03.12-05/01/95-01544

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# Remedial Investigation Report
# Operable Unit No. 4
# (Sites 41 and 74)

## Marine Corps Base
## Camp Lejeune, North Carolina

## Text and Figures
## Volume 2 of 2

Prepared For:

**Department of the Navy**
**Atlantic Division**
**Naval Facilities**
**Engineering Command**
Norfolk, Virginia

Under the

**LANTDIV CLEAN Program**

**Comprehensive Long-Term**
**Environmental Action Navy**

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**LIST OF APPENDICES**

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AOC | Area of concern |
| AQUIRE | Aquatic Information Retrieval Database |
| ARARs | Applicable or Relevant and Appropriate Requirements |
| ASTM | American Society for Testing and Materials |
| AT | averaging time |
| ATV | all terrain vehicle |
| AWQC | Federal Ambient Water Quality Criteria |
| | |
| Baker | Baker Environmental, Inc. |
| BCF | bioconcentration factor |
| bgs | below ground surface |
| BI | biotoxic index |
| BOD | biological oxygen demand |
| BRA | baseline risk assessment |
| | |
| $CaCO_3$ | calcium carbonate |
| CAMA | Coastal Area Management Act |
| CDI | chronic daily intake |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CH | high plasticity clay |
| CL | low plasticity clay |
| CLEAN | Comprehensive Long-Term Environmental Action Navy |
| CLP | Contract Laboratory Program |
| CN | chloroacetophene |
| COE | Corps of Engineers |
| COPC | contaminant of potential concern |
| COD | chemical oxygen demand |
| CRAVE | Carcinogen Risk Assessment Verification Endeavor |
| CRQL | Contract Required Quantitation Limit |
| CSA | Chemical Storage Area |
| CSF | Cancer Slope Factor |
| CSM | chemical surety material |
| | |
| DON | Department of the Navy |
| DQOs | data quality objectives |
| 1,2-DCE | 1,2-dichloroethene |
| DEM | Division of Environmental Management |
| DDE | dichlorodiphenyldichloroethylene |
| DDT | diphenyltrichloroethane |
| DS | downslope |
| | |
| ECD | electron capture detector |
| ED | exposure duration |
| EF | exposure frequency |
| Eh | oxidation reduction potential |
| EM | electromagnetic |

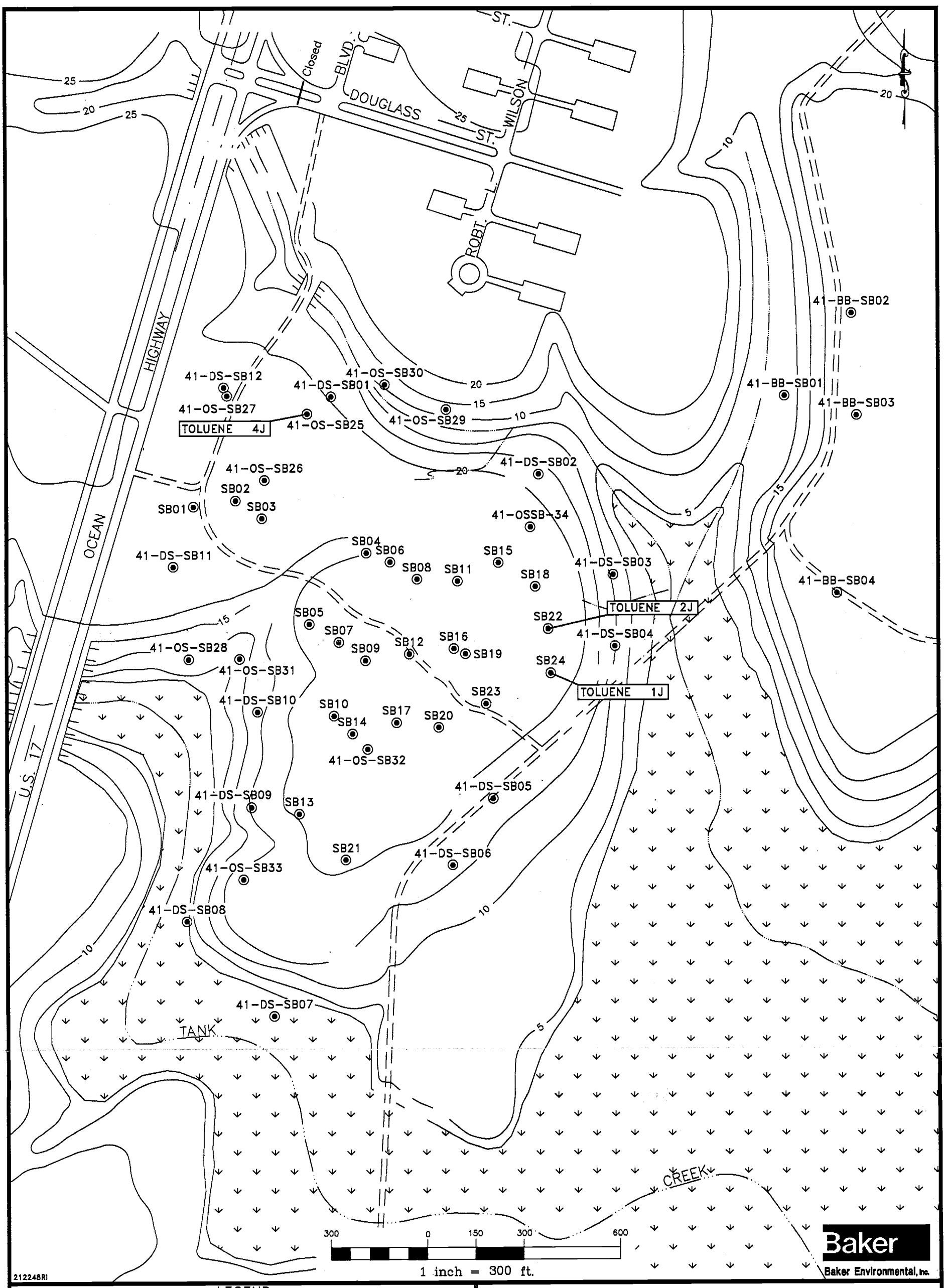
| | |
|---|---|
| EMD | Environmental Management Department |
| EPIC | Environmental Photographic Interpretation Center |
| ERA | ecological risk assessment |
| ER-L | Effects Range - Low |
| ER-M | Effects Range-Median |
| ESE | Environmental Science and Engineering, Inc. |
| ETC | electromagnetic terrain conductivity |
| | |
| FAWQC | Federal Ambient Water Quality Criteria |
| FDA | Former Disposal Area |
| FFA | Federal Facilities Agreement |
| FID | flame ionization detector |
| FPA | Former Pesticide Control Area |
| FSAP | Field Sampling and Analysis Plan |
| FWS | Fish and Wildlife Service |
| FWQSV | Freshwater Water Quality Screening Values |
| | |
| gpd/ft | gallons per day per foot |
| gpm | gallons per minute |
| GP | GP Environmental Services |
| GPR | ground penetrating radar |
| GW | groundwater well |
| | |
| H' | Diversity Index |
| HA | health advisory |
| HEAST | Health Effects Assessment Summary Tables |
| HHAG | Human Health Assessment Group |
| HHI | Hardin and Huber, Inc. |
| HHRA | Human Health Risk Assessment |
| HI | hazard index |
| Hoggard-Eure | Hoggard-Eure Associates |
| HCl | hydrochloric acid |
| $HNO_3$ | nitric acid |
| HQ | hazard quotient |
| HQW | high quality water |
| HTH | high-test hypochlorite |
| | |
| i | hydraulic gradient |
| IAS | Initial Assessment Study |
| ICR | incremental cancer risk |
| ID | inside diameter |
| IDW | investigative derived wastes |
| IR | ingestion rate |
| IRA | interim remedial action |
| IRIS | Integrated Risk Information System |
| IRP | Installation Restoration Program |
| | |
| K | hydraulic conductivity |
| $K_d$ | soil sorption coefficient |
| $K_{oc}$ | organic carbon partition coefficient |
| $K_{ow}$ | octanol-water partition coefficient |

| | |
|---|---|
| LANTDIV | Naval Facilities Engineering Command, Atlantic Division |
| LANTNAVFACENGCOM | Naval Facilities Engineering Command, Atlantic Division |
| LEL | lower explosive limit |
| LOAEL | lowest observed adverse effect level |
| | |
| MBI | Macroinvertebrate Biotic Index |
| MCAS | Marine Corps Air Station |
| MCB | Marine Corps Base |
| MCL | maximum contaminant level |
| MEK | methylethyl ketone |
| MIBK | methyl isobutyl ketone |
| mg/kg | milligram per kilogram |
| mg/L | milligram per liter |
| MF | modifying factor |
| MH | plastic silt |
| MI | mobility index |
| ml | milliliter |
| ML | low plasticity silt |
| mL/g | milliliters per gram |
| mmhos/m | millimohos/meter |
| msl | mean sea level |
| MW | monitoring well |
| | |
| NACIP | Navy Assessment and Control of Installation Pollutants Program |
| NC DEHNR | North Carolina Department of Environment, Health and Natural Resources |
| NCMFC | North Carolina Marine Fisheries Commission |
| NCSPCS | North Carolina State Plane Coordinate System |
| NCWP | Near Coastal Waters Program |
| NCWQS | North Carolina Water Quality Standards |
| NCWRC | North Carolina Wildlife Resources Commission |
| $N_e$ | effective porosity |
| NEESA | Naval Energy and Environmental Support Activity |
| NEP | National Estuary Program |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAEL or NOEL | No observed adverse effect level |
| NPL | National Priorities List |
| NPS | National Park Service |
| NSW | nutrient sensitive waters |
| NWI | national wetlands inventory |
| | |
| OD | outside diameter |
| OS | on-site |
| OU | Operable Unit |
| | |
| PAH | polynuclear aromatic hydrocarbon |
| PA/SI | preliminary assessments/site investigations |
| PC | permeability constant |
| PCBs | polychlorinated biphenyls |
| PCE | tetrachloroethene |
| PDA | Potential Disposal Area |

| | |
|---|---|
| PEF | particulate emissions factor |
| PHA | public health assessment |
| PID | photoionization detector |
| POL | petroleum, oil, lubricants |
| ppb | parts per billion |
| ppm | parts per million |
| psi | pounds per square inch |
| PVC | polyvinyl chloride |
| | |
| QA/QC | quality assurance/quality control |
| QI | quotient index |
| | |
| RA | risk assessment |
| RBC | risk based concentrations |
| RCRA | Resource Conservation and Recovery Act |
| RfD | reference dose |
| | |
| RI/FS | remedial investigation/feasibility study |
| ROD | record of decision |
| | |
| S, S | storativity, water solubility |
| SA | site assessment or surface area |
| SARA | Superfund Amendments and Reauthorization Act |
| Sj | Jaccard Coefficient |
| Ss | Sorenson Index |
| SB | soil boring |
| SCS | Soil Conservation Service |
| SD | sediment |
| SMCL | Secondary Drinking Water Regulations |
| SQC | sediment quality criteria |
| SOPs | standard operating procedures |
| SSV | sediment screening value |
| STP | sewage treatment plant |
| SVOCs | semivolatile organic compounds |
| SW | surface water |
| SWQSVs | surface water quality screening values |
| | |
| T | transmissivity |
| TAL | target analyte list |
| TBC | to be considered |
| TCE | trichloroethene |
| TCL | target compound list |
| TCLP | toxicity characteristic leaching procedure |
| TDS | total dissolved solids |
| TEF | toxicity equivalency factor |
| TEU | Technical Escort Unit |
| TICs | tentatively identified compounds |
| TOC | total organic carbon or top of casing |
| trans-1,2-DCE | trans-1,2-dichloroethene |
| TRC | Technical Review Committee |

| | |
|---|---|
| TRVs | terrestrial reference values |
| TSS | total suspended solids |
| TVS | total volatile solids |
| | |
| UCL | upper confidence limit |
| UF | uncertainty factor |
| $\mu$g/g | micrograms per gram |
| µg/L | micrograms per liter |
| USAEC | United States Army Environmental Center |
| USATHAMA | United States Army Toxic and Hazardous Materials Agency |
| USDA | United States Department of Agriculture |
| USDI | United States Department of the Interior |
| USEPA | United States Environmental Protection Agency |
| USCS | Unified Soil Classification System |
| USGS | United States Geological Survey |
| USMC | United States Marine Corps |
| UST | underground storage tank |
| | |
| VOCs | volatile organic compounds |
| VP | vapor pressure |
| $V_x$ | average seepage velocity |
| | |
| WAR | Water and Air Research, Inc. |
| Weston | Weston Geophysical Corporation |
| WOE | weight of evidence |
| WQS | water quality standards |
| WQSV | water quality screening values |
| WS | Wilderness Society |

