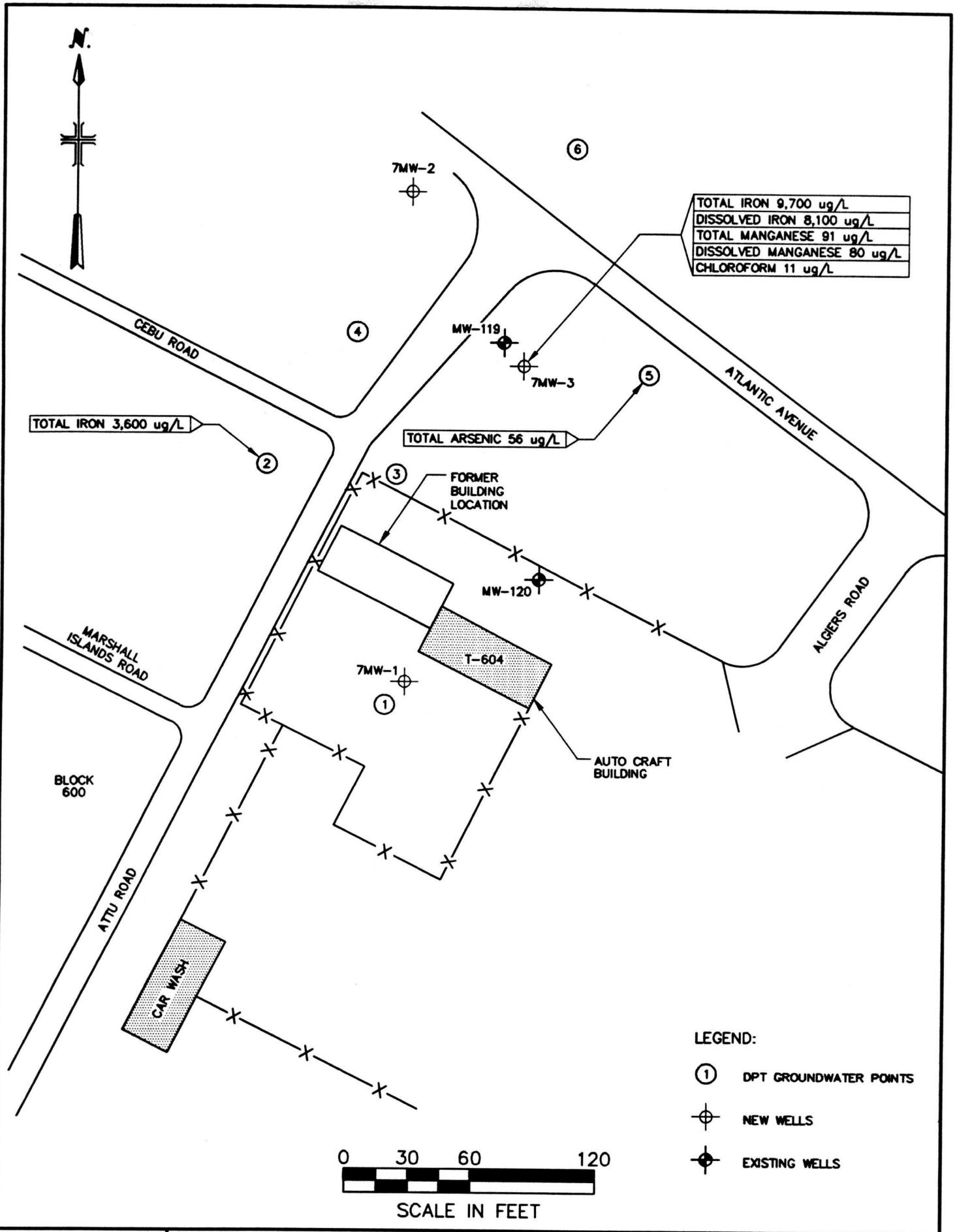
FORT STORY, VIRGINIA

REMEDIAL INVESTIGATION REPORT
AUTO CRAFT SOIL CONCENTRATIONS ABOVE EPA/VDEQ SCREENING CRITERIA

MALCOLM PIRNIE, INC.

APRIL 2002

FIGURE 4-5



File: L:\0285 - US Army Corps of Engineers\589 - Ft Story LARC RI\Cadd\April 2002\FIG4-6.DWG Scale: 1:1 Date: 04/08/2002 Time: 08:15 Layout: Layout1

MALCOLM PIRNIE

FORT STORY, VIRGINIA

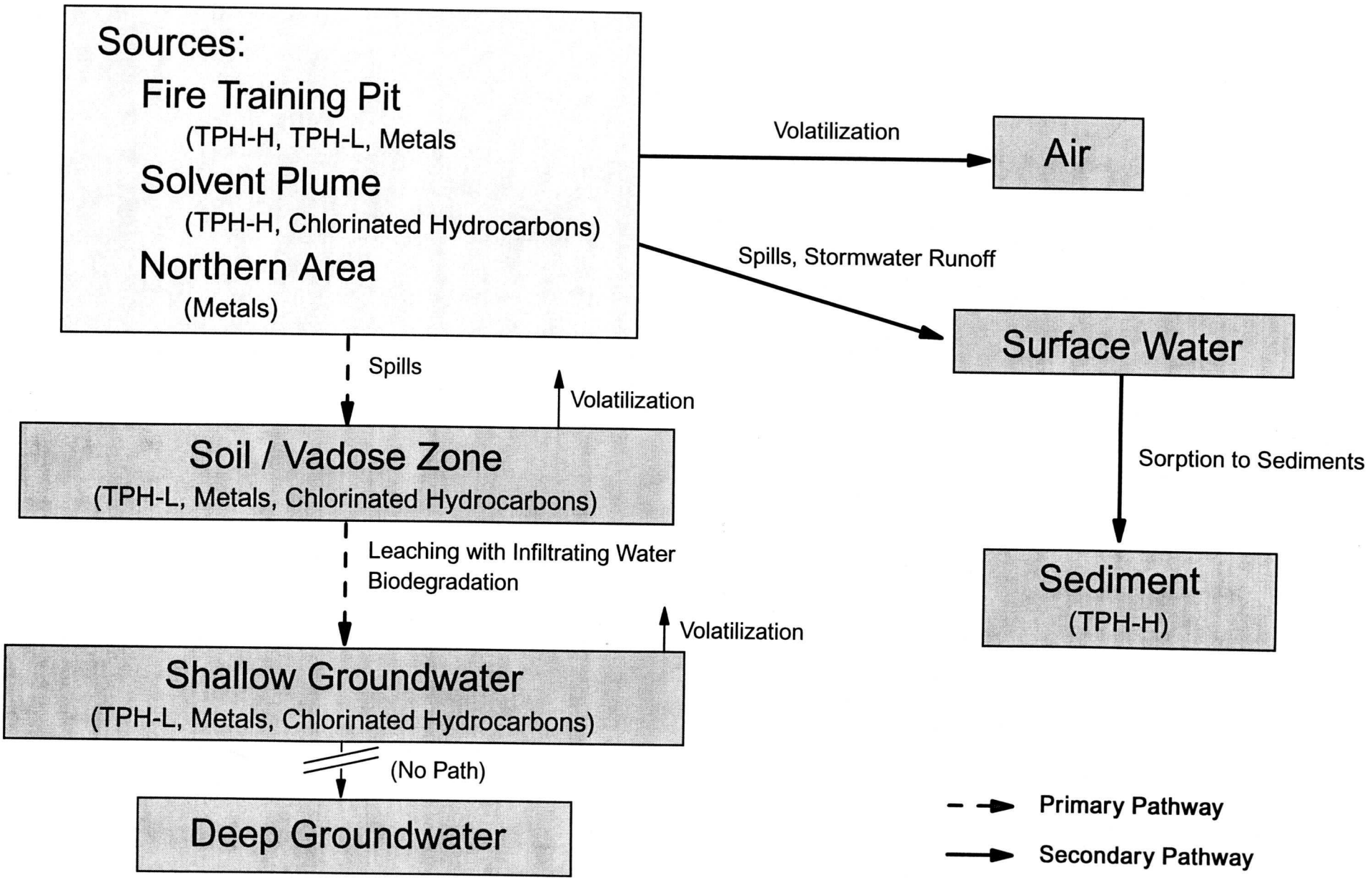
REMEDIAL INVESTIGATION REPORT
AUTO CRAFT GROUNDWATER CONCENTRATIONS ABOVE EPA/VDEQ SCREENING CRITERIA

MALCOLM PIRNIE, INC.

APRIL 2002

FIGURE 4-6

FTA Transport Pathways



0285-588

Figure 5-1

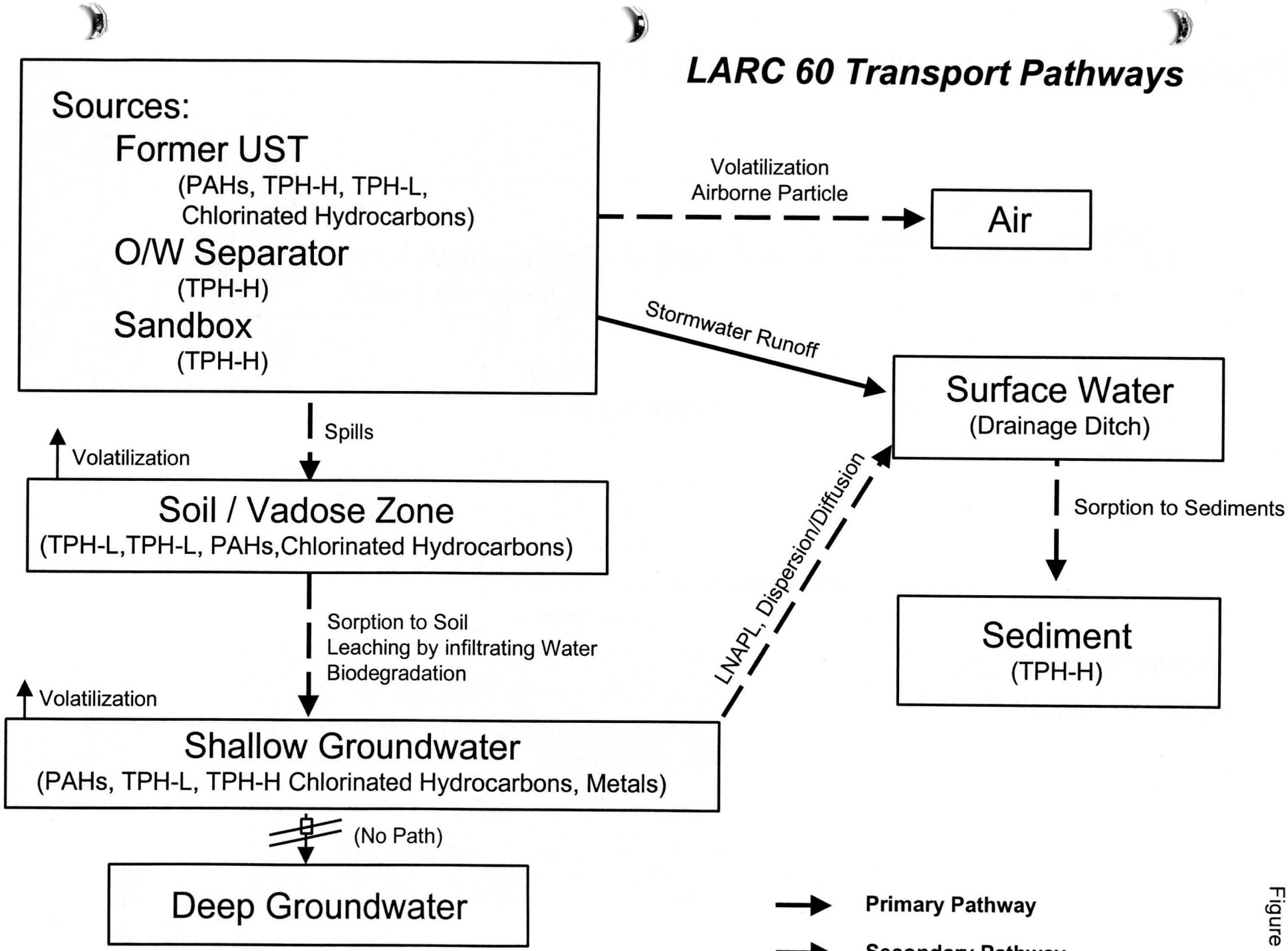


Figure 5-2

0285-588

TABLES

Remedial Investigation Report
FTA, LARC 60, and Auto Craft Sites
Fort Story, Virginia

TABLE 2-1
SURVEY DATA
FORT STORY, VIRGINIA

Type	ID	Vertical Elevations (ft, NGVD)		Horizontal Location (VSPCS)	
		Top PVC	Top Concrete	Northing	Easting
FIREFIGHTER TRAINING AREA					
Monitoring Wells	4MW-1	12.83	13.06	224288.3	2720483.7
	4MW-2S	13.55	13.86	223765.2	2720771.0
	4MW-2D	13.38	13.78	223776.7	2720769.3
	4MW-3	14.08	14.41	223680.3	2720866.4
	4MW-4	11.07	11.38	223636.2	2721275.8
	4MW-5	13.50	13.92	223840.7	2721088.1
	MW-111	13.90	---	223674.5	2720726.2
	MW-112	13.74	---	223835.8	2721089.1
	MW-113A	15.95	---	---	---
	MW-114A	19.66	---	---	---
DPT Groundwater Points	GW04-001	---	---	224367.8	2720785.8
	GW04-002	---	---	224258.6	2720863.0
	GW04-003	---	---	224103.2	2720722.2
	GW04-004	---	---	224046.4	2720773.4
	GW04-005	---	---	223820.9	2720667.8
	GW04-006	---	---	223785.4	2720723.8
	GW04-007	---	---	223709.8	2720772.4
	GW04-008	---	---	223884.5	2720943.5
	GW04-009	---	---	223795.6	2720979.8
	GW04-010	---	---	223766.4	2721098.6
	GW04-011	---	---	223775.6	2721153.7
	GW04-012	---	---	223642.1	2720786.2
	GW04-013	---	---	223775.2	2720814.9
	GW04-014	---	---	223834.7	2721077.7
	GW04-015	---	---	223865.9	2721126.1
	GW04-016	---	---	223875.2	2721024.6
	GW04-017	---	---	223743.8	2720665.7
	GW04-018	---	---	223849.2	2720822.7
	GW04-019	---	---	223901.5	2721106.3
	GW04-020	---	---	223931.7	2721020.2
	GW04-021	---	---	223883.7	2721175.0
	GW04-022	---	---	223747.9	2720873.1
	GW04-023	---	---	223689.7	2720578.0
Soil Borings	SB04-001	---	---	224321.3	2720810.9
	SB04-002	---	---	224283.0	2720819.9
	SB04-003	---	---	224291.1	2720858.0
	SB04-004	---	---	224103.2	2720722.2

TABLE 2-1
SURVEY DATA
FORT STORY, VIRGINIA

Type	ID	Vertical Elevations (ft, NGVD)		Horizontal Location (VSPCS)	
		Top PVC	Top Concrete	Northing	Easting
Soil Borings	SB04-005	---	---	224068.2	2720803.0
	SB04-006	---	---	224050.9	2720735.2
	SB04-007	---	---	223819.8	2720692.1
	SB04-009	---	---	223725.6	2720693.9
	SB04-010	---	---	223742.6	2720748.3
	SB04-011	---	---	223800.4	2720756.7
	SB04-012	---	---	223808.3	2720707.6
	SB04-013	---	---	223735.7	2720728.5
	SB04-014	---	---	223767.6	2720661.3
	SB04-015	---	---	223882.7	2720985.7
	SB04-016	---	---	223867.5	2721038.5
	SB04-017	---	---	223842.8	2721004.5
	SB04-018	---	---	223834.3	2721076.4
	SB04-019	---	---	223830.7	2721033.6
	SB04-020	---	---	223865.9	2721126.1
	SB04-021	---	---	223779.5	2721145.2
	SB04-022	---	---	223743.6	2721026.8
Surface Soil Points	SS04-023	---	---	224289.2	2720794.0
	SS04-024	---	---	224302.3	2720833.0
	SS04-025	---	---	224279.4	2720834.8
	SS04-026	---	---	224090.9	2720755.0
	SS04-027	---	---	224065.1	2720748.6
	SS04-028	---	---	224079.0	2720785.1
Sediment	SD04-001	---	---	223720.2	2721193.1
	SD04-002	---	---	223650.8	2721111.4
	SD04-003	---	---	223602.5	2720931.1
	SD04-004	---	---	223574.1	2720741.5
LARC 60 MAINTENANCE AREA					
Monitoring Wells	6MW-1	11.42	11.81	225959.0	2724148.7
	6MW-2	13.52	13.77	225426.9	2724484.8
	6MW-3S	9.86	10.22	226033.3	2724551.2
	6MW-3D	10.09	10.24	226033.4	2724546.9
	6MW-4	6.98	7.39	226409.2	2724351.0
	MW-115	9.45	---	---	---
	MW-117	16.01	---	225436.9	2724496.3
	MW-118	13.24	---	225250.7	2724498.5

TABLE 2-1
SURVEY DATA
FORT STORY, VIRGINIA

Type	ID	Vertical Elevations (ft, NGVD)		Horizontal Location (VSPCS)	
		Top PVC	Top Concrete	Northing	Easting
DPT Groundwater Points	GW06-001	---	---	225448.7	2724567.8
	GW06-002	---	---	225531.7	2724506.9
	GW06-003	---	---	225884.9	2724581.9
	GW06-004	---	---	225968.9	2724515.1
	GW06-005	---	---	225539.4	2724370.2
	GW06-006	---	---	226168.4	2724703.4
	GW06-007	---	---	226069.0	2724415.3
	GW06-008	---	---	226064.0	2724691.7
	GW06-009	---	---	226159.1	2724541.0
	GW06-010	---	---	226186.4	2724495.5
	GW06-011	---	---	225988.1	2724584.8
	GW06-012	---	---	225774.6	2724468.9
	GW06-013	---	---	225741.4	2724249.1
	GW06-014	---	---	226422.9	2723951.9
	GW06-015	---	---	226079.2	2725175.6
	GW06-016	---	---	225567.4	2724792.9
	GW06-017	---	---	225531.7	2724506.9
	GW06-018	---	---	226273.8	2724675.5
	GW06-019	---	---	226182.3	2724589.4
	GW06-020	---	---	226196.6	2724330.9
	GW06-021	---	---	226180.1	2724849.4
	GW06-022	---	---	226576.0	2724684.5
	GW06-023	---	---	226561.9	2725219.2
	GW06-024	---	---	225887.7	2724903.4
	GW06-025	---	---	226934.5	2724792.7
Soil Borings	SB06-001	---	---	225395.1	2724481.1
	SB06-002	---	---	225385.0	2724460.6
	SB06-003	---	---	225414.2	2724469.3
	SB06-004	---	---	225884.9	2724581.9
	SB06-005	---	---	225958.7	2724550.6
	SB06-006	---	---	225968.9	2724515.1
	SB06-007	---	---	225988.1	2724584.8
	SB06-008	---	---	226032.6	2724450.8
	SB06-009	---	---	226025.9	2724631.5
	SB06-010	---	---	226030.9	2724719.4
	SB06-011	---	---	226114.1	2724493.0
	SB06-012	---	---	226104.2	2724585.1
	SB06-013	---	---	226091.5	2724691.7
	SB06-014	---	---	226149.9	2724690.9

TABLE 2-1
SURVEY DATA
FORT STORY, VIRGINIA

Type	ID	Vertical Elevations (ft, NGVD)		Horizontal Location (VSPCS)	
		Top PVC	Top Concrete	Northing	Easting
Soil Borings	SB06-015	---	---	226155.3	2724583.9
	SB06-016	---	---	226146.0	2724494.0
	SB06-017	---	---	226188.4	2724730.8
	SB06-018	---	---	226191.7	2724643.0
	SB06-019	---	---	226196.3	2724548.4
	SB06-020	---	---	226199.3	2724445.6
	SB06-021	---	---	226247.8	2724299.4
	SB06-022	---	---	226251.4	2724493.6
	SB06-023	---	---	226251.5	2724387.2
Sediment	SD06-001	---	---	226224.9	2724382.2
	SD06-002	---	---	226219.0	2724529.5
Surface Water	SW06-001	4.40	---	226224.9	2724382.2
	SW06-002	4.60	---	226219.0	2724529.5
AUTO CRAFT BUILDING AREA					
Monitoring Wells	7MW-1	15.60	15.92	224644.2	2728675.8
	7MW-2	12.76	13.23	224902.7	2728642.8
	7MW-3	12.28	12.71	224818.2	2723719.5
	MW-119	12.34	---	224825.0	2728717.7
	MW-120	15.21	---	224724.7	2728729.2
DPT Groundwater Points	GW07-001	---	---	224649.4	2728664.1
	GW07-002	---	---	224778.0	272591.5
	GW07-003	---	---	224781.6	2728676.0
	GW07-004	---	---	224851.5	2728629.9
	GW07-005	---	---	224800.4	2728755.0
	GW07-006	---	---	224920.0	2728751.0
Soil Borings	SB07-001	---	---	224649.4	2728664.1
	SB07-002	---	---	224778.0	2728591.5
	SB07-003	---	---	224782.7	2728672.9
	SB07-004	---	---	224851.5	2728629.9
	SB07-005	---	---	224800.4	2728755.0
	SB07-006	---	---	224761.4	2728712.8

Notes:
NGVD - National Geodetic Value Datum of 1929
VSPCS - Virginia State Plane Coordinate System

TABLE 2-2
ANALYTICAL METHODS

ANALYSES WITH PARAMETERS		METHODS
OFF-SITE LABORATORY ANALYSIS		
TPH LIGHT		Modified EPA Method 8015
TPH as Gasoline		
TPH HEAVY		Modified EPA Method 8015
TPH as Kerosene	TPH as Mineral Spirits	
TPH as Diesel Fuel	TPH as Varsol	
TPH as Heavy Oils	TPH as Naphtha	
TPH as Fuel Oil		
TAL METALS		
Aluminum	Iron	SW-846, Method 6010
Antimony	Magnesium	
Barium	Manganese	
Beryllium	Nickel	
Cadmium	Potassium	
Calcium	Silver	
Chromium	Sodium	
Cobalt	Vanadium	
Copper	Zinc	
Arsenic		SW-846, Method 7060
Lead		SW-846, Method 7421
Mercury		SW-846, Method 7470
Selenium		SW-846, Method 7740
Thallium		SW-846, Method 7481
TAL CYANIDE		SW-846, Method 9010
TCL VOLATILE ORGANICS		SW-846, Method 8240
Acetone	1,2-Dichloropropane	
Benzene	cis 1,3-Dichloropropene	
Bromoform	trans 1,3-Dichloropropene	
Bromodichloroemethane	Ethylbenzene	
Bromomethane	2-Hexanone	
2-Butanone (MEK)	Methylene chloride	
Carbon disulfide	4-Methyl-2-pentanone	
Carbon tetrachloride	Styrene	
Chlorobenzene	1,1,2,2-Tetrachloroethane	
Chloroethane	Tetrachloroethene	
Chloroform	Toluene	
Chloromethane	1,1,1-Trichloroethane	
Dibromochloromethane	1,1,2-Trichloroethane	
1,1-Dichloroethane	Trichloroethene	
1,2-Dichloroethane	Trichlorotrifluoroethane	
1,1-Dichloroethene	Vinyl acetate	
cis 1,2-Dichloroethene	Vinyl chloride	
trans 1,2-Dichloroethene	Xylenes	

TABLE 2-2
ANALYTICAL METHODS

ANALYSES WITH PARAMETERS		METHODS
TCL SEMIVOLATILE ORGANICS		SW-846, Method 8270
Phenol	2,4-Dinitrophenol	
bis(2-chloroethyl)ether	4-Nitrophenol	
2-Chlorophenol	Dibenzofuran	
1,3-Dichlorobenzene	2,4-Dinitrotoluene	
1,4-Dichlorobenzene	2,6-Dinitrotoluene	
Benzyl alcohol	Diethylphthalate	
1,2-Dichlorobenzene	4-Chlorophenyl-phenyl ether	
2-Methylphenol (o-cresol)	Fluorene	
bis(2-chloroisopropyl)ether	4-Nitroaniline	
3-/4-Methylphenol(m&p-cresol)	4,6-Dinitro-2-methylphenol	
N-Nitroso-di-n-propylamine	N-Nitrosodiphenylamine	
Hexachloroethane	4-Bromophenyl-phenyl ether	
Nitrobenzene	Hexachlorobenzene	
Isophorone	Pentachlorophenol	
2-Nitrophenol	Phenanthrene	
2,4-Dimethylphenol	Anthracene	
Benzoic acid	Di-n-butylphthalate	
bis(2-Chloroethoxy)methane	Fluoranthene	
2,4-Dichlorophenol	Pyrene	
1,2,4-Trichlorobenzene	Butylbenzylphthalate	
Naphthalene	3,3'-Dichlorobenzidine	
4-Chloroaniline	Benzo(a)anthracene	
Hexachlorobutadiene	bis(2-ethylhexy)phthalate	
4-Chloro-3-methylphenol	Chrysene	
2-Methylnaphthalene	Di-n-octylphthalate	
Hexachlorocyclopentadiene	Benzo(b)fluoranthene	
2,4,6-Trichlorophenol	Benzo(k)fluoranthene	
2,4,5-Trichlorophenol	Benzo(a)pyrene	
2-Chloronaphthalene	Indeno(1,2,3-cd)pyrene	
2-Nitroaniline	Dibenz(a,h)anthracene	
Dimethylphthalate	Benzo(g,h,i)perylene	
Acenaphthylene	Acenaphthene	
3-Nitroaniline		
TCL PESTICIDES/PCBs		SW-846 8081A/8082
Aldrin	Endrin	
apha BHC	Endrin aldehyde	
beta BHC	Endrin ketone	
delta BHC	Heptachlor	
gamma BHC (Lindane)	Heptachlor epoxide	
alpha Chlordane	Methoxychlor	
gamma Chlordane	Toxaphene	
4,4'-DDD	PCB 1016	
4,4'-DDE	PCB 1221	
4,4'-DDT	PCB 1232	
Dieldrin	PCB 1242	
Endosulfan I	PCB 1248	
Endosulfan II	PCB 1254	
Endosulfan sulfate	PCB 1260	

TABLE 2-2
ANALYTICAL METHODS

ANALYSES WITH PARAMETERS	METHODS
ON-SITE GC ANALYSIS	
TPH LIGHT TPH as Gasoline	Modified EPA Method 8015
VOLATILE ORGANICS Benzene cis 1,2-Dichloroethene Tetrachloroethene Trichloroethene Vinyl chloride	EPA Method 3810

TABLE 2-3
SUMMARY OF FTA FIELD INVESTIGATIONS

Location	Soil Borings/ Soil Samples	Surface Soil Samples	Sediment Samples	DPT Groundwater Samples	Monitoring Well Samples	Monitoring Wells Installed
1995 FIELD ACTIVITIES						
Northern Area						
Upgradient of Northern Area	2/4	2	0	2	1	1
Northern Area	4/8	10	0	2	0	0
Former FTP Area						
Upgradient of Former FTP	1/2	1	0	1	0	0
Former FTP Area	7/14	7	0	1	2	2
Downgradient of Former FTP	0	0	0	7	2	1
Solvent Plume Area						
Upgradient of Solvent Plume Area	2/4	2	0	2	0	0
Solvent Plume Area	3/6	3	0	4	2	1
Downgradient of Solvent Plume Area	3/6	3	0	5	3	1
Drainage Area South of Solvent Plume	0/0	0	4	0	0	0
1995 Totals	22/44	28	4	24	10	6
2000 SAMPLING EVENT						
Northern Area						
Upgradient of Northern Area	0	1	0	0	1	0
Northern Area	0	1	0	0	0	0
Former FTP Area						
Former FTP Area	0	2	0	0	1	0
Solvent Plume Area						
Solvent Plume Area	0	2	0	0	2	0
Drainage Area South of Solvent Plume	0	2	0	0	0	0
2000 Totals	0	8	0	0	4	0

TABLE 2-4
FTA ANALYTICAL SUMMARY

Sample Type	Sample ID	Analysis						
		VOCs	SVOCs	TPH Light	TPH Heavy	Pest/ PCBs	Total Metals/CN	Dissolved Metals/CN
Groundwater (Monitoring Wells)	4MW-1	S	S	S	S	S	S	S
	4MW-2S	S	S	S	S		S	S
	4MW-2D	S	S	S	S			
	4MW-3	S	S	S	S			
	4MW-4	S	S	S	S			
	4MW-5	S	S	S	S			
	MW-111	S	S	S	S	S	S	S
	MW-112	S	S	S	S	S	S	S
	MW-113A	S	S	S	S			
	MW-114A	S	S	S	S	S	S	S
Groundwater (DPT Points)	GW04-001	S-GC	S	S-GC	S		S	
	GW04-002	S-GC	S	S-GC	S		S	
	GW04-003	S-GC	S	S-GC	S			
	GW04-004	S-GC	S	S-GC	S			
	GW04-005	S-GC	S	S-GC	S			
	GW04-006	S-GC	S	S-GC	S			
	GW04-007	S-GC	S	S-GC	S		S	
	GW04-008	S-GC	S	S-GC	S		S	
	GW04-009	S-GC	S	S-GC	S			
	GW04-010	S-GC	S	S-GC	S			
	GW04-011	S-GC	S	S-GC	S			
	GW04-012	S-GC	S	S-GC	S			
	GW04-013	S-GC	S	S-GC	S			
	GW04-014[(1)]	GC		GC				
	GW04-015	S-GC	S	S-GC	S			
	GW04-016	S-GC	S	S-GC	S			
	GW04-017	S-GC	S	S-GC	S			
	GW04-018	S		S				
	GW04-019	GC		GC				
	GW04-020	GC		GC				
	GW04-021	GC		GC				
	GW04-022	GC		GC				
	GW04-023	GC		GC				

Notes:

S - Savannah Laboratory analysis only
GC - On site GC analysis only
S-GC - Savannah Laboratory and on-site GC analysis

(1) Two groundwater samples collected at two different depths at this location.

TABLE 2-4
FTA ANALYTICAL SUMMARY

Sample Type	Sample ID	Analysis						
		VOCs	SVOCs	TPH Light	TPH Heavy	Pest/ PCBs	Total Metals/CN	Dissolved Metals/CN
Soil Borings (samples collected from 3 depths)	SB04-001	S	S	S	S		S	
	SB04-002	S	S	S	S			
	SB04-003	S	S	S	S			
	SB04-004	S	S	S	S			
	SB04-005	S	S	S	S		S	
	SB04-006	S	S	S	S			
	SB04-007	S	S	S	S			
	SB04-009	S	S	S	S			
	SB04-010	S	S	S	S		S	
	SB04-011	S	S	S	S			
	SB04-012	S	S	S	S			
	SB04-013	S	S	S	S			
	SB04-014	S	S	S	S			
	SB04-015	S	S	S	S		S	
	SB04-016	S	S	S	S			
	SB04-017	S	S	S	S			
	SB04-018	S	S	S	S			
	SB04-019	S	S	S	S			
	SB04-020	S	S	S	S		S	
	SB04-021	S	S	S	S			
	SB04-022	S	S	S	S			
Surface Soil	SS04-023	S	S	S	S			
	SS04-024	S	S	S	S			
	SS04-025	S	S	S	S			
	SS04-026	S	S	S	S			
	SS04-027	S	S	S	S			
	SS04-028	S	S	S	S			
	FTA-SS1					S		
	FTA-SS2					S		
	FTA-SS3					S		
	FTA-SS4					S		
	FTA-SS1					S		
	FTA-SS5					S		
	FTA-SS7					S		
	FTA-SS8					S		
Sediment	SD04-001	S	S	S	S		S	
	SD04-002	S	S	S	S		S	
	SD04-003	S	S	S	S		S	
	SD04-004	S	S	S	S		S	

Notes:

S - Savannah Laboratory analysis only

GC - On site GC analysis only

S-GC - Savannah Laboratory and on-site GC analysis

TABLE 2-5
SUMMARY OF LARC 60 FIELD INVESTIGATIONS

Location	Soil Borings/ Samples	Surface Soil Samples	Sediment Samples	Surface Water Samples	DPT GW Samples	Monitoring Well Samples	Monitoring Wells Installed	Temporary Well Points Sampled/Installed
1995 FIELD INVESTIGATIONS								
Former UST Area								
Upgradient of UST Area	0/0	0	0	0	0	1	0	0
UST Area	2/3	2	0	0	0	0	0	2
Downgradient of UST Area	1/1	1	0	0	7	3	2	1
OWS Area								
Upgradient of OWS	1/2	1	0	0	1	0	0	0
OWS Area	1/3	1	0	0	0	0	0	0
Downgradient of OWS	5/5	4	0	0	3	3	2	0
Sandbox Area								
Sandbox Area	10/10	10	0	0	7	0	0	0
Downgradient of Sandbox Area	3/3	3	2	2	7	1	1	0
1995 Totals	23/27	22	2	2	25	8	5	3
2000 SAMPLING EVENT								
Former UST Area								
Upgradient of UST Area	0	0	0	0	0	1	0	0
UST Area	0	1	0	0	0	0	0	0
Downgradient of UST Area	0	1	0	0	0	1	0	0
OWS Area								
Upgradient of OWS	0	2	0	0	0	0	0	0
OWS Area	0	0	0	0	0	0	0	0
Downgradient of OWS	0	0	0	0	0	3	0	0
Sandbox Area								
Sandbox Area	0	2	0	0	0	0	0	0
Downgradient of Sandbox Area	0	2	0	0	0	1	0	0
2000 Totals	0	8	0	0	0	6	0	0

TABLE 2-6
LARC 60 ANALYTICAL SUMMARY

Sample Type	Sample ID	Analyses						
		VOCs	SVOCs	TPH Light	TPH Heavy	Pest/ PCBs	Total Metals/CN	Dissolved Metals/CN
Groundwater (Monitoring Wells)	6MW-1	S	S	S	S	S	S	S
	6MW-2	S	S	S	S		S	S
	6MW-3S	S	S	S	S	S	S	S
	6MW-3D	S	S	S	S			
	6MW-4	S	S	S	S	S	S	S
	MW-115	S	S	S	S	S	S	S
	MW-117	S	S	S	S	S	S	S
	MW-118	S	S	S	S	S	S	S
Groundwater (DPT Points)	GW06-001	S-GC	S	S-GC	S			
	GW06-002	S-GC	S	S-GC	S			
	GW06-003	S-GC	S	S-GC	S			
	GW06-004	S	S	S	S		S	
	GW06-005	S-GC	S	S-GC	S			
	GW06-006	S-GC	S	S-GC	S			
	GW06-007	S-GC	S	S-GC	S		S	
	GW06-008	S-GC	S	S-GC	S			
	GW06-009	S-GC	S	S-GC	S		S	
	GW06-010	S-GC	S	S-GC	S			
	GW06-011	S	S	S	S			
	GW06-012	S	S	S	S			
	GW06-013	S	S	S	S			
	GW06-014	S	S	S	S			
	GW06-015	S	S	S	S			
	GW06-016	S	S	S	S			
	GW06-017	S	S	S	S			
	GW06-018	S-GC		S-GC				
	GW06-019	GC		GC				
	GW06-020	GC		GC				
	GW06-021	S-GC		S-GC				
	GW06-022	S-GC		S-GC				
	GW06-023	GC		GC				
	GW06-024	GC		GC				
	GW06-025	S						
Groundwater (Well Points)	WP-1	S		S	S			
	WP-2	S		S	S			
	WP-3				S			
Soil Borings (samples collected from 3 depths)	SB06-001	S	S	S	S		S	
	SB06-002	S	S	S	S			
	SB06-004	S	S	S	S			
	SB06-005	S	S	S	S		S	

TABLE 2-6
LARC 60 ANALYTICAL SUMMARY

Sample Type	Sample ID	Analyses						
		VOCs	SVOCs	TPH Light	TPH Heavy	Pest/ PCBs	Total Metals/CN	Dissolved Metals/CN
Soil Boring (sample collected from 1 depth)	SB06-007	S	S	S	S			
Soil Borings (samples collected from 2 depths)	SB06-003	S	S	S	S			
	SB06-006	S	S	S	S			
	SB06-008	S	S	S	S			
	SB06-009	S	S	S	S			
	SB06-010	S	S	S	S		S	
	SB06-011	S	S	S	S			
	SB06-012	S	S	S	S			
	SB06-013	S	S	S	S			
	SB06-014	S	S	S	S			
	SB06-015	S	S	S	S		S	
	SB06-016	S	S	S	S			
	SB06-017	S	S	S	S			
	SB06-018	S	S	S	S			
	SB06-019	S	S	S	S			
	SB06-020	S	S	S	S		S	
	SB06-021	S	S	S	S			
	SB06-022	S	S	S	S			
	SB06-023	S	S	S	S			
Surface Soil	LARC60-SS1					S		
	LARC60-SS2					S		
	LARC60-SS3					S		
	LARC60-SS4					S		
	LARC60-SS5					S		
	LARC60-SS6					S		
	LARC60-SS7					S		
	LARC60-SS8					S		
Surface Water	SW06-001	S	S	S	S		S	
	SW06-002	S	S	S	S		S	
Sediment	SD06-001	S	S	S	S		S	
	SD06-002	S	S	S	S		S	

Notes:

S - Savannah Laboratory analysis only

GC - On site GC analysis only

S-GC - Savannah Laboratory and on-site GC analysis

TABLE 2-7
SUMMARY OF AUTO CRAFT FIELD INVESTIGATIONS

Location	Soil Borings/ Soil Samples	Surface Soil Samples	DPT Groundwater Samples	Monitoring Well Samples	Monitoring Wells Installed
Upgradient of Auto Craft Bldg	1/2	1	1	0	1
Downgradient of Auto Craft Bldg	5/10	5	5	4	2
Totals	6/12	6	6	4	3

TABLE 2-8
AUTO CRAFT ANALYTICAL SUMMARY

Sample Type	Sample ID	Analyses					
		VOCs	SVOCs	TPH Light	TPH Heavy	Total Metals/CN	Dissolved Metals/CN
Groundwater (Monitoring Wells)	7MW-1						
	7MW-2	S	S	S	S		
	7MW-3	S	S	S	S	S	S
	MW-119	S	S	S	S	S	S
	MW-120	S	S	S	S		
Groundwater (DPT Points)	GW07-001	S-GC	S	S-GC	S	S	
	GW07-002	S-GC	S	S-GC	S	S	
	GW07-003	S-GC	S	S-GC	S		
	GW07-004	S-GC	S	S-GC	S		
	GW07-005	S-GC	S	S-GC	S	S	
	GW07-006	S	S	S	S		
Soil Borings (samples collected from 3 depths)	SB07-001	S	S	S	S	S	
	SB07-002	S	S	S	S		
	SB07-003	S	S	S	S		
	SB07-004	S	S	S	S	S	
	SB07-005	S	S	S	S	S	
	SB07-006	S	S	S	S		

Notes:

S - Savannah Laboratory analysis only

GC - On site GC analysis only

S-GC - Savannah Laboratory and on-site GC analysis

TABLE 3-1
SUMMARY OF PHYSICAL CHARACTERISTICS

Site	Physical Characteristics				
	Topography	**Surface Hydrology**	**General Soil Type**	**Depth to Groundwater**	**Avg Hydraulic Conductivity**
Firefighter Training Area	Sandy flat area with little or no relief	Majority of drainage limited to within site. Runoff from southeast corner of site to low area south of site.	Medium sand to silty sand present to 40 foot depth. Fine sands present at depths 40 to 46 feet.	3.4 to 8.3 feet BLS	1.24×10^{-2} cm/sec
LARC 60 Maintenance Area	Sandy flat area with little relief. Majority of site covered by pavement or structures.	Surface runoff controlled by storm drain system with numerous catch basins. Storm water runoff from Sandbox area and wooded area drains into drainage ditch north of site.	Fine, medium and coarse sand present to 35 foot depth. Fine sands present at depths 35 to 46 feet.	2.8 to 7.4 feet BLS	7.42×10^{-2} cm/sec
Auto Craft Area	Sandy flat area with 2 to 3 feet of vertical relief on the northern part of the site.	Surface runoff to several catch basins and grassy area north of former building.	Fine sand to depth of 18 feet below grade with interlayers of medium, fine and coarse sands at depths of 18 to 44 feet below grade.	7.8 to 10.9 feet BLS	5.17×10^{-3} cm/sec

TABLE 3-2
AVERAGE TEMPERATURE AND PRECIPITATION DATA
FORT STORY AREA (1941 - 1970) (NOAA, 1982)

Month	Temperature (F)			Precipitation (inches)
	Daily Min	Daily Max	Daily Mean	
January	32.2	48.8	40.5	3.35
February	32.7	50.0	41.4	3.31
March	38.9	57.3	48.1	3.42
April	47.9	67.7	57.8	2.71
May	57.2	76.2	66.7	3.34
June	65.5	83.5	74.5	3.62
July	69.9	86.6	78.3	5.70
August	68.9	84.9	76.9	5.92
September	63.9	79.6	71.8	4.20
October	53.3	70.1	61.7	3.06
November	42.6	60.5	51.6	2.94
December	34.0	50.6	42.3	3.11
Annual	50.6	68.0	59.3	44.68

TABLE 3-3
WELL CONSTRUCTION DETAILS AND WATER TABLE ELEVATION

Well No.	Casing[1] Elevation (TPVC,MSL)	Ground Elevation (Ft,MSL)	Riser Length (Ft)	Screen[2] Length (Ft)	Screened Interval (MSL)	Filter Pack Length (Ft)	Total Depth (Ft)	Depth to Water (Ft)	Water Elevation (Ft,MSL)
FIREFIGHTER TRAINING AREA									
MW-110	(13.51)	(13.79)	3	10	(10.51 to 0.51)	NA	13.50	NA	NA
MW-111	(13.83) 13.90	(14.03)	3	10	10.04 to 0.4	NA	13.50	5.25	7.84
MW-112	(13.74) 13.74	(14.00)	3.5	10	9.74 to (- 0.26)	NA	14.00	6.05	7.69
MW-113A	(15.78) 15.95	(16.02)	NA	10	NA	NA	NA	8.27	7.68
MW-114A	(19.59) 19.66	(16.46)	5	10	11.5 to 1.5	NA	15	11.98	7.68
4MW-1	12.83	13.06	4	10	8.33 to (-1.67)	11	14.50	5.30	7.53
4MW-2S	13.55	13.86	4	10	9.05 to (- 0.95)	11	14.50	5.86	7.69
4MW-2D	13.38	13.78	30	10	-17.12 to (-27.12)	13	40.50	5.71	7.67
4MW-3	14.08	14.41	4	10	9.58 to (- 0.42)	11	14.50	6.38	7.70
4MW-4	11.07	11.38	4	10	6.57 to (- 3.43)	11	14.50	3.36	7.71
4MW-5	13.50	13.92	30	10	-17.00 to (-27.00)	12.5	40.50	5.80	7.70
LARC 60 MAINTENANCE AREA									
MW-115	(9.36) 9.45	NA	2	10	6.95 to (-03.05)	NA	12.50	4.33	5.12
MW-116[3]	(9.77) NA	NA	2	10	(7.27 to (-02.73))	NA	12.50	NA	NA
MW-117	(16.00) 16.01	NA	3.5	10	12.01 to 2.01	NA	14	9.91	6.10
MW-118	(13.24) 13.24	NA	4.5	10	8.24 to (-1.76)	NA	15	6.91	6.33
6MW-1	11.42	11.81	3.5	10	7.42 to (-2.58)	11	14	6.23	5.19

Well No.	Casing[1] Elevation (TPVC,MSL)	Ground Elevation (Ft,MSL)	Riser Length (Ft)	Screen Length (Ft)	Screened Interval (MSL)	Filter Pack Length (Ft)	Total Depth (Ft)	Depth to Water (Ft)	Water Elevation (Ft,MSL)
6MW-2	13.52	13.77	30	10	-16.98 to (-26.98)	15	40.50	7.38	6.14
6MW-3S	9.86	10.22	3.75	10	5.61 to (-4.39)	11.5	14.25	4.82	5.04
6MW-3D	10.09	10.24	28.75	10	-20.16 to (-30.16)	12.5	40.25	5.05	5.04
6MW-4	6.98	7.39	4	10	2.48 to (-7.52)	11	14.50	2.80	4.18
WP-1	-	-	-	10	-	-	14.5	-	-
WP-2	-	-	-	10	-	-	14.0	-	-
WP-3	-	-	-	10	-	-	14.0	-	-
AUTO CRAFT AREA									
MW-119	(12.47) 12.34	(12.87)	2	10	9.34 to (-0.66)	NA	13	7.87	4.47
MW-120	(15.21) 15.21	(15.59)	9.5	10	5.21 to (-4.79)	NA	20	10.57	4.64
7MW-1	15.60	15.92	8	10	7.10 to (-2.90)	12	18.50	10.89	4.71
7MW-2	12.76	13.23	4	10	8.73 to (-1.27)	11	14.50	8.35	4.40
7MW-3	12.28	12.71	30	10	-18.22 to (-28.22)	14	40.50	7.80	4.48

1. MW - 100 series wells installed during PA/SI; construction details cited from Tables 2-15, 2-19, 2-21 from Final Site Investigation Report, Fort Story PA/SI. Screened interval elevation has been revised based on surveyed elevation of top of casing during RI/FS. PA/SI elevation is shown in ( ). Screen length and riser length were calculated based on details provided in the PA/SI.
2. Screen length shown is length of slotted PVC and does not include the 6-inch length of the bottom well cap.
3. MW-116 was destroyed prior to RI/FS.

Abbreviations:

TPVC = Top PVC casing.
MSL = Mean Sea Level with respect to National Vertical Datum
Ft = Feet
NA = Not Available

TABLE 4-1
CHEMICAL-SPECIFIC ARARs AND TBC FOR SOIL

Parameters	TBC Criteria				
	Virginia Petroleum Program(1) (mg/kg)	EPA Region III BTAG Screening Levels(2)		EPA Region III Risk-Based Concentration Table(3)	
		Flora (mg/kg)	Fauna (mg/kg)	Ind Soils (mg/kg)	Res Soils (mg/kg)
VOCs					
Acetone	-	-	-	200,000	7,800
Sec-Butyl benzene	-	-	-	82,000	3,100
Ethylbenzene	-	-	0.10	200,000	7,800
Isopropylbenzene	-	-	-	-	-
p-Isopropyl toluene	-	-	-	-	-
Methylene Chloride	-	-	0.3	760	85
Methyl ethyl ketone	-	-	-	1,200,000	47,000
Styrene	-	-	0.10	410,000	16,000
Tetrachloroethene	-	-	0.3	110	12
Toluene	-	-	0.10	410,000	16,000
1,2,3-Trichlorobenzene	-	-	-	-	-
Trichloroethene	-	-	0.3	520	58
1,3,5-Trimethylbenzene	-	-	-	100,000	3,900
1,2,4-Trimethylbenzene	-	-	-	100,000	3,900
Xylenes	-	-	-	4,100,000	160,000
SVOCs					
Acenaphthene	-	-	0.10	120,000	4,700
Benzo(a)anthracene	-	-	0.10	7.8	0.87
Benzo(b)fluoranthene	-	-	0.10	7.8	0.88
Benzo(k)fluoranthene	-	-	0.10	78	8.7
Benzo(g,h,i)perylene	-	-	0.10	-	-
Benzo(a)pyrene	-	-	20	0.78	0.087
Bis(2-EH)phthalate	-	5.3	5.3	410	46
Butylbenzylphthalate	-	5.3 to 260	5.3 to 260	410,000	16,000
Chrysene	-	-	0.10	780	87
Di-n-butylphthalate	-	260	260	200,000	7,800
Fluoranthene	-	-	0.10	82,000	3,100
Indeno(1,2,3-cd)pyrene	-	-	0.10	7.8	0.87
Naphthalene	-	-	100	41,000	1,600
Phenanthrene	-	-	0.10	-	-
Pyrene	-	-	0.10	61,000	2,300
TPH					
Total TPH	100	-	-	-	-

TABLE 4-1
CHEMICAL-SPECIFIC ARARs AND TBC FOR SOIL

Parameters	TBC Criteria				
	Virginia Petroleum Program(1) (mg/kg)	EPA Region III BTAG Screening Levels(2)		EPA Region III Risk-Based Concentration Table(3)	
		Flora (mg/kg)	Fauna (mg/kg)	Ind Soils (mg/kg)	Res Soils (mg/kg)
PESTICIDES					
beta-BHC	-	-		3.2	0.35
Chlordane	-	0.1	0.1	16	1.8
DDD	-	0.1	0.1	24	2.7
DDE	-	0.1	0.1	17	1.9
DDT	-	0.1	0.1	17	1.9
Dieldren	-	0.1	0.1	0.36	0.04
Heptachlor epoxide	-	0.1	0.1	0.63	0.07
Total Metals					
Aluminum	-	-	-	2,000,000	78,000
Arsenic	-	5	8.2	3.8	0.43
Barium	-	-	440	140,000	5,500
Beryllium	-	0.02	-	4,100	160
Cadmium	-	2.5	-	1,000	39
Calcium	-	-	-	-	-
Chromium	-	0.02	0.0075	6,100	230
Cobalt	-	0.10	1,500	120,000	4,700
Copper	-	-	0.04	82,000	3,100
Iron	-	100	-	610,000	23,000
Lead	-	0.0125	0.01	1,200 (4)	400 (4)
Magnesium	-	-	-	-	-
Manganese	-	-	330	41,000	1,600
Mercury	-	-	0.058	-	-
Nickel	-	2.5	-	41,000	1,600
Potassium	-	-	-	-	-
Silver	-	0.0000098	-	10,000	390
Sodium	-	-	-	-	-
Vanadium	-	-	58	14,000	550
Zinc	-	-	4.8	610,000	23,000

Notes:

(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)

(2) EPA Region III BTAG Screening Levels for Ecological risks (Jan 1995)

(3) EPA Region III Risk-based Concentration Table for Industrial and Residential Soils (Sept 2001) for Human Health risks

(4) EPA Standards for Lead in Soil, OPPT Lead Programs, 1/2/2001

TABLE 4-2
CHEMICAL-SPECIFIC ARARs AND TBC FOR SEDIMENT

Parameters	TBC Criteria		
	Virginia Petroleum Program(1) (mg/kg)	EPA Region III BTAG Screening Levels(2)	
		Flora (mg/kg)	Fauna (mg/kg)
VOCs			
Toluene	-	-	0.10
TPH			
Total TPH	100	-	-
Total Metals			
Aluminum	-	-	-
Arsenic	-	5	8.2
Barium	-	-	440
Calcium	-	-	-
Chromium	-	0.005	260,000
Cobalt	-	0.10	1,500
Copper	-	-	34
Iron	-	100	-
Lead	-	0.0125	46.7
Magnesium	-	-	-
Manganese	-	-	330
Mercury	-	-	0.15
Potassium	-	-	-
Sodium	-	-	-
Thallium	-	0.001	-
Vanadium	-	-	58
Zinc	-	-	150

Notes:
(1) Virginia DEQ Petroleum Program Manual (March 1995)
(2) EPA Region III BTAG Screening Levels for Ecological risks (Jan 1995)

TABLE 4-3
CHEMICAL-SPECIFIC ARARs AND TBC FOR SURFACE WATER

Parameters	ARARs								TBC Criteria	
	Virginia Surface Water (Freshwater) Quality Standards(1)				Federal Ambient Water (Freshwater) Quality Criteria(2)				EPA Region III BTAG Screening (Freshwater)(3)	
	Acute (ug/l)	Chronic (ug/l)	Public Water (ug/l)	Other Surface Waters (ug/l)	Acute (ug/l)	Chronic (ug/l)	Water/Fish Cons.(ug/l)	Fish Cons. (ug/l)	Flora (ug/l)	Fauna (ug/l)
VOCs										
Acetone	-	-	-	-	-	-	-	-	-	9,000,000
Total Metals										
Aluminum	-	-	-	-	-	-	-	-	460	25
Calcium	-	-	-	-	-	-	-	-	-	-
Iron	-	-	300	-	-	-	-	-	-	320
Lead	120	14	15	-	65	2.5	-	-	-	3.2
Magnesium	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	50	-	-	-	-	-	-	14,500
Potassium	-	-	-	-	-	-	-	-	-	-
Sodium	-	-	-	-	-	-	-	-	-	-
Zinc	120	110	5,000	-	120	120	9,100	69,000	30	110

Notes:

(1) Virginia Surface Water Quality Standards

(2) Federal Ambient Water Quality Criteria (40 CFR 131)

(3) EPA Region III BTAG Screening Levels for Aquatics in Surface Water (Jan 1995)

TABLE 4-4
CHEMICAL-SPECIFIC ARARs AND TBC FOR GROUNDWATER

Parameters	ARARs				TBC Criteria	
	EPA MCLs(1) (ug/l)	EPA Secondary MCLs(2) (ug/l)	Virginia GW Stds(3) (ug/l)	Va GW Protection Levels(4) (ug/l)	Virginia Groundwater Criteria(5) (ug/l)	EPA Region III RBC Table(6) for Tap Water (ug/l)
Metals						
Aluminum	-	50 - 200	-	-	-	37,000
Antimony	6	-	-	-	-	15
Arsenic	50	-	50	50	-	0.045
Barium	2,000	-	1,000	1,000	-	2,600
Beryllium	4	-	-	-	-	73
Cadmium	5	-	0.4	0.4	-	18
Calcium	-	-	-	-	-	-
Chromium	100	-	50	50	-	110
Cobalt	-	-	-	-	-	2,200
Copper	-	1,000	1,000	1,000	-	1,500
Iron	-	300	-	-	300	11,000
Lead	15 (7)	-	50	50	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	50	-	-	50	730
Mercury	2	-	0.05	0.05	-	-
Nickel	-	-	-	-	-	730
Potassium	-	-	-	-	-	-
Selenium	50	-	10	10	-	180
Silver	-	100	-	-	-	180
Sodium	-	-	270,000	270,000	100,000	-
Thallium	2	-	-	-	-	2.6
Vanadium	-	-	-	-	-	260
Zinc	-	5,000	50	50	-	11,000

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations
(5) Virginia Water Quality Criteria for Groundwater
(6) EPA Region III Risk-based Concentration Table for Tap Water (Oct 2000)
(7) USEPA action level for drinking water

TABLE 4-4
CHEMICAL-SPECIFIC ARARs AND TBC FOR GROUNDWATER

Parameters	ARARs				TBC Criteria	
	EPA MCLs(1) (ug/l)	EPA Secondary MCLs(2) (ug/l)	Virginia GW Stds(3) (ug/l)	Va GW Protection Levels(4) (ug/l)	Virginia Groundwater Criteria(5) (ug/l)	EPA Region III RBC Table(6) for Tap Water (ug/l)
VOCs						
Acetone	-	-	-	-	-	610
Benzene	5	-	-	5	-	0.32
Carbon disulfide	-	-	-	1,000	-	1,000
Chloroform	100	-	-	5	-	0.15
1,1-Dichloroethane	-	-	-	-	-	800
cis 1,2-Dichloroethene	70	-	-	-	-	61
Ethylbenzene	700	-	-	-	-	1,300
p-Isopropyl Toluene	-	-	-	-	-	-
Methyl isobutyl ketone	-	-	-	-	-	140
Methylene Chloride	5	-	-	600	-	4.1
Tetrachloroethene	5	-	-	7	-	1.1
Toluene	1,000	-	-	1,000	-	750
1,1,1-Trichloroethane	200	-	-	200	-	3,200
Trichloroethene	5	-	-	5	-	1.6
1,2,4-Trimethylbenzene	-	-	-	-	-	12
1,3,5-Trimethylbenzene	-	-	-	-	-	12
Vinyl acetate	-	-	-	-	-	410
Vinyl chloride	2	-	-	2	-	0.04
Xylenes	10,000	-	-	-	-	12,000
SVOCs						
Acenaphthene	-	-	-	-	-	370
Bis(2-ethylhexyl)phthalate	-	-	-	-	-	4.8
m&p cresol	-	-	-	700	-	-
Di-n-butylphthalate	-	-	-	-	-	3,700
Fluorene	-	-	-	-	-	240
2-Methylnaphthalene	-	-	-	-	-	120
Naphthalene	-	-	-	-	-	6.5
Phenanthrene	-	-	-	-	-	-
TPH						
Total TPH	-	-	1,000	1,000	-	-

TABLE 4-5
SOIL RESULTS - FTA SITE

Parameters	SB04-001			SB04-002			SB04-003			SB04-004			SB04-005			EPA RBC
	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	Criteria(1)
VOCs (ug/kg)																
Acetone	<28	39J	<29	<28	72J	<30	220DJ	70J	110J	<26	51J	<28	<26	<28	41J	20,000,000/780,000
Methylene Chloride	<5.7	<5.7	<5.8	<5.6	<5.7	<6.1	<5.6	<5.7	<5.8	<5.3	<5.5	<5.7	<5.3	<5.6	<6	760,000/85,000
Methyl ethyl ketone	<28	31J	<29	<28	<29	<30	28	<28	<.29	<26	69J	36J	<26	32J	110J	100,000,000/4,700,000
Styrene	<5.7	<5.7	<5.8	<5.6	<5.7	<6.1	<5.6	<5.7	<5.8	<5.3	<5.5	<5.7	<5.3	<5.6	<6	41,000,000/1,600,000
Toluene	21	8.6	7.4	68	18	<6.1	99	9.2	10	19	14	<5.7	24	14	16J	41,000,000/1,600,000
Xylenes	<5.7	<5.7	<5.8	<5.6	<5.7	<6.1	<5.6	<5.7	<5.8	<5.3	<5.5	<5.7	<5.3	<5.6	<6	100,000,000/16,000,000
SVOCs (ug/kg)																
Benzo(b)fluoranthene	BDL(2)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000,8,700
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/1,600
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)																
TPH as Gasoline	<.28	<.28	<.29	<.28	<.29	<.30	<.28	<.28	<.29	<.26	<.27	<.28	<.26	<.28	<.3	100 (4)
TPH as Kerosene	<11	<11	<12	<11	<11	<12	<11	<11	<12	<10	<11	<11	<10	<11	<12	100
TPH as Diesel Fuel	<11	<11	<12	<11	<11	<12	<11	<11	<12	<10	<11	<11	<10	<11	<12	100
TPH as Heavy Oils	<37	<37	<38	<36	<38	<40	<37	<37	<38	<34	<36	<36	<35	<37	<39	100
TPH as Fuel Oil	<37	<37	<38	<36	<38	<40	<37	<37	<38	<34	<36	<36	<35	<37	<39	100
Total Metals (mg/kg)																
Aluminum	420K	350K	360K	NT(3)	NT	NT	NT	NT	NT	NT	NT	NT	850K	770K	590K	100,000/7,800
Arsenic	<1.1	<1.1	<1.2	NT	NT	NT	NT	NT	NT	NT	NT	NT	**1.5**	<1.1	<1.2	3.8/0.43
Barium	3.9	2.5	3.3	NT	NT	NT	NT	NT	NT	NT	NT	NT	9.0	8.4	8.4	14,000/550
Calcium	71	<58	<57	NT	NT	NT	NT	NT	NT	NT	NT	NT	150	260	99	-
Chromium	1.7	1.9	6.7	NT	NT	NT	NT	NT	NT	NT	NT	NT	2.3	3.1	4.1	610/23
Cobalt	<1.1	<1.1	<1.2	NT	NT	NT	NT	NT	NT	NT	NT	NT	<1.1	<1.1	<1.2	4,100/160
Copper	3.5	<2.8	<2.9	NT	NT	NT	NT	NT	NT	NT	NT	NT	5.7	3.8	<3.0	8,200/310
Iron	1200K	740K	1100K	NT	NT	NT	NT	NT	NT	NT	NT	NT	3,200K	3,200K	1,300K	120,000/4,700
Lead	7	3.6	4.8	NT	NT	NT	NT	NT	NT	NT	NT	NT	33K	12	7	1,200/400
Magnesium	88	<57	<58	NT	NT	NT	NT	NT	NT	NT	NT	NT	100	86	69	-
Manganese	10	6.7	9.5	NT	NT	NT	NT	NT	NT	NT	NT	NT	34	26	11	4,100/160
Mercury	<0.011	<0.011	<0.012	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 0.011	<0.011	<0.012	-
Nickel	<4.5	<4.5	<4.7	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 4.2	< 4.4	< 4.8	4,100,000/160,000
Potassium	<110	<110	120	NT	NT	NT	NT	NT	NT	NT	NT	NT	<110	<110	<120	-
Sodium	< 57	< 57	< 58	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 52	< 56	< 60	-
Vanadium	1.8	1.5	1.4	NT	NT	NT	NT	NT	NT	NT	NT	NT	3.1	2.2	2.1	1,400/55
Zinc	18	5.9	6.6	NT	NT	NT	NT	NT	NT	NT	NT	NT	14	14	13	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) BDL - Below detection limit
(3) NT - Not tested
(4) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value
D - Concentration from secondary dilution
E - Concentration exceeded linear range of calibration
K - Representative value may be biased high

TABLE 4-5
SOIL RESULTS - FTA SITE

Parameters	SB04-006			SB04-007			SB04-008			SB04-009			SB04-010			EPA RBC Criteria(1)
	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	
VOCs (ug/kg)																
Acetone	<26	27J	<29	<26	320D	170J	<27	47J	53J	<27	110J	36J	<27	<26	79J	20,000,000/780,000
Methylene Chloride	<5.3	<5.4	<5.7	<5.2	<5.3	<5.6	<5.4	<5.3	<5.5	<5.4	3.1 J	5.6 J	<5.4	<5.3	<5.7	760,000/85,000
Methyl ethyl ketone	<26	48J	<29	<26	<26	<28	<27	<26	<27	<27	35J	57J	<27	<26	<28	100,000,000/4,700,000
Styrene	<5.3	<5.4	<5.7	<5.2	<5.3	<5.6	<5.4	<5.3	<5.5	<5.4	2 J	<5.4	<5.4	<5.3	<5.7	41,000,000/1,600,000
Toluene	<5.3	11	<5.7	<5.2	35	31	34	17	15	18	7.1	<5.4	<5.4	8.6	6.3	41,000,000/1,600,000
Xylenes	<5.3	<5.4	<5.7	<5.2	<5.3	<5.6	<5.4	<5.3	<5.5	<5.4	<5.4	<5.4	<5.4	<5.3	<5.7	100,000,000/16,000,000
SVOCs (ug/kg)																
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000,8,700
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1,300	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	45	BDL	BDL	BDL	4,100,000/1,600
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)																
TPH as Gasoline	<.26	<.27	<.27	<.26	<.26	<.28	<.27	<.26	<.27	<.27	<.26	<.27	<.27	<.26	<.28	100 (4)
TPH as Kerosene	<11	<11	<11	<10	<10	<11	<11	<10	<11	<11	<10	<11	<11	<10	<11	100
TPH as Diesel Fuel	<11	<11	<11	<10	<10	<11	<11	<10	<11	<11	<10	<11	<11	<10	<11	100
TPH as Heavy Oils	<35	<35	<38	<34	<34	<37	<35	<34	<36	<36	<34	<36	<35	<35	<37	100
TPH as Fuel Oil	<35	<35	<38	<34	<34	<37	<35	<34	<36	<36	<34	<36	<35	<35	<37	100
Total Metals (mg/kg)																
Aluminum	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	980K	450K	350K	100,000/7,800
Arsenic	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**1.6**	**1.5**	**1.2**	3.8/0.43
Barium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	12	3.3	2.2	14,000/550
Calcium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	370	85	<57	-
Chromium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	3.1	1.8	2.7	610/23
Cobalt	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 1.1	< 1.1	< 1.1	4,100/160
Copper	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	4.3	<2.6	<2.8	8,200/310
Iron	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	2100K	940K	960K	120,000/4,700
Lead	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	33K	9.5K	3.6K	1,200/400
Magnesium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	190	55	<57	-
Manganese	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	25	8.2	7.2	4,100/160
Mercury	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	0.011	<.011	<.011	-
Nickel	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 4.3	< 4.2	< 4.5	4,100,000/160,000
Potassium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	160	<110	<110	-
Sodium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 54	< 53	< 57	-
Vanadium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	3.7	1.9	1.3	1,400/55
Zinc	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	22	8.3	5.9	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) BDL - Below detection limit
(3) NT - Not tested
(4) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value
D - Concentration from secondary dilution
E - Concentration exceeded linear range of calibration
K - Representative value may be biased high

TABLE 4-5
SOIL RESULTS - FTA SITE

Parameters	SB04-011			SB06-012			SB04-013			SB04-014			SB04-015			EPA RBC Criteria(1)
	0 to 1 ft	2 to 4 ft	6 to 8ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	
VOCs (ug/kg)																
Acetone	<35	210J	120J	<26	150D	36	140J	1500E	420D	<26	150J	60J	<26	700D	210J	20,000,000/780,000
Methylene Chloride	<6.9	<5.4	<5.5	<5.2	<5.3	<5.7	<5.3	<5.4	<5.6	<5.3	<5.2	<5.6	<5.2	<5.2	<5.6	760,000/85,000
Methyl ethyl ketone	<35	<27	<27	<26	<26	<29	<26	<27	<28	<26	<26	<28	<26	<26	<28	100,000,000/4,700,000
Styrene	<6.9	<5.4	<5.5	<5.2	<5.3	<5.7	<5.3	<5.4	<5.6	<5.3	<5.2	<5.6	<5.2	<5.2	<5.6	41,000,000/1,600,000
Toluene	19	31	18	24	55	17	21	<5.4	13	20	34	5.8	140	<5.2	<5.6	41,000,000/1,600,000
Xylenes	<6.9	<5.4	<5.5	<5.2	<5.3	<5.7	<5.3	<5.4	<5.6	<5.3	<5.2	<5.6	<5.2	<5.2	<5.6	100,000,000/16,000,000
SVOCs (ug/kg)																
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000,8,700
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/1,600
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)																
TPH as Gasoline	<.35	<.27	<.27	<.26	<.26	<.29	<.26	<.27	<.28	<.26	<.26	<.28	<.26	<.26	<.28	100 (4)
TPH as Kerosene	<14	<11	<11	<10	<10	<11	<10	<11	<11	<10	<10	<11	<10	<10	<11	100
TPH as Diesel Fuel	<14	<11	<11	<10	<10	<11	<10	<11	<11	<10	<10	<11	<10	<10	<11	100
TPH as Heavy Oils	<45	<35	<36	<34	<35	<38	<35	<36	<37	<34	<34	<36	<34	<34	<37	100
TPH as Fuel Oil	<45	<35	<36	<34	<35	<38	<35	<36	<37	<34	<34	<36	<34	<34	<37	100
Total Metals (mg/kg)																
Aluminum	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	490K	610	250K	100,000/7,800
Arsenic	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**1.2**	**0.98**	**1.4**	3.8/0.43
Barium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	8	3	2.6	14,000/550
Calcium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	<52	37	<56	-
Chromium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	5.8	14	2.4	610/23
Cobalt	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 1.0	0.44 J	< 1.1	4,100/160
Copper	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	13	0.63 J	<2.8	8,200/310
Iron	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**5,400J**	940J	890J	120,000/4,700
Lead	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	15K	6.7K	1.8K	1,200/400
Magnesium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	62	44	<56	-
Manganese	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	32	8.9	5.7	4,100/160
Mercury	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 0.01	0.20	< 0.011	-
Nickel	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 4.2	0.57 J	< 4.5	4,100,000/160,000
Potassium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 100	27 J	< 110	-
Sodium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 52	9.9	< 56	-
Vanadium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	1.8	2.9	3.7	1,400/55
Zinc	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	15	4.2	2.3	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) BDL - Below detection limit
(3) NT - Not tested
(4) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value
D - Concentration from secondary dilution
E - Concentration exceeded linear range of calibration
K - Representative value may be biased high

TABLE 4-5
SOIL RESULTS - FTA SITE

Parameters	SB04-016			SB04-017			SB04-018			SB04-019			SB04-020			EPA RBC Criteria(1)
	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	
VOCs (ug/kg)																
Acetone	<5.4	130J	140J	<26	4400D	1700E	<26	<29	<27	<26	190J	<28	<26	<26	<32	20,000,000/780,000
Methylene Chloride	5 J	<5.6	<5.4	<5.3	<5.4	<5.4	<5.3	<5.7	<5.4	6.4	<5.3	<5.6	<5.2	<5.1	<6.4	760,000/85,000
Methyl ethyl ketone	<27	<28	<27	<26	<27	<27	<26	<29	<27	<26	<26	<28	<26	<26	<32	100,000,000/4,700,000
Styrene	3 J	<5.6	<5.4	<5.3	<5.4	<5.4	<5.3	<5.7	<5.4	<5.3	<5.3	<5.6	<5.2	<5.1	<6.4	41,000,000/1,600,000
Toluene	85	6.9	9.1	8.3	11	<5.4	20	9.3	6.4	21	<5.3	13	15	12	22	41,000,000/1,600,000
Xylenes	7	<5.6	<5.4	<5.3	<5.4	<5.4	<5.3	<5.7	<5.4	<5.3	<5.3	<5.6	<5.2	<5.1	<6.4	100,000,000/16,000,000
SVOCs (ug/kg)																
Benzo(b)fluoranthene	97 J	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	86 J	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000,8,700
Bis(2-EH)phthalate	110 J	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	94 J	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	150 JB	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	75 J	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/1,600
Pyrene	64 J	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)																
TPH as Gasoline	<.27	<.28	<.27	<.26	<.27	<.27	<.26	<.29	<.27	<.26	<.26	<.28	<.26	<.26	<.32	100 (4)
TPH as Kerosene	<11	<11	<11	<10	<11	<11	<11	<11	<11	<520	<52	<11	<10	<10	<13	100
TPH as Diesel Fuel	<11	<11	<11	<10	<11	<11	<11	<11	<11	<520	<52	<11	<10	<10	<13	100
TPH as Heavy Oils	<35	<37	<36	<34	<35	<35	<35	<38	<36	**5,300**	**300**	48	<34	<34	<42	100
TPH as Fuel Oil	<35	<37	<36	<34	<35	<35	<35	<38	<36	<1700	<170	<36	<34	<34	<42	100
Total Metals (mg/kg)																
Aluminum	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	640K	420K	NT	100,000/7,800
Arsenic	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	**1.4**	**1.2**	NT	3.8/0.43
Barium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	9.2	5.1	NT	14,000/550
Calcium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	150	190	NT	-
Chromium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	2.5	2.2	NT	610/23
Cobalt	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 1.0	< 1.0	NT	4,100/160
Copper	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	3.2	<2.6	NT	8,200/310
Iron	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	1600J	1200J	NT	120,000/4,700
Lead	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	31K	12K	NT	1,200/400
Magnesium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	120	<100	NT	-
Manganese	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	19	12	NT	4,100/160
Mercury	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	0.013	< 0.01	NT	-
Nickel	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 4.1	< 4.1	NT	4,100,000/160,000
Potassium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	<100	<100	NT	-
Sodium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	< 52	< 51	NT	-
Vanadium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	3.1	2.2	NT	1,400/55
Zinc	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	22	11	NT	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) BDL - Below detection limit
(3) NT - Not tested
(4) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value
D - Concentration from secondary dilution
E - Concentration exceeded linear range of calibration
K - Representative value may be biased high

TABLE 4-5
SOIL RESULTS - FTA SITE

Parameters	SB04-021			SB04-022			SS04-023	SS04-024	SS04-025	SS04-026	SS04-027	SS04-028	EPA RBC
	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	0 to 1 ft	0 to 1 ft	0 to 1 ft	0 to 1 ft	0 to 1 ft	Criteria(1)
VOCs (ug/kg)													
Acetone	<27	<26	<26	<26	18000DJ	480DJ	<29	<27	134	<26	<26	<26	20,000,000/780,000
Methylene Chloride	<5.5	<5.2	<5.3	<5.2	<5.3	<5.3	<5.7	<5.5	<5.7	<5.3	<5.3	<5.3	760,000/85,000
Methyl ethyl ketone	<27	<5.2	<26	<26	<26	<26	<29	<27	<29	<26	<26	<26	100,000,000/4,700,000
Styrene	<5.5	<5.2	<5.3	<5.2	<5.3	<5.3	<5.7	<5.5	<5.7	<5.3	<5.3	<5.3	41,000,000/1,600,000
Toluene	19	<5.2	16	22	17	7	13	40	18	17	39J	12	41,000,000/1,600,000
Xylenes	<5.5	<5.2	<5.3	<5.2	<5.3	<5.3	<5.7	<5.5	<5.7	<5.3	<5.3	<5.3	100,000,000/16,000,000
SVOCs (ug/kg)													
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000,8,700
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	650	1100	600	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/1,600
Pyrene	BDL	BDL	BDL	720	700	440	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)													
TPH as Gasoline	<.27	<.26	<.26	<.26	<.26	<.26	<.29	<.27	<.29	<.26	<.26	<.26	100 (4)
TPH as Kerosene	<11	<10	<10	<10	<10	<10	<11	<11	<11	<11	<11	<11	100
TPH as Diesel Fuel	<11	<10	<10	<10	<10	<10	<11	<11	<11	<11	<11	<11	100
TPH as Heavy Oils	48	<34	<35	66	**150**	95	<38	<36	<38	<35	<35	<35	100
TPH as Fuel Oil	<36	<34	<35	<34	<34	<34	<38	<38	<38	<35	<35	<35	100
Total Metals (mg/kg)													
Aluminum	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	100,000/7,800
Arsenic	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	3.8/0.43
Barium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	14,000/550
Calcium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	-
Chromium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	610/23
Cobalt	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	4,100/160
Copper	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	8,200/310
Iron	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	120,000/4,700
Lead	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	1,200/400
Magnesium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	-
Manganese	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	4,100/160
Mercury	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	-
Nickel	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	4,100,000/160,000
Potassium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	-
Sodium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	-
Vanadium	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	1,400/55
Zinc	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) BDL - Below detection limit
(3) NT - Not tested
(4) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value
D - Concentration from secondary dilution
E - Concentration exceeded linear range of calibration
K - Representative value may be biased high