# SECTION 4.0 FIGURES




LEGEND

- SB01 – SOIL BORING LOCATION
- – MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- – ROAD (IMPROVED)
- – ROAD (UNIMPROVED)
- – INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-1
POSITIVE DETECTIONS OF VOLATILES
IN SURFACE SOILS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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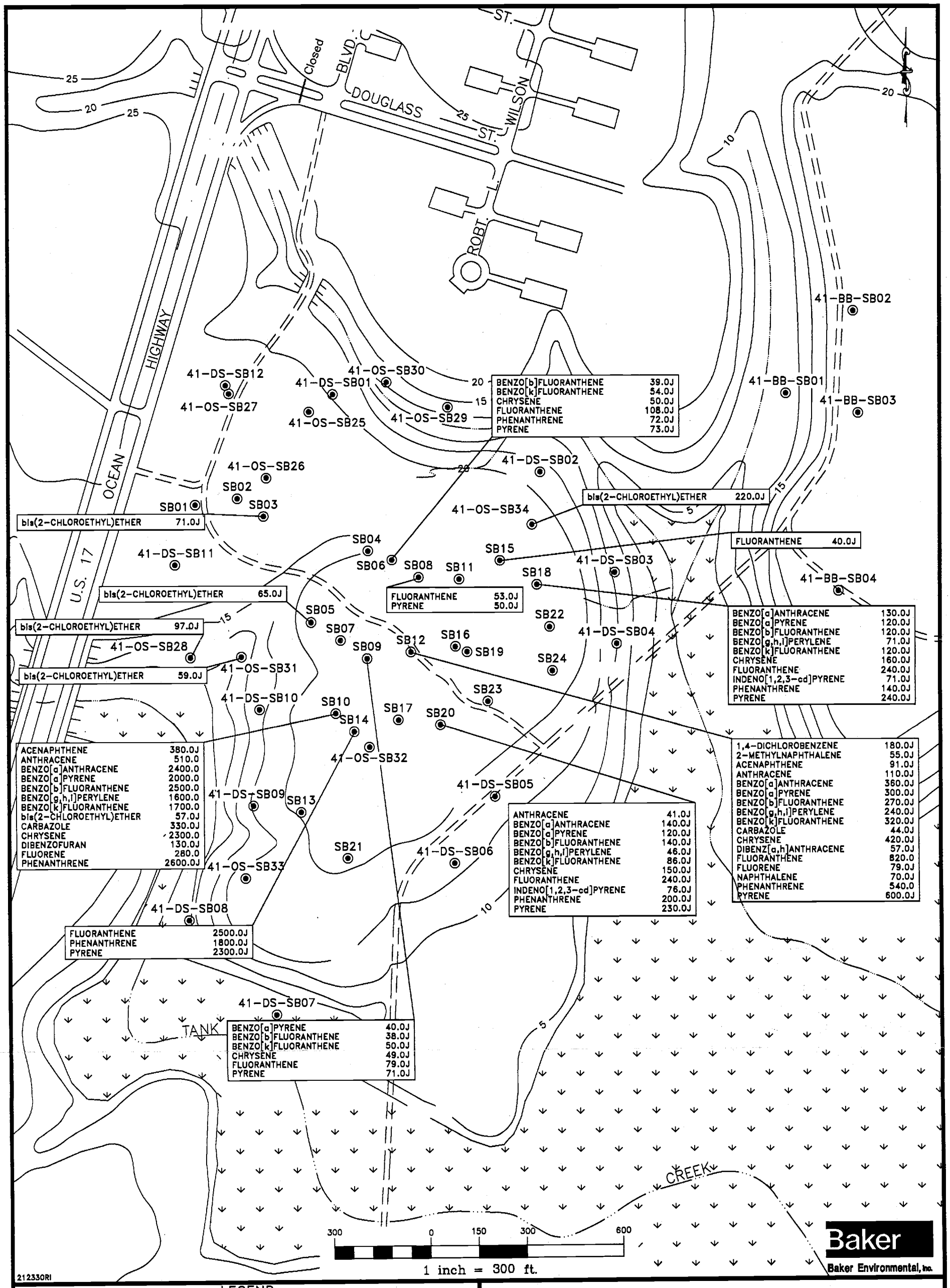
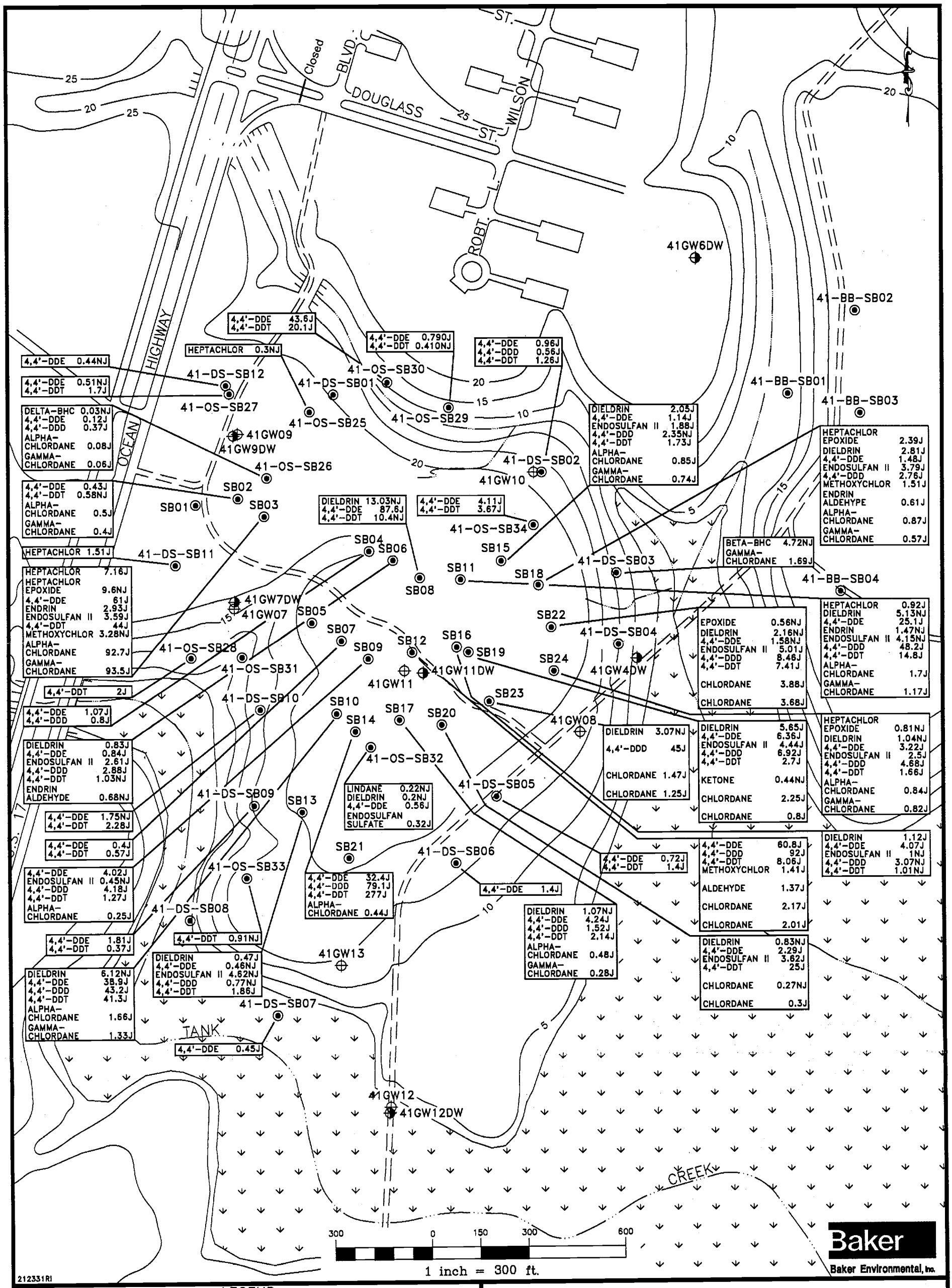



## LEGEND

- SB01 – SOIL BORING LOCATION
- – MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- – ROAD (IMPROVED)
- – ROAD (UNIMPROVED)
- – INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

# FIGURE 4-2
# POSITIVE DETECTIONS OF SEMIVOLATILES IN SURFACE SOILS – SITE 41
# CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
# REMEDIAL INVESTIGATION CTO-0212
# MARINE CORPS BASE, CAMP LEJEUNE
# NORTH CAROLINA

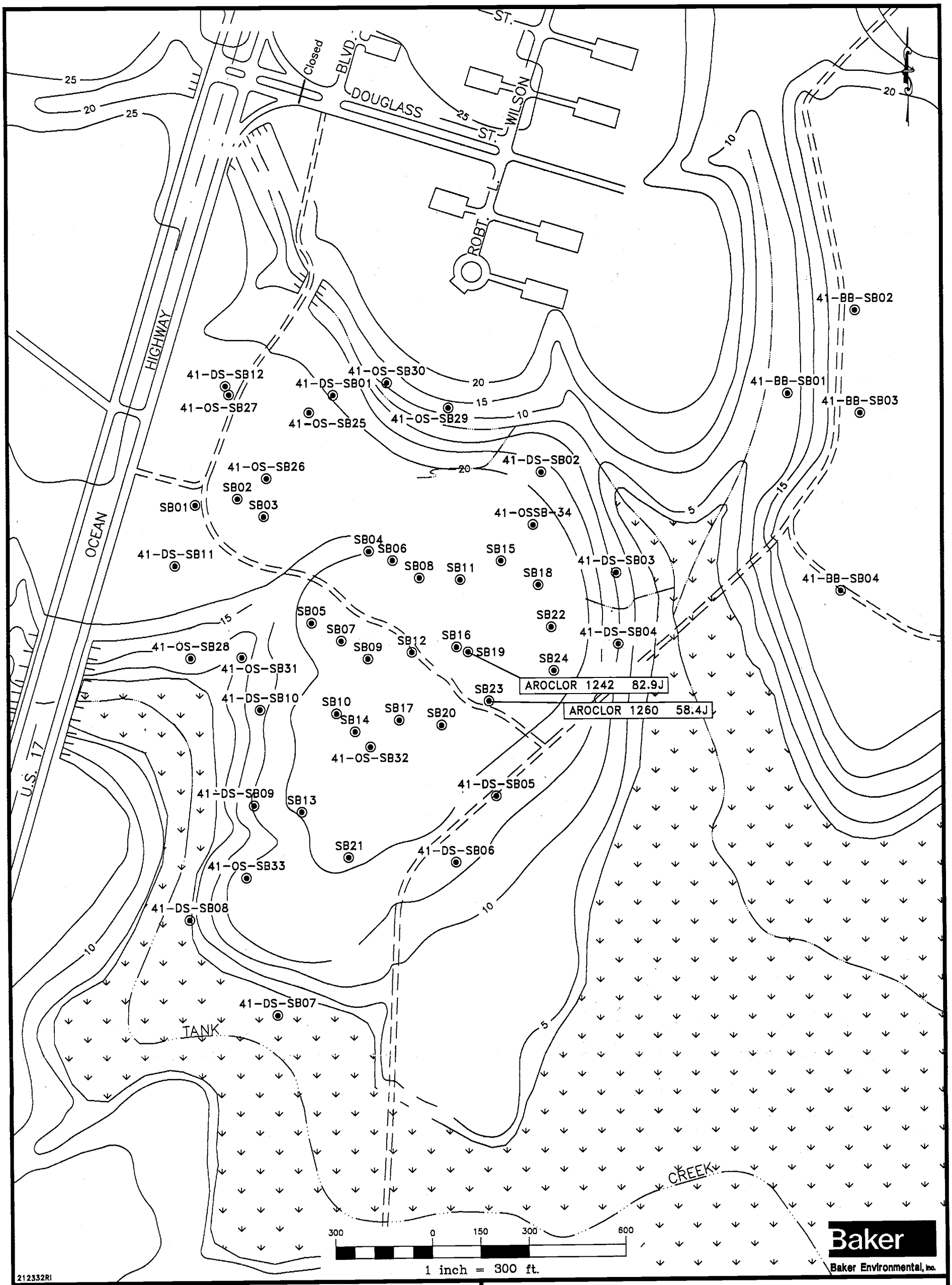



## LEGEND

- 41GW07 – SHALLOW MONITORING WELL LOCATION
- 41GW4D – DEEP MONITORING WELL LOCATION
- SB01 – SOIL BORING LOCATION
- – MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- – ROAD (IMPROVED)
- – ROAD (UNIMPROVED)
- – INTERMITTENT STREAM

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-3
POSITIVE DETECTIONS OF PESTICIDES ABOVE
1 ug/kg IN SURFACE SOILS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

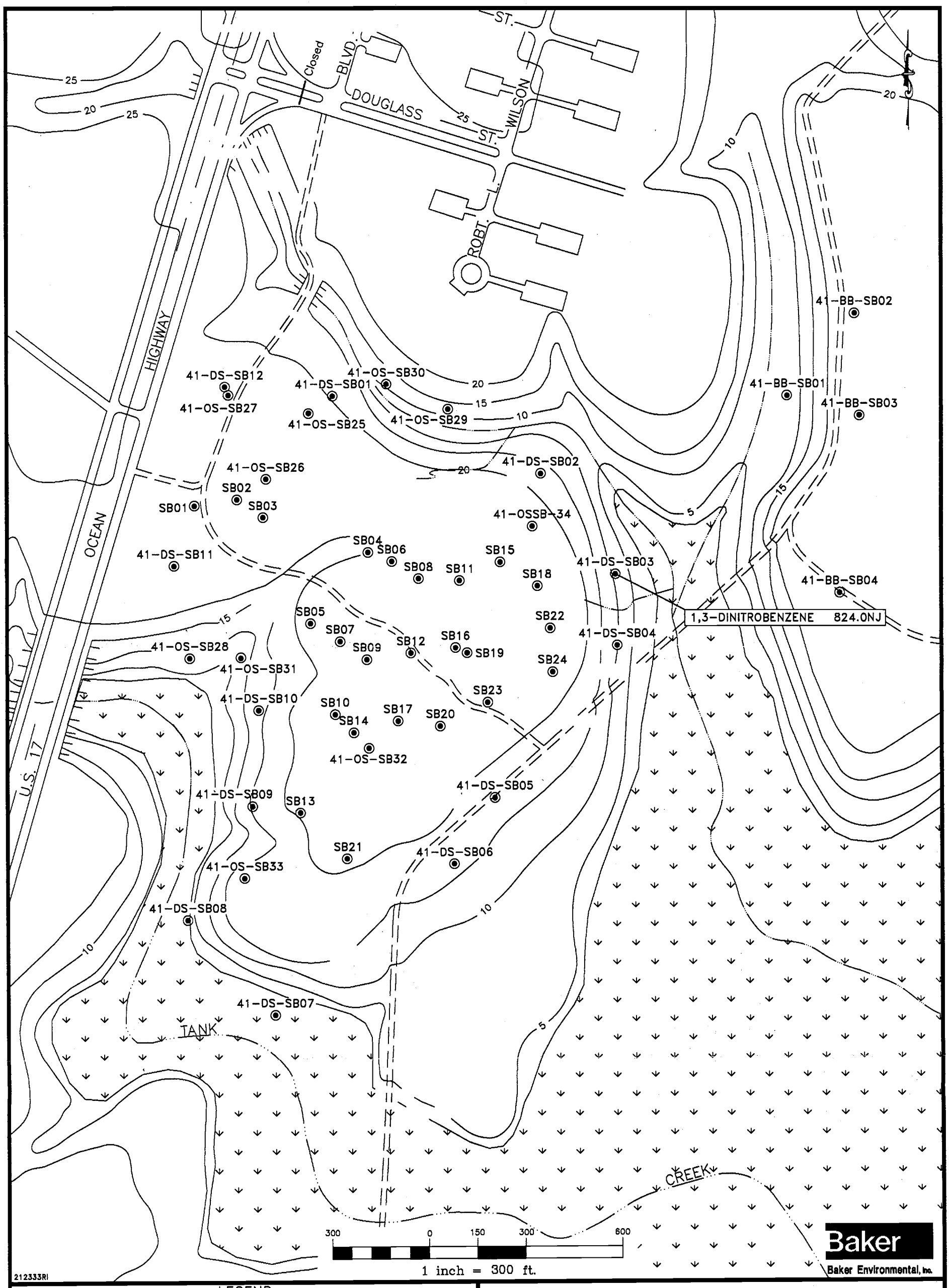



LEGEND

- SB01 – SOIL BORING LOCATION
- MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- ROAD (IMPROVED)
- ROAD (UNIMPROVED)
- INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-4
POSITIVE DETECTIONS OF PCBs IN SURFACE SOILS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

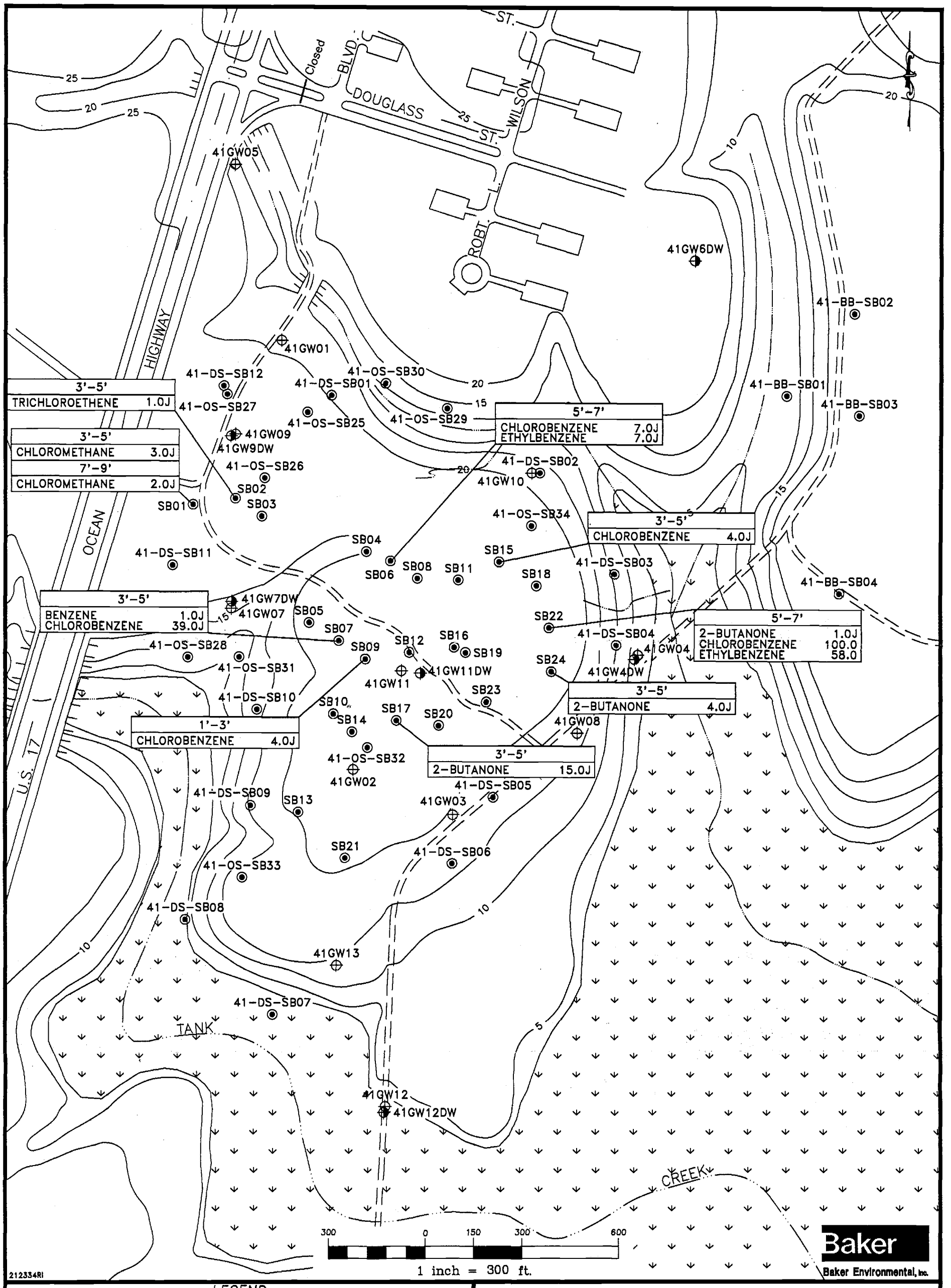



LEGEND

- SB01 – SOIL BORING LOCATION
- – MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- – ROAD (IMPROVED)
- – ROAD (UNIMPROVED)
- – INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-5
POSITIVE DETECTIONS OF ORDNANCE
IN SURFACE SOILS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




LEGEND

41GW07 – SHALLOW MONITORING WELL LOCATION

41GW4D – DEEP MONITORING WELL LOCATION

SB01 – SOIL BORING LOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

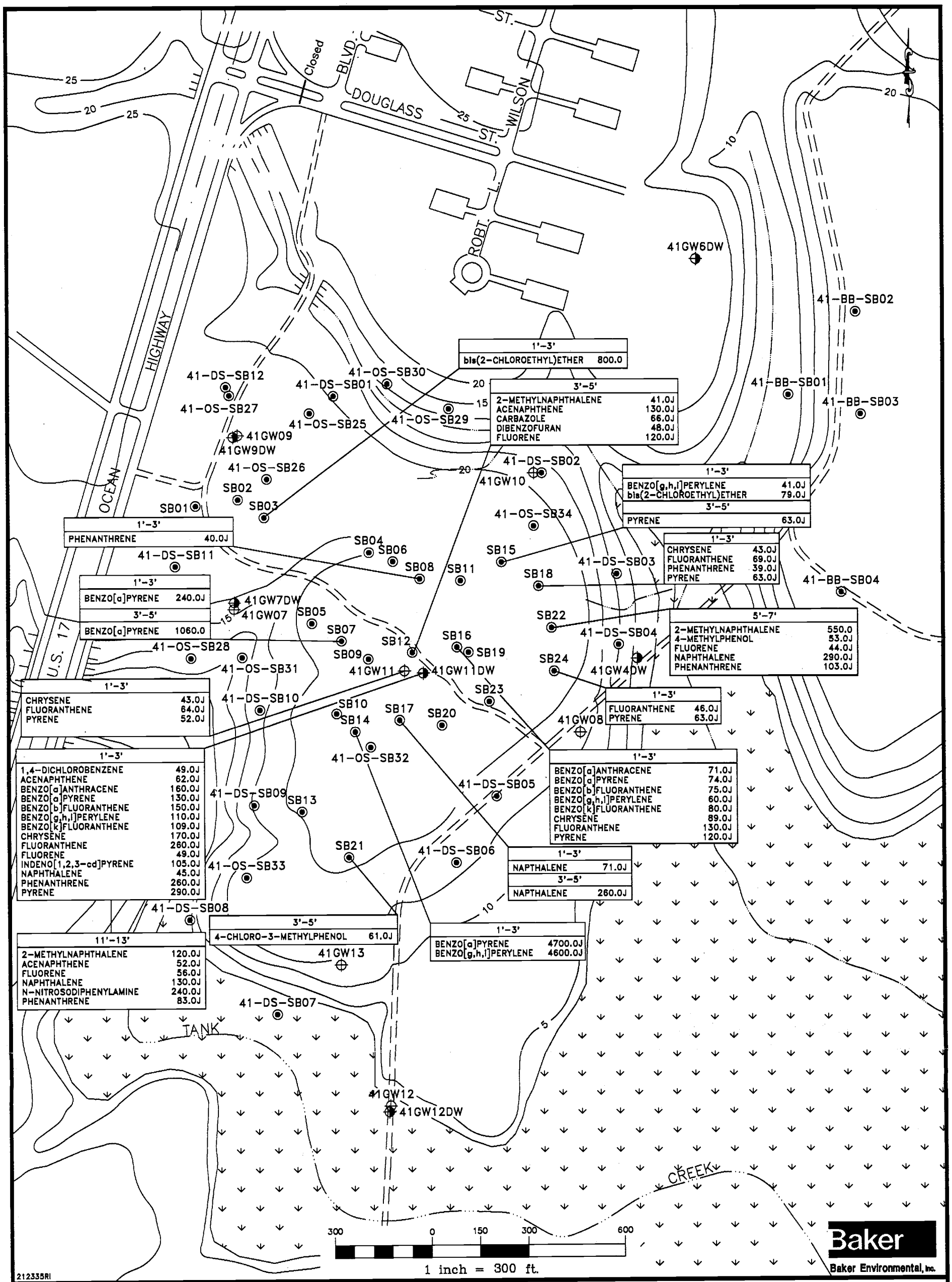
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

SOURCE: LANTDIV, OCT. 1991

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

FIGURE 4-6
POSITIVE DETECTION OF VOLATILES
IN SUBSURFACE SOILS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




Baker

Baker Environmental, Inc.

LEGEND

41GW07 – SHALLOW MONITORING WELL LOCATION

41GW4D – DEEP MONITORING WELL LOCATION

SB01 – SOIL BORING LOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

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

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-7

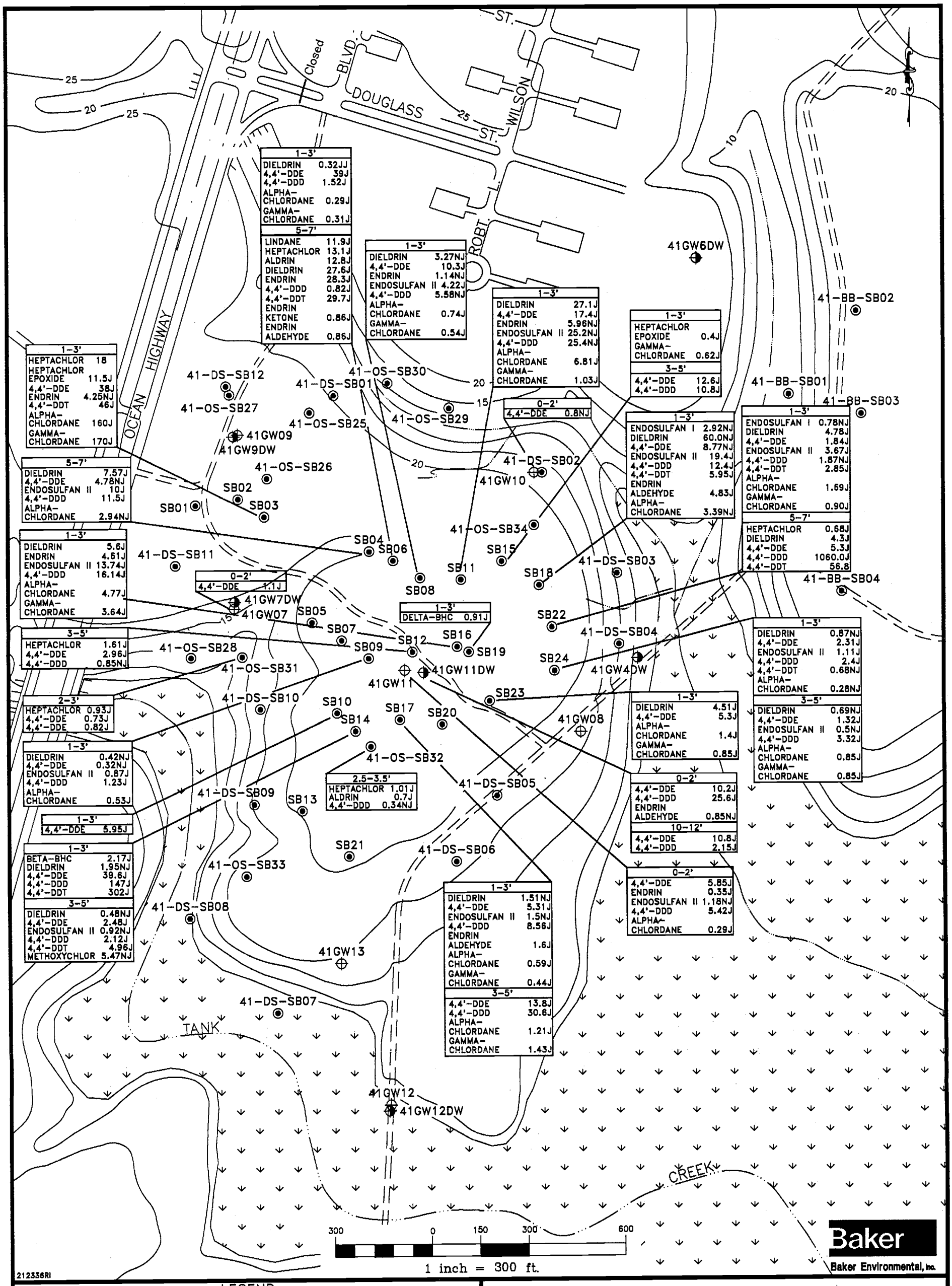
POSITIVE DETECTION OF SEMIVOLATILES IN SUBSURFACE SOILS – SITE 41

CAMP GEIGER DUMP NEAR FORMER TRAILER PARK

REMEDIAL INVESTIGATION CTO-0212

MARINE CORPS BASE, CAMP LEJEUNE

NORTH CAROLINA




| 1-3' | |
|---|---|
| DIELDRIN | 0.32JJ |
| 4,4'-DDE | 39J |
| 4,4'-DDD | 1.52J |
| ALPHA-CHLORDANE | 0.29J |
| GAMMA-CHLORDANE | 0.31J |

| 5-7' | |
|---|---|
| LINDANE | 11.9J |
| HEPTACHLOR | 13.1J |
| ALDRIN | 12.8J |
| DIELDRIN | 27.6J |
| ENDRIN | 28.3J |
| 4,4'-DDD | 0.82J |
| 4,4'-DDT | 29.7J |
| ENDRIN KETONE | 0.86J |
| ENDRIN ALDEHYDE | 0.86J |

| 1-3' | |
|---|---|
| DIELDRIN | 3.27NJ |
| 4,4'-DDE | 10.3J |
| ENDRIN | 1.14NJ |
| ENDOSULFAN II | 4.22J |
| 4,4'-DDD | 5.58NJ |
| ALPHA-CHLORDANE | 0.74J |
| GAMMA-CHLORDANE | 0.54J |

| 1-3' | |
|---|---|
| DIELDRIN | 27.1J |
| 4,4'-DDE | 17.4J |
| ENDRIN | 5.96NJ |
| ENDOSULFAN II | 25.2NJ |
| 4,4'-DDD | 25.4NJ |
| ALPHA-CHLORDANE | 6.81J |
| GAMMA-CHLORDANE | 1.03J |

| 1-3' | |
|---|---|
| HEPTACHLOR EPOXIDE | 0.4J |
| GAMMA-CHLORDANE | 0.62J |

| 3-5' | |
|---|---|
| 4,4'-DDE | 12.6J |
| 4,4'-DDD | 10.8J |

| 1-3' | |
|---|---|
| HEPTACHLOR | 18 |
| HEPTACHLOR EPOXIDE | 11.5J |
| 4,4'-DDE | 38J |
| ENDRIN | 4.25NJ |
| 4,4'-DDT | 46J |
| ALPHA-CHLORDANE | 160J |
| GAMMA-CHLORDANE | 170J |

| 0-2' | |
|---|---|
| 4,4'-DDE | 0.8NJ |

| 1-3' | |
|---|---|
| ENDOSULFAN I | 2.92NJ |
| DIELDRIN | 60.0NJ |
| 4,4'-DDE | 8.77NJ |
| ENDOSULFAN II | 19.4J |
| 4,4'-DDD | 12.4J |
| 4,4'-DDT | 5.95J |
| ENDRIN ALDEHYDE | 4.83J |
| ALPHA-CHLORDANE | 3.39NJ |

| 1-3' | |
|---|---|
| ENDOSULFAN I | 0.78NJ |
| DIELDRIN | 4.78J |
| 4,4'-DDE | 1.84J |
| ENDOSULFAN II | 3.67J |
| 4,4'-DDD | 1.87NJ |
| 4,4'-DDT | 2.85J |
| ALPHA-CHLORDANE | 1.69J |
| GAMMA-CHLORDANE | 0.90J |