TABLE 4-5
SOIL RESULTS (2000 Sampling) - FTA SITE

Parameters	SS1 0 to 6 in.	SS2 0 to 6 in.	SS3 0 to 6 in.	SS4 0 to 6 in.	SS5 0 to 6 in.	SS6 0 to 6 in.	SS7 0 to 6 in.	SS8 0 to 6 in.	EPA RBC Criteria(1)
PCBs (ug/kg)									
Aroclor-1016	< 36	< 35	< 34	< 35	< 36	< 37	< 36	< 40	82,000/5,500
Aroclor-1221	< 73	< 70	< 70	< 72	< 73	< 74	< 74	< 82	2,900/320
Aroclor-1232	< 36	< 35	< 34	< 35	< 36	< 37	< 36	< 40	2,900/320
Aroclor-1242	< 36	< 35	< 34	< 35	< 36	< 37	< 36	< 40	2,900/320
Aroclor-1248	< 36	< 35	< 34	< 35	< 36	< 37	< 36	< 40	2,900/320
Aroclor-1254	< 36	< 35	< 34	< 35	< 36	< 37	< 36	< 40	2,900/320
Aroclor-1260	< 36	< 35	< 34	< 35	< 36	< 37	< 36	< 40	2,900/320
Pesticides (ug/kg)									
Aldrin	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	340/38
alpha-BHC	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	910/100
beta-BHC	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	3,200/350
delta-BHC	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	-
gamma-BHC (Lindane)	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	4,400/490
alpha-Chlordane	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	0.36 JP	< 1.8	< 1.7	16,000/1,800
gamma-Chlordane	< 1.8	< 1.7	< 8.8	0.30 J	< 1.8	< 1.8	0.84 J	0.45 J	16,000/1,800
DDD	< 3.4	< 3.4	< 17	< 3.3	< 3.4	< 3.5	< 3.5	< 3.3	24,000/2,700
DDE	0.37 J	0.72 J	9.0 J	0.61 J	< 3.4	0.58 J	2.6 J	0.91 J	17,000/1,900
DDT	0.90 J	1.2 J	24	1.7 J	1.5 J	1.8 J	7.8	2.8 J	17,000/1,900
Dieldrin	< 3.4	< 3.4	< 17	< 3.3	< 3.4	< 3.5	< 3.5	< 3.3	360/40
Endosulfan I	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	1,200,000/47,000
Endosulfan II	< 3.4	< 3.4	< 17	< 3.3	< 3.4	< 3.5	< 3.5	< 3.3	1,200,000/47,000
Endosulfan sulfate	< 3.4	< 3.4	< 17	< 3.3	< 3.4	< 3.5	< 3.5	< 3.3	-
Endrin	< 3.4	< 3.4	< 17	< 3.3	< 3.4	< 3.5	< 3.5	< 3.3	61,000/2,300
Endrin aldehyde	< 3.4	< 3.4	< 17	< 3.3	< 3.4	< 3.5	< 3.5	< 3.3	-
Endrin ketone	< 3.4	< 3.4	< 17	< 3.3	< 3.4	< 3.5	< 3.5	< 3.3	-
Heptachlor	< 1.8	< 1.7	< 8.8	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	1,300/140
Heptachlor epoxide	< 1.8	< 1.7	0.94 JP	< 1.7	< 1.8	< 1.8	< 1.8	< 1.7	630/70
Methoxyclor	< 18	< 17	< 88	< 17	< 18	< 18	< 18	< 17	1,000,000/39,000
Toxaphene	< 180	< 170	< 880	< 170	< 180	< 180	< 180	< 170	5,200/580

Notes:

(1) EPA Region III RBCs for Industrial/Residential Soils (Sept 2001)
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated concentration
P - Greater than 25% difference for detected levels in two GC columns

TABLE 4-6
SEDIMENT RESULTS
FIREFIGHTER TRAINING AREA

Parameters	Sample ID and Results				EPA RBC Criteria(1)
	SD04-001	SD04-002	SD04-003	SD04-004	
VOCs (ug/kg)					
Toluene	180	40	23	93	41,000,000/1,600,000
SVOCs (ug/kg)	BDL(2)	BDL	BDL	BDL	
TPH (mg/kg)					
TPH as Gasoline	< 0.34	< 0.36	< 0.26	< 0.27	100(3)
TPH as Kerosene	< 27	< 14	< 11	< 11	100
TPH as Diesel Fuel	< 27	< 14	< 11	< 11	100
TPH as Heavy Oils	**350**	**180**	< 35	**130**	100
TPH as Fuel Oil	< 89	< 47	< 35	< 35	100
Total Metals (mg/kg)					
Aluminum	7,600 K	560 K	160 K	160 K	100,000/7,800
Arsenic	**2.5**	< 1.4	< 1.1	< 1.1	3.8/0.43
Barium	110	6.5	3.6	2.4	14,000/550
Calcium	120	120	64	77	-
Chromium	21	< 1.4	< 1.1	< 1.1	610/23
Cobalt	2.6	< 1.4	< 1.1	< 1.1	4,100/160
Copper	26	< 3.6	< 2.7	< 2.7	8,200/310
Iron	**17,000 J**	440 J	230 J	280 J	120,000/4,700
Lead	210 K	15 K	7.2 K	4.3 K	1,200/400
Magnesium	960	< 71	< 53	< 54	-
Manganese	42	< 1.4	3.1	1.7	4,100/160
Mercury	0.051	0.017	< 0.011	< 0.011	61/2.3
Nickel	9.4	< 5.7	< 4.3	< 4.3	41,000/1,600
Potassium	260	< 140	< 110	< 110	-
Sodium	180	87	< 53	< 54	-
Thallium	< 1.4	**1.4**	< 1.1	< 1.1	14/0.55
Vanadium	18	2.0	< 1.1	< 1.1	1,400/55
Zinc	76	6	< 2.1	< 2.2	61,000/2,300

Notes:

(1) EPA Region III Risk-based Concentration for Industrial/Residential Soils (Sept 2001)

(2) BDL - Below detection limit

(3) Virginia DEQ Petroleum Program Reporting Level

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value

K - Representative value may be biased high

TABLE 4-7

MONITORING WELL GROUNDWATER RESULTS

FIREFIGHTER TRAINING AREA

Parameters	Well ID and Results										EPA RBC Criteria(1)
	4MW-1	4MW-2S	4MW-2D	4MW-3	4MW-4	4MW-5	MW-111	MW-112	MW-113A	MW-114A	
VOCs (ug/l)											
Acetone	<25 / 10 J	<25	<25	<25	28	<25	<25 / <5	<25 / <5	<25	<25 / 15 J	370
Carbon Disulfide	<5 / <5	<5	7.0 J	8.3 J	<5	<5	5.0 J / <5	<5 / <5	<5	<5 / < 5	100
1,1-Dichloroethane	<5 / <5	<5	<5	<5	<5	<5	<5 / <5	<5 / 0.6 J	<5	<5 / 0.86 J	81
Ethylbenzene	<5 / <5	<5	47	<5	<5	<5	<5 / <5	<5 / <5	<5	<5 / < 5	130
Xylenes	<5 / <10	200	25	<5	<5	<5	<5 / <10	<5 / <10	<5	<5 / < 10	1,200
SVOCs (ug/l)											
Naphthalene	<10	11	<10	<10	<10	<10	<10	<10	<10	<10	150
Pest/PCBs	BDL	NT (3)	NT	NT	NT	NT	BDL	BDL	NT	BDL	
TPH (mg/l)											
TPH as Gasoline	<0.05	<0.25	0.66	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.0 (2)
TPH as Diesel Fuel	<0.30	<0.30	**2.0**	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	1.0 (2)
TPH as Heavy Oils	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0 (2)
TPH as Fuel Oil	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0 (2)
TPH as Kerosene	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	1.0 (2)
Total Metals (ug/l)											
Aluminum	17,000 R / 470	7,000 R	NT	NT	NT	NT	NT / 580	670 R / < 6	NT	NT / 920	3,700
Antimony	< 50 / < 2.7	< 50	NT	NT	NT	NT	NT / < 2.7	< 50 / < 2.7	NT	NT / < 2.7	1.5
Arsenic	**10** / < 3	**12**	NT	NT	NT	NT	NT / < 3	< 10 / < 3	NT	NT / **3.4**	0.045
Barium	110 / 18	110	NT	NT	NT	NT	NT / 19	< 10 / 6.1	NT	NT / 13	260
Beryllium	< 5 / < 0.1	< 5	NT	NT	NT	NT	NT / < 0.10	< 5 / < 0.10	NT	NT / < 0.10	73
Cadmium	< 5 / < 0.5	< 5	NT	NT	NT	NT	NT / < 0.50	< 5 / < 0.50	NT	NT / < 0.50	18
Calcium	13,000 / 6,200	18,000	NT	NT	NT	NT	NT / 9,300	15,000 / 19,000	NT	NT / 11,000	-
Chromium	30 / < 0.70	14	NT	NT	NT	NT	NT / < 0.70	< 10 / < 0.70	NT	NT / 1.2	110
Cobalt	< 10 / < 0.9	< 10	NT	NT	NT	NT	NT / < 0.90	< 10 / < 0.90	NT	NT / < 0.90	73
Copper	< 25 / 21	< 25	NT	NT	NT	NT	NT / 4.7	< 25 / 3.1	NT	NT / 1.3	140
Iron	15,000 R / 280	12,000R	NT	NT	NT	NT	NT / 280	1,700 R / 320	NT	NT / **4,100**	2,200
Lead	**52** / 4	12	NT	NT	NT	NT	NT / 2.8	< 5 / < 2.4	NT	NT / < 2.4	15 (4)
Magnesium	3,000 / 980	3,000	NT	NT	NT	NT	NT / 1,200	5,900 / 4,900	NT	NT / 8,700	-
Manganese	**150** / 3.7	**120**	NT	NT	NT	NT	NT / 7.9	12 / 4.2	NT	NT / 24	73
Mercury	< 0.2 / < 0.1	< 0.2	NT	NT	NT	NT	NT / < 0.10	< 0.2 / < 0.10	NT	NT / < 0.10	-
Nickel	< 40 / < 1.1	< 40	NT	NT	NT	NT	NT / < 1.1	< 40 / < 1.1	NT	NT / 2.2	73
Potassium	3400 / 1,300	3,600	NT	NT	NT	NT	NT / 3,000	2,100 / 1,800	NT	NT / 2,600	-
Selenium	10 R / < 3.4	10 R	NT	NT	NT	NT	NT / < 3.4	10 R / < 3.4	NT	NT / < 3.4	18
Silver	< 10 / < 0.5	< 10	NT	NT	NT	NT	NT / < 0.50	< 10 / < 0.50	NT	NT / < 0.50	18
Sodium	5,800 / 5,500	3,800	NT	NT	NT	NT	NT / 7,200	7,700 / 6,700	NT	NT / 36,000	270,000
Thallium	< 10 / < 4.3	< 10	NT	NT	NT	NT	NT / < 4.3	< 10 / < 4.3	NT	NT / < 4.3	2.6
Vanadium	**28** / 0.81	16	NT	NT	NT	NT	NT / < 0.70	< 10 / 1.6	NT	NT / 2.6	26
Zinc	160 / 83	160	NT	NT	NT	NT	NT / 20	< 20 / 18	NT	NT / 73	1,100

TABLE 4-7

MONITORING WELL GROUNDWATER RESULTS

FIREFIGHTER TRAINING AREA

Parameters	Well ID and Results										EPA RBC Criteria(1)
	4MW-1	4MW-2S	4MW-2D	4MW-3	4MW-4	4MW-5	MW-111	MW-112	MW-113A	MW-114A	
Dissolved Metals (ug/l)											
Aluminum	< 200 R / 200	250 R	NT	NT	NT	NT	NT / 410	120 R / 64	NT	NT / 590	3,700
Antimony	< 50 / **3.8**	< 50	NT	NT	NT	NT	NT / < 2.7	< 50 / **5.7**	NT	NT / < 2.7	1.5
Arsenic	< 10 / < 3	< 10	NT	NT	NT	NT	NT / < 3	< 10 / < 3	NT	NT / < 3	0.045
Barium	52 / 17	140	NT	NT	NT	NT	NT / 18	21 / 6.2	NT	NT / 12	260
Beryllium	< 5 / < 0.10	< 5	NT	NT	NT	NT	NT / < 0.10	< 5 / < 0.10	NT	NT / < 0.10	73
Cadmium	< 5 / < 0.50	< 5	NT	NT	NT	NT	NT / < 0.50	< 5 / < 0.50	NT	NT / < 0.50	18
Calcium	12,000 / 5,900	18,000	NT	NT	NT	NT	NT / 8,800	16,000 / 18,000	NT	NT / 10,000	-
Chromium	< 10 / < 0.70	< 10	NT	NT	NT	NT	NT / 1.3	< 10 / 0.99	NT	NT / 1.7	110
Cobalt	< 10 / < 0.90	< 10	NT	NT	NT	NT	NT / < 0.90	< 10 / < 0.90	NT	NT / 1.2	73
Copper	< 25 / 7.9	< 25	NT	NT	NT	NT	NT / 2.7	25 / 2.6	NT	NT / < 0.90	140
Iron	< 50 R / 130	3,600 R	NT	NT	NT	NT	NT / 180	280 R / 140	NT	NT / 2,100	2,200
Lead	< 5 / 4.6	< 5	NT	NT	NT	NT	NT / 4.5	< 5 / < 2.4	NT	NT / < 2.4	15 (4)
Magnesium	1,700 / 920	2,500	NT	NT	NT	NT	NT / 1,100	5,800 / 4,900	NT	NT / 8,400	-
Manganese	< 10 / 2.5	**81**	NT	NT	NT	NT	NT / 6.5	11 / 4.7	NT	NT / 23	73
Mercury	< 0.2 / < 0.10	< 0.2	NT	NT	NT	NT	NT / < 0.10	< 0.2 / < 0.10	NT	NT / < 0.10	-
Nickel	< 40 / < 1.1	< 40	NT	NT	NT	NT	NT / < 1.1	< 40 / < 1.1	NT	NT / 3	73
Potassium	1,700 / 1,300	2,900	NT	NT	NT	NT	NT / 3,000	2,200 / 2,000	NT	NT / 2,600	-
Selenium	< 10 / < 3.4	< 10	NT	NT	NT	NT	NT / < 3.4	< 10 / < 3.4	NT	NT / < 3.4	18
Silver	< 10 / < 0.50	< 10	NT	NT	NT	NT	NT / < 0.50	< 10 / < 0.50	NT	NT / < 0.50	18
Sodium	6,600 / 5,100	4,700	NT	NT	NT	NT	NT / 6,700	8,400 / 6,800	NT	NT / 36,000	270,000
Thallium	< 10 / < 4.3	< 10	NT	NT	NT	NT	NT / < 4.3	< 10 / < 4.3	NT	NT / < 4.3	2.6
Vandium	< 10 / 1.4	< 10	NT	NT	NT	NT	NT / 1.2	< 10 / 1.8	NT	NT / 1.4	26
Zinc	44 / 70	120	NT	NT	NT	NT	NT / 13	21 / 15	NT	NT / 65	1,100
Miscellaneous (mg/l)											
TSS	NT / < 5	NT	NT	NT	NT	NT	NT / < 5	NT / < 5	NT	NT / < 5	-
TDS	NT / 62	NT	NT	NT	NT	NT	NT / 91	NT / 120	NT	NT / 220	-

Notes:

(1) EPA Region III Risk-based Concentration Table Criteria for Tap Water (Sept 2001)

(2) Virginia Groundwater Standard for Petroleum Hydrocarbons

(3) NT - Not tested

(4) USEPA Action Level for Lead in Drinking Water

Result / Result = 1995 sampling result / 2000 sampling result (select wells for VOCs and metals only)

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

R - Data rejected based on data validation results

J - Estimated value

TABLE 4-8

DPT GROUNDWATER RESULTS - FTA

Parameters	Sample ID and Results								EPA RBC Criteria(1)
	GW04-001	GW04-002	GW04-003	GW04-004	GW04-005	GW04-006	GW04-007	GW04-008	
VOCs (ug/l)									
Acetone	<25	<25	<25	<25	<25	27 J	<25	<25	370
Benzene	<5 / <10(2)	<5 / <5	<5 / <5	<5 / <10	<5 / <10	<5 / <10	<5 / <10	<5 / <10	0.32
cis 1,2-DCE	<5 / <10	<5 / <5	<5 / <5	<5 / <10	<5 / <10	<5 / <10	<5 / <10	<5 / <10	6.1
Tetrachloroethene	<5 / <10	**6.4 / <5**	<5 / <5	<5 / <10	<5 / <10	<5 / <10	<5 / <10	<5 / <10	1.1
Trichloroethene	<5 / <10	<5 / <5	<5 / <5	<5 / <10	<5 / <10	<5 / <10	<5 / <10	<5 / <10	1.6
Vinyl chloride	<10 / <10	<10 / 7R	<10 / 7.4R	<10 / <10	<10 / <10	<10 / >50R	<10 / <10	<10 / <10	0.015
Xylenes	<5	<5	<5	<5	<5	46 J	<5	<5	1,200
SVOCs (ug/l)									
Fluorene	<10	<10	<10	<10	<10	15	<10	<10	24
2-Methylnaphthalene	<10	<10	<10	<10	<10	**120**	<10	<10	12
Naphthalene	<10	<10	<10	<10	<10	**60**	<10	<10	0.65
Phenanthrene	<10	<10	<10	<10	<10	18	<10	<10	-
TPH (mg/l)									
TPH as Gasoline	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	**2.0 / 13.0**	<0.05 / <0.5	<0.05 / <0.5	1.0 (3)
TPH as Diesel Fuel	<0.30	<0.30	<0.30	<0.30	<0.30	**7.2**	<0.30	<0.30	1.0 (3)
TPH as Heavy Oils	<1.0	<1.0	<1.0	<1.0	**1.4**	<5.0	<1.0	<1.0	1.0 (3)
TPH as Fuel Oil	<1.0	<1.0	<1.0	<1.0	<1.0	<5.0	<1.0	<1.0	1.0 (3)
TPH as Kerosene	<0.30	<0.30	<0.30	<0.30	<0.30	<1.5	<0.30	<0.30	1.0 (3)
Total Metals (ug/l)									
Aluminum	**4,700 J**	**11,000 J**	NT (4)	NT	NT	NT	**3,600**	**5,100**	3,700
Barium	24 J	55	NT	NT	NT	NT	40	110	260
Calcium	3,200	4,200	NT	NT	NT	NT	3,200	3,900	-
Chromium	17	13	NT	NT	NT	NT	19	< 10	110
Copper	< 25	32	NT	NT	NT	NT	< 25	< 25	140
Iron	**4,300**	**4,800**	NT	NT	NT	NT	**4,100**	**4,900**	2,200
Lead	**18**	**23**	NT	NT	NT	NT	6.1	**24**	15 (5)
Magnesium	920	1,300	NT	NT	NT	NT	1,500	870	-
Manganese	50	68	NT	NT	NT	NT	53	60	73
Potassium	1,600	2,100	NT	NT	NT	NT	3,100	1,700	-
Sodium	2,100	2,900	NT	NT	NT	NT	3,500	2,600	270,000 (6)
Zinc	190	190	NT	NT	NT	NT	190	61	1,100

Notes:

(1) EPA Region III Risk-based Concentration Criteria for Tap Water

(2) <20 / <10 = Savannah Lab result / Earth Tech on-site GC result

(3) Virginia Groundwater Standard for Petroleum Hydrocarbons

(4) NT - Not tested

(5) USEPA Action Level for Drinking Water

(6) Virginia Groundwater Quality Standard

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

R - Rejected value, on-site GC results for vinyl chloride not confirmed by Savannah Lab GC/MS analysis

J - Estimated value

TABLE 4-8
DPT GROUNDWATER RESULTS
FIREFIGHTER TRAINING AREA

Parameters	Sample ID and Results								EPA RBC Criteria(1)
	GW04-009	GW04-010	GW04-011	GW04-012	GW04-013	GW04-014 (10 ft depth)	GW04-014 (20 ft depth)	GW04-015	
VOCs (ug/l)									
Benzene	<5 / <10 (2)	<5 / <10	<5 / <10	**10 / <10**	<5 / <5	NT(3) / <5	NT / <5	<5 / <10	0.32
1,1-DCA	<5	20J	<5	<5	<5	NT	NT	<5	80
cis 1,2-DCE	<5 / <10	<5 / <10	<5 / <10	<5 / <10	<5 / <5	NT / <5	NT / <5	<5 / <10	6.1
Tetrachloroethene	<5 / <10	<5 / <10	**78J / <10**	<5 / <10	<5 / <5	NT / <5	NT / <5	<5 / <10	1.1
Toluene	< 5	< 5	< 5	20	< 5	NT	NT	< 5	75
1,1,1-TCA	<5	31J	9.4J	<5	<5	NT	NT	<5	320
Trichloroethene	<5 / <10	<5 / <10	<5 / <10	<5 / <10	<5 / <5	NT / <5	NT / <5	<5 / <10	1.6
Vinyl chloride	<10 / <10	<10 / <10	<10 / <10	<10 / <10	<10 / 12 R	NT / 26R	NT / 6.6R	<10 / 12R	0.015
SVOCs (ug/l)									
Bis(2-EH)phthalate	< 10	< 10	< 10	1.0 J	< 10	NT	NT	< 10	4.8
TPH (mg/l)									
TPH as Gasoline	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	NT / <0.5	NT / <0.5	<0.05 / <0.5	1.0 (5)
TPH as Diesel Fuel	<0.30	<0.30	<0.30	<0.30	<0.30	NT	NT	<0.30	1.0 (5)
TPH as Heavy Oils	<1.0	<1.0	<1.0	<1.0	<1.0	NT	NT	<1.0	1.0 (5)
TPH as Fuel Oil	<1.0	<1.0	<1.0	<1.0	<1.0	NT	NT	<1.0	1.0 (5)
TPH as Kerosene	<0.30	<0.30	<0.30	<0.30	<0.30	NT	NT	<0.30	1.0 (5)
Total Metals (mg/l)	NT	NT	NT	NT	NT	NT	NT	NT	

Notes:

(1) EPA Region III Risk-based Concentration Criteria for Tap Water

(2) <20 / <10 = Savannah Lab result / Earth Tech on-site GC result

(3) NT - Not tested

(4) Virginia Groundwater Standard for Petroleum Hydrocarbons

R - rejected value, on-site GC results for vinyl chloride not confirmed by Savannah lab GC/MS analysis

J - Estimated value

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

TABLE 4-8
DPT GROUNDWATER RESULTS
FIREFIGHTER TRAINING AREA

Parameters	Sample ID and Results								EPA RBC Criteria(1)
	GW04-016	GW04-017	GW04-018	GW04-019	GW04-020	GW04-021	GW04-022	GW04-023	
VOCs (ug/l)									
Benzene	<5 / <5(2)	<5 / <5	<5	NT (3) / <5	NT / <5	NT / <5	NT / <5	NT / <5	0.32
1,1-DCA	<5	<5	<5	NT	NT	NT	NT	NT	80
cis 1,2-DCE	<5 / <5	<5 / <5	<5	NT / <5	NT / <5	NT / <5	NT / <5	NT / <5	6.1
Tetrachloroethene	<5 / <5	<5 / <5	<5	NT / <5	NT / <5	NT / <5	NT / <5	NT / <5	1.1
1,1,1-TCA	<5	<5	<5	NT	NT	NT	NT	NT	320
Trichloroethene	<5 / <5	<5 / <5	<5	NT / <5	NT / <5	NT / <5	NT / <5	NT / <5	1.6
Vinyl chloride	<10 / 83R	<10 / 6.7R	<10	NT / <5	NT / <5	NT / <5	NT / <5	NT / <5	0.015
SVOCs (ug/l)	BDL (4)	BDL	NT	NT	NT	NT	NT	NT	
TPH (mg/l)									
TPH as Gasoline	<0.05 / <0.5	<0.05 / <0.5	<0.5	NT / <0.5	NT / <0.5	NT / <0.5	NT / <0.5	NT / <0.5	1.0 (5)
TPH as Diesel Fuel	<0.30	<0.30	NT	NT	NT	NT	NT	NT	1.0 (5)
TPH as Heavy Oils	<1.0	<1.0	NT	NT	NT	NT	NT	NT	1.0 (5)
TPH as Fuel Oil	<1.0	<1.0	NT	NT	NT	NT	NT	NT	1.0 (5)
TPH as Kerosene	<0.30	<0.30	NT	NT	NT	NT	NT	NT	1.0 (5)
Total Metals (mg/l)	NT	NT	NT	NT	NT	NT	NT	NT	

Notes:

(1) EPA Region III Risk-based Concentration Criteria for Tap Water

(2) <20 / <10 = Savannah Lab result / Earth Tech on-site GC result

(3) NT - Not tested

(4) BDL - Below detection limit

(5) Virginia Groundwater Standard for Petroleum Hydrocarbons

R - rejected value, on-site GC results for vinyl chloride not confirmed by Savannah Lab GC/MS analysis

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

TABLE 4-9
SOIL RESULTS - LARC 60 SITE

Parameters	SB06-001			SB06-002			SB06-003		EPA Risk
	0 to 1 ft	5 to 7 ft	10 to 12 ft	0 to 1 ft	4 to 5 ft	8 to 9 ft	0 to 1 ft	5 to 7 ft	Criteria(1)
VOCs (ug/kg)									
Acetone	<26	<26	<27	<25	200	62	<26	<26	20,000,000/780,000
sec-Butyl benzene	NA	NA	NA	NA	NA	NA	< 1.4	NA	8,200,000/310,000
Ethylbenzene	<5.3	<5.2	<5.4	<5.0	<5.2	<5.7	<5.2	<5.2	20,000,000/780,000
Isopropyl benzene	NA	NA	NA	NA	NA	NA	< 1.5	NA	---
p-Isopropyl toluene	NA	NA	NA	NA	NA	NA	< 1.4	NA	---
Methylene Chloride	<5.3	<5.2	<5.4	<5.0	<5.2	<5.7	<5.2	<5.2	760,000/85,000
Methyl ethyl ketone	<26	<26	<27	<25	<26	<28	<26	<26	120,000,000/4,700,000
n-Propyl benzene	NA	NA	NA	NA	NA	NA	< 1.4	NA	820,000/310,000
Styrene	<5.3	<5.2	<5.4	<5.0	<5.2	<5.7	<5.2	<5.2	41,000,000/1,600,000
Tetrachloroethene	<5.3	<5.2	<5.4	<5.0	<5.2	<5.7	<5.2	10	110,000/12,000
Toluene	12	<5.2	<5.4	<5.0	<5.2	<5.7	<5.2	8.2	41,000,000/1,600,000
1,2,3-Trichlorobenzene	NA	NA	NA	NA	NA	NA	< 2.3	NA	---
Trichloroethene	<5.3	<5.2	<5.4	<5.0	<5.2	<5.7	<5.2	<5.2	520,000/58,000
1,2,4-Trimethylbenzene	NA	NA	NA	NA	NA	NA	< 1.4	NA	10,000,000/390,000
1,3,5-Trimethylbenzene	NA	NA	NA	NA	NA	NA	< 1.5	NA	10,000,000/390,000
Xylenes	<5.3	<5.2	<5.4	<5.0	<5.2	<5.7	<5.2	<5.2	41,000,000/1,400,000
SVOCs (ug/kg)									
Benzo(a)anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000/8,700
Benzo(g,h,i)perylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	---
Benzo(a)pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780/87
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	51 JB	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	59 J	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/160,000
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)									
TPH as Gasoline	<.26	<.26	<.27	<.25	<.26	<.28	<.26	<.26	100 (4)
TPH as Kerosene	<10	<10	<11	<10	<10	<11	<10	NT	100
TPH as Diesel Fuel	<10	<10	<11	<10	<10	<11	<10	NT	100
TPH as Heavy Oils	100	<34	<36	42	<34	<38	<34	NT	100
TPH as Fuel Oil	<34	<34	<36	<33	<34	<38	<34	NT	100
Total Metals (mg/kg)									
Aluminum	2,700 J	280J	250J	NT	NT	NT	NT	NT	100,000/7,800
Arsenic	**1.1**	**1.1**	<1.1	NT	NT	NT	NT	NT	3.8/0.43
Barium	19J	2.3J	2.1J	NT	NT	NT	NT	NT	14,000/550
Cadmium	BDL	BDL	BDL	NT	NT	NT	NT	NT	100/0.39
Calcium	980	<52	<54	NT	NT	NT	NT	NT	-
Chromium	4.3	1.9	3.1	NT	NT	NT	NT	NT	610/23
Cobalt	2.3	<1.0	<1.1	NT	NT	NT	NT	NT	4,100/160
Copper	9.1	<2.6	<2.7	NT	NT	NT	NT	NT	8,200/310
Iron	510	900	870	NT	NT	NT	NT	NT	120,000/4,700
Lead	7.6J	1.3J	1.4J	NT	NT	NT	NT	NT	1,200/400
Magnesium	1400	<52	<54	NT	NT	NT	NT	NT	-
Manganese	120	8.6	6.9	NT	NT	NT	NT	NT	4,100/160
Mercury	BDL	BDL	BDL	NT	NT	NT	NT	NT	-
Nickel	BDL	BDL	BDL	NT	NT	NT	NT	NT	4,100/160
Potassium	1200	<100	<110	NT	NT	NT	NT	NT	-
Silver	BDL	BDL	BDL	NT	NT	NT	NT	NT	1,000/39
Sodium	<53	<52	<54	NT	NT	NT	NT	NT	-
Vanadium	9.2	1.4	<1.3	NT	NT	NT	NT	NT	1,400/55
Zinc	26	3.1	3	NT	NT	NT	NT	NT	61,000/2,300

Notes:
(1) EPA Region III RBCs for Industrial/Residential Soils
(2) BDL - Below detection limit
(3) NT - Not tested
(4) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

NA - Not analyzed. Parameter detected by USACE NED Lab via use of SW-846 Method 8260.
J - Estimated value
K - Reported value may be biased high
L - Reported value may be biased low

Comment #21

TABLE 4-9
SOIL RESULTS - LARC 60 SITE

Parameters	SB06-004			SB06-005		SB06-006			EPA Risk Criteria(1)
	0 to 1 ft	3 to 5 ft	7 to 9 ft	0 to 1 ft	5 to 7 ft	7 to 9 ft	0 to 1 ft	4 to 5 ft	
VOCs (ug/kg)									
Acetone	<25	<26	<27	<25	<26	<27	<26	<30	20,000,000/780,000
sec-Butyl benzene	NA	NA	< 1.4	NA	NA	NA	NA	NA	8,200,000/310,000
Ethylbenzene	<5.0	<5.2	<5.5	<5.0	<5.2	<5.4	<5.2	<6.0	20,000,000/780,000
Isopropyl benzene	NA	NA	< 1.5	NA	NA	NA	NA	NA	---
p-Isopropyl toluene	NA	NA	< 1.4	NA	NA	NA	NA	NA	---
Methylene Chloride	<5.0	<5.2	7 B	<5.0	<5.2	<5.4	<5.2	17	760,000/85,000
Methyl ethyl ketone	<25	<26	<27	<25	<26	<27	<26	31	120,000,000/4,700,000
n-Propyl benzene	NA	NA	< 1.4	NA	NA	NA	NA	NA	820,000/310,000
Styrene	<5.0	<5.2	<5.5	<5.0	<5.2	<5.4	<5.2	<6.0	41,000,000/1,600,000
Tetrachloroethene	<5.0	<5.2	<5.5	<5.0	<5.2	<5.4	<5.2	<6.0	110,000/12,000
Toluene	<5.0	6.1	<5.5	<5.0	<5.2	<5.4	<5.2	<6.0	41,000,000/1,600,000
1,2,3-Trichlorobenzene	NA	NA	2.7 JB	NA	NA	NA	NA	NA	---
Trichloroethene	<5.0	<5.2	<5.5	<5.0	<5.2	<5.4	<5.2	<6.0	520,000/58,000
1,2,4-Trimethylbenzene	NA	NA	< 1.4	NA	NA	NA	NA	NA	10,000,000/390,000
1,3,5-Trimethylbenzene	NA	NA	< 1.5	NA	NA	NA	NA	NA	10,000,000/390,000
Xylenes	<5.0	<5.2	<5.5	<5.0	<5.2	<5.4	<5.2	<6.0	41,000,000/1,400,000
SVOCs (ug/kg)									
Benzo(a)anthracene	BDL	BDL	27 J	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(b)fluoranthene	BDL	BDL	36 J	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	47 J	BDL	BDL	BDL	BDL	BDL	78,000/8,700
Benzo(g,h,i)perylene	BDL	BDL	24 J	BDL	BDL	BDL	BDL	BDL	---
Benzo(a)pyrene	BDL	BDL	35 J	BDL	BDL	BDL	BDL	BDL	780/87
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	33 J	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	55 J	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	4 J	BDL	BDL	BDL	BDL	BDL	4,100,000/160,000
Pyrene	BDL	BDL	50 J	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)									
TPH as Gasoline	<.25	<.26	<.27	<.25	<.26	<.27	<.26	<.30	100 (4)
TPH as Kerosene	<20	<10	<11	<10	<21	<11	<10	<12	100
TPH as Diesel Fuel	<20	<10	<11	<10	<21	<11	<10	<12	100
TPH as Heavy Oils	**260**	**240**	**150**	**220**	**270**	**110**	**290**	<39	100
TPH as Fuel Oil	<67	<34	<36	<33	<69	<36	<34	<39	100
Total Metals (mg/kg)									
Aluminum	NT	NT	NT	310J	NT	310K	NT	NT	100,000/7,800
Arsenic	NT	NT	NT	<1.0	NT	<1.1	NT	NT	3.8/0.43
Barium	NT	NT	NT	3.9J	NT	3.5	NT	NT	14,000/550
Cadmium	NT	NT	NT	BDL	NT	BDL	NT	NT	100/0.39
Calcium	NT	NT	NT	160	NT	94	NT	NT	-
Chromium	NT	NT	NT	2.4	NT	2.3	NT	NT	610/23
Cobalt	NT	NT	NT	<1.0	NT	<1.1	NT	NT	4,100/160
Copper	NT	NT	NT	41	NT	3.2	NT	NT	8,200/310
Iron	NT	NT	NT	1000	NT	670L	NT	NT	120,000/4,700
Lead	NT	NT	NT	11J	NT	5.6	NT	NT	1,200/400
Magnesium	NT	NT	NT	94	NT	74	NT	NT	-
Manganese	NT	NT	NT	12	NT	6	NT	NT	4,100/160
Mercury	NT	NT	NT	BDL	NT	BDL	NT	NT	-
Nickel	NT	NT	NT	BDL	NT	BDL	NT	NT	4,100/160
Potassium	NT	NT	NT	<100	NT	<110	NT	NT	-
Silver	NT	NT	NT	BDL	NT	BDL	NT	NT	1,000/39
Sodium	NT	NT	NT	<51	NT	<54	NT	NT	-
Vanadium	NT	NT	NT	1.6	NT	1.6	NT	NT	1,400/55
Zinc	NT	NT	NT	33	NT	8.6	NT	NT	61,000/2,300

Notes:

(1) EPA Region III Risk-based Concentrations for Industrial Soils

(2) BDL - Below detection limit

(3) NT - Not tested

(4) Virginia DEQ Petroleum Program Reporting Level

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

NA - Not analyzed. Parameter detected by USACE NED Lab via use of SW-846 Method 8260.