| 5-7' | |
|---|---|
| HEPTACHLOR | 0.68J |
| DIELDRIN | 4.3J |
| 4,4'-DDE | 5.3J |
| 4,4'-DDD | 1060.0J |
| 4,4'-DDT | 56.8 |

| 5-7' | |
|---|---|
| DIELDRIN | 7.57J |
| 4,4'-DDE | 4.78NJ |
| ENDOSULFAN II | 10J |
| 4,4'-DDD | 11.5J |
| ALPHA-CHLORDANE | 2.94NJ |

| 1-3' | |
|---|---|
| DIELDRIN | 5.6J |
| ENDRIN | 4.61J |
| ENDOSULFAN II | 13.74J |
| 4,4'-DDD | 16.14J |
| ALPHA-CHLORDANE | 4.77J |
| GAMMA-CHLORDANE | 3.64J |

| 0-2' | |
|---|---|
| 4,4'-DDE | 1.1J |

| 1-3' | |
|---|---|
| DELTA-BHC | 0.91J |

| 1-3' | |
|---|---|
| DIELDRIN | 0.87NJ |
| 4,4'-DDE | 2.31J |
| ENDOSULFAN II | 1.11J |
| 4,4'-DDD | 2.4J |
| 4,4'-DDT | 0.68NJ |
| ALPHA-CHLORDANE | 0.28NJ |

| 3-5' | |
|---|---|
| DIELDRIN | 0.69NJ |
| 4,4'-DDE | 1.32J |
| ENDOSULFAN II | 0.5NJ |
| 4,4'-DDD | 3.32J |
| ALPHA-CHLORDANE | 0.85J |
| GAMMA-CHLORDANE | 0.85J |

| 3-5' | |
|---|---|
| HEPTACHLOR | 1.61J |
| 4,4'-DDE | 2.96J |
| 4,4'-DDD | 0.85NJ |

| 2-3' | |
|---|---|
| HEPTACHLOR | 0.93J |
| 4,4'-DDE | 0.73J |
| 4,4'-DDE | 0.82J |

| 1-3' | |
|---|---|
| DIELDRIN | 4.51J |
| 4,4'-DDE | 5.3J |
| ALPHA-CHLORDANE | 1.4J |
| GAMMA-CHLORDANE | 0.85J |

| 1-3' | |
|---|---|
| DIELDRIN | 0.42NJ |
| 4,4'-DDE | 0.32NJ |
| ENDOSULFAN II | 0.87J |
| 4,4'-DDD | 1.23J |
| ALPHA-CHLORDANE | 0.53J |

| 2.5-3.5' | |
|---|---|
| HEPTACHLOR | 1.01J |
| ALDRIN | 0.7J |
| 4,4'-DDD | 0.34NJ |

| 0-2' | |
|---|---|
| 4,4'-DDE | 10.2J |
| 4,4'-DDD | 25.6J |
| ENDRIN ALDEHYDE | 0.85NJ |

| 10-12' | |
|---|---|
| 4,4'-DDE | 10.8J |
| 4,4'-DDD | 2.15J |

| 1-3' | |
|---|---|
| 4,4'-DDE | 5.95J |

| 1-3' | |
|---|---|
| BETA-BHC | 2.17J |
| DIELDRIN | 1.95NJ |
| 4,4'-DDE | 39.6J |
| 4,4'-DDD | 147J |
| 4,4'-DDT | 302J |

| 3-5' | |
|---|---|
| DIELDRIN | 0.48NJ |
| 4,4'-DDE | 2.48J |
| ENDOSULFAN II | 0.92NJ |
| 4,4'-DDD | 2.12J |
| 4,4'-DDT | 4.96J |
| METHOXYCHLOR | 5.47NJ |

| 0-2' | |
|---|---|
| 4,4'-DDE | 5.85J |
| ENDRIN | 0.33J |
| ENDOSULFAN II | 1.18NJ |
| 4,4'-DDD | 5.42J |
| ALPHA-CHLORDANE | 0.29J |

| 1-3' | |
|---|---|
| DIELDRIN | 1.51NJ |
| 4,4'-DDE | 5.31J |
| ENDOSULFAN II | 1.5NJ |
| 4,4'-DDD | 8.56J |
| ENDRIN ALDEHYDE | 1.6J |
| ALPHA-CHLORDANE | 0.59J |
| GAMMA-CHLORDANE | 0.44J |

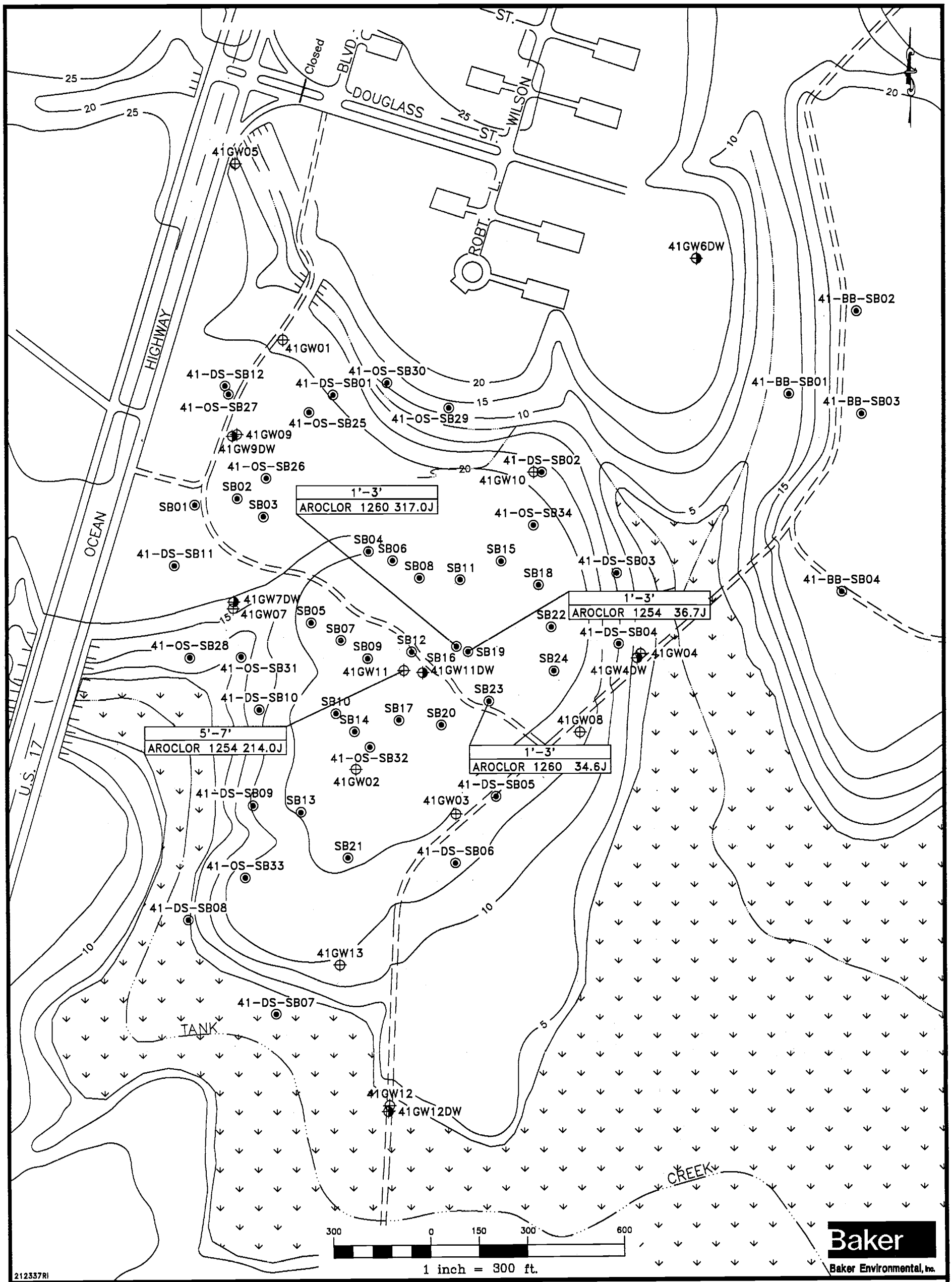
| 3-5' | |
|---|---|
| 4,4'-DDE | 13.8J |
| 4,4'-DDD | 30.6J |
| ALPHA-CHLORDANE | 1.21J |
| GAMMA-CHLORDANE | 1.43J |

## LEGEND

- 41GW07 – SHALLOW MONITORING WELL LOCATION
- 41GW4D – DEEP MONITORING WELL LOCATION
- SB01 – SOIL BORING LOCATION
- – MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- – ROAD (IMPROVED)
- – ROAD (UNIMPROVED)
- – INTERMITTENT STREAM

SOURCE: LANTDIV, OCT. 1991

# FIGURE 4-8
# POSITIVE DETECTIONS OF PESTICIDES IN SUBSURFACE SOILS – SITE 41
# CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
# REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



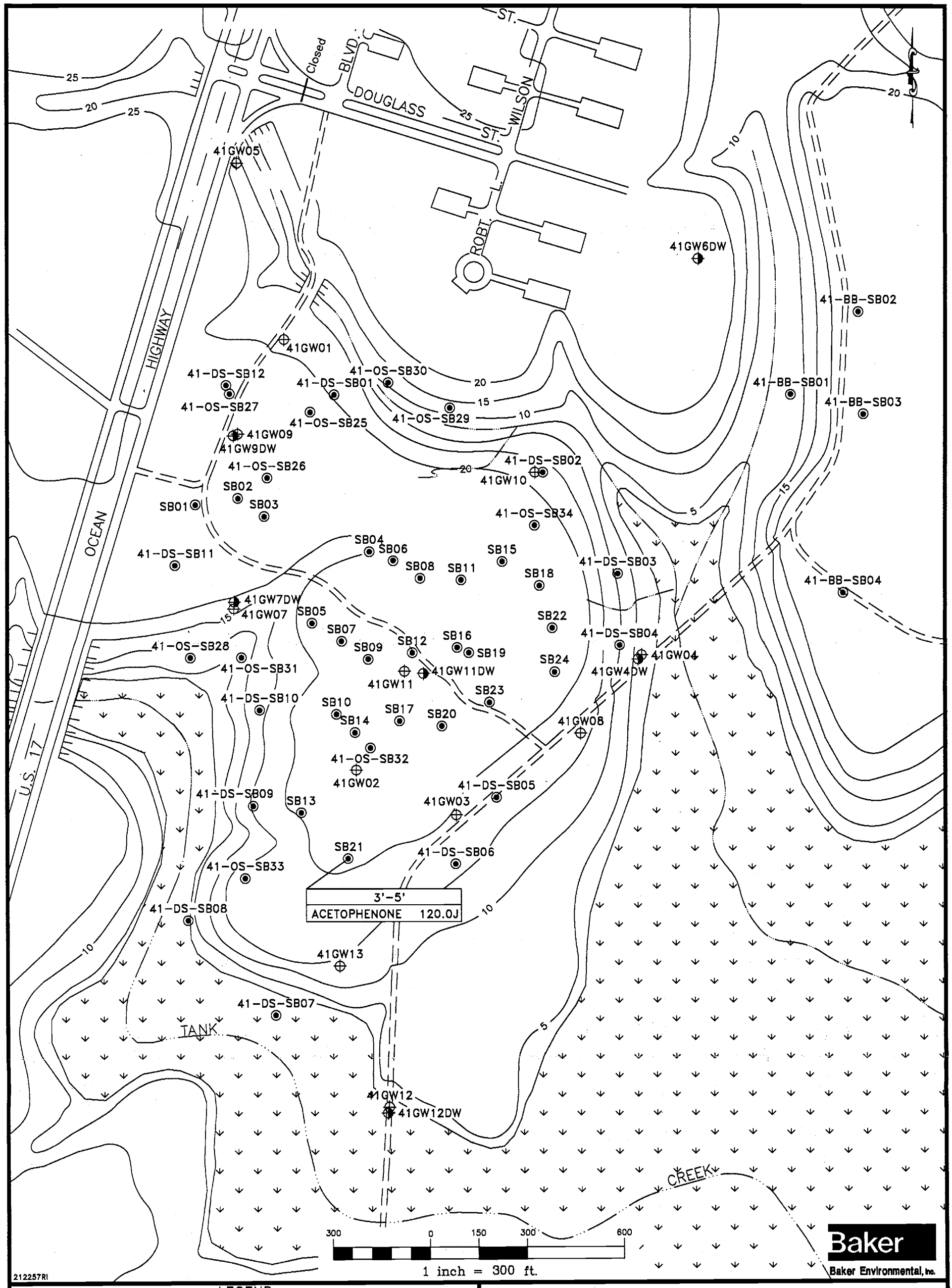

LEGEND

- 41GW07 – SHALLOW MONITORING WELL LOCATION
- 41GW4D – DEEP MONITORING WELL LOCATION
- SB01 – SOIL BORING LOCATION
- MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- ROAD (IMPROVED)
- ROAD (UNIMPROVED)
- INTERMITTENT STREAM

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

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-9
POSITIVE DETECTION OF PCBs IN SUBSURFACE SOILS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




LEGEND

41GW07 – SHALLOW MONITORING WELL LOCATION

41GW4D – DEEP MONITORING WELL LOCATION

SB01 – SOIL BORING LOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

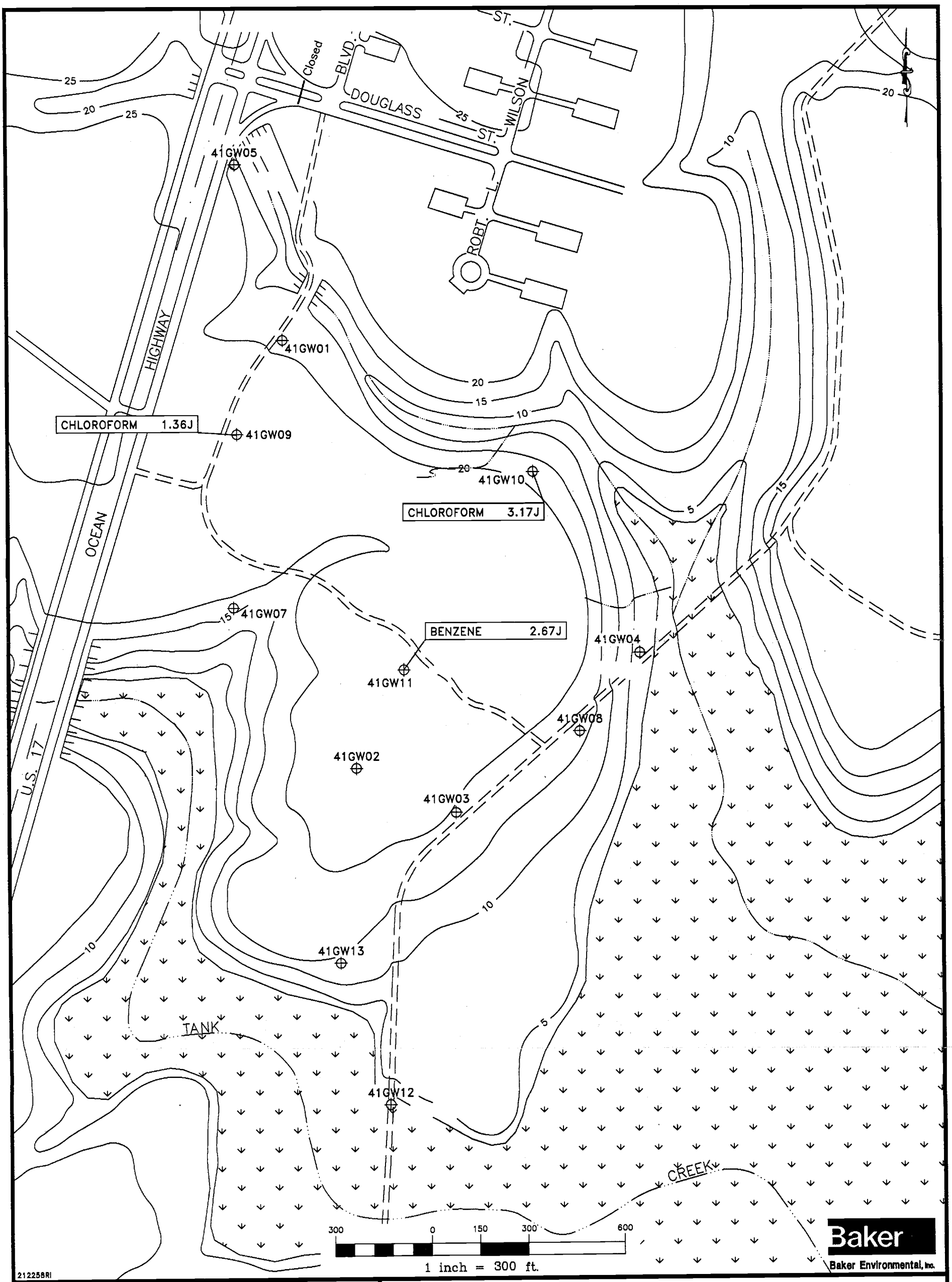
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

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

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-10
POSITIVE DETECTION OF CHEMICAL SURETY MATERIALS IN SUBSURFACE SOILS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

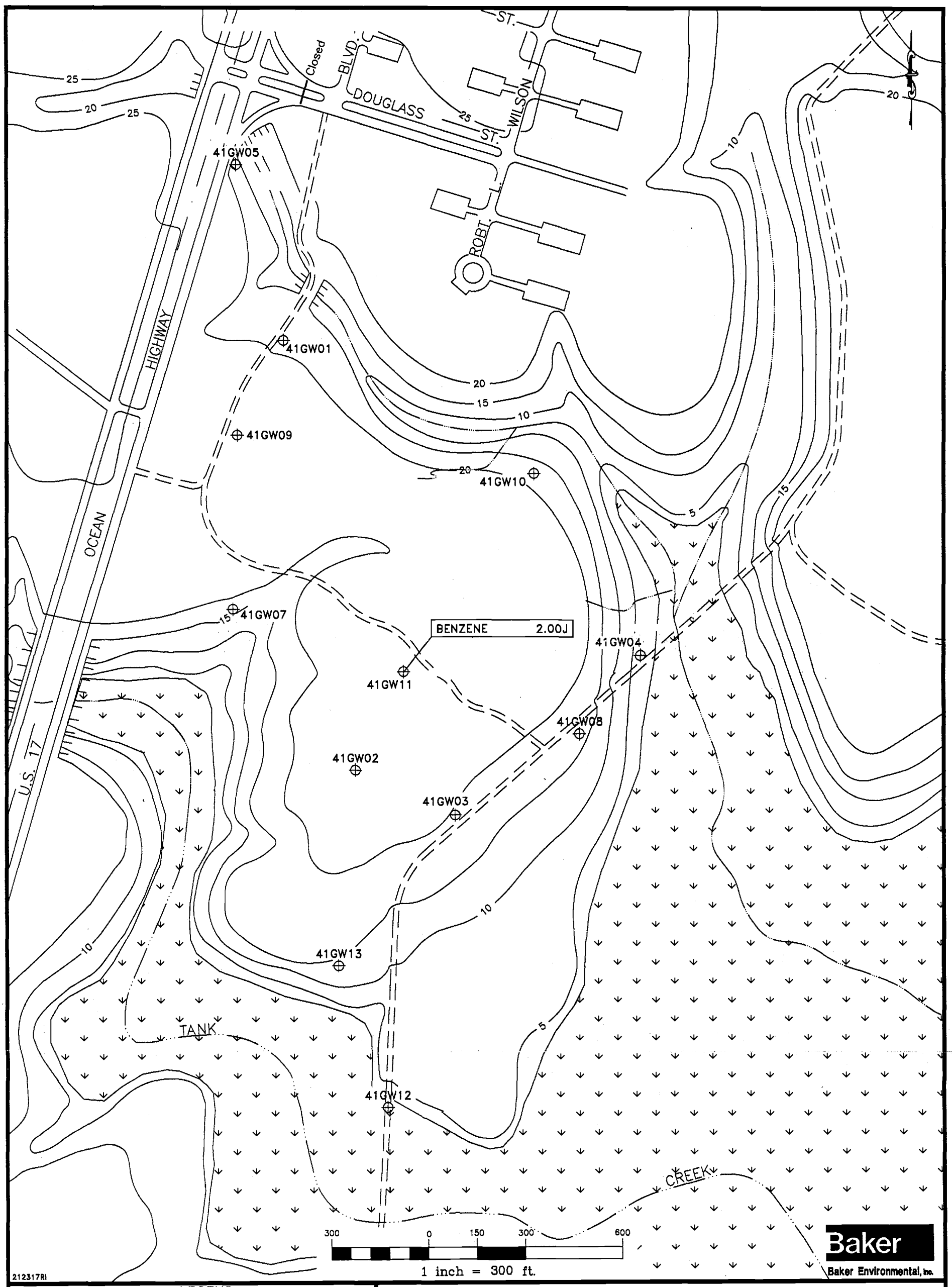



LEGEND

41GW01 – SHALLOW MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-11
POSITIVE DETECTIONS OF VOLATILES FOR ROUND 1 ABOVE FEDEREAL MCLs AND/OR NCWQS IN SHALLOW WELLS
SITE 41 – CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

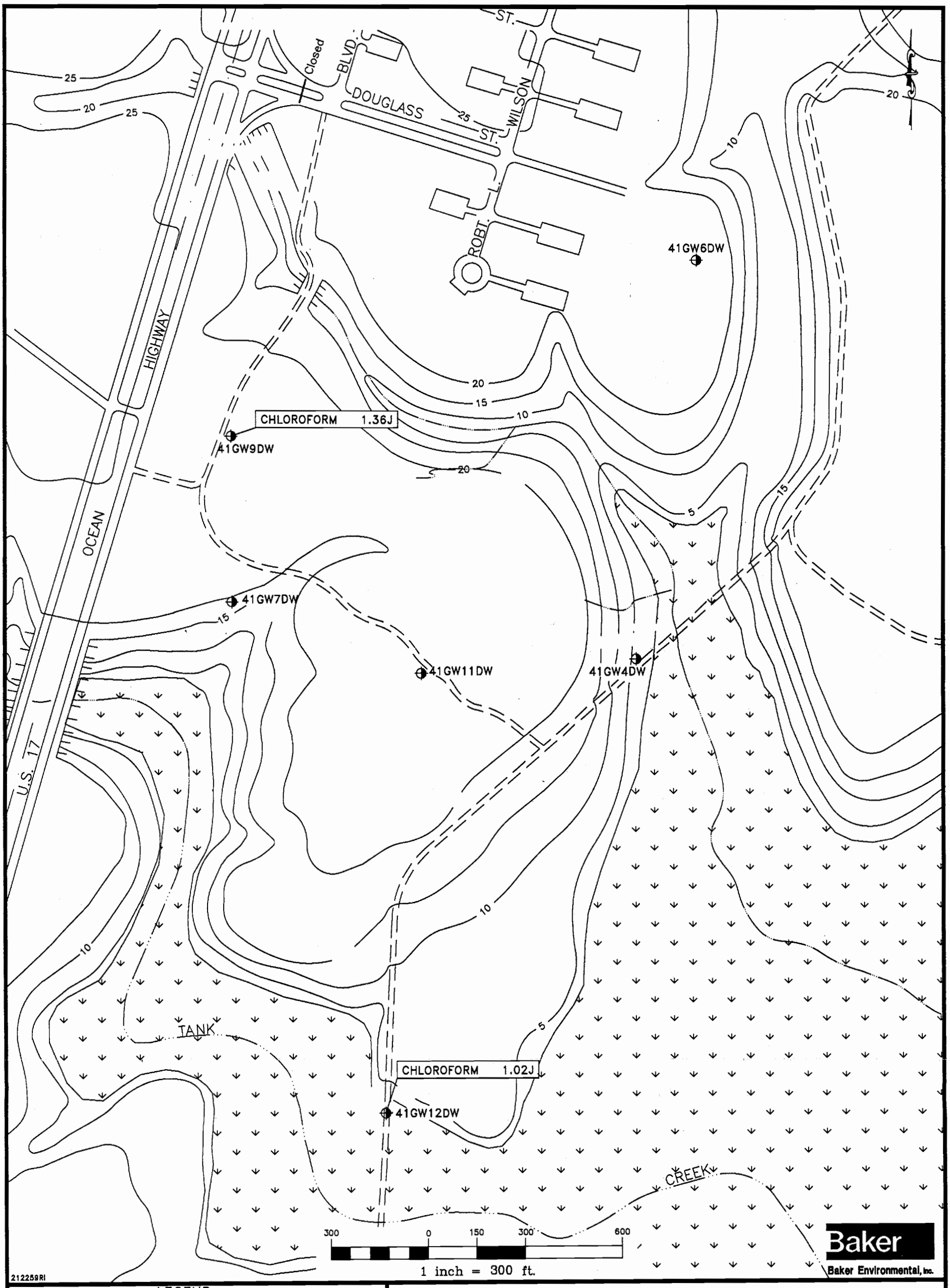



LEGEND

41GW01 – SHALLOW MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-12
POSITIVE DETECTIONS OF VOLATILES FOR ROUND 2 ABOVE FEDEREAL MCLs AND/OR NCWQS IN SHALLOW WELLS
SITE 41 – CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

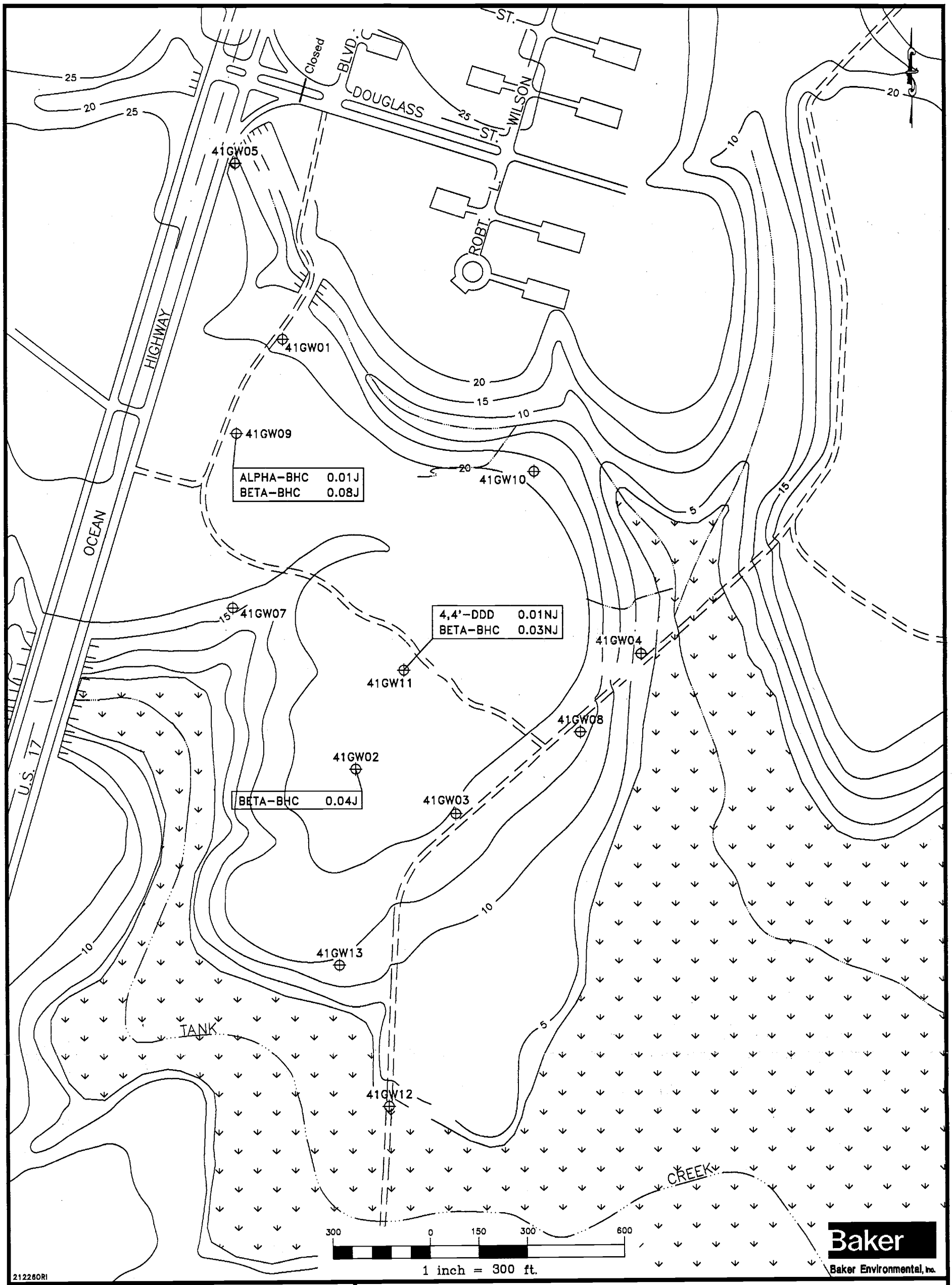



LEGEND

41GW4D – EXISTING DEEP MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-13
POSITIVE DETECTIONS OF VOLATILES FOR ROUND 1 ABOVE FEDERAL MCLs AND/OR NCWQS IN DEEP WELLS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