J - Estimated value

K - Reported value may be biased high

L - Reported value may be biased low

TABLE 4-9
SOIL RESULTS - LARC 60 SITE

Parameters	SB06-007	SB06-008		SB06-009		SB06-010		EPA Risk
	4 to 5 ft	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	Criteria(1)
VOCs (ug/kg)								
Acetone	<27	<26	<26	36	51	<26	65	20,000,000/780,000
sec-Butyl benzene	2.6 J	NA	NA	NA	NA	NA	NA	8,200,000/310,000
Ethylbenzene	2.3 J	<5.2	<5.2	<5.2	<5.2	<5.2	<5.5	20,000,000/780,000
Isopropyl benzene	1.8 J	NA	NA	NA	NA	NA	NA	---
p-Isopropyl toluene	9.1	NA	NA	NA	NA	NA	NA	---
Methylene Chloride	32	8.9	11	<5.2	<5.2	12	150	760,000/85,000
Methyl ethyl ketone	<27	<26	<26	<26	<26	<26	41	120,000,000/4,700,000
n-Propyl benzene	4.3 J	NA	NA	NA	NA	NA	NA	820,000/310,000
Styrene	1.8 J	<5.2	<5.2	<5.2	<5.2	<5.2	<5.5	41,000,000/1,600,000
Tetrachloroethene	<5.4	<5.2	<5.2	<5.2	<5.2	<5.2	8.8	110,000/12,000
Toluene	<5.4	<5.2	<5.2	<5.2	<5.2	<5.2	6.7	41,000,000/1,600,000
1,2,3-Trichlorobenzene	< 2.6	NA	NA	NA	NA	NA	NA	---
Trichloroethene	<5.4	<5.2	<5.2	<5.2	<5.2	<5.2	8.8	520,000/58,000
1,2,4-Trimethylbenzene	29	NA	NA	NA	NA	NA	NA	10,000,000/390,000
1,3,5-Trimethylbenzene	26	NA	NA	NA	NA	NA	NA	10,000,000/390,000
Xylenes	11	<5.2	<5.2	<5.2	<5.2	<5.2	<5.5	41,000,000/1,400,000
SVOCs (ug/kg)								
Benzo(a)anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000/8,700
Benzo(g,h,i)perylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	---
Benzo(a)pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780/87
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/160,000
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)								
TPH as Gasoline	<.27	<.26	<.26	<.26	<.26	<.26	<.27	100 (4)
TPH as Kerosene	<110	<10	<10	<10	<10	<10	<11	100
TPH as Diesel Fuel	<110	<10	<10	<10	<10	<10	<11	100
TPH as Heavy Oils	**880**	<34	<34	<34	<34	**170**	**110**	100
TPH as Fuel Oil	<360	<34	<34	<34	<34	<34	<36	100
Total Metals (mg/kg)								
Aluminum	NT	NT	NT	NT	NT	440	300	100,000/7,800
Arsenic	NT	NT	NT	NT	NT	<1.0	<1.1	3.8/0.43
Barium	NT	NT	NT	NT	NT	3.7	2.9	14,000/550
Cadmium	NT	NT	NT	NT	NT	BDL	BDL	100/0.39
Calcium	NT	NT	NT	NT	NT	110	300	-
Chromium	NT	NT	NT	NT	NT	2.3	1.8	610/23
Cobalt	NT	NT	NT	NT	NT	<1.0	<1.1	4,100/160
Copper	NT	NT	NT	NT	NT	<2.6	<2.7	8,200/310
Iron	NT	NT	NT	NT	NT	1100L	770L	120,000/4,700
Lead	NT	NT	NT	NT	NT	6.4L	4.7L	1,200/400
Magnesium	NT	NT	NT	NT	NT	110	59	-
Manganese	NT	NT	NT	NT	NT	7.2	13	4,100/160
Mercury	NT	NT	NT	NT	NT	BDL	BDL	-
Nickel	NT	NT	NT	NT	NT	BDL	BDL	4,100/160
Potassium	NT	NT	NT	NT	NT	<100	<110	-
Silver	NT	NT	NT	NT	NT	BDL	BDL	1,000/39
Sodium	NT	NT	NT	NT	NT	<52	<55	-
Vanadium	NT	NT	NT	NT	NT	1.9	1.7	1,400/55
Zinc	NT	NT	NT	NT	NT	6.4	5.2	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentrations for Industrial Soils
(2) BDL - Below detection limit
(3) NT - Not tested
(4) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

NA - Not analyzed. Parameter detected by USACE NED Lab via use of SW-846 Method 8260.
J - Estimated value
K - Reported value may be biased high
L - Reported value may be biased low

TABLE 4-9
SOIL RESULTS - LARC 60 SITE

Parameters	SB06-011		SB06-012		SB06-013		SB06-014		EPA Risk Criteria(1)
	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	
VOCs (ug/kg)									
Acetone	<25	<27	<34	<27	<25	<27	<25	<26	20,000,000/780,000
sec-Butyl benzene	NA	NA	NA	NA	NA	NA	NA	NA	8,200,000/310,000
Ethylbenzene	<5.0	<5.5	<6.8	<5.5	<5.0	<5.5	<5.0	<5.2	20,000,000/780,000
Isopropyl benzene	NA	NA	NA	NA	NA	NA	NA	NA	---
p-Isopropyl toluene	NA	NA	NA	NA	NA	NA	NA	NA	---
Methylene Chloride	<5.0	220	<6.8	91	<5.0	19	<5.0	5.4	760,000/85,000
Methyl ethyl ketone	<25	36	<34	44	<25	<27	<25	<26	120,000,000/4,700,000
n-Propyl benzene	NA	NA	NA	NA	NA	NA	NA	NA	820,000/310,000
Styrene	<5.0	9.2	<6.8	7.3	<5.0	<5.5	<5.0	<5.2	41,000,000/1,600,000
Tetrachloroethene	<5.0	<5.5	<6.8	<5.5	<5.0	<5.5	<5.0	<5.2	110,000/12,000
Toluene	<5.0	13	<6.8	11	<5.0	<5.5	<5.0	<5.2	41,000,000/1,600,000
1,2,3-Trichlorobenzene	NA	NA	NA	NA	NA	NA	NA	NA	---
Trichloroethene	<5.0	16	<6.8	9.3	<5.0	<5.5	<5.0	<5.2	520,000/58,000
1,2,4-Trimethylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	10,000,000/390,000
1,3,5-Trimethylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	10,000,000/390,000
Xylenes	<5.0	<5.5	<6.8	<5.5	<5.0	<5.5	<5.0	<5.2	41,000,000/1,400,000
SVOCs (ug/kg)									
Benzo(a)anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000/8,700
Benzo(g,h,i)perylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	---
Benzo(a)pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780/87
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/160,000
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)									
TPH as Gasoline	<.25	<.27	<.34	<.27	<.25	<.27	<.25	<.26	100 (4)
TPH as Kerosene	<10	<110	<14	<55	<10	<110	<20	<52	100
TPH as Diesel Fuel	<10	<110	<14	<55	<10	<110	<20	<52	100
TPH as Heavy Oils	**170**	**1,200**	**160**	**550**	**290**	**1,400**	**310**	**680**	100
TPH as Fuel Oil	<33	<360	<44	<180	<33	<360	<66	<170	100
Total Metals (mg/kg)									
Aluminum	NT	NT	NT	NT	NT	NT	NT	NT	100,000/7,800
Arsenic	NT	NT	NT	NT	NT	NT	NT	NT	3.8/0.43
Barium	NT	NT	NT	NT	NT	NT	NT	NT	14,000/550
Cadmium	NT	NT	NT	NT	NT	NT	NT	NT	100/0.39
Calcium	NT	NT	NT	NT	NT	NT	NT	NT	-
Chromium	NT	NT	NT	NT	NT	NT	NT	NT	610/23
Cobalt	NT	NT	NT	NT	NT	NT	NT	NT	4,100/160
Copper	NT	NT	NT	NT	NT	NT	NT	NT	8,200/310
Iron	NT	NT	NT	NT	NT	NT	NT	NT	120,000/4,700
Lead	NT	NT	NT	NT	NT	NT	NT	NT	1,200/400
Magnesium	NT	NT	NT	NT	NT	NT	NT	NT	-
Manganese	NT	NT	NT	NT	NT	NT	NT	NT	4,100/160
Mercury	NT	NT	NT	NT	NT	NT	NT	NT	-
Nickel	NT	NT	NT	NT	NT	NT	NT	NT	4,100/160
Potassium	NT	NT	NT	NT	NT	NT	NT	NT	-
Silver	NT	NT	NT	NT	NT	NT	NT	NT	1,000/39
Sodium	NT	NT	NT	NT	NT	NT	NT	NT	-
Vanadium	NT	NT	NT	NT	NT	NT	NT	NT	1,400/55
Zinc	NT	NT	NT	NT	NT	NT	NT	NT	61,000/2,300

Notes:

(1) EPA Region III Risk-based Concentrations for Industrial Soils

(2) BDL - Below detection limit

(3) NT - Not tested

(4) Virginia DEQ Petroleum Program Reporting Level

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

NA - Not analyzed. Parameter detected by USACE NED Lab via use of SW-846 Method 8260.

J - Estimated value

K - Reported value may be biased high

L - Reported value may be biased low

TABLE 4-9
SOIL RESULTS - LARC 60 SITE

Parameters	SB06-015		SB06-016		SB06-017		SB06-018		EPA Risk
	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	0 to 1 ft	4 to 5 ft	Criteria(1)
VOCs (ug/kg)									
Acetone	<25	<26	<25	<29	<25	<26	<25	<26	20,000,000/780,000
sec-Butyl benzene	NA	NA	NA	NA	NA	NA	NA	NA	8,200,000/310,000
Ethylbenzene	<5.0	<5.2	<5.0	<5.9	<5.0	<5.2	<5.0	<5.2	20,000,000/780,000
Isopropyl benzene	NA	NA	NA	NA	NA	NA	NA	NA	---
p-Isopropyl toluene	NA	NA	NA	NA	NA	NA	NA	NA	---
Methylene Chloride	<5.0	<5.2	<5.0	11	5.5	<5.2	5.2	<5.2	760,000/85,000
Methyl ethyl ketone	<25	<26	<25	<29	<25	<26	<25	<26	120,000,000/4,700,000
n-Propyl benzene	NA	NA	NA	NA	NA	NA	NA	NA	820,000/310,000
Styrene	<5.0	<5.2	<5.0	<5.9	<5.0	<5.2	<5.0	<5.2	41,000,000/1,600,000
Tetrachloroethene	<5.0	<5.2	<5.0	<5.9	<5.0	<5.2	<5.0	<5.2	110,000/12,000
Toluene	<5.0	<5.2	<5.0	<5.9	5.1	<5.2	7.1	<5.2	41,000,000/1,600,000
1,2,3-Trichlorobenzene	NA	NA	NA	NA	NA	NA	NA	NA	---
Trichloroethene	<5.0	<5.2	<5.0	<5.9	<5.0	<5.2	<5.0	<5.2	520,000/58,000
1,2,4-Trimethylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	10,000,000/390,000
1,3,5-Trimethylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	10,000,000/390,000
Xylenes	<5.0	<5.2	<5.0	<5.9	<5.0	<5.2	<5.0	<5.2	41,000,000/1,400,000
SVOCs (ug/kg)									
Benzo(a)anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000/8,700
Benzo(g,h,i)perylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	---
Benzo(a)pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780/87
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/160,000
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)									
TPH as Gasoline	<.25	<.26	<.25	<.29	<.25	<.26	<.25	<.26	100 (4)
TPH as Kerosene	<10	<52	<10	<59	<10	<10	<50	<10	100
TPH as Diesel Fuel	<10	<52	<10	<59	<10	<10	<50	<10	100
TPH as Heavy Oils	77	**520**	**190**	**240**	**250**	<34	**800**	<34	100
TPH as Fuel Oil	<33	<170	<33	<190	<33	<34	<10	<34	100
Total Metals (mg/kg)									
Aluminum	250K	360K	NT	NT	NT	NT	NT	NT	100,000/7,800
Arsenic	<1	<1	NT	NT	NT	NT	NT	NT	3.8/0.43
Barium	1.8	5.3	NT	NT	NT	NT	NT	NT	14,000/550
Cadmium	BDL	BDL	NT	NT	NT	NT	NT	NT	100/0.39
Calcium	<51	66	NT	NT	NT	NT	NT	NT	-
Chromium	1.7	3.6	NT	NT	NT	NT	NT	NT	610/23
Cobalt	<1	<1	NT	NT	NT	NT	NT	NT	4,100/160
Copper	2.5	6.9	NT	NT	NT	NT	NT	NT	8,200/310
Iron	400L	780	NT	NT	NT	NT	NT	NT	120,000/4,700
Lead	3.1	17L	NT	NT	NT	NT	NT	NT	1,200/400
Magnesium	<51	79J	NT	NT	NT	NT	NT	NT	-
Manganese	2.4	4.6	NT	NT	NT	NT	NT	NT	4,100/160
Mercury	BDL	BDL	NT	NT	NT	NT	NT	NT	-
Nickel	BDL	BDL	NT	NT	NT	NT	NT	NT	4,100/160
Potassium	<100	<100	NT	NT	NT	NT	NT	NT	-
Silver	BDL	BDL	NT	NT	NT	NT	NT	NT	1,000/39
Sodium	<51	<52	NT	NT	NT	NT	NT	NT	-
Vanadium	1.2	1.5	NT	NT	NT	NT	NT	NT	1,400/55
Zinc	3.8	17	NT	NT	NT	NT	NT	NT	61,000/2,300

Notes:

(1) EPA Region III Risk-based Concentrations for Industrial Soils

(2) BDL - Below detection limit

(3) NT - Not tested

(4) Virginia DEQ Petroleum Program Reporting Level

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

NA - Not analyzed. Parameter detected by USACE NED Lab via use of SW-846 Method 8260.

J - Estimated value

K - Reported value may be biased high

L - Reported value may be biased low

TABLE 4-9
SOIL RESULTS - LARC 60 SITE

Parameters	SB06-019		SB06-020		SB06-021		SB06-022		SB06-023		EPA Risk Criteria(1)
	0-1 ft	4-5 ft	0-1 ft	4-5 ft	0-1 ft	3-4 ft	0-1 ft	4-5 ft	0-1 ft	2-3 ft	
VOCs (ug/kg)											
Acetone	<25	<26	<25	<26	<26	<29	<28	<29	<27	<29	20,000,000/780,000
sec-Butyl benzene	NA	NA	NA	< 1.4	NA	NA	NA	NA	NA	NA	8,200,000/310,000
Ethylbenzene	<5.0	<5.3	<5.0	<5.3	<5.2	<5.8	<5.6	<5.9	<5.4	<5.8	20,000,000/780,000
Isopropyl benzene	NA	NA	NA	< 1.5	NA	NA	NA	NA	NA	NA	---
p-Isopropyl toluene	NA	NA	NA	< 1.4	NA	NA	NA	NA	NA	NA	---
Methylene Chloride	<5.0	<5.3	<5.0	43	34	70	160	<5.9	62	<5.8	760,000/85,000
Methyl ethyl ketone	<25	<26	<25	<26	<26	36	<28	<29	<27	<29	120,000,000/4,700,000
n-Propyl benzene	NA	NA	NA	< 1.4	NA	NA	NA	NA	NA	NA	820,000/310,000
Styrene	<5.0	<5.3	<5.0	<5.3	<5.2	<5.8	<5.6	<5.9	<5.4	<5.8	41,000,000/1,600,000
Tetrachloroethene	<5.0	<5.3	<5.0	71	<5.2	<5.8	<5.6	<5.9	<5.4	<5.8	110,000/12,000
Toluene	<5.0	<5.3	<5.0	<5.3	<5.2	<5.8	<5.6	<5.9	<5.4	<5.8	41,000,000/1,600,000
1,2,3-Trichlorobenzene	NA	NA	NA	< 2.4	NA	NA	NA	NA	NA	NA	---
Trichloroethene	<5.0	<5.3	<5.0	<5.3	<5.2	<5.8	6.4	<5.9	5.9	<5.8	520,000/58,000
1,2,4-Trimethylbenzene	NA	NA	NA	< 1.4	NA	NA	NA	NA	NA	NA	10,000,000/390,000
1,3,5-Trimethylbenzene	NA	NA	NA	< 1.5	NA	NA	NA	NA	NA	NA	10,000,000/390,000
Xylenes	<5.0	<5.3	<5.0	<5.3	<5.2	<5.8	<5.6	<5.9	<5.4	<5.8	41,000,000/1,400,000
SVOCs (ug/kg)											
Benzo(a)anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(b)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7,800/870
Benzo(k)fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	78,000/8,700
Benzo(g,h,i)perylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	---
Benzo(a)pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780/87
Bis(2-EH)phthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	410,000/46,000
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	780,000/87,000
Di-n-butylphthalate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20,000,000/780,000
Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8,200,000/310,000
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4,100,000/160,000
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6,100,000/230,000
TPH (mg/kg)											
TPH as Gasoline	<.25	<.26	<.25	<.26	<.26	<.29	<.28	<.29	<.27	<.29	100 (4)
TPH as Kerosene	<50	<10	<100	<11	<21	<12	<22	<12	<22	<12	100
TPH as Diesel Fuel	<50	<10	<100	<11	<21	<12	<22	<12	<22	<12	100
TPH as Heavy Oils	**660**	<35	**1,500**	<35	**500**	<38	**140**	<39	**250**	<38	100
TPH as Fuel Oil	<170	<35	<330	<35	<69	<98	<74	<39	<71	<38	100
Total Metals (mg/kg)											
Aluminum	NT	NT	370K	380	NT	NT	NT	NT	NT	NT	100,000/7,800
Arsenic	NT	NT	<1	**0.86**	NT	NT	NT	NT	NT	NT	3.8/0.43
Barium	NT	NT	5.9	2.5	NT	NT	NT	NT	NT	NT	14,000/550
Cadmium	NT	NT	BDL	0.18 J	NT	NT	NT	NT	NT	NT	100/0.39
Calcium	NT	NT	56	43	NT	NT	NT	NT	NT	NT	-
Chromium	NT	NT	3.2	1.5	NT	NT	NT	NT	NT	NT	610/23
Cobalt	NT	NT	<1	0.79	NT	NT	NT	NT	NT	NT	4,100/160
Copper	NT	NT	12	5.5	NT	NT	NT	NT	NT	NT	8,200/310
Iron	NT	NT	840L	770	NT	NT	NT	NT	NT	NT	120,000/4,700
Lead	NT	NT	12	3.2L	NT	NT	NT	NT	NT	NT	1,200/400
Magnesium	NT	NT	77	56	NT	NT	NT	NT	NT	NT	-
Manganese	NT	NT	5.6	4.2	NT	NT	NT	NT	NT	NT	4,100/160
Mercury	NT	NT	BDL	4.6	NT	NT	NT	NT	NT	NT	-
Nickel	NT	NT	BDL	0.81	NT	NT	NT	NT	NT	NT	4,100/160
Potassium	NT	NT	<100	37 J	NT	NT	NT	NT	NT	NT	-
Silver	NT	NT	BDL	0.51 J	NT	NT	NT	NT	NT	NT	1,000/39
Sodium	NT	NT	<50	11	NT	NT	NT	NT	NT	NT	-
Vanadium	NT	NT	1.8	1.7	NT	NT	NT	NT	NT	NT	1,400/55
Zinc	NT	NT	12	7.9	NT	NT	NT	NT	NT	NT	61,000/2,300

Notes:

(1) EPA Region III Risk-based Concentrations for Industrial Soils

(2) BDL - Below detection limit

(3) NT - Not tested

(4) Virginia DEQ Petroleum Program Reporting Level

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening c

NA - Not analyzed. Parameter detected by USACE NED Lab via use of SW-846 Method 8260.

J - Estimated value

K - Reported value may be biased high

L - Reported value may be biased low

TABLE 4-9

SOIL RESULTS (2000 Sampling) - LARC 60 SITE

Parameters	SS1 0 to 6 in.	SS2 0 to 6 in.	SS3 0 to 6 in.	SS4 0 to 6 in.	SS5 0 to 6 in.	SS6 0 to 6 in.	SS7 0 to 6 in.	SS8 0 to 6 in.	EPA RBC Criteria(1)
PCBs (ug/kg)									
Aroclor-1016	< 34	< 33	< 33	< 34	< 34	< 35	< 33	< 34	82,000/5,500
Aroclor-1221	< 68	< 66	< 67	< 69	< 69	< 71	< 67	< 69	2,900/320
Aroclor-1232	< 34	< 33	< 33	< 34	< 34	< 35	< 33	< 34	2,900/320
Aroclor-1242	< 34	< 33	< 33	< 34	< 34	< 35	< 33	< 34	2,900/320
Aroclor-1248	< 34	< 33	< 33	< 34	< 34	< 35	< 33	< 34	2,900/320
Aroclor-1254	< 34	< 33	< 33	< 34	< 34	< 35	< 33	< 34	2,900/320
Aroclor-1260	< 34	< 33	< 33	< 34	< 34	< 35	< 33	< 34	2,900/320
Pesticides (ug/kg)									
Aldrin	< 1.7	< 1.7	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	340/38
alpha-BHC	< 1.7	< 1.7	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	910/100
beta-BHC	< 1.7	1.6 JP	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	3,200/350
delta-BHC	< 1.7	< 1.7	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	-
gamma-BHC (Lindane)	< 1.7	< 1.7	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	4,400/490
alpha-Chlordane	< 1.7	< 1.7	0.51 JP	< 1.7	< 1.8	< 9	< 1.7	< 1.7	16,000/1,800
gamma-Chlordane	< 1.7	< 1.7	0.63 J	< 1.7	< 1.8	< 9	0.49 J	< 1.7	16,000/1,800
DDD	< 3.3	< 3.3	1.6 J	1.2 J	< 3.6	4.3 J	2.1 J	< 3.3	24,000/2,700
DDE	< 3.3	< 3.3	0.30 J	< 3.3	1.7 J	13 J	1.0 J	< 3.3	17,000/1,900
DDT	< 3.3	0.55 J	1.8 J	1.3 J	7.1	39	5.2 P	1.6 J	17,000/1,900
Dieldrin	< 3.3	< 3.3	< 3.3	< 3.3	< 3.6	< 18	0.47 JP	< 3.3	360/40
Endosulfan I	< 1.7	< 1.7	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	1,200,000/47,000
Endosulfan II	< 3.3	< 3.3	< 3.3	< 3.3	< 3.6	< 18	< 3.3	< 3.3	1,200,000/47,000
Endosulfan sulfate	< 3.3	< 3.3	< 3.3	< 3.3	< 3.6	< 18	< 3.3	< 3.3	-
Endrin	< 3.3	< 3.3	< 3.3	< 3.3	< 3.6	< 18	< 3.3	< 3.3	61,000/2,300
Endrin aldehyde	< 3.3	< 3.3	< 3.3	< 3.3	< 3.6	< 18	< 3.3	< 3.3	-
Endrin ketone	< 3.3	< 3.3	< 3.3	< 3.3	< 3.6	< 18	< 3.3	< 3.3	-
Heptachlor	< 1.7	< 1.7	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	1,300/140
Heptachlor epoxide	< 1.7	< 1.7	< 1.7	< 1.7	< 1.8	< 9	< 1.7	< 1.7	630/70
Methoxyclor	< 17	< 17	< 17	< 17	< 18	< 90	< 17	< 17	1,000,000/39,000
Toxaphene	< 170	< 170	< 170	< 170	< 180	< 900	< 170	< 170	5,200/580

Notes:

(1) EPA Region III RBCs for Industrial/Residential Soils (Sept 2001)

Shaded/bolded text identifies compounds with concentrations greater than EPA risk screening criteria

J - Estimated concentration

P - Greater than 25% difference for detected levels in two GC columns

TABLE 4-10
SEDIMENT RESULTS
LARC 60 MAINTENANCE AREA

Parameters	Sample ID and Results		EPA RBC Criteria(1)
	SD06-001	SD06-002	
VOCs (ug/kg)	BDL(2)	BDL	
SVOCs (ug/kg)	BDL	BDL	
TPH (mg/kg)			
TPH as Gasoline	< 0.32	< 0.32	100(3)
TPH-H as Heavy Oils	**2,700**	**530**	100
Total Metals (mg/kg)			
Aluminum	310 J	650 J	100,000 / 7,800
Barium	1.4 J	2.7 J	14,000 / 550
Calcium	53	210	-
Chromium	1.6	2.5	610 / 23
Copper	3.8	9.0	8,200 / 310
Iron	410	940	120,000 / 4,700
Lead	8.2 J	14 J	1,200 / 400
Magnesium	110	250	-
Manganese	3.4	6.9	4,100 / 160
Sodium	< 64	70	-
Vanadium	1.3	2.7	1,400 / 55
Zinc	11	30	61,000 / 2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) BDL - Below detection limit
(3) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria
J - Estimated value

TAB. 4-12

MONITORING WELL GROUNDWATER RESULTS

LARC 60 MAINTENANCE AREA

Parameters	Well ID and Results								EPA RBC Criteria(1)
	6MW-1	6MW-2	6MW-3S	6MW-3D	6MW-4	MW-115	MW-117	MW-118	
VOCs (ug/l)									
cis 1,2-DCE	<5 / <5	<5	<5 / 2 J	<5	<5 / <5	<5 / <5	**20 / 1,900**	<5 / <5	6.1
Ethylbenzene	<5 / <5	<5	<5 / <5	<5	<5 / <5	<5 / <5	66 / 76	<5 / <5	130
MIBK	**<5 / 50**	<5	**<5 / 44**	<5	**<5 / 19**	<5 / <5	<5 / <250	<5 / <5	14
Tetrachloroethene	<5 / <5	<5	<5 / <5	<5	<5 / <5	<5 / <5	**8.5 / <50**	<5 / <5	1.1
Toluene	<5 / <5	<5	<5 / <5	<5	<5 / <5	<5 / <5	**68 / 310**	<5 / <5	75
Trichloroethene	<5 / <5	<5	<5 / 1.3 J	<5	<5 / <5	<5 / <5	**18 / <50**	<5 / <5	1.6
Vinyl chloride	<10 / <10	<10	**<10 / 3.1 J**	<10	<10 / <10	<10 / <10	**<10 / 8.6 J**	<10 / <10	0.015
Xylenes	<5 / <10	<5	<5 / <10	<5	<5 / <10	<5 / <10	290 / 450	<5 / <10	1,200
SVOCs (ug/l)									
2-Methylnaphthalene	<10	<10	**20**	<10	<10	<10	<10	<10	12
Naphthalene	<10	<10	<10	<10	<10	<10	**32**	<10	0.65
Pest/PCBs	BDL	NT (3)	BDL	NT	BDL	BDL	BDL	BDL	
TPH (mg/l)									
TPH as Gasoline	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**3.0**	<0.05	1.0(2)
TPH as Diesel Fuel	<0.30	<0.30	**2.7**	<0.30	<0.30	<0.30	**3.3**	<0.30	1.0(2)
TPH as Heavy Oils	<1.0	<1.0	<5.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0(2)
TPH as Fuel Oil	<1.0	<1.0	<5.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0(2)
TPH as Kerosene	<0.30	<0.30	<1.5	<0.30	<0.30	<0.30	<0.30	<0.30	1.0(2)
Miscellaneous (mg/l)									
TSS	NT / < 5	NT	NT / < 5	NT	NT / < 5	NT / < 5	NT / 6.0	NT / < 5	-
TDS	NT / 74	NT	NT / 130	NT	NT / 280	NT / 110	NT / 65	NT / 160	-

TAB. 4-12

MONITORING WELL GROUNDWATER RESULTS

LARC 60 MAINTENANCE AREA

Parameters	Well ID and Results								EPA RBC Criteria(1)
	6MW-1	6MW-2	6MW-3S	6MW-3D	6MW-4	MW-115	MW-117	MW-118	
Total Metals (ug/l)									
Aluminum	NT / < 6	590 K	3,700 K / < 6	NT	NT / 260	NT / < 6	1,100 K / 210	3,700 K / < 6	3,700
Antimony	NT / < 2.7	< 50	< 50 / < 2.7	NT	NT / < 2.7	NT / < 2.7	< 50 / < 2.7	< 50 / < 2.7	1.5
Arsenic	NT / < 3	< 10	**14 / < 3**	NT	NT / < 3	NT / < 3	**91 / 21**	< 10 / < 3	0.045
Barium	NT / 5.5 B	14	120 / 22	NT	NT / 17	NT / 16	28 / 19	35 / 5.3 B	260
Beryllium	NT / < 0.10	< 5	< 5 / < 0.10	NT	NT / < 0.10	NT / < 0.10	< 5 / < 0.10	< 5 / < 0.10	7.3
Cadmium	NT / < 0.50	< 5	< 5 / < 0.50	NT	NT / < 0.50	NT / < 0.50	< 5 / < 0.50	< 5 / < 0.50	1.8
Calcium	NT / 6,700	6,400	39,000 / 17,000	NT	NT / 13,000	NT / 18,000	18,000 / 20,000	15,000 / 9,100	-
Chromium	NT / < 0.70	< 10	< 10 / 1.1 B	NT	NT / 2.4 B	NT / < 0.70	< 10 / 2.9 B	< 10 / < 0.70	110
Cobalt	NT / < 0.90	< 10	< 10 / < 0.90	NT	NT / < 0.90	NT / < 0.90	< 10 / < 0.90	< 10 / < 0.90	73
Copper	NT / 1.4 B	< 25	< 25 / 2.1 B	NT	NT / 2.9 B	NT / 14 B	< 25 / 3.4 B	< 25 / 2.4 B	140
Iron	NT / **4,600**	**12,000**	**16,000 / 2,700**	NT	NT / 1,300	NT / **6,900**	**14,000 / 17,000**	**3,500** / 270	2,200
Lead	NT / 2.8 B	< 5	8.9 / < 2.4	NT	NT / 2.6 B	NT / 4.7 B	< 5 / 4.1 B	6.7 / < 2.4	15 (4)
Magnesium	NT / 2,700	4,200	5,900 / 2,100	NT	NT / 9,100	NT / 1,500	5,200 / 3,100	6,400 / 2,800	-
Manganese	NT / 44	**100**	**640 / 140**	NT	NT / 76	NT / **290**	**95 / 110**	25 / 4.2 B	73
Mercury	NT / < 0.10	< 0.20	< 0.20 / < 0.10	NT	NT / < 0.10	NT / < 0.10	< 0.20 / < 0.10	< 0.20 / < 0.10	-
Nickel	NT / < 1.1	< 40	< 40 / < 1.1	NT	NT / < 1.1	NT / < 1.1	< 40 / < 1.1	< 40 / < 1.1	73
Potassium	NT / 2,400	1,800	12,000 / 3,700	NT	NT / 4,400	NT / 5,000	4,300 / 6,400	6,600 / 3,600	-
Selenium	NT / < 3.4	< 10	< 10 / < 3.4	NT	NT / < 3.4	NT / < 3.4	< 10 / < 3.4	< 10 / < 3.4	18
Silver	NT / < 0.50	< 10	< 10 / < 0.50	NT	NT / < 0.50	NT / < 0.50	< 10 / < 0.50	< 10 / < 0.50	18
Sodium	NT / 8,000	25,000	30,000 / 16,000	NT	NT / 69,000	NT / 9,300	8,100 / 8,500	9,300 / 5,300	270,000
Thallium	NT / < 4.3	< 10	< 10 / < 4.3	NT	NT / < 4.3	NT / < 4.3	< 10 / < 4.3	< 10 / < 4.3	0.26
Vanadium	NT / < 0.70	< 10	11 / 1.9 B	NT	NT / 9.5 B	NT / 1.5 B	< 10 / 5.2 B	< 10 / < 0.70	26
Zinc	NT / 3.3 B	33	42 / 4.9 B	NT	NT / 5.4 B	NT / 29	22 / 5.3 B	24 / 3.6 B	1,100

TAE 4-12

MONITORING WELL GROUNDWATER RESULTS
LARC 60 MAINTENANCE AREA

Parameters	Well ID and Results								EPA RBC Criteria(1)
	6MW-1	6MW-2	6MW-3S	6MW-3D	6MW-4	MW-115	MW-117	MW-118	
Dissolved Metals (mg/l)									
Aluminum	NT / < 6	< 200	< 200 / 14 BE	NT	NT / 300 E	NT / < 6	< 200 / 79 BE	< 200 / < 6	3,700
Antimony	NT / < 2.7	< 50	< 50 / ***5.4 B***	NT	NT / ***2.8 B***	NT / < 2.7	< 50 / < 2.7	< 50 / < 2.7	1.5
Arsenic	NT / < 3	< 10	< 10 / < 3	NT	NT / < 3	NT / < 3	***40 / 14***	< 10 / < 3	0.045
Barium	NT / 5.3 B	12	70 / 21	NT	NT / 17	NT / 16	21 / 17	40 / 5 B	260
Beryllium	NT / < 0.10	< 5	< 5 / < 0.10	NT	NT / < 0.10	NT / < 0.10	< 5 < 0.10	< 5 / < 0.10	7.3
Cadmium	NT / < 0.50	< 5	< 5 / < 0.50	NT	NT / < 0.50	NT / < 0.50	< 5 / < 0.50	< 5 / < 0.50	1.8
Calcium	NT / 6,300	6,300	36,000 / 16,000	NT	NT / 12,000	NT / 17,000	18,000 / 18,000	17,000 / 8,400	-
Chromium	NT / 0.75 B	< 10	< 10 / 1.1 B	NT	NT / 2.6 B	NT / 1.2 B	< 10 / 2.7 B	< 10 / < 0.70	110
Cobalt	NT / < 0.90	< 10	< 10 / < 0.90	NT	NT / < 0.90	NT / < 0.90	< 10 / < 0.90	< 10 / < 0.90	73
Copper	NT / < 0.90	< 25	< 25 / < 0.90	NT	NT / 30	NT / < 0.90	< 25 / < 0.90	< 25 / < 0.90	140
Iron	NT / ***3,700***	***9,000***	***6,900 / 2,500***	NT	NT / 1,200	NT / ***3,600***	***5,800 / 15,000***	< 50 / 70	2,200
Lead	NT / 3.8 B	< 10	< 10 / 4.7 B	NT	NT / 4.5 B	NT / < 2.4	< 10 / 4.1 B	< 10 / 3.2 B	15 (4)
Magnesium	NT / 2,500	4,000	5,100 / 2,000	NT	NT / 8,700	NT / 1,400	4,900 / 2,800	6,300 / 2,600	-
Manganese	NT / 38	***95***	***530 / 130***	NT	NT / 72	NT / ***270***	***84 / 96***	< 10 / 3.8 B	73
Mercury	NT / < 0.10	< 0.20	< 0.20 / < 0.10	NT	NT / < 0.10	NT / < 0.10	< 0.20 / < 0.10	< 0.20 / < 0.10	-
Nickel	NT / < 1.1	< 40	< 40 / < 1.1	NT	NT / < 1.1	NT / < 1.1	< 40 / < 1.1	< 40 / < 1.1	73
Potassium	NT / 2,400	1,700	11,000 / 3,700	NT	NT / 4,500	NT / 5,000	3,800 / 6,200	6,400 / 3,500	-
Selenium	NT / < 3.4	< 10	< 10 / < 3.4	NT	NT / < 3.4	NT / < 3.4	< 10 / < 3.4	< 10 / < 3.4	18
Silver	NT < 0.50	< 10	< 10 / < 0.50	NT	NT / < 0.50	NT / < 0.50	< 10 / < 0.50	< 10 / < 0.50	18
Sodium	NT / 7,300	24,000	33,000 / 15,000	NT	NT / 66,000	NT / 8,800	10,000 / 7,800	9,800 / 4,800	270,000
Thallium	NT / < 4.3	< 10	< 10 / < 4.3	NT	NT / < 4.3	NT / < 4.3	< 10 / < 4.3	< 10 / < 4.3	0.26
Vanadium	NT / < 0.70	< 10	< 10 / 2.1 B	NT	NT / 9.6 B	NT / 1.1 B	< 10 / 4.3 B	< 10 / < 0.70	26
Zinc	NT / 3.4 B	< 20	< 20 / 4 B	NT	NT / 20 B	NT / 4.5 B	< 20 / 46	26 / 4.3 B	1,100

Notes:

(1) EPA Region III Risk-based Concentration Criteria for Tap Water

(2) Virginia Groundwater Standard for Petroleum Hydrocarbons

(3) NT - Not tested

(4) USEPA Action Level for Lead in Drinking Water

K - Reported value may be biased high

J - Estimated concentration (result between MDL and PQL for organics)

B - Estimated concentration (result between MDL and PQL for inorganics)

E - Reported value is estimated because interference detected

Organics detected are bolded and italicized.

Concentrations above EPA Region III RBCs for tap water are bolded and shaded.

TABLE 4-13
DPT GROUNDWATER RESULTS
LARC 60 MAINTENANCE AREA

Parameters	Sample ID and Results									EPA RBC Criteria(1)
	GW06-001	GW06-002	GW06-003	GW06-004	GW06-005	GW06-006	GW06-007	GW06-008	GW06-009	
VOCs (ug/l)										
Acetone	<25	<25	<25	<25	<25	<25	<25	<25	30	61
Benzene	<5 / <5(2)	<50 / <25	<5 / <5	<5	<5 / <5	<5 / <10	<5 / <5	<5 / <5	<5 / <10	0.32
cis 1,2-DCE	<5 / <5	**<50 / 150**	**20 / 13**	<5	<5 / <5	<5 / <10	<5 / <5	<5 / <5	<5 / <10	6.1
Ethylbenzene	<5	**530**	<5	<5	<5	<5	<5	<5	<5	130
Tetrachloroethene	<5 / <5	<50 / <25	**170 / 160**	<5	<5 / <5	<5 / <10	<5 / <5	<5 / <5	<5 / <10	1.1
Toluene	<5	**2,200 D**	<5	<5	<5	<5	<5	<5	6.4	75
Trichloroethene	<5 / <5	**<50 / 47**	**260 D / 180**	<5	<5 / <5	<5 / <10	<5 / <5	<5 / <5	<5 / <10	1.6
Vinyl acetate	<10	**220 J**	<10	<10	<10	<10	<10	<10	<10	41
Vinyl chloride	<10 / <5	<100 / <25	<10 / <5	<10	<10 / <10	<10 / 60R	<10 / <5	<10 / 21R	<10 / 85R	0.015
Xylenes	<5	**2,900**	<5	<5	<5	<5	<5	<5	<5	1,200
SVOCs (ug/l)										
m&p-cresol	<10	12	<10	<10	<10	<10	<10	<10	<10	-
2-Methylnaphthalene	<10	**57**	<10	<10	<10	<10	<10	12	<10	12
Naphthalene	<10	**81**	<10	<10	<10	<10	<10	<10	<10	0.65
TPH (mg/l)										
TPH as Gasoline	<0.05 / <0.5	**12 / 8**	<0.05 / <0.5	<0.05	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	<0.05 / <0.5	0.18 / <0.5	1.0(3)
TPH as Diesel Fuel	<0.30	**21**	<0.30	<0.30	<0.30	<3.0	<0.30	<0.30	<3.0	1.0(3)
TPH as Heavy Oils	<1.0	<20	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<10	1.0(3)
TPH as Fuel Oil	<1.0	<20	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	1.0(3)
TPH as Kerosene	<0.30	<6.0	<0.30	<0.30	<0.30	<3.0	<0.30	<0.30	<3.0	1.0(3)
Total Metals (ug/l)										
Aluminum	NT(4)	NT	NT	860	NT	NT	**7,300**	NT	**9,900**	3,700
Arsenic	NT	NT	NT	< 10	NT	NT	**20**	NT	**54**	0.045
Barium	NT	NT	NT	14	NT	NT	74	NT	**330**	260
Cadmium	NT	NT	NT	< 5	NT	NT	< 5	NT	**6.8**	1.8
Calcium	NT	NT	NT	6,400	NT	NT	10,000	NT	70,000	-
Chromium	NT	NT	NT	19	NT	NT	**200**	NT	100	110
Cobalt	NT	NT	NT	< 10	NT	NT	< 10	NT	30	73
Copper	NT	NT	NT	< 25	NT	NT	63	NT	**250**	140
Iron	NT	NT	NT	**3,600 L**	NT	NT	**19,000 L**	NT	**52,000**	2,200
Lead	NT	NT	NT	< 5	NT	NT	**54**	NT	**460**	15 (5)
Magnesium	NT	NT	NT	1,300	NT	NT	3,400	NT	19,000	-
Manganese	NT	NT	NT	63	NT	NT	**160**	NT	**1,700**	73
Nickel	NT	NT	NT	< 40	NT	NT	< 40	NT	52	73
Potassium	NT	NT	NT	1,500	NT	NT	3,000	NT	9,800	-
Sodium	NT	NT	NT	4,100	NT	NT	7,300	NT	18,000	-
Vanadium	NT	NT	NT	10	NT	NT	26	NT	**33**	26
Zinc	NT	NT	NT	60	NT	NT	**1,200**	NT	**2,700**	1,100

Notes:

(1) EPA Region III Risk-based Concentration Criteria for Tap Water

(2) <20 / <10 = Savannah Lab result / Earth Tech on-site GC result

(3) BDL - Below detection limit

(4) NT - Not tested

(5) USEPA Action Level for Drinking Water

Concentrations above EPA Region III RBCs for tap water are bolded and shaded.