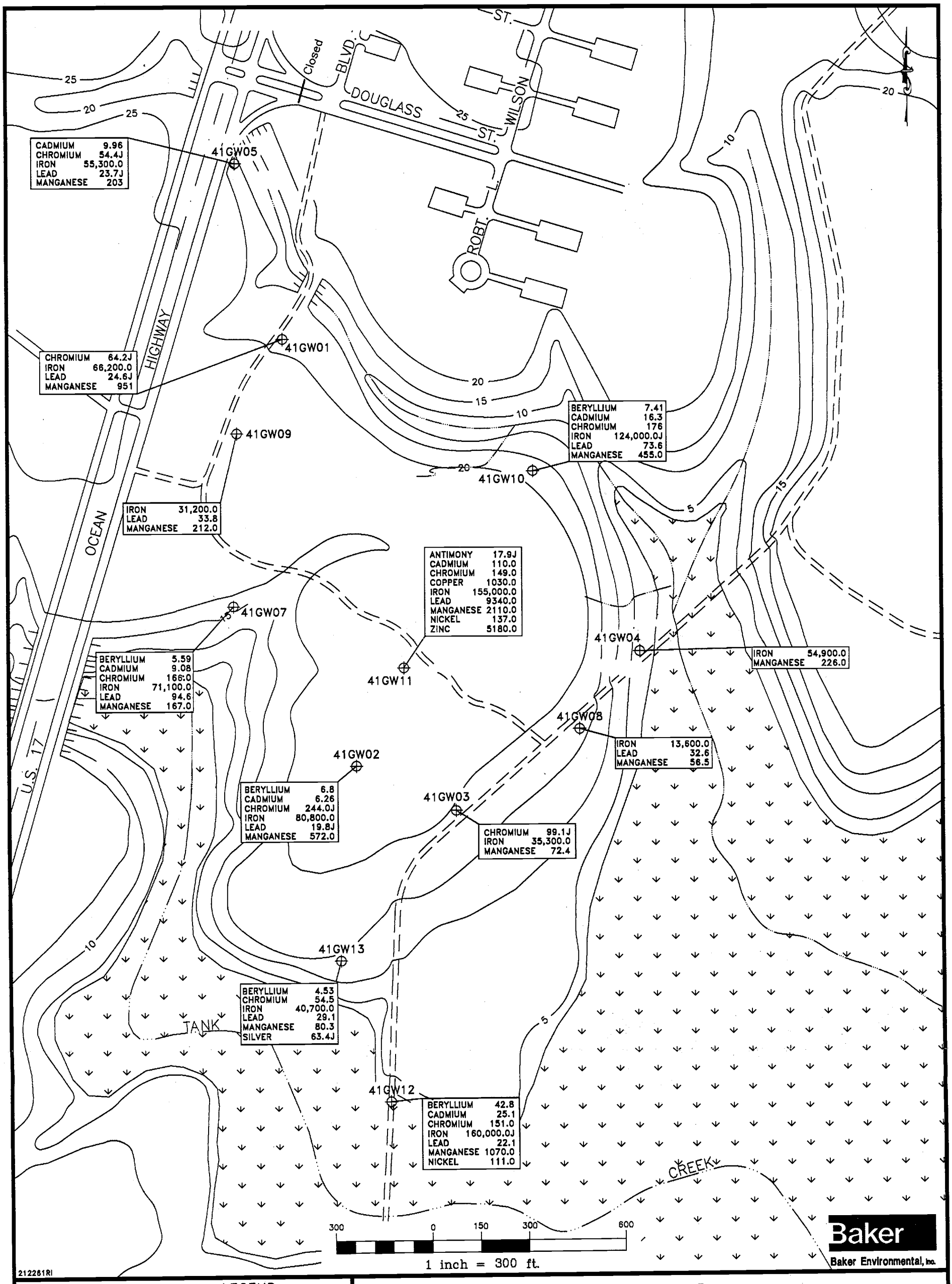



LEGEND

41GW01 – SHALLOW MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-14
POSITIVE DETECTIONS OF PESTICIDES FOR ROUND 1 ABOVE FEDERAL MCLs AND/OR NCWQS IN SHALLOW WELLS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

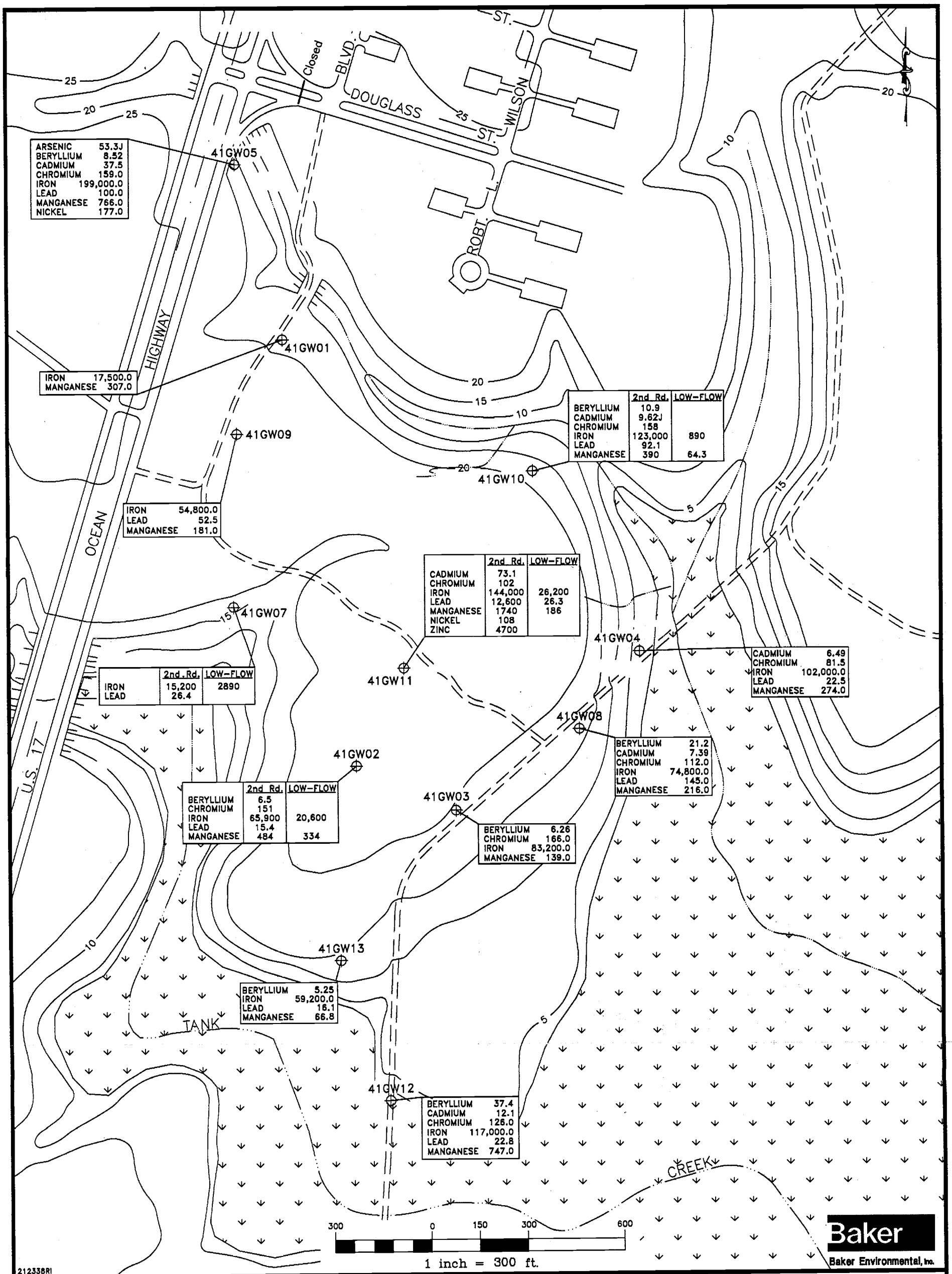



## LEGEND

- 41GW01 – SHALLOW MONITORING WELL
- – MARSH
- 5 – TOPOGRAPHIC ELEVATION LINES
- – ROAD (IMPROVED)
- – ROAD (UNIMPROVED)
- – INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

# FIGURE 4-15
## POSITIVE DETECTIONS OF TAL METALS FOR ROUND 1 ABOVE FEDERAL MCLs AND/OR NCWQS IN SHALLOW WELLS – SITE 41
## CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
## REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

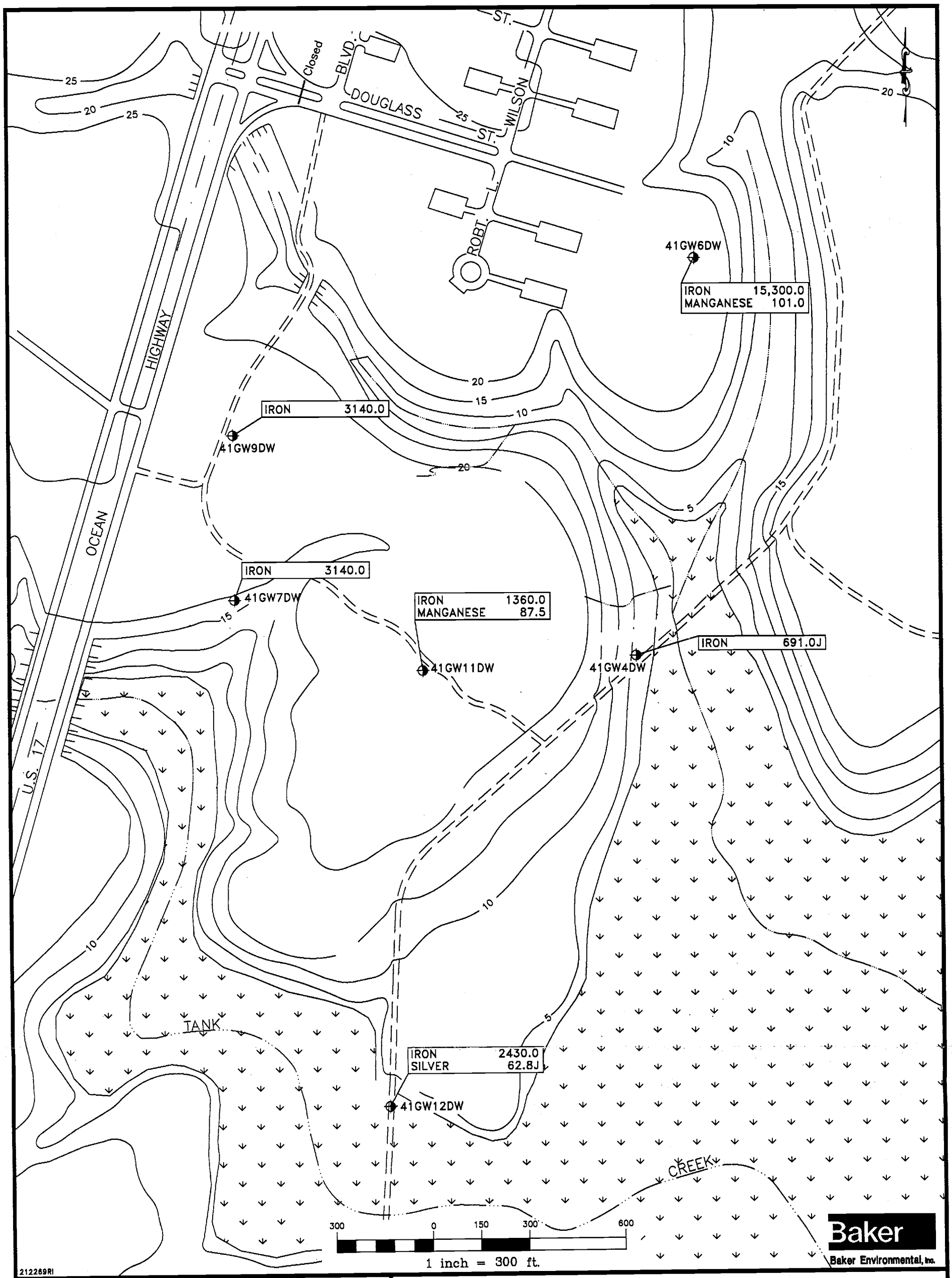



LEGEND

41GW01 – SHALLOW MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4–16
POSITIVE DETECTIONS OF TOTAL METALS FOR ROUND 2 ABOVE FEDERAL MCLs AND/OR NCWQS IN SHALLOW WELLS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO–0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

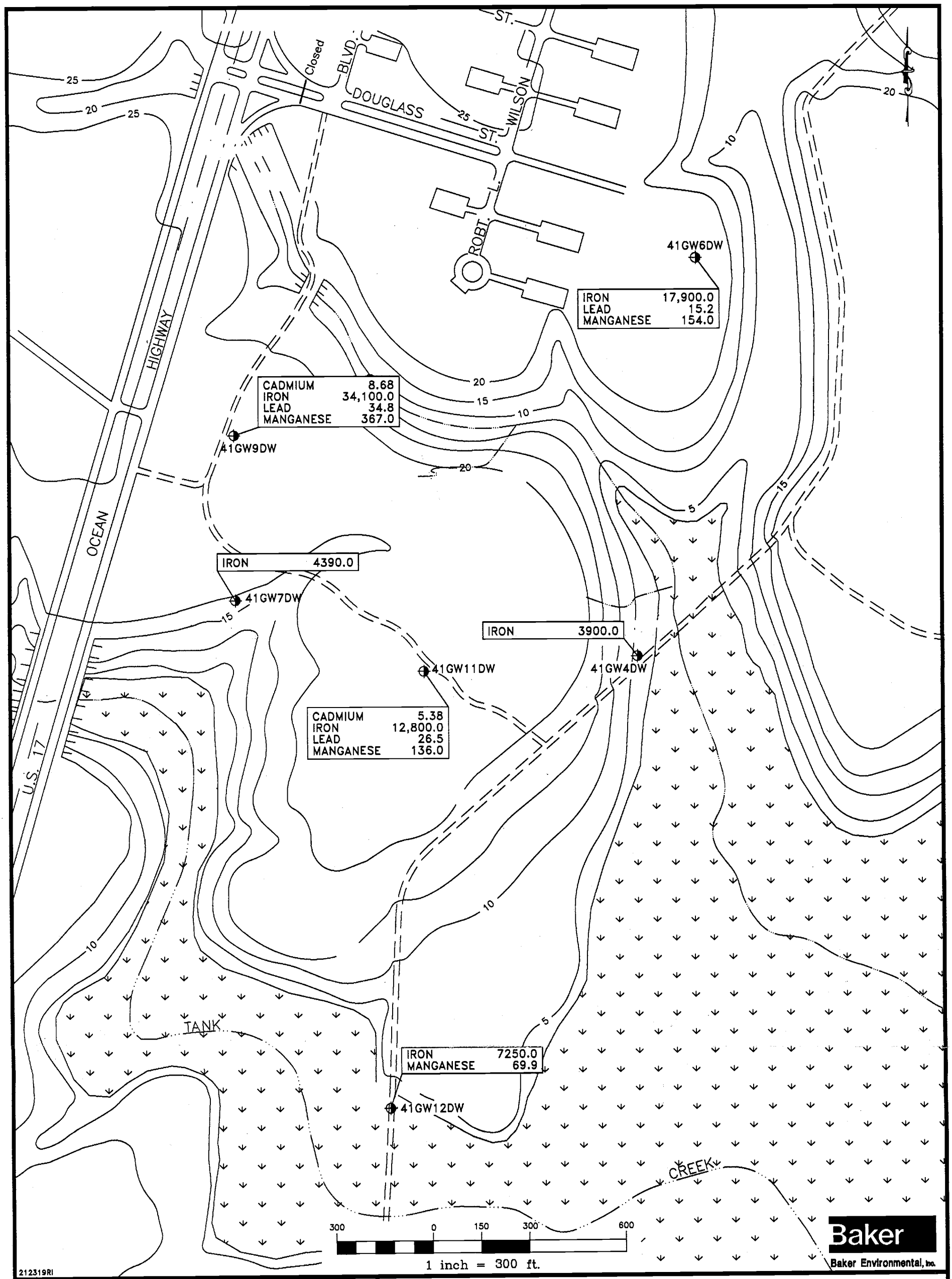



LEGEND

41GW4D – DEEP MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-17
POSITIVE DETECTIONS OF TAL METALS FOR ROUND 1 ABOVE FEDERAL MCLs AND/OR NCWQS IN DEEP WELLS – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