R - rejected value, on-site GC results for vinyl chloride not confirmed by Savannah Lab GC/MS analysis

D - Concentration from secondary dilution

L - Reported value may be biased low

TABLE 4-13
DPT GROUNDWATER RESULTS - LARC 60 SITE

Parameters	Sample ID and Results								EPA RBC Criteria(1)
	GW06-010	GW06-011	GW06-012	GW06-013	GW06-014	GW06-015	GW06-016	GW06-017	
VOCs (ug/l)									
Benzene	<5 / <5(2)	<5	<5	<5	<5	<5	<5	<5	0.32
Chloroform	<5	**4.6 J**	<5	<5	<5	<5	<5	<5	0.15
cis 1,2-DCE	<5 / <5	3.5 J	<5	<5	<5	<5	<5	<5	6.1
Ethylbenzene	<5	6.6 J	<5	9.3 J	<5	<5	<5	<5	130
p-Isopropyl toluene	NA	2.3 J	NA	NA	NA	NA	NA	NA	--
Methylene chloride	<5	2.7 JB	<5	<5	<5	<5	<5	<5	4.1
MIBK	<25	<25	<25	<25	<25	<25	**54**	<25	14
Tetrachloroethene	<5 / <5	**16**	<5	<5	<5	<5	<5	<5	1.1
Trichloroethene	<5 / <5	**62 J**	<5	<5	<5	<5	<5	<5	1.6
1,2,4-Trimethylbenzene	NA	**5.6**	NA	NA	NA	NA	NA	NA	1.2
1,3,5-Trimethylbenzene	NA	**4.3 J**	NA	NA	NA	NA	NA	NA	1.2
Vinyl chloride	<10 / 200 R	<10	<10	<10	<10	<10	<10	<10	0.015
Xylenes	<5	37 J	<5	<5	<5	<5	<5	<5	1,200
SVOCs (ug/l)									
Acenaphthene	BDL	1 J	BDL	BDL	BDL	BDL	BDL	BDL	37
Bis(2-EH)phthalate	BDL	2 J	BDL	BDL	BDL	BDL	BDL	BDL	4.8
Di-n-butylphthalate	BDL	2 J	BDL	BDL	BDL	BDL	BDL	BDL	370
Fluorene	BDL	1 J	BDL	BDL	BDL	BDL	BDL	BDL	24
2-Methylnaphthalene	BDL	3 J	BDL	BDL	BDL	BDL	BDL	BDL	12
Naphthalene	BDL	**2.8 J**	BDL	BDL	BDL	BDL	BDL	BDL	0.65
Phenanthrene	BDL	2 J	BDL	BDL	BDL	BDL	BDL	BDL	--
TPH (mg/l)									
TPH as Gasoline	<0.05/<0.5	0.40	<0.05	0.25	<0.05	<0.05	<0.05	<0.05	1.0(4)
TPH as Diesel Fuel	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	1.0(4)
TPH as Heavy Oils	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0(4)
TPH as Fuel Oil	<1.0	**2.3**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0(4)
TPH as Kerosene	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	1.0(4)
Total Metals (mg/l)	NT	NT	NT	NT	NT	NT	NT	NT	

Notes:

(1) EPA Region III Risk-based Concentration Criteria for Tap Water

(2) <5 / <5 = Savannah Lab result / Earth Tech on-site GC result

(3) BDL - Below detection limit

(4) Virginia Groundwater Standard for Petroleum Hydrocarbons

(5) NT - Not tested

Concentrations above EPA Region III RBCs for tap water are bolded and shaded.

NA - Not analyzed. Samples not analyzed by 8260 method like USACE NED lab did for QA split sample for GW06-011.

R - rejected value, on-site GC results for vinyl chloride not confirmed by Savannah Lab GC/MS analysis

J - Estimated value

TABLE 4-13
DPT GROUNDWATER RESULTS
LARC 60 MAINTENANCE AREA

Parameters	Sample ID and Results								EPA RBC Criteria1)
	GW06-018	GW06-019	GW06-020	GW06-021	GW06-022	GW06-023	GW06-024	GW06-025	
VOCs (ug/l)									
Benzene	<5 / <5(2)	NT (3) / <5	NT / <5	<5 / <5	<5 / <5	NT / <5	NT / <5	<5	0.32
Carbon disulfide	10	NT	NT	<5	<5	NT	NT	<5	100
cis 1,2-DCE	<5 / <5	NT / <5	NT / <5	<5 / <5	<5 / <5	NT / <5	NT / <5	<5	6.1
MIBK	<25	<25	<25	<25	<25	<25	<25	**50**	14
Tetrachloroethene	<5 / <5	NT / <5	NT / <5	<5 / <5	<5 / <5	NT / <5	NT / <5	<5	1.1
Trichloroethane	<5 / <5	NT / <5	NT / <5	<5 / <5	<5 / <5	NT / <5	NT / <5	<5	1.6
Vinyl chloride	<10 / 110R	NT / 11R	NT / 24R	<10 / 56R	<10 / 18R	NT / 13R	NT / 24R	<10	0.015
SVOCs (ug/l)	NT	NT	NT	NT	NT	NT	NT	NT	
TPH (mg/l)									
TPH as Gasoline	<0.05 / <0.5	NT / <0.5	NT / <0.5	<0.05 / <0.5	<0.05 / <0.5	NT / <0.5	NT / <0.5	NT	1.0(4)
TPH as Diesel Fuel	NT	NT	NT	NT	NT	NT	NT	NT	1.0(4)
TPH as Heavy Oils	NT	NT	NT	NT	NT	NT	NT	NT	1.0(4)
TPH as Fuel Oil	NT	NT	NT	NT	NT	NT	NT	NT	1.0(4)
TPH as Kerosene	NT	NT	NT	NT	NT	NT	NT	NT	1.0(4)
Total Metals (mg/l)	NT	NT	NT	NT	NT	NT	NT	NT	

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Tap Water
(2) < 5 / <5 = Savannah Lab result / Earch Tech on-site GC result
(3) NT - Not tested
(4) Virginia Groundwater Standard for Petroleum Hydrocarbons
Concentrations above EPA Region III RBCs for tap water are bolded and shaded.

R - rejected value, on-site GC results for vinyl chloride not confirmed by Savannah Lab GC/MS analysis

TABLE 4-14
SOIL RESULTS - AUTO CRAFT SITE

Parameters	SB07-001			SB07-002			SB07-003			EPA RBC Criteria(1)
	0 to 1 ft	5 to 7 ft	9 to 11 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	5 to 7 ft	9 to 11 ft	
VOCs (ug/kg)										
Acetone	<26	<26	<26	<27	31	<27	<26	<26	<27	20,000,000/780,000
Ethylbenzene	<5.2	1.6 J	<5.2	<5.5	<5.2	<5.4	<5.2	<5.3	<5.4	20,000,000/780,000
Methylene Chloride	41	<5.2	<5.2	<5.5	<5.2	<5.4	<5.2	<5.3	<5.4	760,000/85,000
Methyl ethyl ketone	55	<26	<26	<27	58J	69	<26	<26	100	100,000,000/4,700,000
Styrene	<5.2	4.8 J	<5.2	<5.5	<5.2	<5.4	<5.2	<5.3	<5.4	41,000,000/1,600,000
Toluene	11	7 J	<5.2	34	<5.2	12	7.9	<5.3	<5.4	41,000,000/1,600,000
Trichloroethene	33	<5.2	<5.2	<5.5	<5.2	<5.4	<5.2	<5.3	<5.4	520,000/58,000
Xylenes	<5.2	16	<5.2	<5.5	<5.2	<5.4	<5.2	<5.3	<5.4	41,000,000/1,600,000
SVOCs (ug/kg)										
Acenaphthene	440	70 J	<340	<360	<340	<350	<340	<350	<360	12,000,000/470,000
Anthracene	<340	250 J	<340	<360	<340	<350	<340	<350	<360	61,000,000/2,300,000
Benzo(a)anthracene	**2,500**	620 J	<340	<360	<340	<350	<340	<350	<360	7,800/870
Benzo(b)fluoranthene	**4,100**	**1,100**	<340	<360	<340	<350	<340	<350	<360	7,800/870
Benzo(k)fluoranthene	490	770	<340	<360	<340	<350	<340	<350	<360	78,000/8,700
Benzo(g,h,i)perylene	2,000	<340	<340	<360	<340	<350	<340	<350	<360	-
Benzo(a)pyrene	**3,400**	**940**	<340	<360	<340	<350	<340	<350	<360	780/87
Butylbenzylphthalate	<340	230 J	<340	<360	<340	<350	<340	<350	<360	41,000,000/1,600,000
Chrysene	2,000	520 J	<340	<360	<340	<350	<340	<350	<360	780,000/88,000
Dibenz(a,h)anthracene	<340	80 J	<340	<360	<340	<350	<340	<350	<360	780/87
Fluoranthene	5,800	900	<340	<360	<340	<350	<340	<350	<360	8,200,000/310,000
Fluorene	<340	65 J	<340	<360	<340	<350	<340	<350	<360	8,200,000/310,000
Indeno(1,2,3-cd)pyrene	**1,500**	260 J	<340	<360	<340	<350	<340	<350	<360	7,800/870
Naphthalene	<340	8.2 J	<340	<360	<340	<350	<340	<350	<360	4,100,000/160,000
Phenanthrene	1,300	890	<340	<360	<340	<350	<340	<350	<360	-
Pyrene	11,000E	1,600	<340	<360	<340	<350	<340	<350	<360	6,100,000/230,000
TPH (mg/kg)										
TPH as Gasoline	<0.26	<0.26	<0.26	<0.27	<0.26	<0.27	<0.26	<0.26	<0.27	100(3)
TPH as Kerosene	<100	<10	<10	<11	<10	<11	<10	<10	<11	100
TPH as Diesel Fuel	<100	<10	<10	<11	<10	<11	<10	<10	<11	100
TPH as Heavy Oils	<340	**160**	<34	<36	<34	<36	**220**	<35	<36	100
TPH as Fuel Oil	<340	<34	<34	<36	<34	<36	<34	<35	<36	100

TABLE 4-14
SOIL RESULTS - AUTO CRAFT SITE

Parameters	SB07-004			SB07-005			SB07-006			EPA RBC Criteria(1)
	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	9 to 11 ft	
VOCs (ug/kg)										
Acetone	<27	<26	<26	<26	<26	<26	<26	<26	<26	20,000,000/780,000
Ethylbenzene	<5.4	<5.2	<5.3	<5.3	<5.3	<5.3	<5.2	<5.2	<5.2	20,000,000/780,000
Methylene Chloride	<5.4	<5.2	<5.3	<5.3	<5.3	<5.3	<5.2	<5.2	<5.2	760,000/85,000
Methyl ethyl ketone	<27	<26	<26	<26	<26	<26	<26	<26	<26	100,000,000/4,700,000
Styrene	<5.4	<5.2	<5.3	<5.3	<5.3	<5.3	<5.2	<5.2	6.0	41,000,000/1,600,000
Toluene	13	8.5	14	13	<5.3	<5.3	10	<5.2	14	41,000,000/1,600,000
Trichloroethene	<5.4	<5.2	<5.3	<5.3	<5.3	<5.3	<5.2	<5.2	<5.2	520,000/58,000
Xylenes	<5.4	<5.2	<5.3	<5.3	<5.3	<5.3	<5.2	<5.2	<5.2	41,000,000/1,600,000
SVOCs (ug/kg)										
Acenaphthene	<360	<340	<350	<350	<350	<350	<340	<340	<340	12,000,000/470,000
Anthracene	<360	<340	<350	<350	<350	<350	<340	<340	<340	61,000,000/2,300,000
Benzo(a)anthracene	<360	<340	<350	<350	<350	<350	<340	<340	<340	7,800/870
Benzo(b)fluoranthene	<360	<340	<350	<350	<350	<350	<340	<340	<340	7,800/870
Benzo(k)fluoranthene	<360	<340	<350	<350	<350	<350	<340	<340	<340	78,000/8,700
Benzo(g,h,i)perylene	<360	<340	<350	<350	<350	<350	<340	<340	<340	-
Benzo(a)pyrene	<360	<340	<350	<350	<350	<350	<340	<340	<340	780/87
Butylbenzylphthalate	550	<340	<350	<350	<350	<350	<340	<340	<340	41,000,000/1,600,000
Chrysene	<360	<340	<350	<350	<350	<350	<340	<340	<340	780,000/88,000
Dibenz(a,h)anthracene	<360	<340	<350	<350	<350	<350	<340	<340	<340	780/87
Fluoranthene	<360	<340	<350	<350	<350	<350	<340	<340	<340	8,200,000/310,000
Fluorene	<360	<340	<350	<350	<350	<350	<340	<340	<340	8,200,000/310,000
Indeno(1,2,3-cd)pyrene	<360	<340	<350	<350	<350	<350	<340	<340	<340	7,800/870
Naphthalene	<360	<340	<350	<350	<350	<350	<340	<340	<340	4,100,000/160,000
Phenanthrene	<360	<340	<350	<350	<350	<350	<340	<340	<340	-
Pyrene	<360	<340	<350	<350	<350	<350	<340	<340	<340	6,100,000/230,000
TPH (mg/kg)										
TPH as Gasoline	<0.27	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	100(3)
TPH as Kerosene	<11	<10	<10	<53	<11	<10	<52	<21	<10	100
TPH as Diesel Fuel	<11	<10	<10	<53	<11	<10	<52	<21	<10	100
TPH as Heavy Oils	<35	<34	<35	**370**	<35	<35	**390**	**330**	72	100
TPH as Fuel Oil	<35	<34	<35	<180	<35	<35	<170	<69	<34	100

TABLE 4-14
SOIL RESULTS - AUTO CRAFT SITE

Parameters	SB07-001			SB07-002			SB07-003			EPA RBC Criteria(1)
	0 to 1 ft	5 to 7 ft	9 to 11 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	5 to 7 ft	9 to 11 ft	
Total Metals (mg/kg)										
Aluminum	NT(2)	NT	500K	NT	NT	NT	NT	NT	NT	100,000/7,800
Arsenic	NT	NT	**1.1**	NT	NT	NT	NT	NT	NT	3.8/0.43
Barium	NT	NT	2.8	NT	NT	NT	NT	NT	NT	14,000/550
Beryllium	NT	NT	< 0.52	NT	NT	NT	NT	NT	NT	410/16
Cadmium	NT	NT	< 0.52	NT	NT	NT	NT	NT	NT	100/3.9
Calcium	NT	NT	84	NT	NT	NT	NT	NT	NT	-
Chromium	NT	NT	4.0	NT	NT	NT	NT	NT	NT	610/23
Cobalt	NT	NT	<1.0	NT	NT	NT	NT	NT	NT	4,100/160
Copper	NT	NT	<2.6	NT	NT	NT	NT	NT	NT	8,200/310
Iron	NT	NT	1,300L	NT	NT	NT	NT	NT	NT	120,000/4,700
Lead	NT	NT	1.7J	NT	NT	NT	NT	NT	NT	1,200/400
Magnesium	NT	NT	130	NT	NT	NT	NT	NT	NT	-
Manganese	NT	NT	14	NT	NT	NT	NT	NT	NT	4,100/160
Mercury	NT	NT	<0.01	NT	NT	NT	NT	NT	NT	-
Nickel	NT	NT	< 4.1	NT	NT	NT	NT	NT	NT	4,100/160
Potassium	NT	NT	130	NT	NT	NT	NT	NT	NT	-
Sodium	NT	NT	<52	NT	NT	NT	NT	NT	NT	-
Vanadium	NT	NT	2.3	NT	NT	NT	NT	NT	NT	1,400/55
Zinc	NT	NT	4.5	NT	NT	NT	NT	NT	NT	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) NT - Not tested
(3) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value
K - Reported value may be biased high
L - Reported value may be biased low

TABLE 4-14
SOIL RESULTS - AUTO CRAFT SITE

Parameters	SB07-004			SB07-005			SB07-006			EPA RBC Criteria(1)
	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	6 to 8 ft	0 to 1 ft	2 to 4 ft	9 to 11 ft	
Total Metals (mg/kg)										
Aluminum	5200K	940	NT	NT	440K	NT	NT	NT	NT	100,000/7,800
Arsenic	**1.3**	**1.5**	NT	NT	**1.1**	NT	NT	NT	NT	3.8/0.43
Barium	82	7.9	NT	NT	5.7	NT	NT	NT	NT	14,000/550
Beryllium	< 0.54	0.058	NT	NT	< 0.53	NT	NT	NT	NT	410/16
Cadmium	< 0.54	0.18	NT	NT	< 0.53	NT	NT	NT	NT	100/3.9
Calcium	1200	200	NT	NT	<53	NT	NT	NT	NT	-
Chromium	8.6	4.1 J	NT	NT	2.3	NT	NT	NT	NT	610/23
Cobalt	4.4	0.79	NT	NT	<1.1	NT	NT	NT	NT	4,100/160
Copper	18	5.0	NT	NT	<2.7	NT	NT	NT	NT	8,200/310
Iron	**9,100 L**	2,200	NT	NT	1200L	NT	NT	NT	NT	120,000/4,700
Lead	95J	11J	NT	NT	8.4J	NT	NT	NT	NT	1,200/400
Magnesium	2400	230	NT	NT	96	NT	NT	NT	NT	-
Manganese	**170**	25	NT	NT	10	NT	NT	NT	NT	4,100/160
Mercury	0.022	0.10	NT	NT	0.011	NT	NT	NT	NT	-
Nickel	4.8	1.1	NT	NT	< 4.2	NT	NT	NT	NT	4,100/160
Potassium	2700	180	NT	NT	<110	NT	NT	NT	NT	-
Sodium	64.0	20	NT	NT	<53	NT	NT	NT	NT	-
Vanadium	18.0	4.4	NT	NT	1.8	NT	NT	NT	NT	1,400/55
Zinc	64.0	14.0	NT	NT	5.4	NT	NT	NT	NT	61,000/2,300

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Industrial/Residential Soils
(2) NT - Not tested
(3) Virginia DEQ Petroleum Program Reporting Level
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value
K - Reported value may be biased high
L - Reported value may be biased low

TABLE 4-15

MONITORING WELL GROUNDWATER RESULTS
AUTO CRAFT BUILDING AREA

Parameters	Well ID and Results					EPA RBC Criteria(1)
	7MW-1	7MW-2	7MW-3	MW-119	MW-120	
VOCs (ug/l)						
Chloroform	NT(2)	<5	**11**	<5	<5	0.15
SOCs (ug/l)	NT	BDL(3)	BDL	BDL	BDL	
TPH (mg/l)						
TPH as Gasoline	NT	<0.05	<0.05	<0.05	<0.05	1.0(4)
TPH as Diesel Fuel	NT	<0.30	<0.30	<0.30	<0.30	1.0(4)
TPH as Heavy Oils	NT	<1.0	<5.0	<1.0	<1.0	1.0(4)
TPH as Fuel Oil	NT	<1.0	<5.0	<1.0	<1.0	1.0(4)
TPH as Kerosene	NT	<0.30	<1.5	<0.30	<0.30	1.0(4)
Total Metals (ug/l)						
Aluminum	NT	NT	240	540	NT	3,700
Barium	NT	NT	12	< 10	NT	260
Calcium	NT	NT	6,400	30,000	NT	-
Iron	NT	NT	**9,700**	790	NT	2,200
Magnesium	NT	NT	5,200	3,700	NT	-
Manganese	NT	NT	**91**	< 10	NT	73
Potassium	NT	NT	1,600	2,600	NT	-
Sodium	NT	NT	16,000	12,000	NT	-
Zinc	NT	NT	< 20	22	NT	1,100
Dissolved Metals (ug/l)						
Calcium	NT	NT	5,800	31,000	NT	-
Iron	NT	NT	**8,100**	110	NT	2,200
Magnesium	NT	NT	4,600	3.7	NT	-
Manganese	NT	NT	**80**	< 10	NT	73
Potassium	NT	NT	15,000	2,100	NT	-
Sodium	NT	NT	15,000	11,000	NT	-

Notes:

(1) EPA Region III Risk-based Concentration Criteria for Tap Water

(2) NT - Not tested

(3) BDL - Below detection limit

(4) Virginia Groundwater Standard for Petroleum Hydrocarbons

Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

J - Estimated value

TABLE 4-16
DPT GROUNDWATER RESULTS
AUTO CRAFT BUILDING AREA

Parameters	Sample ID and Results						EPA RBC Criteria(1)
	GW07-001	GW07-002	GW07-003	GW07-004	GW07-005	GW07-006	
VOCs (ug/l)							
Methylene chloride	< 5	< 5	< 5	< 5	3.9 B	< 5	4.1
Vinyl chloride	<10 / <30(2)	<10 / <50	<10 / <50	<10 / 8.9R(6)	<10 / 7.2R	<10 / NT(3)	0.015
SOCs (ug/l)							
Bis(2-EH)phthalate	< 10	< 10	< 10	< 10	**8 J**	< 10	4.8
Di-n-butylphthalate	< 10	< 10	< 10	< 10	5 JB	< 10	270
TPH (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	
Total Metals (ug/l)							
Aluminum	360	< 200	NT	NT	630	NT	3,700
Arsenic	< 10	< 10	NT	NT	**56**	NT	0.045
Barium	14	21	NT	NT	12	NT	260
Calcium	36,000	17,000	NT	NT	18,000	NT	-
Iron	1,800	**3,600**	NT	NT	1,600	NT	2,200
Lead	< 5	< 5	NT	NT	< 5	NT	15 (5)
Magnesium	3,000	7,400	NT	NT	2,800	NT	-
Manganese	42	14	NT	NT	24	NT	73
Mercury	< 0.20	< 0.20	NT	NT	< 0.20	NT	-
Potassium	1,800	8,200	NT	NT	3,500	NT	-
Sodium	9,900	9,900	NT	NT	12,000	NT	-
Zinc	35	< 20	NT	NT	8.4	NT	1,100

Notes:
(1) EPA Region III Risk-based Concentration Criteria for Tap Water
(2) <10 / <50 = Savannah Lab result / Earth Tech on-site GC result
(3) NT - Not tested
(4) BDL - Below detection limit
(5) USEPA Action Level for Drinking Water
(6) R - rejected value, on-site GC results for vinyl chloride not confirmed by Savannah Lab GC/MS analysis
Shaded/bolded text identifies compounds with concentrations greater than the EPA risk screening criteria

TABLE 5-1
CHEMICAL PROPERTIES OF ORGANIC COMPOUNDS

COMPOUNDS	CHEMICAL PARAMETER							
	CAS No.	Vp (mm Hg)	Sw (mg/L)	Log Kow	Log Koc (ml/g)	S.Den. (g/cc)	Kh (atm x m3/mol)	MI
VOCs (ug/l)								
Acetone	67-64-1	270	1,000,000	0.24	-0.43	0.7906	3.97E-05	EM
Carbon disulfide	75-15-0	297	2,100	1.7 - 4.16	1.73	1.26	1.40E-03	VM
Chloroform	67-66-3	160	8220	1.97	1.64	1.485	3.75E-03	EM
1,1-DCA	75-34-3	182	5500	1.78	1.48	1.176	4.30E-03	EM
cis 1,2-DCE	156-60-5	2.7	3500	1.86	1.54	1.284	7.50E-04	EM
Ethylbenzene	100-41-4	7.08	161	3.13	2.94	0.867	8.44E-03	EM
Methylene chloride	75-09-2	350	13,200	1.25	0.94	1.325	2.57E-03	EM
Methyl ethyl ketone	78-93-3	70.6	353,000	0.29	-0.03	0.805	4.35E-05	EM
Methyl isobutyl ketone	108-10-1	14.5	20,400	1.19	1.28 - 2.03	0.80	9.40E-05	EM-VM
PCE	127-18-4	14	150	2.6	2.42	1.623	1.53E-02	SM
Styrene	100-42-5	6.6	310	2.95	2.43 - 2.74	0.906	2.81E-03	SM
Toluene	108-88-3	28.05	534.8	2.69	2.52	0.867	5.94E-03	SM
1,1,1-TCA	71-55-6	100	1360	2.47	2.18	1.339	1.80E-02	SM
TCE	79-01-6	57.8	1100	2.53	2.1	1.464	9.10E-03	VM
Vinyl acetate	108-05-4	85	20,000	0.73			4.81E-04	
Vinyl chloride	75-01-4	2580	1100	0.6	0.39	0.9106	5.60E-02	EM
Xylenes	106-42-3	8.78	156	3.18	2.31	0.86	7.10E-03	SM
SVOCs (ug/l)								
Butybenzylphthalate	85-68-7	0.0000086	2.9	4.77	4.45	1.113 - 1.121	1.20E-06	VIM
m&p-cresol	1319-77-3	0.24	31,000	1.97	2.7		1.10E-06	IM
Fluoranthene		0.000005	0.0022	4.90	4.58	1.252	6.50E-06	VIM
Fluorene	86-73-7	0.0007	1.69	4.18	3.7	1.203	2.10E-04	VIM
2-Methylnaphthalene	91-57-6	0.054	24.6	3.86	3.43 - 3.93	1.0058	3.18E-04	VIM
Naphthalene	91-20-3	10.4	31.7	3.35	3.11	1.025	4.60E-04	VIM
Phenanthrene	87-86-5	0.00068	1	4.52	4.36	1.179	2.10E-06	VIM
Pyrene		0.0000025	0.165	4.88	4.58	1.271	5.10E-06	VIM
TPH (mg/l)								
TPH as Gasoline	8006-61-9	263 - 675	Insoluble	2.13 - 4.87	1.81 - 4.81	0.7321	4.80E-04	VM - VIM
TPH as Diesel Fuel	68476-31-3	2.12 - 26.4	5	3.3 - 7.06	2.94 - 6.74	0.87 - 0.95	5.90E-05	EM
TPH as Heavy Oils						0.902		

NOTES:

EM = Extremely Mobile
VM = Very Mobile
SM = Slightly Mobile
IM = Immobile
VIM = Very Immobile

CHEMICAL PARAMETERS ABBREVIATIONS:

Vp = Vapor Pressure
Sw = Aqueous Solubility
Log Kow = Octanol/Water partition coefficient
Log Koc = Organic carbon adsorption coefficient
S. Den. = Specific density in water
Kh = Henry's law constant
MI = Mobility Index (from Ford and Gurba, 1984; and Dragun, 1988)

TABLE 5-2
FATE AND TRANSPORT MECHANISMS AND PATHWAYS

Mechanisms	Pathways						
	S to Air	SW to Air	SW to Sed	Sed to SW	S/VZ to GW	GW to S/VZ	GW
ORGANICS							
Volatilization	X	X		X		X	X
Hydrolysis				X	X		
Biodegradation							X
Advection							X
Dispersion							X
Diffusion							X
Desorption/Adsorption			X	X	X	X	X
Partitioning			X	X		X	X
Solubility				X	X	X	X
INORGANICS							
Particle Transport			X				
Ion Exchange					X		X
Dissolution			X	X	X		X
Desorption/Adsorption			X	X	X	X	X
Solubility			X	X	X		X

Notes:
S to Air - Soil to Air
SW to Air - Surface Water to Air
SW to Sed - Surface Water to Sediment
Sed to SW - Sediment to Surface Water
S/VZ to GW - Soil/Vadose Zone to Groundwater
GW to S/VZ - Groundwater to Soil/Vadose Zone
GW - Groundwater

TABLE 5-3
SITE-SPECIFIC TRANSPORT PATHWAYS

Transport Pathways	Site		
	FTA	LARC 60	Auto Craft
S to Air	**No**	**Yes**	**No**
SW to Air	**No**	**No**	**No**
SW to Sed	**No**	**No**	**No**
Sed to SW	**Yes** (stormwater transport)	**Yes** (stormwater transport)	**No**
S/VZ to GW	**Yes**	**Yes**	**No**
GW to S/VZ	**Yes** (through fluctuating water table)	**Yes** (through fluctuating water table)	**No**
GW	**Yes** (Horizontal but no vertical)	**Yes** (Horizontal but no vertical)	**No**

Notes:
S to Air - Soil to Air
SW to Air - Surface Water to Air
SW to Sed - Surface Water to Sediment
Sed to SW - Sediment to Surface Water
S/VZ to GW - Soil/Vadose Zone to Groundwater
GW to S/VZ - Groundwater to Soil/Vadose Zone
GW - Groundwater

TABLE 6-1
HAZARD ASSESSMENT FOR SURFACE SOILS - FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
VOCs (ug/kg)							
Acetone	3/28	134 - 290	-	20,000,000	780,000	D	
Methylene Chloride	2/28	5.0 - 6.4	-	760,000	85,000	B2	
Methyl ethyl ketone	1/28	28	-	100,000,000	4,700,000	D	
Styrene	1/28	3	-	41,000,000	1,600,000	D	
Toluene	24/28	8.3 - 140	-	41,000,000	1,600,000	D	
Xylenes	1/28	7	-	100,000,000	16,000,000	D	
SVOCs (ug/kg)							
Benzo(b)fluoranthene	1/28	97	-	7,800	880	B2	
Benzo(k)fluoranthene	1/28	86	-	78,000	8,800	B2	
Bis(2-EH)phthalate	1/28	110	-	410,000	46,000	B2	
Chrysene	1/28	94	-	780,000	88,000	B2	
Di-n-butylphthalate	1/28	150	-	20,000,000	780,000	D	
Fluoranthene	1/28	650	-	8,200,000	310,000	D	
Pyrene	1/28	720	-	6,100,000	230,000	D	
TPH (mg/kg)							
Total TPH	3/28	48 - 5,300	100	-	-	-	
PCBs (ug/kg)							
Aroclors	0/8	-	-	2,900	320	B2	
Pesticides (ug/kg)							
Chlordane (alpha)	1/8	0.36	-	16,000	1,800	B2	
Chlordane (gamma)	3/8	0.30 - 0.84	-	16,000	1,800	B2	
DDE	7/8	0.37 - 9.0	-	17,000	1,900	B2	
DDT	8/8	0.60 - 24	-	17,000	1,900	B2	
Heptachlor epoxide	1/8	0.94	-	630	70	B2	

TABLE 6-1
HAZARD ASSESSMENT FOR SURFACE SOILS - FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
Total Metals (mg/kg)							
Aluminum	5/5	420 - 980	-	100,000	7,800	-	
Arsenic	4/5	1.2 - 1.6	-	3.8	0.43	A	**Yes**
Barium	5/5	3.9 - 12	-	14,000	550	-	
Calcium	4/5	71 - 370	-	-	-	-	
Chromium	5/5	1.7 - 5.8	-	610	23	-	
Copper	5/5	3.2 - 13	-	8,200	310	D	
Iron	5/5	1,200 - 5,400	-	120,000	4,700	-	**Yes**
Lead	5/5	7 - 33	-	1,200	400	B2	
Magnesium	5/5	62 - 190	-	-	-	-	
Manganese	5/5	10 - 34	-	4,100	160	D	
Mercury	2/5	0.011 - 0.013	-	-	-	-	
Potassium	1/5	160	-	-	-	-	
Vanadium	5/5	1.8 - 3.7	-	1,400	55	D	
Zinc	5/5	14 - 22	-	61,000	2,300	D	

Notes:

(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)

(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Sept 2001)

(3) Weight of Evidence Classification:

A = Human carcinogen

B1 = Probable human carcinogen, limited human data

B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans

C = Possible human carcinogen

D = Not classified as to carcinogenicity

TABLE 6-2
HAZARD ASSESSMENT FOR GROUNDWATER
FIREFIGHTER TRAINING AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				TBC Criteria		EPA Carcinogen Class(7)	Potential Concern?
			EPA MCLs(1)	EPA Secondary MCLs(2)	Virginia GW Stds(3)	Va GW Protection Levels(4)	Virginia GW Criteria(5)	EPA RBC Criteria(6) Tap Water		
VOCs (ug/l)										
Acetone	2/10	10 - 15	-	-	-	-	-	370	D	
Carbon disulfide	2/10	7.0 - 8.3	-	-	-	1,000	-	100	-	
1,1-Dichloroethane	2/10	0.60 - 0.86	-	-	-	-	-	81	C	
Ethylbenzene	1/10	47	700	-	-	-	-	130	D	
Xylenes	2/10	25 - 200	10,000	-	-	-	-	1,200	D	
SVOCs (ug/l)										
Naphthalene	1/10	11	-	-	-	-	-	150	D	
TPH (mg/l)										
Total TPH	1/10	2	-	-	1	1	-	-	-	
Dissolved Metals (ug/l)										
Aluminum	4/4	64 - 590	-	50 - 200	-	-	-	3,700	-	
Antimony	2/5	3.8 - 5.7	6	-	-	-	-	1.5	-	**Yes**
Barium	5/5	6.2 - 140	1,000	-	1,000	1,000	-	260	-	
Calcium	5/5	5,900 - 18,000	-	-	-	-	-	-	-	
Chromium	3/5	0.99 - 1.7	100	-	50	50	-	11	-	
Cobalt	1/5	1.2	-	-	-	-	-	73	-	
Copper	1/3	0.025	1,300	-	1,000	1,000	-	140	D	
Iron	4/4	130 - 2,100	-	300	-	-	300	2,200	-	
Lead	2/5	4.5 - 4.6	15	-	-	-	-	-	-	
Magnesium	5/5	920 - 8,400	-	-	-	-	-	-	-	
Manganese	5/5	2.5 - 81	-	50	-	-	50	73	D	**Yes**
Nickel	1/5	3	-	-	-	-	-	73	-	
Potassium	5/5	1,300 - 3,000	-	-	-	-	-	-	-	
Sodium	5/5	4,700 - 36,000	-	-	270,000	270,000	100,000	-	-	
Vanadium	4/5	1.2 - 1.8	-	-	-	-	-	26	-	
Zinc	5/5	13 - 120	-	5,000	50	50	-	1,100	D	

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations
(5) Virginia Water Quality Criteria for Groundwater
(6) EPA Region III Risk-based Concentration Table for Tap Water (Sept 2001)

(7) Weight-of-Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6-3
HAZARD ASSESSMENT FOR SEDIMENT
FIREFIGHTER TRAINING AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class(3)	Potential Concern?
			Virginia Petroleum Program(1)	EPA Region III RBC Criteria			
				Industrial Soils(2)	Residential Soils(2)		
VOCs (ug/kg)							
Toluene	4/4	23 - 180	-	41,000,000	1,600,000	D	
SVOCs (ug/kg)		BDL					
TPH (mg/kg)							
Total TPH	3/4	130 - 350	100	-	-	-	
Total Metals (mg/kg)							
Aluminum	4/4	160 - 7600	-	100,000	7,800	-	
Arsenic	1/4	2.5	-	3.8	0.43	A	**Yes**
Barium	4/4	2.4 - 110	-	14,000	550	-	
Calcium	4/4	64 - 120	-	-	-	-	
Chromium	1/4	21	-	610	23	-	
Cobalt	1/4	2.6	-	4100	160	-	
Copper	1/4	26	-	8,200	310	D	
Iron	4/4	230 - 17,000	-	120,000	4,700	-	**Yes**
Lead	4/4	4.3 - 210	-	1,200	400	B2	
Magnesium	1/4	960	-	-	-	-	
Manganese	3/4	1.7 - 42	-	4,100	160	D	
Mercury	2/4	0.017 - 0.051	-	61	2.3	D	
Nickel	1/4	9.4	-	41,000	1,600	-	
Potassium	1/4	260	-	-	-	-	
Sodium	2/4	87 - 180	-	-	-	-	
Thallium	1/4	1.4	-	14	0.55	-	**Yes**
Vanadium	2/4	2 - 18	-	1,400	55	D	
Zinc	2/4	6 - 76	-	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Sept 2001)
(3) Weight-of-Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6-4
HAZARD ASSESSMENT FOR SURFACE AND SUBSURFACE SOILS - FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
VOCs (ug/kg)							
Acetone	34/72	27 - 18,000	-	20,000,000	780,000	D	
Methylene Chloride	4/72	3.1 - 6.4	-	760,000	85,000	B2	
Methyl ethyl ketone	9/72	28 - 110	-	100,000,000	4,700,000	D	
Styrene	2/72	2 - 3	-	41,000,000	1,600,000	D	
Toluene	59/72	6.4 - 140	-	41,000,000	1,600,000	D	
Xylenes	1/72	7	-	100,000,000	16,000,000	D	
SVOCs (ug/kg)							
Benzo(b)fluoranthene	1/72	97	-	7,800	870	B2	
Benzo(k)fluoranthene	1/72	86	-	78,000	8,700	B2	
Bis(2-EH)phthalate	1/72	110	-	410,000	46,000	B2	
Chrysene	1/72	94	-	780,000	87,000	B2	
Di-n-butylphthalate	2/72	150 - 1,300	-	20,000,000	780,000	D	
Fluoranthene	3/72	600 - 1,100	-	8,200,000	310,000	D	
Naphthalene	1/72	45	-	4,100,000	160,000	D	
Pyrene	3/72	440 - 720	-	6,100,000	230,000	D	
TPH (mg/kg)							
Total TPH	3/28	48 - 5,300	100	-	-	-	
PCBs (ug/kg)							
Aroclors	0/8	-	-	2,900	320	B2	
Pesticides (ug/kg)							
Chlordane (alpha)	1/8	0.36	-	16,000	1,800	B2	
Chlordane (gamma)	3/8	0.30 - 0.84	-	16,000	1,800	B2	
DDE	7/8	0.37 - 9.0	-	17,000	1,900	B2	
DDT	8/8	0.60 - 24	-	17,000	1,900	B2	
Heptachlor epoxide	1/8	0.94	-	630	70	B2	

TABLE 6-5
GENERIC EQUATION FOR CALCULATING CHEMICAL INTAKES

$$I = [(C \times CR \times EFD)/BW] \times 1/AT$$

Where:

I = intake; the amount of chemical at the exchange boundary (mg/kg body weight-day)

C = chemical concentration; the "average" concentration contacted over the exposure period (e.g., mg/liters water)

CR = contact rate; the amount of contaminated medium contacted per unit time or event (e.g., liters/day)

EFD = exposure frequency and duration; describes how long and how often exposure occurs; often calculated using two terms (EF and ED)

EF = exposure frequency (day/year)

ED = exposure durations (years)

BW = body weight; the average body weight over the exposure period (kg)

AT = averaging time; time period over which exposure is averaged (days)

TABLE 6-6
COMPARISON OF EXPOSURE CONCENTRATIONS
FIREFIGHTER TRAINING AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Soils and Sediment		
Ingestion of and Dermal Contact with Chemicals	mg/kg	mg/kg
Arsenic	2.5	**1.4**
Iron	17,000	**3,634**
Thallium	1.4	**0.6**
Groundwater		
Ingestion of and Dermal Contact with Chemicals	ug/l	ug/l
Antimony	**5.7**	NA
Manganese	**81**	NA

Notes:
Bolded/shaded numbers indicate the concentrations to be used in the quantitative assessment
NA - Not applicable because insufficient number of samples to calculate 95th percentile UCL.