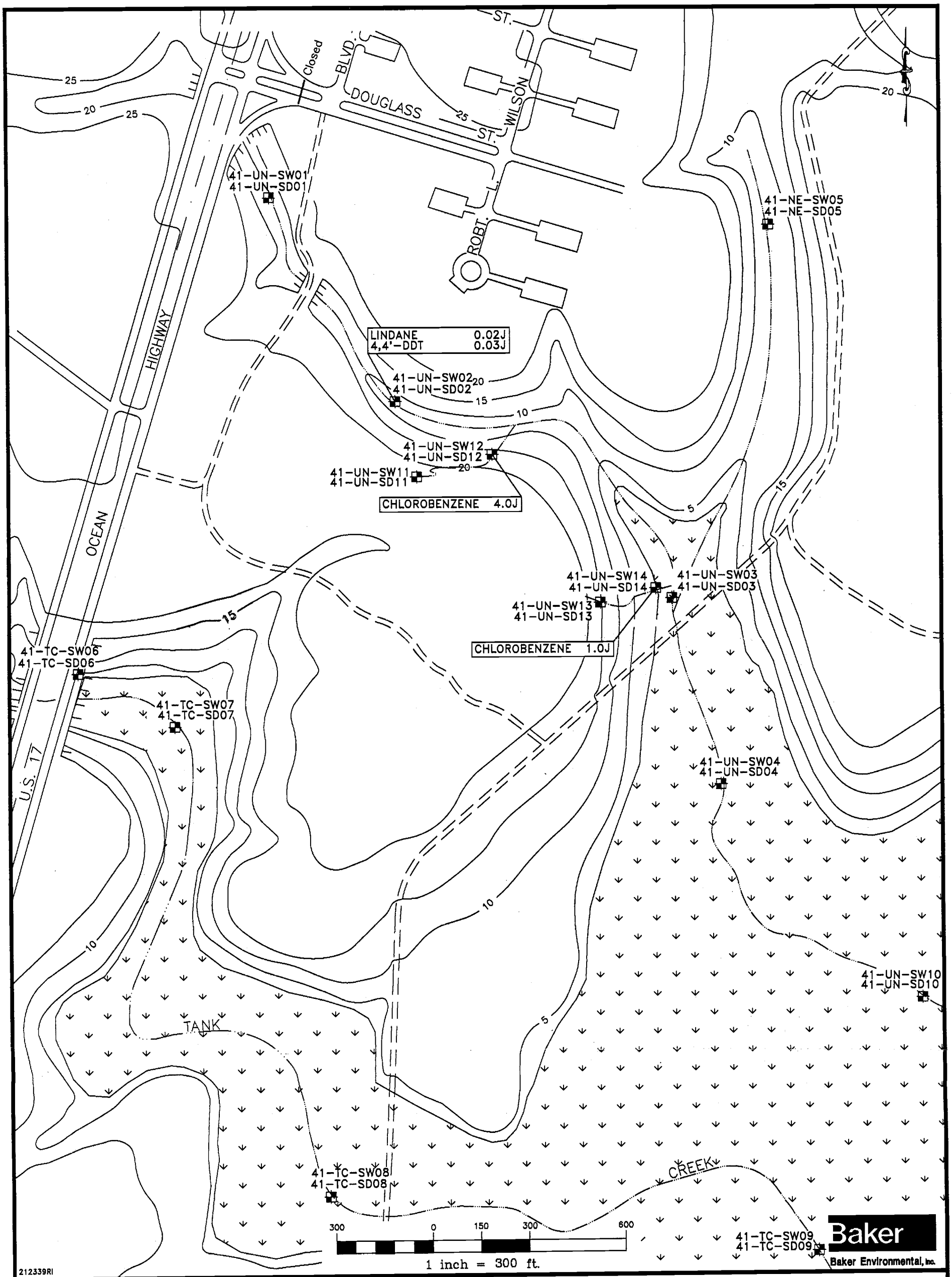



LEGEND

41GW4D – EXISTING DEEP MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-18
POSITIVE DETECTIONS OF TOTAL METALS FOR ROUND 2 ABOVE FEDERAL MCLs AND/OR NCWQS IN DEEP WELLS
SITE 41 – CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




LEGEND

41-UN-SW01
41-UN-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

– MARSH

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

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-19

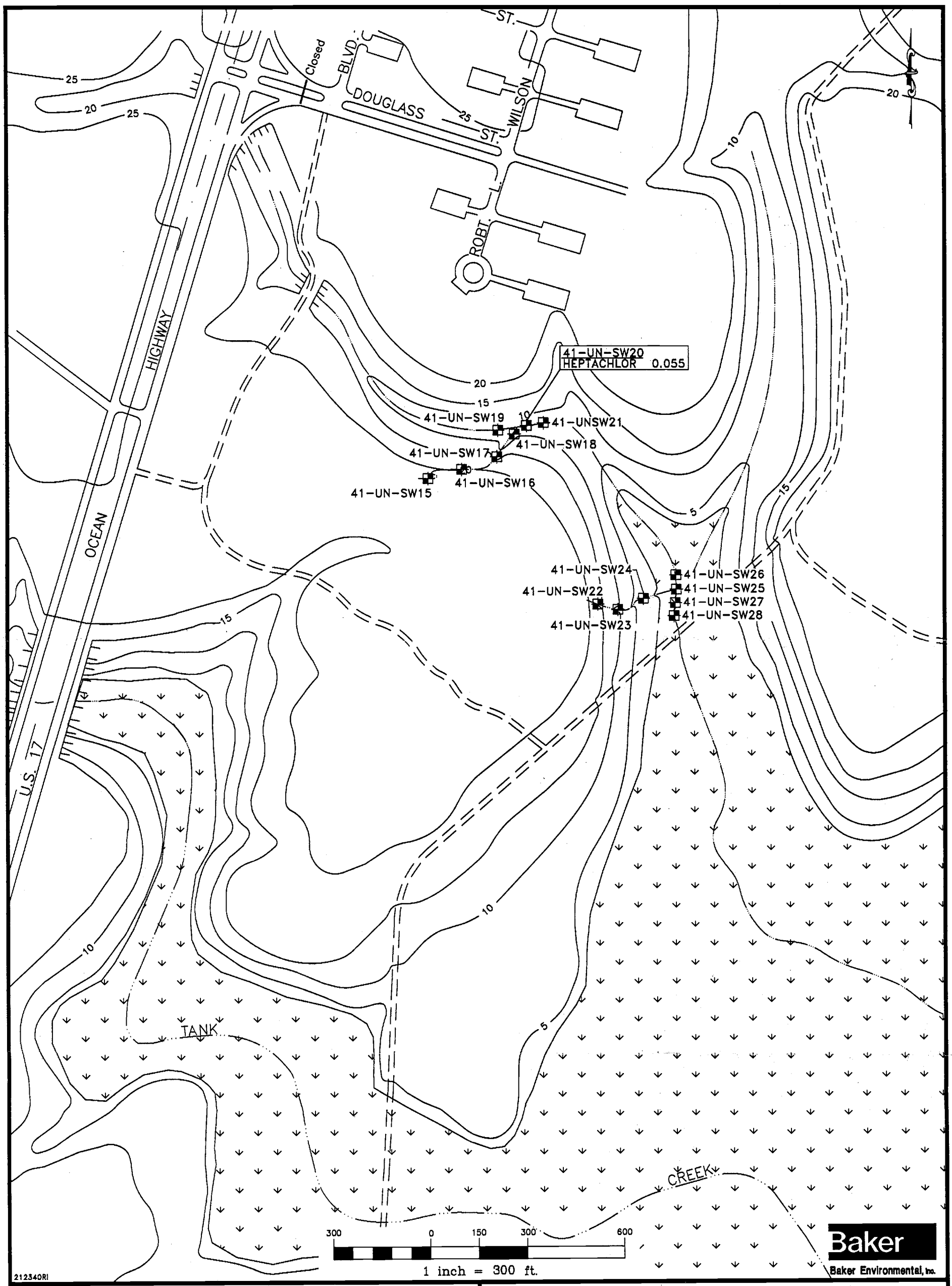
POSITIVE DETECTIONS OF VOLATILES AND PESTICIDES IN SURFACE WATER – SITE 41

CAMP GEIGER DUMP NEAR FORMER TRAILER PARK

REMEDIAL INVESTIGATION CTO-0212

MARINE CORPS BASE, CAMP LEJEUNE

NORTH CAROLINA




LEGEND

41-UN-SW15 – SURFACE WATER/SEDIMENT SAMPLE LLOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

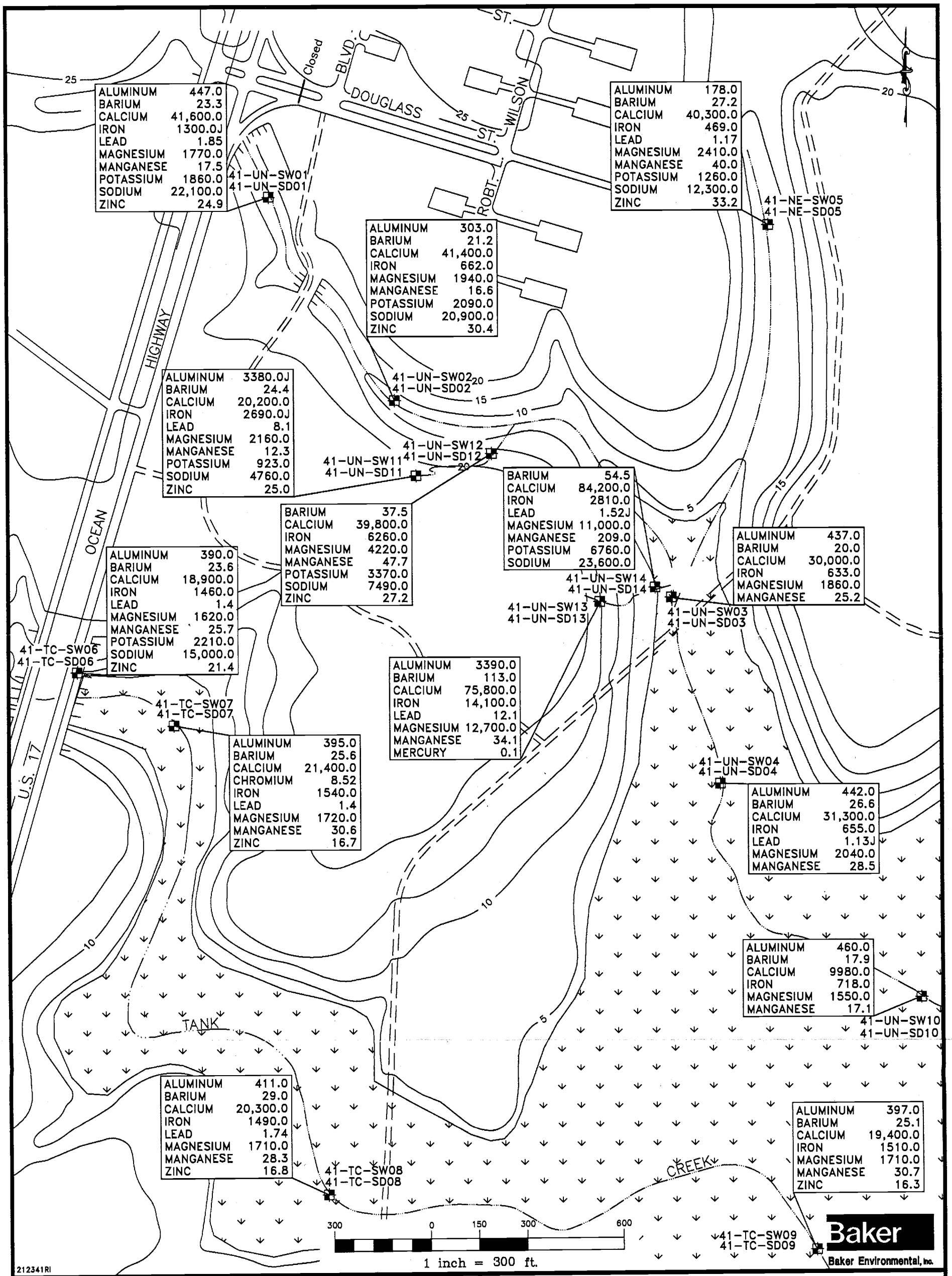
– ROAD (IMPROVED)

– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-20
POSITIVE DETECTIONS OF PESTICIDES FOR SECOND SAMPLING EVENT IN SURFACE WATER – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