TABLE 6-7a
RESIDENTIAL EXPOSURE:
INGESTION OF CHEMICALS IN SOIL

EQUATION:

Intake (mg/kg-day) = (CS x IR x CF x FI x EF x ED)/(BW x AT)

Where:

CS = Chemical concentration in soil (mg/kg)
IR = Ingestion rate (mg soil/day)
CF = Conversion factor (10^{-6} kg/mg)
FI = Fraction ingested from contaminated source (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CS = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 100 mg/day for adults estimated from all age groups greater than 6 years old
200 mg/day for children ages 1 through 6

CF = 10^{-6} kg/mg

FI = 1; assumes 100% of soil is contaminated

EF = 350 days per year with 15 days expected to be away from the residence

ED = 24 years based on the national upper-bound (90th percentile) at one residence for adults
6 years for children which assumes that the oldest child is under 6 and has lived at the residence since birth.

BW = 70 kg represents the average adult and 15 kg for children ages 1 through 6

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-7b
RESIDENTIAL EXPOSURE:
DERMAL CONTACT WITH CHEMICALS IN SOIL

EQUATION:

Absorbed Dose (mg/kg-day) = (CS x CF x SA x AF x ABS x EF x ED)/(BW x AT)

Where:

CS = Chemical concentration in soil (mg/kg)
CF = Conversion factor (10^{-6} kg/mg)
SA = Skin surface area available for contact (cm^2/event)
AF = Soil to skin adherence factor (mg/cm^2)
ABS = Absorption factor (unitless)
EF = Exposure frequency (events/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CS = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

CF = 10^{-6} kg/mg

SA = 3,600 cm^2/event; represents the 50th percentile hand, forearm, neck, and head surface areas, adult male (USEPA, 1997a) and 2,074 cm^2/event represents 25% of the 50th percentile total body surface area for children ages 3 to 9 (1997a)

AF = 0.20 mg/cm^2 (USEPA, 1997a)

ABS = Arsenic – 0.032/Other Metals – 0.01

EF = 350 events/year

ED = 24 years for adults and 6 years for children (USEPA, 1989a)

BW = 70 kg; represents the average adult and 15 kg for children ages 1 to 6 (USEPA, 1989a)

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-8
RESIDENTIAL EXPOSURE
INGESTION OF CHEMICALS IN GROUND WATER

EQUATION:

Intake (mg/kg-day) = (CW x IR x EF x ED)/(BW x AT)

Where:

CW = Chemical concentration in water (mg/l)
IR = Ingestion rate (liters/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CW = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 2 liters/day for an adult
1 liter/day for a child

EF = 350 days/year for adults and children

ED = 24 years for adults
6 years for children

BW = 70 kg represents the average adult and 15 kg for children ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-9
RESIDENTIAL EXPOSURE
DERMAL CONTACT WITH CHEMICALS IN GROUND WATER

EQUATION:

Absorbed Dose (mg/kg-day) = (CW x SA x PC x ET x EF x ED x CF)/(BW x AT)

Where:

CW = Chemical concentration in water (mg/l)
SA = Skin surface area available for contact (cm^2)
PC = Chemical-specific dermal permeability coefficient (cm/hr)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CS = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

SA = 19,400 cm^2; represents the 50th percentile total body surface area, adult male
7,310 cm^2; represents the 50th percentile total body surface area, male child

PC = Chemical-specific values estimated from the octanol/water coefficient

ET = 0.3 hours/day

EF = 350 days/year

ED = 24 years for adults and 6 years for children

CF = 0.001 (1 liter/1000 cm^3)

BW = 70 kg represents the average adult and 15 kg the average child ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-10
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL ROUTE

COPC	Chronic RfDo (mg/kg-day)	Adjusted RfD [1] (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
Antimony	4.00E-04	8.00E-06	Low	Lung irritation, CVS	Oral/IRIS	1000	1
Arsenic	3.00E-04	1.23E-04	Low	Perpigmentation, keratosis	Oral/IRIS	3	1
Iron	3.00E-01	4.50E-02	Medium	Hemosiderosis		10	1
Manganese	2.30E-02	9.20E-04	Medium	CNS effects	IRIS	1	1
Thallium	7.00E-05	1.05E-05	Medium	Increased SGOT	IRIS	1	1

Notes:

(1) RfD adjusted for dermal exposures by using absorption efficiency factors
(Adjusted RfD = RfDo x absorption efficiency factor)

TABLE 6-11
TOXICITY VALUES: CARCINOGENIC EFFECTS FOR ORAL ROUTES

COPC	CPSo $(mg/kg\text{-}day)^{-1}$	Adjusted CPS[(1)] $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Class	Type of Cancer	SF Basis	SF Source
Antimony	---	---	D			
Arsenic	1.50E+00	3.66E+00	A	Skin and lung	Oral	IRIS
Iron	---	---	D			
Manganese	---	---	D			
Thallium	---	---	D			

Notes:

(1) CPS adjusted for dermal exposures by using absorption efficiency factors
(Adjusted CPS = CPSo/absorption efficiencey factor)

(2) IRIS - Integrated Risk Information System (USEPA database)

(3) HEAST - Health Effects Assessment Summary Table

TABLE 6-13
CANCER RISK ESTIMATES
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	CPS Adjusted For Absorption	CPS $(mg/kg\text{-}day)^{-1}$	Chemical Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Soil	Arsenic	6.58E-07	No	1.50E+00	9.87E-07	
	Iron	1.71E-03	---	---	---	
	Thallium	2.82E-07	---	---	---	9.87E-07
Dermal Contact with COPC in Soil	Arsenic	1.51E-07	Yes	3.66E+00	5.53E-07	
	Iron	1.23E-04	---	---	---	
	Thallium	2.03E-08	---	---	---	5.53E-07
Ingestion of COPC in Groundwater	Antimony	5.35E-05	---	---	---	
	Manganese	7.61E-04	---	---	---	0.00E+00
Dermal Contact with COPC in Groundwater	Antimony	1.56E-07	---	---	---	
	Manganese	2.21E-06	---	---	---	0.00E+00
				Total Exposure Hazard Index		**1.54E-06**
CHILDREN						
Ingestion of COPC in Soil	Arsenic	1.53E-06	No	1.50E+00	2.30E-06	
	Iron	3.98E-03	---	---	---	
	Thallium	6.58E-07	---	---	---	2.30E-06
Dermal Contact with COPC in Soil	Arsenic	1.02E-07	Yes	3.66E+00	3.73E-07	
	Iron	8.26E-05	---	---	---	
	Thallium	1.36E-08	---	---	---	3.73E-07
Ingestion of COPC in Groundwater	Antimony	3.12E-05	---	---	---	
	Manganese	4.44E-04	---	---	---	0.00E+00
Dermal Contact with COPC in Groundwater	Antimony	7.53E-08	---	---	---	
	Manganese	1.07E-06	---	---	---	0.00E+00
				Total Exposure Hazard Index		**2.67E-06**

Notes:
CDI = Chronic Daily Intake
CPS - Cancer Potency Slope
Risk = CDI x CPS

TABLE 6-14
HAZARD ASSESSMENT FOR SURFACE SOILS - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
VOCs (ug/kg)							
Acetone	1/22	36	-	20,000,000	780,000	D	
Methylene Chloride	7/22	5.2 - 160	-	760,000	85,000	B2	
Toluene	3/22	5.1 - 12	-	41,000,000	1,600,000	D	
Trichloroethene	2/22	5.9 - 6.4	-	520,000	58,000	D	
SVOCs (ug/kg)	0/22	-					
TPH (mg/kg)							
Total TPH	19/22	42 - 1,500	100	-	-	-	
PCBs (ug/kg)							
Aroclors	0/8	-	-	2,900	320	B2	
Pesticides (ug/kg)							
BHC (beta)	1/8	1.6	-	3,200	350	B2	
Chlordane (alpha)	1/8	0.51	-	16,000	1,800	B2	
Chlordane (gamma)	2/8	0.49 - 0.63	-	16,000	1,800	B2	
DDD	4/8	1.2 - 4.3	-	24,000	2,700	B2	
DDE	4/8	0.3 - 13	-	17,000	1,900	B2	
DDT	7/8	0.55 - 39	-	17,000	1,900	B2	
Dieldrin	1/8	0.47	-	360	40	B2	

TABLE 6-14
HAZARD ASSESSMENT FOR SURFACE SOILS - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
Total Metals (mg/kg)							
Aluminum	5/5	250 - 2,700	-	100,000	7,800	-	**Yes**
Arsenic	1/5	1.1	-	3.8	0.43	A	
Barium	5/5	1.8 - 19	-	14,000	550	-	
Calcium	4/5	56 - 980	-	-	-	-	
Chromium	5/5	1.7 - 4.3	-	610	23	-	
Cobalt	1/5	2.3	-	4,100	160	-	
Copper	4/5	2.5 - 41	-	8,200	310	D	
Iron	5/5	400 - 1,100	-	120,000	4,700	-	
Lead	5/5	3.1 - 12	-	1,200	400	B2	
Magnesium	4/5	77 - 1,400	-	-	-	-	
Manganese	5/5	2.4 - 120	-	4,100	160	D	
Potassium	1/5	1,200	-	-	-	-	
Vanadium	5/5	1.2 - 9.2	-	1,400	55	D	
Zinc	5/5	3.8 - 33	-	61,000	2,300	D	

Notes:

(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)

(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Sept 2001)

(3) Weight of Evidence Classification:

A = Human carcinogen

B1 = Probable human carcinogen, limited human data

B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans

C = Possible human carcinogen

D = Not classified as to carcinogenicity

TABLE 6-15
HAZARD ASSESSMENT FOR GROUNDWATER
LARC 60 MAINTENANCE AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				TBC Criteria		EPA Carcinogen Class(7)	Potential Concern?
			EPA MCLs(1)	EPA Secondary MCLs(2)	Virginia GW Stds(3)	Va GW Protection Levels(4)	Virginia GW Criteria(5)	EPA RBC Criteria(6) Tap Water		
VOCs (ug/l)										
cis 1,2-DCE	2/6	2 - 1,900	70	-	-	-	-	6.1	D	Yes
Ethylbenzene	1/6	76	700	-	-	-	-	130	D	
MIBK	3/6	19 - 50	-	-	-	-	-	14	D	Yes
Toluene	1/6	310	1,000	-	-	1,000	-	75	D	Yes
TCE	1/6	1.3	5	-	-	5	-	1.6	B2	
Vinyl chloride	2/6	3.1 - 8.6	2	-	-	2	-	0.015	B2	Yes
Xylenes	1/6	450	10,000	-	-	-	-	1,200	D	
SVOCs (ug/l)										
2-Methylnaphthalene	1/8	20	-	-	-	-	-	12	D	Yes
Naphthalene	1/8	32	-	-	-	-	-	0.65	D	Yes
Pesticides/PCBs (ug/l)	0/6	-	-	-	-	-	-	-	-	
Total TPH (mg/l)	2/8	2.7 - 6.3	-	-	1	1	-	-	-	
Dissolved Metals (ug/l)										
Aluminum	3/6	14 - 300	-	50 - 200	-	-	-	3,700	-	
Antimony	2/6	2.8 - 5.4	6	-	-	-	-	1.5	-	Yes
Arsenic	1/6	14	50	-	-	-	-	0.045	B2	Yes
Barium	6/6	5 - 21	1,000	-	1,000	1,000	-	260	-	
Calcium	6/6	6,300 - 18,000	-	-	-	-	-	-	-	
Chromium	5/6	0.75 - 2.7	100	-	50	50	-	11	-	
Copper	1/6	30	1,300	-	1,000	1,000	-	140	D	
Iron	6/6	70 - 15,000	-	300	-	-	300	2,200	-	Yes
Lead	5/6	3.2 - 4.7	15	-	-	-	-	-	-	
Magnesium	6/6	1,400 - 8,700	-	-	-	-	-	-	-	
Manganese	6/6	3.8 - 270	-	50	-	-	50	73	D	Yes
Potassium	6/6	2,400 - 6,200	-	-	-	-	-	-	-	
Sodium	6/6	4,800 - 66,000	-	-	270,000	270,000	100,000	-	-	
Vanadium	4/6	1.1 - 9.6	-	-	-	-	-	26	-	
Zinc	6/6	3.4 - 46	-	5,000	50	50	-	1,100	D	

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations
(5) Virginia Water Quality Criteria for Groundwater
(6) EPA Region III Risk-based Concentration Table for Tap Water (Sept 2001)

(7) Weight-of-Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6-16
HAZARD ASSESSMENT FOR SEDIMENT
LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class(3)	Potential Concern?
			Virginia Petroleum Program(1)	EPA Region III RBC Criteria			
				Industrial Soils(2)	Residential Soils(2)		
VOCs (ug/kg)	0/2	-					
SVOCs (ug/kg)	0/2	-					
TPH (mg/kg)							
Total TPH	2/2	530 - 2,700	100	-	-	-	
Total Metals (mg/kg)							
Aluminum	2/2	310 - 650	-	100,000	7,800	-	
Barium	2/2	1.4 - 2.7	-	14,000	550	-	
Calcium	2/2	53 - 210	-	-	-	-	
Chromium	2/2	1.6 - 2.5	-	610	23	-	
Copper	2/2	3.8 - 9.0	-	8,200	310	D	
Iron	2/2	310 - 940	-	120,000	4,700	-	
Lead	2/2	8.2 - 14	-	1,200	400	B2	
Magnesium	2/2	110 - 250	-	-	-	-	
Manganese	2/2	3.4 - 6.9	-	4,100	160	D	
Sodium	1/2	70	-	-	-	-	
Vanadium	2/2	1.3 - 2.7	-	1,400	55	D	
Zinc	2/2	11 - 30	-	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Sept 2001)
(3) Weight-of-Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6-17
HAZARD ASSESSMENT FOR SURFACE WATER
LARC 60 MAINTENANCE AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				EPA RBC [3]	EPA Carcinogen Class [4]	Potential Concern?
			Virginia SW (Freshwater) Quality Standards[1]		Federal AWQC (Freshwater)[2]				
			Water/Fish	Fish Cons.	Water/Fish	Fish Cons.			
VOCs (ug/l)									
Acetone	2/2	30 - 35	-	-	-	-		D	
SVOCs (ug/l)	0/2	BDL							
Total TPH (mg/l)	0/2	BDL							
Total Metals (ug/l)									
Aluminum	2/2	390 - 420	-	-	-	-	3,700	-	
Calcium	2/2	11,000 - 12,000	-	-	-	-	-	-	
Iron	2/2	840 - 1,400	300	-	-	-	2,200	-	**Yes**
Lead	2/2	7.8 - 9.0	15	-	50	-	-	B2	
Magnesium	2/2	15,000 - 17,000	-	-	-	-	-	-	
Manganese	2/2	83 - 140	50	-	-	-	73	D	**Yes**
Potassium	2/2	9,100 - 9,400	-	-	-	-	-	-	
Sodium	1/2	120,000	-	-	-	-	-	-	
Zinc	2/2	40 - 62	5,000	-	-	-	1,100	D	

Notes:

(1) Virginia Surface Water Quality Standards

(2) Federal Ambient Water Quality Criteria (40 CFR 131)

(3) Weight of Evidence Classification:

A = Human carcinogen

B1 = Probable human carcinogen, limited human data

B2 = Probable human carcinogen

C = Possible human carcinogen

D = Not classified as to carcinogenicity

(4) EPA Region III Risk-based Concentration Table for Tap Water (Oct 2000)
Non-carcinogenic RBCs have been adjusted to a hazard quotient of 0.1

TABLE 6-18
HAZARD ASSESSMENT FOR SURFACE AND SUBSURFACE SOILS - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
VOCs (ug/kg)							
Acetone	5/49	36 - 200	-	20,000,000	780,000	D	
sec-Butyl benzene	1/4	2.6	-	8,200,000	310,000	D	
Ethylbenzene	1/49	2.3	-	20,000,000	780,000	D	
Isopropyl benzene	1/4	1.8	-	-	-	D	
p-Isopropyl toluene	1/4	9.1	-	-	-	D	
Methylene Chloride	19/49	5.2 - 220	-	760,000	85,000	B2	
Methyl ethyl ketone	5/49	31 - 44	-	120,000,000	4,700,000	D	
n-Propyl benzene	1/4	4.3	-	820,000	310,000	D	
Styrene	3/49	1.8 - 9.2	-	41,000,000	1,600,000	D	
Tetrachloroethene	3/49	8.8 - 71	-	110,000	12,000	B2	
Toluene	8/49	5.1 - 13	-	41,000,000	1,600,000	D	
1,2,3-Trichloroethane	1/4	2.7	-	-	-	D	
Trichloroethene	5/49	5.9 - 16	-	520,000	58,000	D	
1,2,4-Trimethylbenzene	1/4	29	-	10,000,000	390,000	D	
1,3,5-Trimethylbenzene	1/4	26	-	10,000,000	390,000	D	
Xylenes	1/49	11	-	41,000,000	1,600,000	D	
SVOCs (ug/kg)							
Benzo(a)anthracene	1/49	27	-	7,800	870	B2	
Benzo(b)fluoranthene	1/49	36	-	7,800	870	B2	
Benzo(k)fluoranthene	1/49	47	-	78,000	8,700	B2	
Benzo(g,h,I)perylene	1/49	24	-	-	-	D	
Benzo(a)pyrene	1/49	35	-	780	87	B2	
Bis(2-EH)phthalate	1/49	51	-	410,000	46,000	B2	
Chrysene	1/49	33	-	780,000	87,000	B2	
Di-n-butylphthalate	1/49	59	-	20,000,000	780,000	D	
Fluoranthene	1/49	55	-	8,200,000	310,000	D	
Naphthalene	1/49	4	-	4,100,000	160,000	D	
Pyrene	1/49	50	-	6,100,000	230,000	D	
TPH (mg/kg)	19/22	42 - 1,500	100	-	-	-	
PCBs (ug/kg)	0/8	-	-	2,900	320	B2	

TABLE 6-18
HAZARD ASSESSMENT FOR SURFACE AND SUBSURFACE SOILS - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
Pesticides (ug/kg)							
BHC (beta)	1/8	1.6	-	3,200	350	B2	
Chlordane (alpha)	1/8	0.51	-	16,000	1,800	B2	
Chlordane (gamma)	2/8	0.49 - 0.63	-	16,000	1,800	B2	
DDD	4/8	1.2 - 4.3	-	24,000	2,700	B2	
DDE	4/8	0.3 - 13	-	17,000	1,900	B2	
DDT	7/8	0.55 - 39	-	17,000	1,900	B2	
Dieldrin	1/8	0.47	-	360	40	B2	
Total Metals (mg/kg)							
Aluminum	11/11	250 - 2,700	-	100,000	7,800	-	
Arsenic	3/11	0.86 - 1.1	-	3.8	0.43	A	**Yes**
Barium	11/11	1.8 - 19	-	14,000	550	-	
Cadmium	1/11	0.18	-	100	0.39	D	
Calcium	11/11	43 - 980	-	-	-	-	
Chromium	11/11	1.5 - 4.3	-	610	23	-	
Cobalt	2/11	0.79 - 2.3	-	4,100	160	-	
Copper	7/11	2.5 - 41	-	8,200	310	D	
Iron	11/11	400 - 1,100	-	120,000	4,700	-	
Lead	11/11	1.3 - 17	-	1,200	400	B2	
Magnesium	8/11	56 - 1,400	-	-	-	-	
Manganese	11/11	2.4 - 120	-	4,100	160	D	
Mercury	1/11	4.6	-	-	-	D	
Nickel	1/11	0.81	-	4,100	160	D	
Potassium	2/11	37 - 1,200	-	-	-	-	
Silver	1/11	0.51	-	1,000	39	D	
Vanadium	10/11	1.2 - 9.2	-	1,400	55	D	
Zinc	11/11	3 - 33	-	61,000	2,300	D	

Notes:

(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)

(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Sept 2001)

(3) Weight of Evidence Classification:

A = Human carcinogen

B1 = Probable human carcinogen, limited human data

B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans

C = Possible human carcinogen

D = Not classified as to carcinogenicity

TABLE 6-19
COMPARISON OF EXPOSURE CONCENTRATIONS
LARC 60 Maintenance Area

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Soils		
Ingestion of and Dermal Contact with Chemicals	mg/kg	mg/kg
Arsenic	1.1	**0.86**
Groundwater		
Ingestion of, Dermal Contact with, and Inhalation of Chemicals	ug/l	ug/l
Cis 1,2-DCE	1,900	**1,900**
MIBK	**50**	125
Toluene	310	**310**
Vinyl chloride	8.6	**7.4**
2-Methylnaphthalene	20	**20**
Naphthalene	32	**32**
Antimony	5.4	**5.4**
Arsenic	14	**14**
Iron	15,000	**15,000**
Manganese	270	**191**

Notes:
Bolded/shaded numbers indicate the concentrations to be used in the quantitative assessment
NA - Not applicable because insufficient number of samples to calculate 95th percentile UCL.

TABLE 6-20
RESIDENTIAL EXPOSURE
INHALATION OF AIRBORNE CHEMICALS IN GROUND WATER

EQUATION:

Intake (mg/kg-day) = (CA x IR x ET x EF x ED)/(BW x AT)

Where:

CA = Chemical concentration in air (mg/m^3)
IR = Inhalation rate (m^3/hour)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CA = 95th percentile UCL on the mean of the measured concentrations in site groundwater samples, except when it exceeds the maximum detected concentration, is used to calculated the concentration in air for each COPC utilizing the VDEQ shower model

IR = 0.83 m^3/hour for adults
0.50 m^3/hour for children

ET = 0.2 hours/day

EF = 350 days/year

ED = 24 years; represents the national upper-bound at one residence for adults
6 years for children ages 1 through 6

BW = 70 kg represents the average adult and 15 kg for child ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-21
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL ROUTE
LARC 60 MAINTENANCE AREA

COPC	Chronic RfDo (mg/kg-day)	Adjusted RfD [1] (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
METALS							
Antimony	4.00E-04	8.00E-06	Low	Lung irritation, CVS	Oral/IRIS	1000	1
Arsenic	3.00E-04	1.23E-04	Low	Perpigmentation, keratosis	Oral/IRIS	3	1
Iron	3.00E-01	4.50E-02	Medium	Hemosiderosis	Oral	10	1
Manganese	2.30E-02	9.20E-04	Medium	CNS effects	IRIS	1	1
VOCs							
cis 1,2-DCE	1.00E-02	1.00E-02	Pending	Decreased hematocrit	Oral/EPA	3000	1
MIBK	8.00E-02	6.40E-02	Medium	Lethargy	Oral/EPA	3000	1
Toluene	2.00E-01	1.60E-01	Medium	Changes in weight	Oral/NTP	1000	1
Vinyl chloride (child)	3.00E-03	3.00E-03	Low	Increased liver weights, hematological changes	Oral/IRIS	1000	1
Vinyl chloride (adult)	3.00E-03	3.00E-03	Low	Increased liver weights, hematological changes	Oral/IRIS	1000	1
SVOCs							
2-Methylnaphthalene	2.00E-02	1.60E-02	Medium	Increased relative liver weight	Oral	1000	1
Naphthalene	2.00E-02	1.60E-02	Medium	Increased relative liver weight	Oral	1000	1

Notes:
(1) RfD adjusted for dermal exposures by using absorption efficiency factors
(Adjusted RfD = RfDo x absorption efficiency factor)

TABLE 6-22
TOXICITY VALUES: CARCINOGENIC EFFECTS FOR ORAL ROUTES
LARC 60 MAINTENANCE AREA

COPC	CPSo $(mg/kg\text{-}day)^{-1}$	Adjusted CPS[(1)] $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Class	Type of Cancer	SF Basis	SF Source
METALS						
Antimony	---	---	D			
Arsenic	1.50E+00	3.66E+00	A	Skin and lung	Oral	IRIS
Iron	---	---	D			
Manganese	---	---	D			
VOCs						
cis 1,2-DCE	---	---	D			
MIBK	---	---	D			
Toluene	---	---	D			
Vinyl chloride (child)	1.40E+00	1.40E+00	A	Liver, kidney, lung, and brain tumors	Oral	IRIS
Vinyl chloride (adult)	7.20E-01	7.20E-01	A	Liver, kidney, lung, and brain tumors	Oral	IRIS
SVOCs						
2-Methylnaphthalene	---	---	D			
Naphthalene	---	---	D			

Notes:

(1) CPS adjusted for dermal exposures by using absorption efficiency factors
(Adjusted CPS = CPSo/absorption efficiencey factor)

(2) IRIS - Integrated Risk Information System (USEPA database)

(3) HEAST - Health Effects Assessment Summary Table

TABLE 6-23
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	RfD Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC in Soil	Arsenic	1.18E-06	No	3.00E-04	3.93E-03	3.93E-03
Dermal Contact with COPC in Soil	Arsenic	2.71E-07	Yes	1.23E-04	2.20E-03	2.20E-03
Ingestion of COPCs in Groundwater	cis 1,2-DCE	5.21E-02	No	1.00E-02	5.21E+00	
	MIBK	1.37E-03	No	8.00E-02	1.71E-02	
	Toluene	8.49E-03	No	2.00E-01	4.25E-02	
	Vinyl chloride	2.03E-04	No	3.00E-03	6.77E-02	
	2-Methylnaphthalene	5.48E-04	No	2.00E-02	2.74E-02	
	Naphthalene	8.77E-04	No	2.00E-02	4.39E-02	
	Antimony	1.48E-04	No	4.00E-04	3.70E-01	
	Arsenic	3.84E-04	No	3.00E-04	1.28E+00	
	Iron	4.11E-01	No	3.00E-01	1.37E+00	
	Manganese	5.23E-03	No	2.30E-02	2.27E-01	8.66E+00
Dermal Contact with COPCs in Groundwater	cis 1,2-DCE	1.51E-03	Yes	1.00E-02	1.51E-01	
	MIBK	1.32E-05	Yes	6.40E-02	2.06E-04	
	Toluene	1.11E-03	Yes	1.60E-01	6.94E-03	
	Vinyl chloride	4.31E-06	Yes	3.00E-03	1.44E-03	
	2-Methylnaphthalene	2.39E-04	Yes	1.60E-02	1.49E-02	
	Naphthalene	1.76E-04	Yes	1.60E-02	1.10E-02	
	Antimony	4.31E-07	Yes	8.00E-06	5.39E-02	
	Arsenic	1.12E-06	Yes	1.23E-04	9.11E-03	
	Iron	1.20E-03	Yes	4.50E-02	2.67E-02	
	Manganese	1.52E-05	Yes	9.20E-04	1.65E-02	2.92E-01
Inhalation of COPCs in Groundwater	cis 1,2-DCE	3.73E-01	No	---	---	
	MIBK	1.01E-02	No	2.00E-02	5.05E-01	
	Toluene	6.32E-02	No	1.14E-01	5.54E-01	
	Vinyl chloride	1.76E-03	No	2.80E-02	6.29E-02	
	2-Methylnaphthalene	2.59E-03	No	---	---	
	Naphthalene	4.23E-03	No	9.00E-04	4.70E+00	
	Antimony	0.00E+00	No	---	---	
	Arsenic	0.00E+00	No	---	---	
	Iron	0.00E+00	No	---	---	
	Manganese	0.00E+00	No	---	---	5.82E+00
					Total Exposure Hazard Index	**1.48E+01**

TABLE 6-23
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	RfD Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
CHILDREN						
Ingestion of COPC in Soil	Arsenic	1.10E-05	No	3.00E-04	3.67E-02	3.67E-02
Dermal Contact with COPC in Soil	Arsenic	7.30E-07	Yes	1.23E-04	5.93E-03	5.93E-03
Ingestion of COPCs in Groundwater	cis 1,2-DCE	1.21E-01	No	1.00E-02	1.21E+01	
	MIBK	3.20E-03	No	8.00E-02	4.00E-02	
	Toluene	1.98E-02	No	2.00E-01	9.90E-02	
	Vinyl chloride	4.73E-04	No	3.00E-03	1.58E-01	
	2-Methylnaphthalene	1.28E-03	No	2.00E-02	6.40E-02	
	Naphthalene	2.05E-03	No	2.00E-02	1.03E-01	
	Antimony	3.45E-04	No	4.00E-04	8.63E-01	
	Arsenic	8.95E-04	No	3.00E-04	2.98E+00	
	Iron	9.59E-01	No	3.00E-01	3.20E+00	
	Manganese	1.22E-02	No	2.30E-02	5.30E-01	2.01E+01
Dermal Contact with COPCs in Groundwater	cis 1,2-DCE	2.66E-03	Yes	1.00E-02	2.66E-01	
	MIBK	2.31E-05	Yes	6.40E-02	3.61E-04	
	Toluene	1.96E-03	Yes	1.60E-01	1.23E-02	
	Vinyl chloride	7.57E-06	Yes	3.00E-03	2.52E-03	
	2-Methylnaphthalene	4.21E-04	Yes	1.60E-02	2.63E-02	
	Naphthalene	3.10E-04	Yes	1.60E-02	1.94E-02	
	Antimony	7.57E-07	Yes	8.00E-06	9.46E-02	
	Arsenic	1.96E-06	Yes	1.23E-04	1.59E-02	
	Iron	2.10E-03	Yes	4.50E-02	4.67E-02	
	Manganese	2.68E-05	Yes	9.20E-04	2.91E-02	5.13E-01
Inhalation of COPCs in Groundwater	cis 1,2-DCE	1.05E+00	No	---	---	
	MIBK	2.83E-02	No	2.00E-02	1.42E+00	
	Toluene	1.78E-01	No	1.14E-01	1.56E+00	
	Vinyl chloride	4.95E-03	No	2.80E-02	1.77E-01	
	2-Methylnaphthalene	7.29E-03	No	---	---	
	Naphthalene	1.19E-02	No	9.00E-04	1.32E+01	
	Antimony	0.00E+00	No	---	---	
	Arsenic	0.00E+00	No	---	---	
	Iron	0.00E+00	No	---	---	
	Manganese	0.00E+00	No	---	---	1.64E+01
					Total Exposure Hazard Index	**3.71E+01**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

TABLE 6-24
CANCER RISK ESTIMATES
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	CPS Adjusted For Absorption	CPS $(mg/kg\text{-}day)^{-1}$	Chemical Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Soil	Arsenic	4.04E-07	No	1.50E+00	6.06E-07	6.06E-07
Dermal Contact with COPC in Soil	Arsenic	9.31E-08	Yes	3.66E+00	3.41E-07	3.41E-07
Ingestion of COPCs in Groundwater	cis 1,2-DCE	1.78E-02	No	---	0.00E+00	
	MIBK	4.70E-04	No	---	0.00E+00	
	Toluene	2.91E-03	No	---	0.00E+00	
	Vinyl chloride	6.95E-05	No	7.20E-01	5.00E-05	
	2-Methylnaphthalene	1.88E-04	No	---	0.00E+00	
	Naphthalene	3.01E-04	No	---	0.00E+00	
	Antimony	5.07E-05	No	---	0.00E+00	
	Arsenic	1.32E-04	No	1.50E+00	1.98E-04	
	Iron	1.41E-01	No	---	0.00E+00	
	Manganese	1.79E-03	No	---	0.00E+00	2.48E-04
Dermal Contact with COPCs in Groundwater	cis 1,2-DCE	5.19E-04	Yes	---	0.00E+00	
	MIBK	4.51E-06	Yes	---	0.00E+00	
	Toluene	3.81E-04	Yes	---	0.00E+00	
	Vinyl chloride	1.48E-06	Yes	7.20E-01	1.06E-06	
	2-Methylnaphthalene	8.20E-05	Yes	---	0.00E+00	
	Naphthalene	6.04E-05	Yes	---	0.00E+00	
	Antimony	1.48E-07	Yes	---	0.00E+00	
	Arsenic	3.83E-07	Yes	3.66E+00	1.40E-06	
	Iron	4.10E-04	Yes	---	0.00E+00	
	Manganese	5.22E-06	Yes	---	0.00E+00	2.46E-06
Inhalation of COPCs in Groundwater	cis 1,2-DCE	1.28E-01	No	---	0.00E+00	
	MIBK	3.45E-03	No	---	0.00E+00	
	Toluene	2.17E-02	No	---	0.00E+00	
	Vinyl chloride	6.04E-04	No	3.00E-02	1.81E-05	
	2-Methylnaphthalene	8.89E-04	No	---	0.00E+00	
	Naphthalene	1.45E-03	No	---	0.00E+00	
	Antimony	0.00E+00	No	---	0.00E+00	
	Arsenic	0.00E+00	No	---	0.00E+00	
	Iron	0.00E+00	No	---	0.00E+00	
	Manganese	0.00E+00	No	---	0.00E+00	1.81E-05
				Total Exposure Hazard Index		**2.70E-04**

TABLE 6-24
CANCER RISK ESTIMATES
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	CPS Adjusted For Absorption	CPS $(mg/kg\text{-}day)^{-1}$	Chemical Risk	Total Pathway Risk
CHILDREN						
Ingestion of COPC in Soil	Arsenic	9.42E-07	No	1.50E+00	1.41E-06	1.41E-06
Dermal Contact with COPC in Soil	Arsenic	6.52E-08	Yes	3.66E+00	2.39E-07	2.39E-07
Ingestion of COPCs in Groundwater	cis 1,2-DCE	1.04E-02	No	---	0.00E+00	
	MIBK	2.74E-04	No	---	0.00E+00	
	Toluene	1.70E-03	No	---	0.00E+00	
	Vinyl chloride	4.05E-05	No	1.40E+00	5.68E-05	
	2-Methylnaphthalene	1.10E-04	No	---	0.00E+00	
	Naphthalene	1.75E-04	No	---	0.00E+00	
	Antimony	2.96E-05	No	---	0.00E+00	
	Arsenic	7.67E-05	No	1.50E+00	1.15E-04	
	Iron	8.22E-02	No	---	0.00E+00	
	Manganese	1.05E-03	No	---	0.00E+00	1.72E-04
Dermal Contact with COPCs in Groundwater	cis 1,2-DCE	2.28E-04	Yes	---	0.00E+00	
	MIBK	1.98E-06	Yes	---	0.00E+00	
	Toluene	1.68E-04	Yes	---	0.00E+00	
	Vinyl chloride	6.49E-07	Yes	1.40E+00	9.09E-07	
	2-Methylnaphthalene	3.60E-05	Yes	---	0.00E+00	
	Naphthalene	2.65E-05	Yes	---	0.00E+00	
	Antimony	6.49E-08	Yes	---	0.00E+00	
	Arsenic	1.68E-07	Yes	3.66E+00	6.16E-07	
	Iron	1.80E-04	Yes	---	0.00E+00	
	Manganese	2.30E-06	Yes	---	0.00E+00	1.52E-06
Inhalation of COPCs in Groundwater	cis 1,2-DCE	8.99E-02	No	---	0.00E+00	
	MIBK	2.42E-03	No	---	0.00E+00	
	Toluene	1.52E-02	No	---	0.00E+00	
	Vinyl chloride	4.25E-04	No	1.50E-02	6.37E-06	
	2-Methylnaphthalene	6.25E-04	No	---	0.00E+00	
	Naphthalene	1.02E-03	No	---	0.00E+00	
	Antimony	0.00E+00	No	---	0.00E+00	
	Arsenic	0.00E+00	No	---	0.00E+00	
	Iron	0.00E+00	No	---	0.00E+00	
	Manganese	0.00E+00	No	---	0.00E+00	6.37E-06
				Total Exposure Hazard Index		**1.81E-04**

Notes:
CDI = Chronic Daily Intake
CPS - Cancer Potency Slope
Risk = CDI x CPS

TABLE 6-25
HAZARD ASSESSMENT FOR SURFACE SOILS - AUTO CRAFT BUILDING SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
VOCs (ug/kg)							
Methylene Chloride	1/6	41	-	760,000	85,000	B2	
Methyl ethyl ketone	1/6	55	-	100,000,000	4,700,000	D	
Toluene	6/6	7.9 - 34	-	41,000,000	1,600,000	D	
Trichloroethene	1/6	33	-	520,000	58,000	D	
SVOCs (ug/kg)							
Acenaphthene	1/6	440	-	12,000,000	470,000	D	
Benzo(a)anthracene	1/6	2,500	-	7,800	870	B2	**Yes**
Benzo(b)fluoranthene	1/6	4,100	-	7,800	880	B2	**Yes**
Benzo(k)fluoranthene	1/6	490	-	78,000	8,800	B2	
Benzo(g,h,I)perylene	1/6	2,000	-	-	-	D	
Benzo(a)pyrene	1/6	3,400	-	780	87	B2	**Yes**
Butyllbenzylphthalate	1/6	550	-	41,000,000	1,600,000	D	
Chrysene	1/6	2,000	-	780,000	88,000	B2	
Fluoranthene	1/6	5,800	-	8,200,000	310,000	D	
Indeno(1,2,3-cd)pyrene	1/6	1,500	-	7,800	870	B2	**Yes**
Phenanthrene	1/6	1,300	-	-	-	D	
Pyrene	1/6	11,000	-	6,100,000	230,000	D	
TPH (mg/kg)							
Total TPH	3/6	220 - 390	100	-	-	-	

TABLE 6-25
HAZARD ASSESSMENT FOR SURFACE SOILS - AUTO CRAFT BUILDING SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
Total Metals (mg/kg)							
Aluminum	1/1	5,200	-	100,000	7,800	-	
Arsenic	1/1	1.3	-	3.8	0.43	A	**Yes**
Barium	1/1	82	-	14,000	550	-	
Calcium	1/1	1200	-	-	-	-	
Chromium	1/1	8.6	-	610	23	-	
Cobalt	1/1	4.4	-	4,100	160	D	
Copper	1/1	18	-	8,200	310	D	
Iron	1/1	9,100	-	120,000	4,700	-	**Yes**
Lead	1/1	95	-	1,200	400	B2	
Magnesium	1/1	2,400	-	-	-	-	
Manganese	1/1	170	-	4,100	160	D	**Yes**
Mercury	1/1	0.022	-	-	-	-	
Nickel	1/1	4.8	-	4,100	160	D	
Potassium	1/1	2,700	-	-	-	-	
Sodium	1/1	64	-	-	-	-	
Vanadium	1/1	18	-	1,400	55	D	
Zinc	1/1	64	-	61,000	2,300	D	

Notes:

(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)

(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Sept 2001)

(3) Weight of Evidence Classification:

A = Human carcinogen

B1 = Probable human carcinogen, limited human data

B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans

C = Possible human carcinogen

D = Not classified as to carcinogenicity

TABLE 6-26
HAZARD ASSESSMENT FOR GROUNDWATER
AUTOCRAFT BUILDING AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				TBC Criteria		EPA Carcinogen Class(7)	Potential Concern?
			EPA MCLs(1)	EPA Secondary MCLs(2)	Virginia GW Stds(3)	Va GW Protection Levels(4)	Virginia GW Criteria(5)	EPA RBC Criteria(6) Tap Water		
VOCs (ug/l)										
Chloroform	1/4	11	100	-	-	-	-	0.15	B2	**Yes**
SVOCs (ug/l)	0/4	-								
TPH (mg/l)										
Total TPH	0/4	-								
Dissolved Metals (ug/l)										
Calcium	2/2	5,800 - 31,000	-	-	-	-	-	-	-	
Iron	2/2	110 - 8,100	-	300	-	-	300	2,200	-	**Yes**
Magnesium	2/2	3.7 - 4,600	-	-	-	-	-	-	-	
Manganese	1/2	80	-	50	-	-	50	73	D	**Yes**
Potassium	2/2	2,100 - 15,000	-	-	-	-	-	-	-	
Sodium	2/2	11,000 - 15,000	-	-	270,000	270,000	100,000	-	-	

Notes:

(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations
(5) Virginia Water Quality Criteria for Groundwater
(6) EPA Region III Risk-based Concentration Table for Tap Water (Sept 2001)
(7) Weight-of-Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6-27
HAZARD ASSESSMENT FOR SURFACE AND SUBSURFACE SOILS - AUTO CRAFT BUILDING SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
VOCs (ug/kg)							
Acetone	1/18	31	-	20,000,000	780,000	D	
Ethylbenzene	1/18	1.6	-	20,000,000	780,000	D	
Methylene Chloride	1/18	41	-	760,000	85,000	B2	
Methyl ethyl ketone	4/16	55 - 100	-	100,000,000	4,700,000	D	
Styrene	2/18	4.8 - 6	-	41,000,000	1,600,000	D	
Toluene	11/18	7 - 34	-	41,000,000	1,600,000	D	
Trichloroethene	1/18	33	-	520,000	58,000	D	
Xylenes	1/18	16	-	41,000,000	1,600,000	D	
SVOCs (ug/kg)							
Acenaphthene	2/18	70 - 440	-	12,000,000	470,000	D	
Anthracene	1/18	250	-	61,000,000	2,300,000	D	
Benzo(a)anthracene	2/18	620 - 2500	-	7,800	870	B2	**Yes**
Benzo(b)fluoranthene	2/18	1,100 - 4,100	-	7,800	880	B2	**Yes**
Benzo(k)fluoranthene	2/18	490 - 770	-	78,000	8,800	B2	
Benzo(g,h,I)perylene	1/18	2,000	-	-	-	D	
Benzo(a)pyrene	2/18	940 - 3,400	-	780	87	B2	**Yes**
Butyllbenzylphthalate	2/18	550	-	41,000,000	1,600,000	D	
Chrysene	2/18	520 - 2,000	-	780,000	88,000	B2	
Fluoranthene	2/18	900 - 5,800	-	8,200,000	310,000	D	
Fluorene	1/18	65	-	8,200,000	310,000	D	
Indeno(1,2,3-cd)pyrene	2/18	260 - 1,500	-	7,800	870	B2	**Yes**
Naphthalene	1/18	8.2	-	4,100,000	160,000	D	
Phenanthrene	2/18	890 - 1,300	-	-	-	D	
Pyrene	2/18	1,600 - 11,000	-	6,100,000	230,000	D	
TPH (mg/kg)							
Total TPH	5/18	160 - 390	100	-	-	-	

TABLE 6-27
HAZARD ASSESSMENT FOR SURFACE AND SUBSURFACE SOILS - AUTO CRAFT BUILDING SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class (3)	Potential Concern?
			Virginia Petroleum Program (1)	EPA RBC Criteria			
				Industrial Soils (2)	Residential Soils (2)		
Total Metals (mg/kg)							
Aluminum	4/4	500 - 5,200	-	100,000	7,800	-	
Arsenic	4/4	1.1 - 1.5	-	3.8	0.43	A	**Yes**
Barium	4/4	2.8 - 82	-	14,000	550	-	
Beryllium	1/4	0.058	-	410	16	D	
Cadmium	1/4	0.18	-	100	3.9	D	
Calcium	3/4	84 - 1,200	-	-	-	-	
Chromium	4/4	2.3 - 8.6	-	610	23	-	
Cobalt	2/4	0.79 - 4.4	-	4,100	160	D	
Copper	2/4	5 -18	-	8,200	310	D	
Iron	4/4	1,200 - 9,100	-	120,000	4,700	-	**Yes**
Lead	4/4	1.7 - 95	-	1,200	400	B2	
Magnesium	4/4	96 - 2,400	-	-	-	-	
Manganese	4/4	10 - 170	-	4,100	160	D	**Yes**
Mercury	3/4	0.011 - 0.1	-	-	-	-	
Nickel	2/4	1.1 - 4.8	-	4,100	160	D	
Potassium	3/4	130 - 2,700	-	-	-	-	
Sodium	2/4	20 - 64	-	-	-	-	
Vanadium	4/4	1.8 - 18	-	1,400	55	D	
Zinc	4/4	4.5 - 64	-	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Sept 2001)
(3) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6-28
COMPARISON OF EXPOSURE CONCENTRATIONS
AUTOCRAFT BUILDING AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Soils		
Ingestion of and Dermal Contact with Chemicals	ug/kg	ug/kg
Benzo(a)anthracene	2,500	**175**
Benzo(b)fluoranthene	4,100	**175**
Benzo(a)pyrene	3,400	**175**
Indeno(1,2,3-cd)pyrene	1,500	**175**
	mg/kg	mg/kg
Arsenic	**1.5**	NA
Iron	**9,100**	NA
Manganese	**170**	NA
Groundwater		
Ingestion of, Dermal Contact with, and Inhalation of Chemicals	ug/l	ug/l
Chloroform	**11**	NA
Iron	**8,100**	NA
Manganese	**80**	NA

Notes:
Bolded/shaded numbers indicate the concentrations to be used in the quantitative assessment
NA - Not applicable because insufficient number of samples to calculate 95th percentile UCL.

TABLE 6-29
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL ROUTE
AUTO CRAFT BUILDING AREA

COPC	Chronic RfDo (mg/kg-day)	Adjusted RfD [1] (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
METALS							
Arsenic	3.00E-04	1.23E-04	Low	Perpigmentation, keratosis	Oral/IRIS	3	1
Iron	3.00E-01	4.50E-02	Medium	Hemosiderosis	Oral	10	1
Manganese	2.30E-02	9.20E-04	Medium	CNS effects	IRIS	1	1
VOCs							
Chloroform	1.00E-02	2.00E-03	Medium	Fatty cyst formation	Oral/IRIS	1000	1
SVOCs							
Benzo(a)anthracene	---	---	---	---	---	---	---
Benzo(b)fluoranthene	---	---	---	---	---	---	---
Benzo(a)pyrene	---	---	---	---	---	---	---
Inden(1,2,3-cd)pyrene	---	---	---	---	---	---	---

Notes:

(1) RfD adjusted for dermal exposures by using absorption efficiency factors
(Adjusted RfD = RfDo x absorption efficiency factor)

TABLE 6-30
TOXICITY VALUES: CARCINOGENIC EFFECTS FOR ORAL ROUTES
AUTO CRAFT BUILDING AREA

COPC	CPSo $(mg/kg\text{-}day)^{-1}$	Adjusted CPS[(1)] $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Class	Type of Cancer	SF Basis	SF Source
METALS						
Arsenic	1.50E+00	3.66E+00	A	Skin and lung	Oral	IRIS
Iron	---	---	D			
Manganese	---	---	D			
VOCs						
Chloroform	6.10E-03	3.05E-02	B2	Tumors	Oral	IRIS
SVOCs						
Benzo(a)anthracene	7.30E-01	2.35E+00	B2	Stomach tumors in mice	Oral	IRIS
Benzo(b)fluoranthene	7.30E-01	2.35E+00	B2	Stomach tumors in mice	Oral	IRIS
Benzo(a)pyrene	7.30E+00	2.35E+01	B2	Stomach tumors in mice	Oral	IRIS
Inden(1,2,3-cd)pyrene	7.30E-01	2.35E+00	B2	Stomach tumors in mice	Oral	IRIS

Notes:

(1) CPS adjusted for dermal exposures by using absorption efficiency factors
(Adjusted CPS = CPSo/absorption efficiencey factor)

(2) IRIS - Integrated Risk Information System (USEPA database)

(3) HEAST - Health Effects Assessment Summary Table

TABLE 6-31
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	RfD Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC In Soil	Arsenic	2.05E-06	No	3.00E-04	6.83E-03	
	Iron	1.11E-02	No	3.00E-01	3.70E-02	
	Manganese	2.33E-04	No	2.30E-02	1.01E-02	
	Benzo(a)anthracene	2.40E-07	No	---	--	
	Benzo(b)fluoranthene	2.40E-07	No	---	---	
	Benzo(a)pyrene	2.40E-07	No	---	---	
	Indeno(1,2,3-cd)pyrene	2.40E-07	No	---	---	5.40E-02
Dermal Contact with COPC in Soil	Arsenic	4.73E-07	Yes	1.23E-04	3.85E-03	
	Iron	7.99E-04	Yes	4.50E-02	1.78E-02	
	Manganese	1.68E-05	Yes	9.20E-04	1.83E-02	
	Benzo(a)anthracene	1.73E-07	Yes	---	--	
	Benzo(b)fluoranthene	1.73E-07	Yes	---	---	
	Benzo(a)pyrene	1.73E-07	Yes	---	---	
	Indeno(1,2,3-cd)pyrene	1.73E-07	Yes	---	---	3.99E-02
Ingestion of COPCs in Groundwater	Chloroform	3.01E-04	No	1.00E-02	3.01E-02	
	Iron	2.22E-01	No	3.00E-01	7.40E-01	
	Manganese	2.19E-03	No	2.30E-02	9.52E-02	8.65E-01
Dermal Contact with COPCs in Groundwater	Chloroform	7.81E-06	Yes	2.00E-03	3.91E-03	
	Iron	6.46E-04	Yes	4.50E-02	1.44E-02	
	Manganese	6.38E-06	Yes	9.20E-04	6.93E-03	2.52E-02
Inhalation of COPCs in Groundwater	Chloroform	1.99E-03	No	8.60E-05	2.31E+01	
	Iron	0.00E+00	No	---	---	
	Manganese	0.00E+00	No	---	---	2.31E+01
				Total Exposure Hazard Index		**2.41E+01**

TABLE 6-31
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	RfD Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
CHILDREN						
Ingestion of COPC In Soil	Arsenic	1.92E-05	No	3.00E-04	6.40E-02	
	Iron	1.04E-01	No	3.00E-01	3.47E-01	
	Manganese	2.17E-03	No	2.30E-02	9.43E-02	
	Benzo(a)anthracene	2.24E-06	No	---	--	
	Benzo(b)fluoranthene	2.24E-06	No	---	---	
	Benzo(a)pyrene	2.24E-06	No	---	---	
	Indeno(1,2,3-cd)pyrene	2.24E-06	No	---	---	5.05E-01
Dermal Contact with COPC in Soil	Arsenic	1.27E-06	Yes	1.23E-04	1.03E-02	
	Iron	2.15E-03	Yes	4.50E-02	4.78E-02	
	Manganese	4.51E-05	Yes	9.20E-04	4.90E-02	
	Benzo(a)anthracene	4.64E-07	Yes	---	--	
	Benzo(b)fluoranthene	4.64E-07	Yes	---	---	
	Benzo(a)pyrene	4.64E-07	Yes	---	---	
	Indeno(1,2,3-cd)pyrene	4.64E-07	Yes	---	---	1.07E-01
Ingestion of COPCs in Groundwater	Chloroform	7.03E-04	No	1.00E-02	7.03E-02	
	Iron	5.18E-01	No	3.00E-01	1.73E+00	
	Manganese	5.11E-03	No	2.30E-02	2.22E-01	2.02E+00
Dermal Contact with COPCs in Groundwater	Chloroform	1.37E-05	Yes	1.00E-02	1.37E-03	
	Iron	1.14E-03	Yes	4.50E-02	2.53E-02	
	Manganese	1.12E-05	Yes	9.20E-04	1.22E-02	3.89E-02
Inhalation of COPCs in Groundwater	Chloroform	5.59E-03	No	8.60E-05	6.50E+01	
	Iron	0.00E+00	No	---	---	
	Manganese	0.00E+00	No	---	---	6.50E+01
				Total Exposure Hazard Index		**6.77E+01**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

TABLE 6-32
CANCER RISK ESTIMATES
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	CPS Adjusted For Absorption	CPS $(mg/kg\text{-}day)^{-1}$	Chemical Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Soil	Arsenic	7.05E-07	No	1.50E+00	1.06E-06	
	Iron	3.80E-03	No	---	---	
	Manganese	7.98E-05	No	---	---	
	Benzo(a)anthracene	8.22E-08	No	7.30E-01	6.00E-08	
	Benzo(b)fluoranthene	8.22E-08	No	7.30E-01	6.00E-08	
	Benzo(a)pyrene	8.22E-08	No	7.30E+00	6.00E-07	
	Indeno(1,2,3-cd)pyrene	8.22E-08	No	7.30E-01	6.00E-08	1.84E-06
Dermal Contact with COPC in Soil	Arsenic	1.62E-07	No	3.66E+00	5.94E-07	
	Iron	2.74E-04	No	---	---	
	Manganese	5.75E-06	No	---	---	
	Benzo(a)anthracene	5.92E-08	No	2.35E+00	1.39E-07	
	Benzo(b)fluoranthene	5.92E-08	No	2.35E+00	1.39E-07	
	Benzo(a)pyrene	5.92E-08	No	2.35E+01	1.39E-06	
	Indeno(1,2,3-cd)pyrene	5.92E-08	No	2.35E+00	1.39E-07	2.40E-06
Ingestion of COPCs in Groundwater	Chloroform	1.03E-04	No	6.10E-03	6.28E-07	
	Iron	7.61E-02	No	---	0.00E+00	
	Manganese	7.51E-04	No	---	0.00E+00	6.28E-07
Dermal Contact with COPCs in Groundwater	Chloroform	2.68E-06	Yes	3.05E-02	8.17E-08	
	Iron	2.21E-04	Yes	---	0.00E+00	
	Manganese	2.19E-06	Yes	---	0.00E+00	8.17E-08
Inhalation of COPCs in Groundwater	Chloroform	6.82E-04	No	8.10E-02	5.52E-05	
	Iron	0.00E+00	No	---	0.00E+00	
	Manganese	0.00E+00	No	---	0.00E+00	5.52E-05
				Total Exposure Hazard Index		**6.02E-05**

TABLE 6-32
CANCER RISK ESTIMATES
RESIDENTIAL POPULATION

Exposure Pathway	COPC	CDI (mg/kg-day)	CPS Adjusted For Absorption	CPS $(mg/kg\text{-}day)^{-1}$	Chemical Risk	Total Pathway Risk
CHILDREN						
Ingestion of COPC in Soil	Arsenic	1.64E-06	No	1.50E+00	2.47E-06	
	Iron	8.88E-03	No	---	---	
	Manganese	1.86E-04	No	---	---	
	Benzo(a)anthracene	1.92E-07	No	7.30E-01	1.40E-07	
	Benzo(b)fluoranthene	1.92E-07	No	7.30E-01	1.40E-07	
	Benzo(a)pyrene	1.92E-07	No	7.30E+00	1.40E-06	
	Indeno(1,2,3-cd)pyrene	1.92E-07	No	7.30E-01	1.40E-07	4.29E-06
Dermal Contact with COPC in Soil	Arsenic	1.09E-07	No	3.66E+00	3.99E-07	
	Iron	1.84E-04	No	---	---	
	Manganese	3.86E-06	No	---	---	
	Benzo(a)anthracene	3.98E-08	No	2.35E+00	9.35E-08	
	Benzo(b)fluoranthene	3.98E-08	No	2.35E+00	9.35E-08	
	Benzo(a)pyrene	3.98E-08	No	2.35E+01	9.35E-07	
	Indeno(1,2,3-cd)pyrene	3.98E-08	No	2.35E+00	9.35E-08	1.62E-06
Ingestion of COPCs in Groundwater	Chloroform	6.03E-05	No	6.10E-03	3.68E-07	
	Iron	4.44E-02	No	---	0.00E+00	
	Manganese	4.38E-04	No	---	0.00E+00	3.68E-07
Dermal Contact with COPCs in Groundwater	Chloroform	1.18E-06	Yes	3.05E-02	3.60E-08	
	Iron	9.73E-05	Yes	---	0.00E+00	
	Manganese	9.61E-07	Yes	---	0.00E+00	3.60E-08
Inhalation of COPCs in Groundwater	Chloroform	4.79E-04	No	8.10E-02	3.88E-05	
	Iron	0.00E+00	No	---	0.00E+00	
	Manganese	0.00E+00	No	---	0.00E+00	3.88E-05
					Total Exposure Hazard Index	**4.51E-05**

Notes:
CDI = Chronic Daily Intake
CPS - Cancer Potency Slope
Risk = CDI x CPS

Table 7-1
Dominant Vegetation at the FTA Site
Fort Story, Virginia

Common Name	Scientific Name
Vegetation at the FTA Site	
Clover	*Trifolium sp.*
Grasses	*Poa sp.*
Aster	*Aster sp.*
Mustard	Family *Cruciferae*
Pixie	*Diapensia sp.*
Wild Onion	*Allium canadense*
Common Dandelion	*Taraxacum officinale*
Vegetation in the Adjacent Woodland Area	
Live Oak	*Quercus virginiana*
Loblolly Pine	*Pinus taeda*
Water Oak	*Quercus nigra*
Sweet Bay	*Magnolia virginiana*
Lowbush Blueberry	*Vaccinium angustifolium*
Red Maple	*Acer ruburm*
American Holly	*Ilex opaca*
Sweet Gum	*Liquidambar styraciflua*
Common Greenbrier	*Smilax rotundifolia*
Broom Sedge	*Andropogon virginicus*
Virginia Pine	*Pinus virginiana*
Black Locust	*Robinia pseudo-acacia*
Black Cherry	*Prunus serotina*
European Honeysuckle	*Locinaria xylosteum*
Southern Cane	*Arudinaria gigantea*
Wax Myrtle	*Myrica cerifera*

Table 7-2
Dominant Vegetation at the LARC 60 Site
Fort Story, Virginia

Common Name	Scientific Name
Vegetation at the Former UST Area	
Clover	*Trifolium sp.*
Grasses	*Poa sp.*
Aster	*Aster sp.*
Wild Onion	*Allium canadense*
Vegetation in the Adjacent Wooded Area	
Live Oak	*Quercus virginiana*
Loblolly Pine	*Pinus taeda*
Water Oak	*Quercus nigra*
Red Bay	*Persea borbonia*
Highbush Blueberry	*Vaccinium corymbosum*
Red Maple	*Acer ruburm*
American Holly	*Ilex opaca*
Inkberry	*Ilex glabra*
Common Greenbrier	*Smilax rotundifolia*
Broom Sedge	*Andropogon virginicus*
Virginia Pine	*Pinus virginiana*
Vegetation Associated with the Drainage Ditch in the Adjacent Wooded Area	
Soft Rush	*Juncus effusus*
Seed Box	*Ludwigia alternifolia*
Virginia Sweet Spires	*Itea virginica*
Highbush Blueberry	*Vaccinium corymbosum*
Broom Sedge	*Andropogon virginicus*
Wax Myrtle	*Myrica cerifera*

Table 7-3
Dominant Vegetation at the Auto Craft Site
Fort Story, Virginia

Common Name	Scientific Name
Vegetation in the Auto Craft Site	
Grasses	*Poa sp.*
Aster	*Aster sp.*
Wild Onion	*Allium canadense*
Vegetation in the Adjacent Grassy Area	
Grasses	*Poa sp.*
Aster	*Aster sp.*
Wild Onion	*Allium canadense*
Pixie	*Diapensia sp.*
Clover	*Trifolium sp.*
Vegetation in the Adjacent Wooded Area	
Live Oak	*Quercus virginiana*
Water Oak	*Quercus nigra*
Red Bay	*Persea borbonia*
American Holly	*Ilex opaca*
Common Greenbrier	*Smilax rotundifolia*
Wax Myrtle	*Myrica cerifera*

TABLE 7-4
CHEMICAL-SPECIFIC ARARs AND TBC FOR SOIL AND SEDIMENT

Parameters	TBC Criteria			
	EPA Region III BTAG Screening Levels for Soil		EPA Region III BTAG Screening Levels for Sediment	
	Flora (mg/kg)	Fauna (mg/kg)	Flora (mg/kg)	Fauna (mg/kg)
VOCs				
Acetone	-	-	-	-
Chloroform	-	<0.30	-	-
Methylene chloride	<0.30	<0.30	-	-
Methyl ethyl ketone	-	-	-	-
Styrene	0.1	0.1	-	-
Toluene	-	0.10	-	-
Trichloroethylene	<0.30	<0.30	-	-
Xylene	<0.10	<0.10	-	0.04
SVOCs				
Acenaphthene	0.10	0.10	0.016	0.016
Anthracene	0.10	0.10	-	0.0853
Benz(a)anthracene	0.10	0.10	0.261	0.261
Benzo(b)fluoranthene	0.10	0.10	3.2	3.2
Benzo(k)fluoranthene	0.10	0.10	-	-
Benzo(g,h,i)perylene	0.10	0.10	0.67	0.67
Benzo(a)pyrene	-	0.10	0.43	0.43
Bis(2-EH)phthalate	-	-	-	1.3
Butylbenzylphthalate	-	-	-	0.063
Carbazole	-	-	-	-
Chrysene	0.10	0.10	0.384	0.384
Dibenz(a,h)anthracene	0.10	0.10	0.0634	0.0634
Dibenzofuran	-	-	-	-
Di-n-butylphthalate	-	-	-	1.4
Fluoranthene	0.10	0.10	0.60	0.60
Fluorene	-	-	-	-
Indeno(1,2,3-cd)pyrene	0.10	0.10	0.60	0.60
2-Methylnaphthalene	-	-	0.07	0.07
Naphthalene	0.10	0.10	0.16	0.16
Phenanthrene	0.10	0.10	0.24	0.24
Pyrene	0.10	0.10	0.665	0.665
Pesticides				
alpha-Chlordane	< 0.10	< 0.10	-	-
gamma-Chlordane	< 0.10	< 0.10	-	-
4,4'-DDD	< 0.10	< 0.10	-	<0.016
4,4'-DDE	< 0.10	< 0.10	0.0022	0.0022
4,4'-DDT	< 0.10	< 0.10	0.00158	0.00158
Endosulfan sulfate	-	-	-	-
Endrin ketone *	<0.10	< 0.10	-	-
Heptachlor	-	-	-	-
Methoxychlor	<0.10	< 0.10	-	-

TABLE 7-4
CHEMICAL-SPECIFIC ARARs AND TBC FOR SOIL AND SEDIMENT

Parameters	TBC Criteria			
	EPA Region III BTAG Screening Levels for Soil		EPA Region III BTAG Screening Levels for Sediment	
	Flora (mg/kg)	Fauna (mg/kg)	Flora (mg/kg)	Fauna (mg/kg)
Inorganics				
Aluminum	1.00	-	-	-
Antimony	0.48	-	-	150
Arsenic	328	-	8.2	8.2
Barium	440	440	-	-
Beryllium	0.02	-	-	-
Cadmium	2.5	-	5.1	1.2
Chromium	0.02	0.0075	0.005	260
Cobalt	100	220	-	-
Copper	15	-	-	34
Cyanide	-	>0.005	-	-
Iron	3,260	12	-	-
Lead	2	0.01	-	46.7
Manganese	330	330	-	-
Mercury	0.058	0.058	0.15	0.15
Nickel	2	-	20.9	20.9
Selenium	1.8	1.8	-	-
Thallium	0.001	-	-	-
Vanadium	0.5	58	-	-
Zinc	10	-	-	150

Source:
EPA Region III BTAG Screening Levels for Ecological Risks (August 1995)

TABLE 7- 5
CHEMICAL-SPECIFIC ARARs AND TBC FOR SURFACE WATER

Parameters	ARARs				TBC Criteria	
	Virginia Surface Water (Freshwater) Quality Standards [1]		Federal Ambient Water (Freshwater) Quality Criteria [2]		EPA Region III BTAG Screening (Freshwater) [3]	
	Acute (ug/l)	Chronic (ug/l)	Acute (ug/l)	Chronic (ug/l)	Flora (ug/l)	Fauna (ug/l)
VOCs						
Acetone	-	-	-	-	-	9,000,000
SVOCs						
bis(2-EH)phthalate	-	-	-	-	-	30
2,4-Dimethylphenol	-	-	-	-	-	2,120
4-Methylphenol	-	-	-	-	-	-
Pesticides						
4,4-DDD	-	-	-	-	-	0.60
4,4-DDE	-	-	-	-	-	1,050
4,4-DDT	1.1	0.001	1.1	0.001	5,000	0.001
Total Metals						
Aluminum	-	-	-	-	460	25
Barium	-	-	-	-	10000	10,000
Beryllium	-	-	-	-	-	5.3
Chromium	2,656	316	1,700	210	-	120
Cobalt	-	-	-	-	-	35000
Copper	5	4	18	12	-	6.5
Iron	-	-	-	-	-	320
Lead	14	0.54	82	3.2	-	3.2
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	14,500
Nickel	439	49	1,400	160	340	160
Thallium	-	-	-	-	-	40
Vanadium	-	-	-	-	-	10,000
Zinc	-	-	120	110	30	110

Notes:
(1) Virginia Surface Water Quality Standards
(2) Federal Ambient Water Quality Criteria
(3) EPA Region III BTAG Screening Levels for Aquatics in Surface Water (August 1995)

TABLE 7-6
SITE SPECIFIC AND REGIONAL BACKGROUND CONCENTRATIONS
FORT STORY, VIRGINIA

Parameters	Fort Story Background 95th UCL [1]	USGS Regional Soils Data [2]	
		Observed Range	Mean
Aluminum	Not analyzed	7,000 ->100,000	33,000
Arsenic	2.1	<0.2 - 73	5.4
Barium	5	15 - 1,000	300
Calcium	Not analyzed	<100 - 160,000	3,200
Chromium	2.8	1 - 100	36
Cobalt	Not analyzed	<3 - 70	7
Copper	1.4	<1 - 150	14
Iron	Not analyzed	100 - >100,000	15,000
Lead	7.1	<7 - 300	14
Magnesium	Not analyzed	50 - 50,000	2,300
Manganese	Not analyzed	<2 - 7,000	290
Mercury	0.01	0.01 - 0.34	0.096
Nickel	2	<3 - 700	13
Potassium	Not analyzed	50 - 37,000	7,400
Sodium	Not analyzed	<200 - 15,000	2,600
Thallium	Not analyzed	~	~
Vanadium	Not analyzed	<5 - 300	46
Zinc	5.7	<5 - 400	36

Notes:

(1) James M. Montgomery, Inc. 1992.

(2) Comor et al, 1975.

TABLE 7-7
ECOLOGICAL ASSESSMENT FOR SURFACE SOIL
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels [1]		Exceed or Lacking Criteria?
			Flora	Fauna	
VOCs (ug/kg)					
Acetone	3/28	140 - 220	-	-	**Yes**
Methylene chloride	2/28	5.0 - 6.4	-	<300.0	
Methyl ethyl ketone	1/28	28.0	-	-	**Yes**
Styrene	1/28	3.0	-	100.0	
Toluene	25/28	8.3 - 140	-	100.0	**Yes**
Xylenes	1/28	7	-	-	**Yes**
SOCs (ug/kg)					
Benzo(b)fluoranthene	1/28	97	100.0	100.0	
Benzo(k)fluoranthene	1/28	86	100.0	100.0	
bis(2-EH)phthalate	1/28	110	-	-	**Yes**
Chrysene	1/28	94	100.0	100.0	
Di-n-butylphthalate	1/28	150	-	-	**Yes**
Fluoranthene	2/28	75 - 650	100.0	100.0	**Yes**
Pyrene	2/28	64 - 720	100.0	100.0	**Yes**
TPH (mg/kg)					
TPH as Heavy Oils	3/28	48 - 5300	-	-	**Yes**
Inorganics (mg/kg)					
Aluminum	5/5	420 - 980	1.0	-	**Yes**
Arsenic	4/5	1.2 - 1.6	328.0	-	**Yes**
Barium	5/5	3.9 - 12.0	440.0	440.0	
Calcium	4/5	71 - 370	-	-	
Chromium	5/5	1.7 - 5.8	0.02	0.0075	**Yes**
Copper	5/5	3.2 - 13	15.0	-	**Yes**
Iron	5/5	1,200 - 5,400	3,260.0	12.0	**Yes**
Lead	5/5	7.0 - 33.0	2	0.01	**Yes**
Magnesium	5/5	62 - 190	-	-	
Manganese	5/5	10 - 34	330.0	330.0	
Potassium	1/5	160	-	-	
Vanadium	5/5	1.8 - 3.7	0.5	58.0	
Zinc	5/5	14 - 22	10.0	-	**Yes**

Note:
(1) EPA Region III BTAG Screening Levels for Ecological risks (Aug. 1995)

TABLE 7-8
ECOLOGICAL ASSESSMENT FOR SEDIMENT
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels [1]		Exceed or Lacking Criteria?
			Flora	Fauna	
VOCs (ug/kg)					
Toluene	4/4	23 - 180	-	-	**Yes**
SVOCs (ug/kg)		BDL			
TPH (mg/kg)					
Total TPH	3/4	130 - 350	-	-	**Yes**
Metals (mg/kg)					
Aluminum	4/4	160 - 7600	-	-	**Yes**
Arsenic	1/4	2.5	8.2	8.2	
Barium	4/4	2.4 - 110	-	-	**Yes**
Calcium	4/4	64 - 120	-	-	
Chromium	1/4	21	0.005	260.0	**Flora**
Cobalt	1/4	2.6	-	-	**Yes**
Copper	1/4	26	-	34.0	
Iron	4/4	230 - 17,000	-	-	**Yes**
Lead	4/4	4.3 - 210	0.0125	46.7	**Yes**
Magnesium	1/4	960	-	-	
Manganese	3/4	1.7 - 42	-	-	**Yes**
Mercury	2/4	0.017 - 0.051	0.15	0.15	
Potassium	1/4	260	-	-	
Sodium	2/4	87 - 180	-	-	
Thallium	1/4	1.4	-	-	**Yes**
Vanadium	2/4	2 - 18	-	-	**Yes**
Zinc	2/4	6 - 76	-	150.0	

Note:
(1) EPA Region III BTAG Screening Levels for Ecological Risks (Aug. 1995)

TABLE 7-9
ECOLOGICAL ASSESSMENT FOR SURFACE SOIL
FT. STORY - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels [1]		Exceed or Lacking Criteria?
			Flora	Fauna	
VOCs (ug/kg)					
Acetone	1/22	36	-	-	**Yes**
Methylene Chloride	7/22	5.2 - 160	-	<300.0	
Toluene	1/22	6.0	-	100.0	
Trichloroethene	2/22	5.9 - 6.4	-	<300.0	
SVOCs (ug/kg)	0/22	BDL			
TPH (mg/kg)					
Total TPH	19/22	42 - 1500	-	-	**Yes**
Metals (mg/kg)					
Aluminum	5/5	250 - 2,700	1.0	-	**Yes**
Arsenic	1/5	1.1	328.0	-	**Yes**
Barium	5/5	1.8 - 19	440.0	440.0	
Calcuim	4/5	56 - 980	-	-	
Chromium	5/5	1.7 - 4.3	0.02	0.0075	**Yes**
Cobalt	1/5	2.30	100.0	220.0	
Copper	4/5	2.5 - 41	15.0	-	**Yes**
Iron	5/5	400 - 1,100	3,260.0	12.0	**Yes**
Lead	5/5	3.1 - 12	2	0.01	**Yes**
Magnesium	4/5	77 - 1,400	-	-	
Manganese	5/5	2.4 - 120	330.0	330.0	
Potassium	1/5	1,200	-	-	
Vanadium	5/5	1.2 - 9.2	0.5	58.0	**Flora**
Zinc	5/5	3.8 - 33	10.0	-	**Yes**

Notes:

(1) EPA Region III BTAG Screening Levels for Ecological risks (Aug 1995)

(2) James M. Montgomery, Inc. 1992.

(3) Comor et al, 1975.

TABLE 7-10
ECOLOGICAL ASSESSMENT FOR SEDIMENT
FT. STORY - LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria		Exceed or Lacking Criteria?
			EPA Region III BTAG Screening Levels [1]		
			Flora	Fauna	
VOCs (ug/kg)	0/2	BDL			
SOCs (ug/kg)	0/2	BDL			
TPH (mg/kg)					
Total TPH	2/2	530 - 2700	-	-	**Yes**
Inorganics (mg/kg)					
Aluminum	2/2	310 - 650	-	-	**Yes**
Barium	2/2	1.4 - 2.7	-	-	**Yes**
Calcium	2/2	53 - 210	-	-	
Chromium	2/2	1.6 - 2.5	0.005	260	**Flora**
Copper	2/2	3.8 - 9.0	-	34	
Iron	2/2	310 - 940	-	-	**Yes**
Lead	2/2	8.2 - 14	-	46.7	
Magnesium	2/2	110 - 250	-	-	
Manganese	2/2	3.4 - 6.9	-	-	**Yes**
Sodium	1/2	70.00	-	-	
Vanadium	2/2	1.3 - 2.7	-	-	**Yes**
Zinc	2/2	11 - 30	-	150.0	

Notes:
(1) EPA Region III BTAG Screening Levels for Ecological Risks (August 1995)

TABLE 7-11
ECOLOGICAL ASSESSMENT FOR SURFACE WATER
FT. STORY - LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria		ARARs				Exceed or Lacking Criteria
			EPA Region III BTAG Screening (Freshwater) [1]		Virginia SW (Freshwater) Quality Standards[2]		Federal AWQC (Freshwater)[3]		
			Flora	Fauna	Acute	Chronic	Acute	Chronic	
VOCs (ug/l)									
Acetone	2/2	30 - 35	-	9,000,000	-	-	-	-	
SVOCs (ug/l)	0/2	BDL							
TPH (mg/l)									
Total TPH	0/2	BDL							
Total Metals (ug/l)									
Aluminum	2/2	0.39 - 0.42	460	25	-	-	-	-	
Calcium	2/2	11 - 12	-	-	-	-	-	-	
Iron	2/2	0.84 - 1.4	-	320	-	-	-	-	
Lead	2/2	0.0078 - 0.009	-	3.2	14	0.54	82	3.2	
Magnesium	2/2	15 - 17	-	-	-	-	-	-	**Yes**
Manganese	2/2	0.083 - 0.14	-	14,500	-	-	-	-	
Potassium	2/2	9.1 - 9.4	-	-	-	-	-	-	
Sodium	1/2	120.0	-	-	-	-	-	-	
Zinc	2/2	0.04 - 0.062	30	110	-	-	120	110	

Notes:
(1) EPA Region III BTAG Screening Levels for Aquatics in Surface Water (Aug 1995)
(2) Virginia Surface Water Quality Standards (VR 680-21-01.14)
(3) Federal Ambient Water Quality Criteria (40 CFR 131)

TABLE 7-12
ECOLOGICAL ASSESSMENT FOR SURFACE SOIL
FT. STORY - AUTO CRAFT SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels [1]		Exceed or Lacking Criteria?
			Flora	Fauna	
VOCs (ug/kg)					
Methylene chloride	1/6	41	-	<300.0	
Methyl ethyl ketone	1/6	55	-	-	**Yes**
Toluene	6/6	7.9 - 34	-	100.0	
Trichloroethene	1/6	33	-	<300.0	
SVOCs (ug/kg)					
Acenaphthene	1/6	440.0	100.0	100.0	**Yes**
Benz(a)anthracene	1/6	2,500	100.0	100.0	**Yes**
Benzo(b)fluoranthene	1/6	4,100	100.0	100.0	**Yes**
Benzo(k)fluoranthene	1/6	490	100.0	100.0	**Yes**
Benzo(g,h,i)perylene	1/6	2,000	100.0	100.0	**Yes**
Benzo(a)pyrene	1/6	3,400	-	100.0	**Yes**
Butylbenzylphthalate	1/6	550	-	-	**Yes**
Chrysene	1/6	2,000	100.0	100.0	**Yes**
Fluoranthene	1/6	5,800	100.0	100.0	**Yes**
Indeno(1,2,3-cd)pyrene	1/6	1,500	100.0	100.0	**Yes**
Phenanthrene	1/6	1,300	100.0	100.0	**Yes**
Pyrene	1/6	11,000	100.0	100.0	**Yes**
TPH (mg/kg)					
Total TPH	3/6	220 - 390	-	-	**Yes**
Metals (mg/kg)					
Aluminum	1/1	5,200	1.0	-	**Yes**
Arsenic	1/1	1.30	328.0	-	**Yes**
Barium	1/1	82	440.0	440.0	
Calcuim	1/1	1,200	-	-	
Chromium	1/1	9	0.02	0.0075	**Yes**
Cobalt	1/1	4.40	100.0	220.0	
Copper	1/1	18	15.0	-	**Yes**
Iron	1/1	9,100	3,260.0	12.0	**Flora**
Lead	1/1	95	2.0	0.01	**Yes**
Magnesium	1/1	2,400	-	-	
Manganese	1/1	170	330.0	330.0	
Mercury	1/1	0.022	-	0.058	
Nickel	1/1	4.8	2.0	-	**Yes**
Potassium	1/1	2,700	-	-	
Sodium	1/1	64	-	-	
Vanadium	1/1	18	0.5	58.0	**Yes**
Zinc	1/1	64	10.0	-	**Yes**

Notes:

(1) EPA Region III BTAG Screening Levels for Ecological Risks (Aug 1995)

(2) James M. Montgomery, Inc. 1992.

(3) Comor et al, 1975.

TABLE 7-13
COPCs and EXPOSURE POINT CONCENTRATIONS - SURFACE SOILS
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
VOCs (mg/kg)				
Acetone	3/28	0.14 - 0.22	2.20E-01	3.43E-02
Toluene	25/28	.0083 - 0.140	1.40E-01	4.81E-02
SOCs (mg/kg)				
Fluoranthene	2/28	0.075 - 0.650	6.50E-01	NA
Pyrene	2/28	0.064 - 0.720	7.20E-01	NA
Metals (mg/kg)				
Chromium	5/5	1.7 - 5.8	5.80E+00	NA
Copper	5/5	3.2 - 13	1.30E+01	NA
Lead	5/5	7.0 - 33.0	3.30E+01	NA
Zinc	5/5	14 - 22	2.20E+01	NA

Notes: Shading indicates concentration selected for exposure calculations. The maximum of the soil and sediment values were used. Where COPC concentrations are not shaded, the higher sediment values were used in the exposure calculations.

TABLE 7-14
COPCs and EXPOSURE POINT CONCENTRATIONS - SEDIMENT
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
VOCs (mg/kg)				
Toluene	4/4	.023 - 0.180	1.80E-01	NA
METALS (mg/kg)				
Aluminum	4/4	160 - 7600	7.60E+03	NA
Barium	4/4	2.4 - 110	1.10E+02	NA
Cobalt	1/4	2.6	2.60E+00	NA
Iron	4/4	230 - 17,000	1.70E+04	NA
Lead	4/4	4.3 - 210	2.10E+02	NA
Manganese	3/4	1.7 - 42	4.20E+01	NA
Thallium	1/4	1.4	1.40E+00	NA
Vanadium	2/4	2 - 18	1.80E+01	NA

Notes: Shading indicates concentration selected for exposure calculations. The maximum of the soil and sediment values were used where contaminants were detected in both media. Where COPC concentrations are not shaded, the higher soil values were used in the exposure calculations.

TABLE 7- 15
COPC - SURFACE SOILS CONCENTRATION
FORT STORY - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
Metals (mg/kg)				
Chromium	5/5	1.7-4.3	4.30E+00	NA
Copper	4/5	2.5 - 41	4.10E+01	NA
Lead	5/5	3.1 - 12	1.20E+01	NA
Zinc	5/5	3.8 - 33	3.30E+01	NA

Notes: Shading indicates concentration selected for exposure calculations.

TABLE 7- 16
COPC - SEDIMENT CONCENTRATION
FORT STORY - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
Metals (mg/kg)				
Aluminum	2/2	310 - 650	6.50E+02	NA
Barium	2/2	1.4 - 2.7	2.70E+00	NA
Iron	2/2	310 - 940	9.40E+02	NA
Manganese	2/2	3.4 - 6.9	6.90E+00	NA
Vanadium	2/2	1.3 - 2.7	2.70E+00	NA

Notes: Shading indicates concentration selected for exposure calculations.

TABLE 7-17
COPCs and EXPOSURE POINT CONCENTRATIONS - SURFACE SOILS
FORT STORY - AUTO CRAFT SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
SVOCs (mg/kg)				
Acenaphthene	1/6	0.44	4.40E-01	3.11E-01
Benz(a)anthracene	1/6	2.50	2.50E+00	2.95E+00
Benzo(b)fluoranthene	1/6	4.10	4.10E+00	1.18E+01
Benzo(k)fluoranthene	1/6	0.49	4.90E-01	3.39E-01
Benzo(g,h,i)perylene	1/6	2.00	2.00E+00	2.00E+00
Benzo(a)pyrene	1/6	3.40	3.40E+00	5.33E+00
Butylbenzylphthalate	1/6	0.55	5.50E-01	3.76E-01
Chrysene	1/6	2.00	2.00E+00	2.00E+00
Fluoranthene	1/6	5.80	5.80E+00	1.76E+01
Indeno(1,2,3-cd)pyrene	1/6	1.50	1.50E+00	1.26E+00
Phenanthrene	1/6	1.30	1.30E+00	1.02E+00
Pyrene	1/6	11.00	1.10E+01	8.91E+01
Metals (mg/kg)				
Chromium	1/1	9.0	9.00E+00	NA
Copper	1/1	18	1.80E+01	NA
Iron	1/1	9,100	9.10E+03	NA
Lead	1/1	95	9.50E+01	NA
Nickel	1/1	4.8	4.80E+00	NA
Zinc	1/1	64	6.40E+01	NA

Note: Shading indicates concentration selected for exposure calculations

TABLE 7-18
EXPOSURE FACTORS FOR ECOLOGICAL RECEPTORS
FORT STORY - FTA, LARC, AND AUTO CRAFT SITES

Receptor	Exposure Factors [1]									
			Dietary Composition (% diet)							
	NIR_f (g/g-day)	IR (kg/day)(dw)	Vegetation	Invertebrates	Birds	Small Mammals	Soil/Sediment Ingestion	Body Weight (kg)	Home Range (hectares)	Exposure Duration[2]
Killdeer	0.134	0.0123	10%[3]	90%[3]	-	-	10%[4]	0.092 [5]	10.36 [6]	0.66
Northern Bobwhite	0.078	0.018	14%	86%	-	-	10.4 (Woodcock)	0.167	3.6	1
White-footed Mouse	0.20	0.003	42%	58%	-	-	<2%	0.0225	0.61	1
Gray Fox	0.09	0.24	7%	0%	46.50%	46.50%	2.80%	4.5	96	1

Notes:

NIR_f = Ingestion rate of food, normalized to body weight.

IR = Daily ingestion rate of food.

[1] Reference: USEPA, 1993 (unless otherwise noted)

[2] = Fraction of year spent in region, 0-1 (unitless), Killdeer is migratory

[3] = Martin et. al., 1961.

[4] = Beyer et. al., 1992.

[5] = Dunning Jr., 1993.

[6] = DeGraaf and Rudis, 1986.

Area of Sites:

FTA	1.5 Ha
Auto Craft	.33 Ha
LARC	4.2 Ha

TABLE 7-19

PLANT AND INVERTEBRATE UPTAKE FACTORS
FORT STORY, VIRGINIA

Chemical	Plant Uptake Factor	Reference	Invertebrate (Earthworm) Uptake Factor	Reference
PAHs	0.0122(a)	(b)	0.7(a)	(c)
Acetone	1	(f)	1	(f)
Toluene	0.94	(b)	1	(f)
Aluminum	0.004	(e)	1	(f)
Barium	0.15	(e)	1	(f)
Chromium	0.0075	(e)	0.1	(d)
Cobalt	0.03	(e)	1	(f)
Copper	0.4	(e)	2.4	(h)
Iron	0.004	(e)	1	(f)
Lead	0.045	(e)	0.95	(g)
Manganese	0.25	(e)	1	(f)
Nickel	0.06	(e)	1.9	(g)
Thallium	0.004	(e)	1	(f)
Vanadium	0.0055	(e)	1	(f)
Zinc	1.5	(e)	5.7	(g)

Notes:

(a) Value is for benzo[a]pyrene.
(b) Calculated as $PUF = 38.9(Kow)^{-0.58}$, fromTravis and Hattemer-Frey, 1988.
(c) Beyer, 1990.
(d) Ma, 1982.
(e) Baes et al., 1984
(f) Assumed to equal soil concentration (PUF, EUF = 1) since uptake information was not found for this chemical.
(g) Gish and Christensen, 1973.
(h) Beyer et. al., 1982

TABLE 7-20
ESTIMATED TOXICITY TO TERRESTRIAL PLANTS AND SOIL/SEDIMENT INVERTEBRATES
FORT STORY, VIRGINIA

COPC	FTA Site	LARC Site	Auto Craft Site	Phytotoxicity Value[1]	Invertebrate (Earthworm) Toxicity Value[2]	Exceeds Ecological Criteria?
Surface Soil (mg/kg)						
Acetone	2.20E-01	~	~	NA	NA	
Toluene	1.40E-01	~	~	2.00E+02	NA	No
Acenaphthene	~	~	4.40E-01	2.00E+01	NA	No
Benzo(a)anthracene	~	~	2.50E+00	NA	NA	
Benzo(b)fluoranthene	~	~	4.10E+00	NA	NA	
Benzo(k)fluoranthene	~	~	4.90E-01	NA	NA	
Benzo(g,h,i)perylene	~	~	2.00E+00	NA	NA	
Benzo(a)pyrene	~	~	3.40E+00	NA	NA	
Butylbenzylphthalate	~	~	5.50E-01	NA	NA	
Chrysene	~	~	2.00E+00	NA	NA	
Fluoranthene	6.50E-01	~	5.80E+00	NA	NA	
Indeno(1,2,3-cd)pyrene	~	~	1.50E+00	NA	NA	
Phenanthrene	~	~	1.30E+00	NA	NA	
Pyrene	7.20E-01	~	1.10E+01	NA	NA	
Chromium	5.80E+00	4.30E+00	9.00E+00	1.00E+00	1.00E+01	Yes (veg. - all sites)
Copper	1.30E+01	4.10E+01	1.80E+01	1.00E+02	5.00E+01	No
Iron	1.70E+04	~	9.10E+03	NA	2.00E+02	Yes (invert. - FTA and AC)
Lead	3.30E+01	1.20E+01	9.50E+01	5.00E+01	9.00E+02	Yes (veg. - AC Site)
Nickel	~	~	4.80E+00	3.00E+01	9.00E+01	No
Zinc	2.20E+01	3.30E+01	6.40E+01	5.00E+01	1.00E+02	Yes (veg. - AC Site)
Sediment (mg/kg)						
Toluene	1.80E-01	~	~	2.00E+02	NA	No
Aluminum	7.60E+03	6.50E+02	~	5.00E+01	6.00E+02	Yes (FTA and LARC)
Barium	1.10E+02	2.70E+00	~	5.00E+02	3.00E+03	No
Cobalt	2.60E+00	~	~	2.00E+01	1.00E+03	No
Iron	1.70E+04	9.40E+02	~	NA	2.00E+02	Yes (invert. - FTA and LARC)
Lead	2.10E+02	~	~	5.00E+01	9.00E+02	Yes (veg. - FTA Site)
Manganese	4.20E+01	6.90E+00	~	5.00E+02	1.00E+02	No
Thallium	1.40E+00	~	~	1.00E+00	NA	Yes (veg. - FTA Site)
Vanadium	1.80E+01	2.70E+00	~	2.00E+00	2.00E+01	Yes (veg. -FTA and LARC)

Notes:
~ = Not a COPC or was not tested at the site
NA = Not Available

References:
[1] Will and Suter, 1995b
[2] Will and Suter, 1995a

TABLE 7-21
KILLDEER ESTIMATED EXPOSURE - FTA SITE
FORT STORY, VIRGINIA

Chemical (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acetone	4.40E-05	3.98E-04	4.41E-05	4.87E-04
Toluene	2.31E-04	2.09E-03	2.18E-04	2.54E-03
Fluoranthene	8.34E-04	5.29E-03	1.02E-05	6.13E-03
Pyrene	9.24E-04	5.85E-03	1.13E-05	6.79E-03
Aluminum	9.75E+00	8.83E+01	3.91E-02	9.81E+01
Barium	1.41E-01	1.28E+00	2.12E-02	1.44E+00
Chromium	7.44E-03	6.74E-03	5.60E-05	1.42E-02
Cobalt	3.34E-03	3.02E-02	1.00E-04	3.36E-02
Copper	1.67E-02	3.62E-01	6.69E-03	3.86E-01
Iron	2.18E+01	1.97E+02	8.75E-02	2.19E+02
Lead	2.70E-01	2.32E+00	1.22E-02	2.60E+00
Manganese	5.39E-02	4.88E-01	1.35E-02	5.55E-01
Thallium	1.80E-03	1.63E-02	7.20E-06	1.81E-02
Vanadium	2.31E-02	2.09E-01	1.27E-04	2.32E-01
Zinc	2.82E-02	1.46E+00	4.25E-02	1.53E+00

Notes:
BW = Body Weight

TABLE 7-22
WHITE FOOTED MOUSE ESTIMATED EXPOSURE - FTA SITE
FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acetone	9.15E-05	3.98E-03	2.88E-03	6.95E-03
Toluene	4.80E-04	2.09E-02	1.42E-02	3.56E-02
Fluoranthene	1.73E-03	5.28E-02	6.66E-04	5.52E-02
Pyrene	1.92E-03	5.85E-02	7.38E-04	6.11E-02
Aluminum	2.03E+01	8.82E+02	2.55E+00	9.04E+02
Barium	2.93E-01	1.28E+01	1.39E+00	1.44E+01
Chromium	1.55E-02	6.73E-02	3.65E-03	8.64E-02
Cobalt	6.93E-03	3.02E-01	6.55E-03	3.15E-01
Copper	3.47E-02	3.62E+00	4.37E-01	4.09E+00
Iron	4.53E+01	1.97E+03	5.71E+00	2.02E+03
Lead	5.60E-01	2.31E+01	7.94E-01	2.45E+01
Manganese	1.12E-01	4.87E+00	8.82E-01	5.87E+00
Thallium	3.73E-03	1.62E-01	4.70E-04	1.67E-01
Vanadium	4.80E-02	2.09E+00	8.32E-03	2.14E+00
Zinc	5.87E-02	1.45E+01	2.77E+00	1.74E+01

Notes:
BW = Body Weight

TABLE 7-23
GRAY FOX ESTIMATED EXPOSURE - FTA SITE
FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acetone	8.20E-07	4.59E-05	2.22E-05	6.81E-05	6.89E-05
Toluene	4.30E-06	2.34E-04	1.71E-05	2.51E-04	2.55E-04
Fluoranthene	1.55E-05	3.10E-04	7.86E-07	3.11E-04	3.26E-04
Pyrene	1.72E-05	3.43E-04	8.71E-07	3.44E-04	3.61E-04
Aluminum	1.82E-01	5.11E+00	3.06E-03	5.11E+00	5.29E+00
Barium	2.63E-03	8.47E-02	1.66E-03	8.64E-02	8.90E-02
Chromium	1.39E-04	4.17E-04	4.38E-06	4.22E-04	5.60E-04
Cobalt	6.21E-05	1.79E-03	7.86E-06	1.80E-03	1.86E-03
Copper	3.11E-04	2.44E-02	5.24E-04	2.49E-02	2.52E-02
Iron	4.06E-01	1.14E+01	6.85E-03	1.14E+01	1.18E+01
Lead	5.02E-03	1.40E-01	9.53E-04	1.41E-01	1.46E-01
Manganese	1.00E-03	3.52E-02	1.06E-03	3.62E-02	3.72E-02
Thallium	3.35E-05	9.41E-04	5.64E-07	9.42E-04	9.75E-04
Vanadium	4.30E-04	1.21E-02	9.98E-06	1.21E-02	1.26E-02
Zinc	5.26E-04	1.06E-01	1.15E-02	1.18E-01	1.18E-01

Notes:
BW = Body Weight

TABLE 7- 24
NORTHERN BOBWHITE ESTIMATED EXPOSURE
LARC SITE, FORT STORY, VIRGINIA

Chemical (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Aluminum	7.29E+00	7.15E+00	1.74E-01	1.46E+01
Barium	3.03E-02	2.97E-02	2.71E-02	8.71E-02
Copper	4.60E-01	1.08E+00	1.10E+00	2.64E+00
Iron	1.05E+01	1.03E+01	2.52E-01	2.11E+01
Lead	1.35E-01	1.25E-01	3.62E-02	2.96E-01
Manganese	7.73E-02	7.59E-02	1.16E-01	2.69E-01
Vanadium	3.03E-02	2.97E-02	9.95E-04	6.10E-02
Zinc	3.70E-01	2.07E+00	3.32E+00	5.76E+00

Note:
BW = Body Weight

TABLE 7- 25
WHITE-FOOTED MOUSE ESTIMATED EXPOSURE
LARC SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Aluminum	1.73E+00	7.54E+01	2.18E-01	7.74E+01
Barium	7.20E-03	3.13E-01	3.40E-02	3.54E-01
Copper	1.09E-01	1.14E+01	1.38E+00	1.29E+01
Iron	2.51E+00	1.09E+02	3.16E-01	1.12E+02
Lead	3.20E-02	1.32E+00	4.54E-02	1.40E+00
Manganese	1.84E-02	8.00E-01	1.45E-01	9.64E-01
Vanadium	7.20E-03	3.13E-01	1.25E-03	3.22E-01
Zinc	8.80E-02	2.18E+01	4.16E+00	2.61E+01

Note:
BW = Body Weight

TABLE 7- 26
GRAY FOX ESTIMATED EXPOSURE - LARC SITE
FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Aluminum	4.27E-02	1.20E+00	1.80E-01	1.38E+00	1.42E+00
Barium	1.77E-04	5.72E-03	7.48E-04	6.47E-03	6.64E-03
Copper	2.69E-03	2.11E-01	2.73E-02	2.39E-01	2.41E-01
Iron	6.18E-02	1.74E+00	2.61E-01	2.00E+00	2.06E+00
Lead	7.88E-04	2.20E-02	3.16E-03	2.51E-02	2.59E-02
Manganese	4.53E-04	1.59E-02	1.91E-03	1.78E-02	1.82E-02
Vanadium	1.77E-04	5.00E-03	7.48E-04	5.75E-03	5.92E-03
Zinc	2.17E-03	4.38E-01	5.21E-02	4.90E-01	4.92E-01

Note:
BW = Body Weight

TABLE 7-27
KILLDEER ESTIMATED EXPOSURE- AUTO CRAFT SITE
FORT STORY, VIRGINIA

Chemical (mg/kg)	Estimated Exposure from Soil (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acenaphthene	8.73E-05	5.53E-04	1.07E-06	6.42E-04
Benz(a)anthracene	7.02E-04	4.45E-03	8.58E-06	5.16E-03
Benzo(b)fluoranthene	1.15E-03	7.29E-03	1.41E-05	8.46E-03
Benzo(k)fluoranthene	9.52E-05	6.03E-04	1.16E-06	6.99E-04
Benzo(g,h,i)perylene	5.62E-04	3.56E-03	6.87E-06	4.13E-03
Benzo(a)pyrene	9.55E-04	6.05E-03	1.17E-05	7.01E-03
Butylbenzylphthalate	1.06E-04	6.69E-04	1.29E-06	7.76E-04
Chrysene	5.62E-04	3.56E-03	6.87E-06	4.13E-03
Fluoranthene	1.63E-03	1.03E-02	1.99E-05	1.20E-02
Indeno(1,2,3-cd)pyrene	3.54E-04	2.24E-03	4.33E-06	2.60E-03
Phenanthrene	2.86E-04	1.81E-03	3.50E-06	2.10E-03
Pyrene	3.09E-03	1.96E-02	3.78E-05	2.27E-02
Chromium	2.53E-03	2.29E-03	1.90E-05	4.83E-03
Copper	5.05E-03	1.10E-01	2.03E-03	1.17E-01
Iron	2.55E+00	2.31E+01	1.02E-02	2.57E+01
Lead	2.67E-02	2.29E-01	1.20E-03	2.57E-01
Nickel	1.35E-03	2.32E-02	8.10E-04	2.53E-02
Zinc	1.80E-02	1.32E+02	2.70E-02	1.32E+02

Note:
BW = Body Weight

TABLE 7-28
WHITE-FOOTED MOUSE ESTIMATED EXPOSURE
AUTO CRAFT SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Soil (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acenaphthene	4.48E-04	1.36E-02	1.72E-04	1.43E-02
Benz(a)anthracene	3.60E-03	1.10E-01	1.38E-03	1.15E-01
Benzo(b)fluoranthene	5.90E-03	1.80E-01	2.27E-03	1.88E-01
Benzo(k)fluoranthene	4.88E-04	1.49E-02	1.88E-04	1.55E-02
Benzo(g,h,i)perylene	2.88E-03	8.77E-02	1.11E-03	9.17E-02
Benzo(a)pyrene	4.90E-03	1.49E-01	1.88E-03	1.56E-01
Butylbenzylphthalate	5.41E-04	1.65E-02	2.08E-04	1.72E-02
Chrysene	2.88E-03	8.77E-02	1.11E-03	9.17E-02
Fluoranthene	9.36E-04	2.85E-02	3.60E-04	2.98E-02
Indeno(1,2,3-cd)pyrene	1.81E-03	5.52E-02	6.97E-04	5.78E-02
Phenanthrene	1.47E-03	4.47E-02	5.64E-04	4.68E-02
Pyrene	1.04E-03	3.16E-02	3.98E-04	3.30E-02
Chromium	1.30E-02	5.64E-02	3.06E-03	7.24E-02
Copper	2.59E-02	2.71E+00	3.27E-01	3.06E+00
Iron	1.31E+01	5.70E+02	1.65E+00	5.85E+02
Lead	1.37E-01	5.65E+00	1.94E-01	5.98E+00
Nickel	6.91E-03	5.71E-01	1.31E-01	7.09E-01
Zinc	9.22E-02	3.25E+03	4.35E+00	3.25E+03

Note:
BW = Body Weight

TABLE 7-29
GRAY FOX ESTIMATED EXPOSURE -
AUTO CRAFT SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acenaphthene	1.39E-06	2.78E-05	7.17E-08	2.79E-05	2.93E-05
Benz(a)anthracene	1.12E-05	2.24E-04	5.76E-07	2.24E-04	2.35E-04
Benzo(b)fluoranthene	1.84E-05	3.67E-04	9.45E-07	3.68E-04	3.86E-04
Benzo(k)fluoranthene	1.52E-06	3.03E-05	7.82E-08	3.04E-05	3.19E-05
Benzo(g,h,i)perylene	8.96E-06	1.79E-04	4.61E-07	1.79E-04	1.88E-04
Benzo(a)pyrene	1.52E-05	3.04E-04	7.84E-07	3.05E-04	3.20E-04
Butylbenzylphthalate	1.68E-06	3.36E-05	8.67E-08	3.37E-05	3.54E-05
Chrysene	8.96E-06	1.79E-04	4.61E-07	1.79E-04	1.88E-04
Fluoranthene	2.91E-06	5.81E-05	1.50E-07	5.83E-05	6.12E-05
Indeno(1,2,3-cd)pyrene	5.64E-06	1.13E-04	2.91E-07	1.13E-04	1.19E-04
Phenanthrene	4.57E-06	9.12E-05	2.35E-07	9.14E-05	9.60E-05
Pyrene	3.23E-06	6.44E-05	1.66E-07	6.45E-05	6.78E-05
Chromium	4.03E-05	1.21E-04	1.28E-06	1.23E-04	1.63E-04
Copper	8.06E-05	6.33E-03	1.36E-04	6.46E-03	6.54E-03
Iron	4.08E-02	8.14E-01	2.10E-03	8.16E-01	8.57E-01
Lead	4.26E-04	8.49E-03	2.19E-05	8.52E-03	8.94E-03
Nickel	2.15E-05	1.51E-03	5.44E-05	1.56E-03	1.58E-03
Zinc	2.87E-04	5.72E-03	1.48E-05	5.74E-03	6.02E-03

Note:
BW = Body Weight

TABLE 7-30
NOAELs FOR BIRDS AND MAMMALS: ENVIRONMENTAL ASSESSMENT
FORT STORY, VIRGINIA

COPC	NOAELs[1] (mg/kg BW-day)					
	Test Species (Avian)	Killdeer	Northern Bobwhite	Test Species (Mammal)	White-footed Mouse	Gray Fox
Acetone	NA	NA	NA	10 (rat)	24.96	4.27
Toluene	NA	NA	NA	25.98 (rat)	28.78	4.97
PAHs	NA	NA	NA	1(mus)[2]	1.11	0.19
Aluminum	109.7 (rd)	130.5	107.01	1.93 (mus)	2.12	0.363
Barium	20.8 (chicks)	22.79	18.68	5.1 (rat)	12.73	2.18
Chromium	1 (bd)	2.39	-	2,737 (rat)	6,832.3	1,168.7
Cobalt	NA	NA	-	NA	NA	NA
Copper	47 (ck)	71.80	58.86	11.71 (mk)[3]	41.26	7.13
Iron	NA	NA	NA	NA	NA	NA
Lead	3.85 (ak)	4.21	3.45	8 (rat)	19.94	3.44
Manganese	977 (jq)	1,208.2	990.46	88 (rat)	219.67	37.58
Nickel	77.4 (duckling)	157.96	-	40 (rat)	99.85	17.07
Thallium	NA	NA	NA	0.0074 (rat)	0.018	0.003
Vanadium	11.4 (ma)[4]	26.61	21.81	0.21 (rat)	0.52	0.09
Zinc	3 (ma)[4]	7.0	5.74	160 (rat)	398.72	68.88

Notes:
NA = Not Available
(1) NOAELs for laboratory species converted to receptor species NOAELs as follows (Opresko et al., 1994):

$$NOAEL_r = NOAEL_t\ (bw_t/bw_r)$$

Where: $NOAEL_r$ = receptor NOAEL
$NOAEL_t$ = test species NOAEL
bw_r = receptor body weight
bw_t = test species body weight

Body weights of test species (kg):

American Kestrel (ak) = 0.12
Black Duck (bd) = 1.25
Chicken (ck) = 0.328
Chicken (chicks) = 0.121
Japanese Quail (jq) = 0.174
Mallard (ma) = 1.17
Mallard Duckling (duckling) = 0.782
Mink (mk) = 1.0
Mouse (mus) = 0.03
Rat = 0.35
Ringed Dove (rd) = 0.155

(2) Value is for Benzo(a)pyrene
(3) Source: Heaton, 1992
(4) Source: Opresko et al., 1994
Source unless otherwise noted:
Opresko et al., 1995.

TABLE 7-31
SUMMARY OF EXPOSURE ESTIMATES AND HAZARD QUOTIENTS
FTA SITE, FORT STORY, VIRGINIA

Chemical	Killdeer			White-footed Mouse			Gray Fox		
	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ
	mg/kg BW-day			mg/kg BW-day			mg/kg BW-day		
Acetone	4.87E-04	NA	NA	6.95E-03	2.50E+01	2.79E-04	6.89E-05	4.27E+00	1.61E-05
Toluene	2.54E-03	NA	NA	3.56E-02	2.88E+01	1.24E-03	2.55E-04	4.97E+00	5.13E-05
Fluoranthene	6.13E-03	NA	NA	5.52E-02	1.11E+00	4.98E-02	3.26E-04	1.91E-01	1.71E-03
Pyrene	6.79E-03	NA	NA	6.11E-02	1.11E+00	5.52E-02	3.61E-04	1.91E-01	1.89E-03
Aluminum	9.81E+01	1.31E+02	7.52E-01	9.04E+02	2.12E+00	4.27E+02	5.29E+00	3.63E-01	1.46E+01
Barium	1.44E+00	2.28E+01	6.32E-02	1.44E+01	1.27E+01	1.13E+00	8.90E-02	2.18E+00	4.08E-02
Chromium	1.42E-02	2.39E+00	5.96E-03	8.64E-02	6.83E+03	1.26E-05	5.60E-04	1.17E+03	4.80E-07
Cobalt	3.36E-02	NA	NA	3.15E-01	NA	NA	1.86E-03	NA	NA
Copper	3.86E-01	7.18E+01	5.37E-03	4.09E+00	4.15E+01	9.86E-02	2.52E-02	7.09E+00	3.56E-03
Iron	2.19E+02	NA	NA	2.02E+03	NA	NA	1.18E+01	NA	NA
Lead	2.60E+00	4.21E+00	6.17E-01	2.45E+01	1.99E+01	1.23E+00	1.46E-01	3.44E+00	4.24E-02
Manganese	5.55E-01	1.21E+03	4.60E-04	5.87E+00	2.20E+02	2.67E-02	3.72E-02	3.76E+01	9.90E-04
Thallium	1.81E-02	NA	NA	1.67E-01	1.80E-02	9.26E+00	9.75E-04	3.20E-03	3.05E-01
Vanadium	2.32E-01	2.66E+01	8.73E-03	2.14E+00	5.20E-01	4.12E+00	1.26E-02	9.00E-02	1.40E-01
Zinc	1.53E+00	7.00E+00	2.18E-01	1.74E+01	3.99E+02	4.35E-02	1.18E-01	6.83E+01	1.73E-03

Notes:
BW = Body Weight
NA = Not Available
EE_{total} =Total Estimated Exposure from Soil + Food
NOAEL = No Observed Adverse Effects Level
HQ = Hazard Quotient
Shading indicates Hazard Quotients greater than 1

TABLE 7-32
SUMMARY OF EXPOSURE ESTIMATES AND HAZARD QUOTIENTS
LARC SITE, FORT STORY, VIRGINIA

Chemical (mg/kg)	Northern Bobwhite			White-footed Mouse			Gray Fox		
	EE_{total} mg/kg BW-day	NOAEL mg/kg BW-day	HQ	EE_{total} mg/kg BW-day	NOAEL mg/kg BW-day	HQ	EE_{total} mg/kg BW-day	NOAEL mg/kg BW-day	HQ
Aluminum	1.46E+01	1.07E+02	1.37E-01	7.74E+01	2.12E+00	3.65E+01	1.42E+00	3.63E-01	3.92E+00
Barium	8.71E-02	1.87E+01	4.66E-03	3.54E-01	1.27E+01	2.78E-02	6.64E-03	2.18E+00	3.05E-03
Copper	2.64E+00	5.89E+01	4.49E-02	1.29E+01	4.15E+01	3.11E-01	2.41E-01	7.09E+00	3.40E-02
Iron	2.11E+01	NA	NA	1.12E+02	NA	NA	2.06E+00	NA	NA
Lead	2.96E-01	3.45E+00	8.58E-02	1.40E+00	1.99E+01	7.02E-02	2.59E-02	3.44E+00	7.54E-03
Manganese	2.69E-01	9.90E+02	2.71E-04	9.64E-01	2.20E+02	4.39E-03	1.82E-02	3.76E+01	4.86E-04
Vanadium	6.10E-02	2.18E+01	2.80E-03	3.22E-01	5.20E-01	6.19E-01	5.92E-03	9.00E-02	6.58E-02
Zinc	5.76E+00	5.74E+00	1.00E+00	2.61E+01	3.99E+02	6.53E-02	4.92E-01	6.83E+01	7.20E-03

Notes:
BW = Body Weight
NA = Not Available
EE_{total} = Total Estimated Exposure from Media and Food
NOAEL = No Observed Adverse Effects Level
HQ = Hazard Quotient
Shading indicates Hazard Quotients greater than 1

TABLE 7-33
SUMMARY OF EXPOSURE ESTIMATES AND HAZARD QUOTIENTS
AUTO CRAFT SITE, FORT STORY, VIRGINIA

Chemical	Killdeer			White-footed Mouse			Gray Fox		
	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ
	mg/kg BW-day			mg/kg BW-day			mg/kg BW-day		
Acenaphthene	6.42E-04	NA	NA	1.43E-02	1.11E+00	1.29E-02	2.93E-05	1.91E-01	1.53E-04
Benz(a)anthracene	5.16E-03	NA	NA	1.15E-01	1.11E+00	1.03E-01	2.35E-04	1.91E-01	1.23E-03
Benzo(b)fluoranthene	8.46E-03	NA	NA	1.88E-01	1.11E+00	1.70E-01	3.86E-04	1.91E-01	2.02E-03
Benzo(k)fluoranthene	6.99E-04	NA	NA	1.55E-02	1.11E+00	1.40E-02	3.19E-05	1.91E-01	1.67E-04
Benzo(g,h,i)perylene	4.13E-03	NA	NA	9.17E-02	1.11E+00	8.27E-02	1.88E-04	1.91E-01	9.86E-04
Benzo(a)pyrene	7.01E-03	NA	NA	1.56E-01	1.11E+00	1.41E-01	3.20E-04	1.91E-01	1.68E-03
Butylbenzylphthalate	7.76E-04	NA	NA	1.72E-02	1.11E+00	1.56E-02	3.54E-05	1.91E-01	1.85E-04
Chrysene	4.13E-03	NA	NA	9.17E-02	1.11E+00	8.27E-02	1.88E-04	1.91E-01	9.86E-04
Fluoranthene	1.20E-02	NA	NA	2.98E-02	1.11E+00	2.69E-02	6.12E-05	1.91E-01	3.20E-04
Indeno(1,2,3-cd)pyrene	2.60E-03	NA	NA	5.78E-02	1.11E+00	5.21E-02	1.19E-04	1.91E-01	6.21E-04
Phenanthrene	2.10E-03	NA	NA	4.68E-02	1.11E+00	4.22E-02	9.60E-05	1.91E-01	5.03E-04
Pyrene	2.27E-02	NA	NA	3.30E-02	1.11E+00	2.98E-02	6.78E-05	1.91E-01	3.55E-04
Chromium	4.83E-03	2.39E+00	2.02E-03	7.24E-02	6.83E+03	1.06E-05	1.63E-04	1.17E+03	1.40E-07
Copper	1.17E-01	5.07E+01	2.30E-03	3.06E+00	4.13E+01	7.41E-02	6.54E-03	7.13E+00	9.18E-04
Iron	2.57E+01	NA	NA	5.85E+02	NA	NA	8.57E-01	NA	NA
Lead	2.57E-01	4.21E+00	6.11E-02	5.98E+00	1.99E+01	3.00E-01	8.94E-03	3.44E+00	2.60E-03
Nickel	2.53E-02	1.58E+02	1.60E-04	7.09E-01	9.99E+01	7.10E-03	1.58E-03	1.71E+01	9.27E-05
Zinc	1.32E+02	6.12E+00	2.15E+01	3.25E+03	3.99E+02	8.16E+00	6.02E-03	6.89E+01	8.75E-05

Notes:

BW = Body Weight

NA = Not Available

EE_{total} =Total Estimated Exposure from Soil + Food

NOAEL = No Observed Adverse Effects Level

HQ = Hazard Quotient

Shading indicates Hazard Quotients greater than 1