LEGEND

41-UN-SW01
41-UN-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

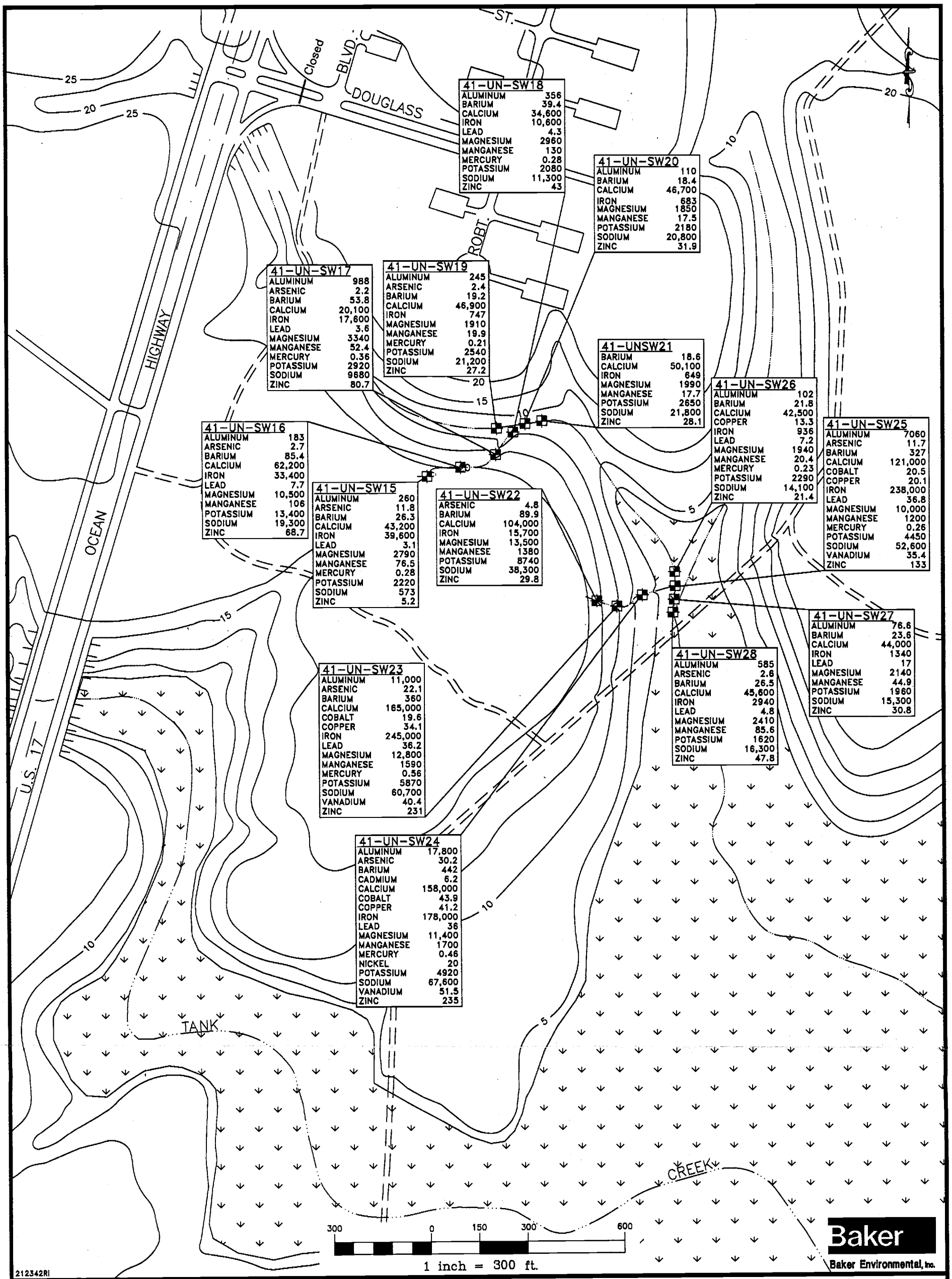
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

– MARSH

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-21
POSITIVE DETECTIONS OF TAL METALS
IN SURFACE WATER – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




## LEGEND

41-UN-SW15 – SURFACE WATER/SEDIMENT SAMPLE LOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

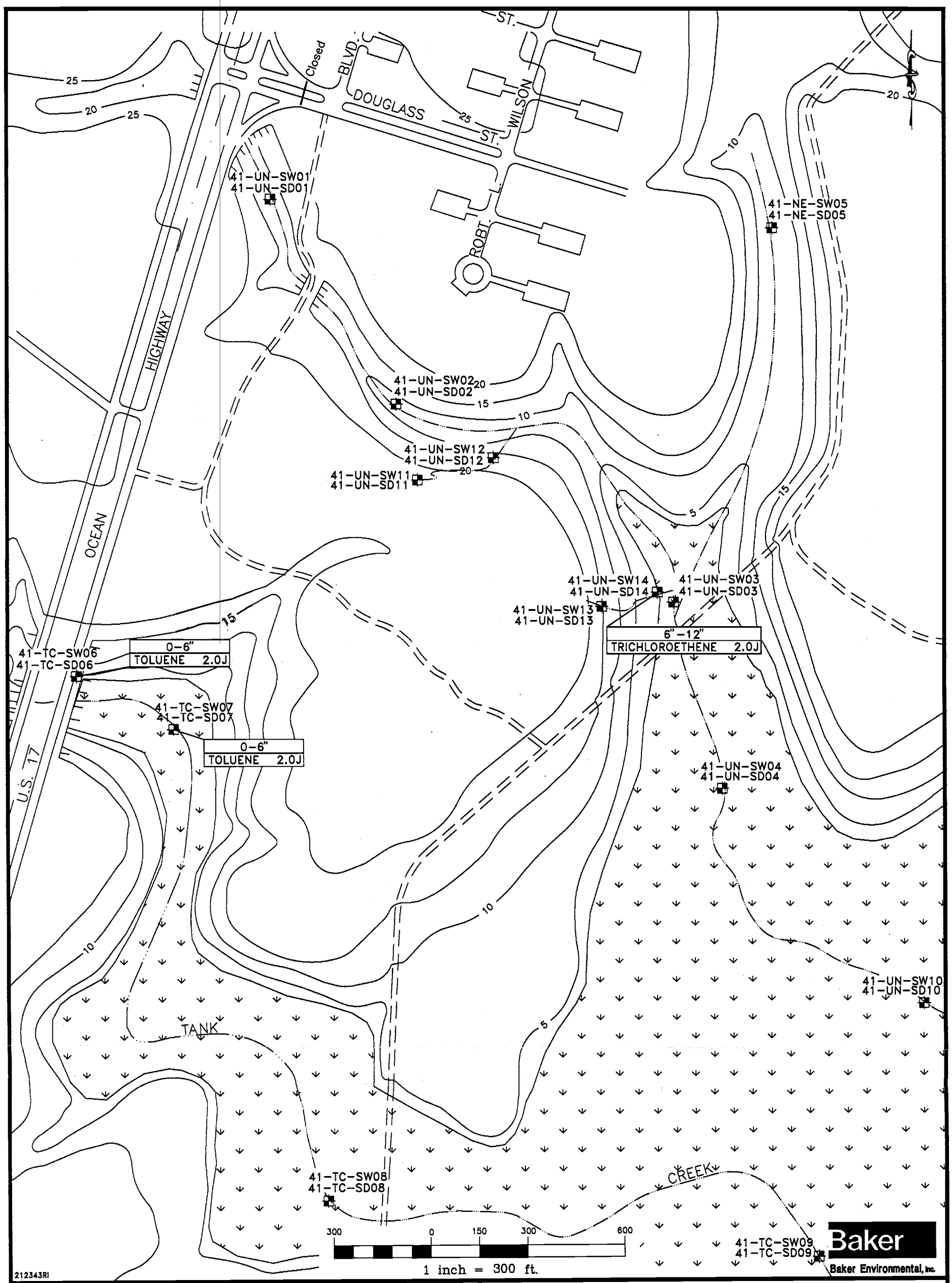
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-22

POSITIVE DETECTIONS OF TAL METALS FOR SECOND SAMPLING EVENT IN SURFACE WATER – SITE 41 CAMP GEIGER DUMP NEAR FORMER TRAILER PARK REMEDIAL INVESTIGATION CTO-0212

MARINE CORPS BASE, CAMP LEJEUNE

NORTH CAROLINA




LEGEND

41-UN-SW01
41-UN-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

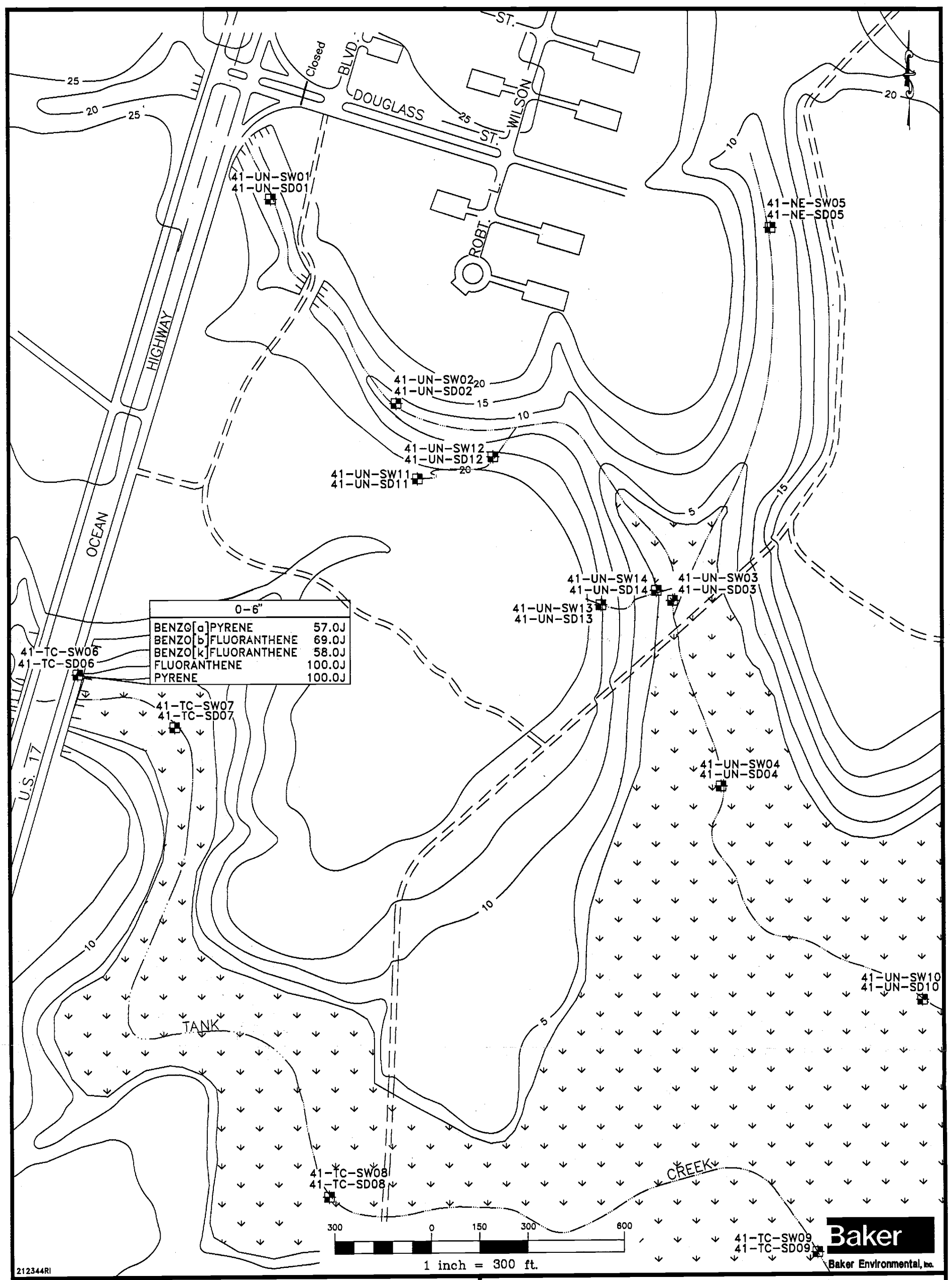
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

– MARSH

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-23
POSITIVE DETECTIONS OF VOLATILES
IN SEDIMENT - SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




LEGEND

41-UN-SW01
41-UN-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

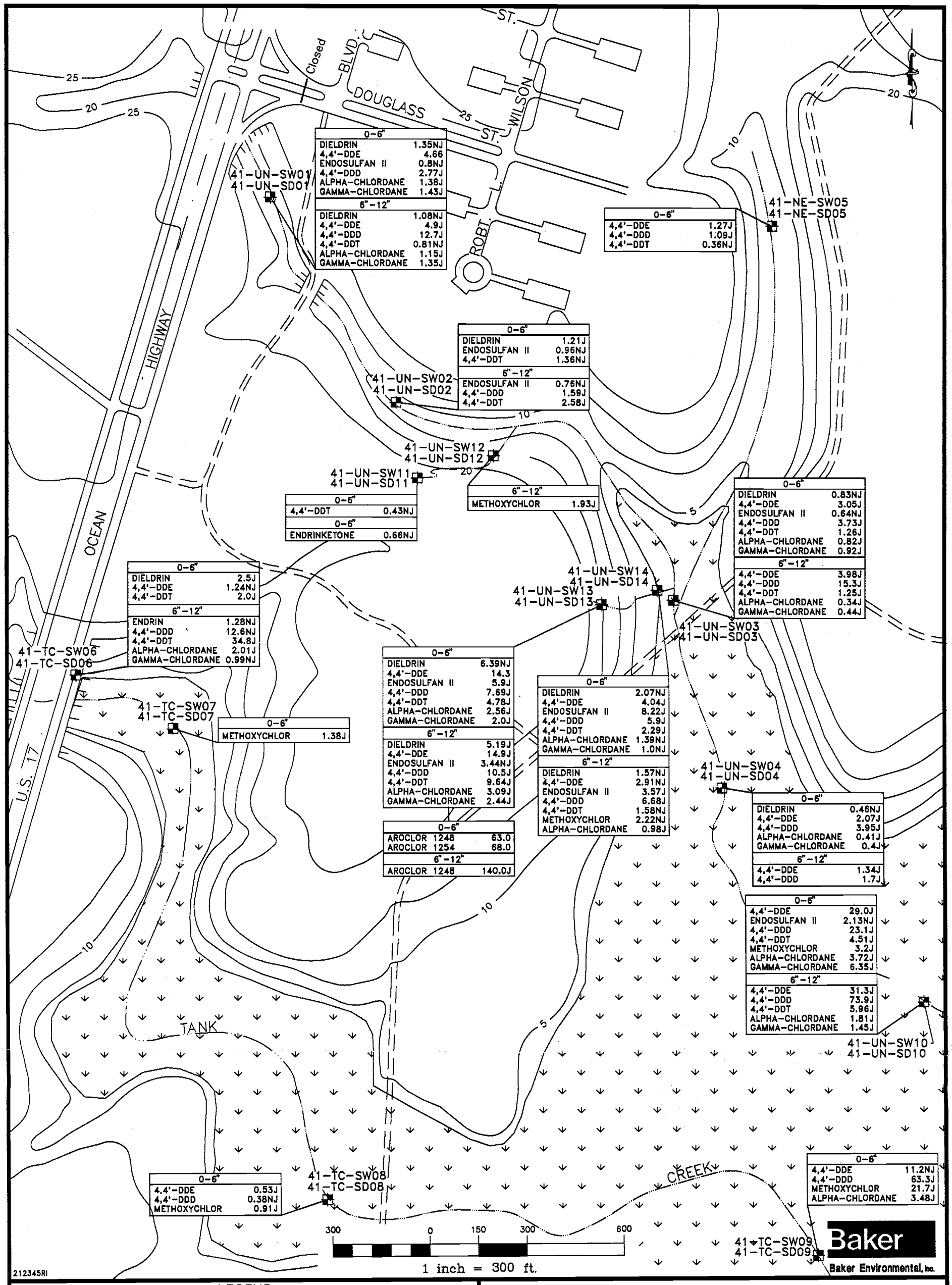
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

– MARSH

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-24
POSITIVE DETECTIONS OF SEMIVOLATILES
IN SEDIMENT – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




## LEGEND

41-UN-SW01
41-UN-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

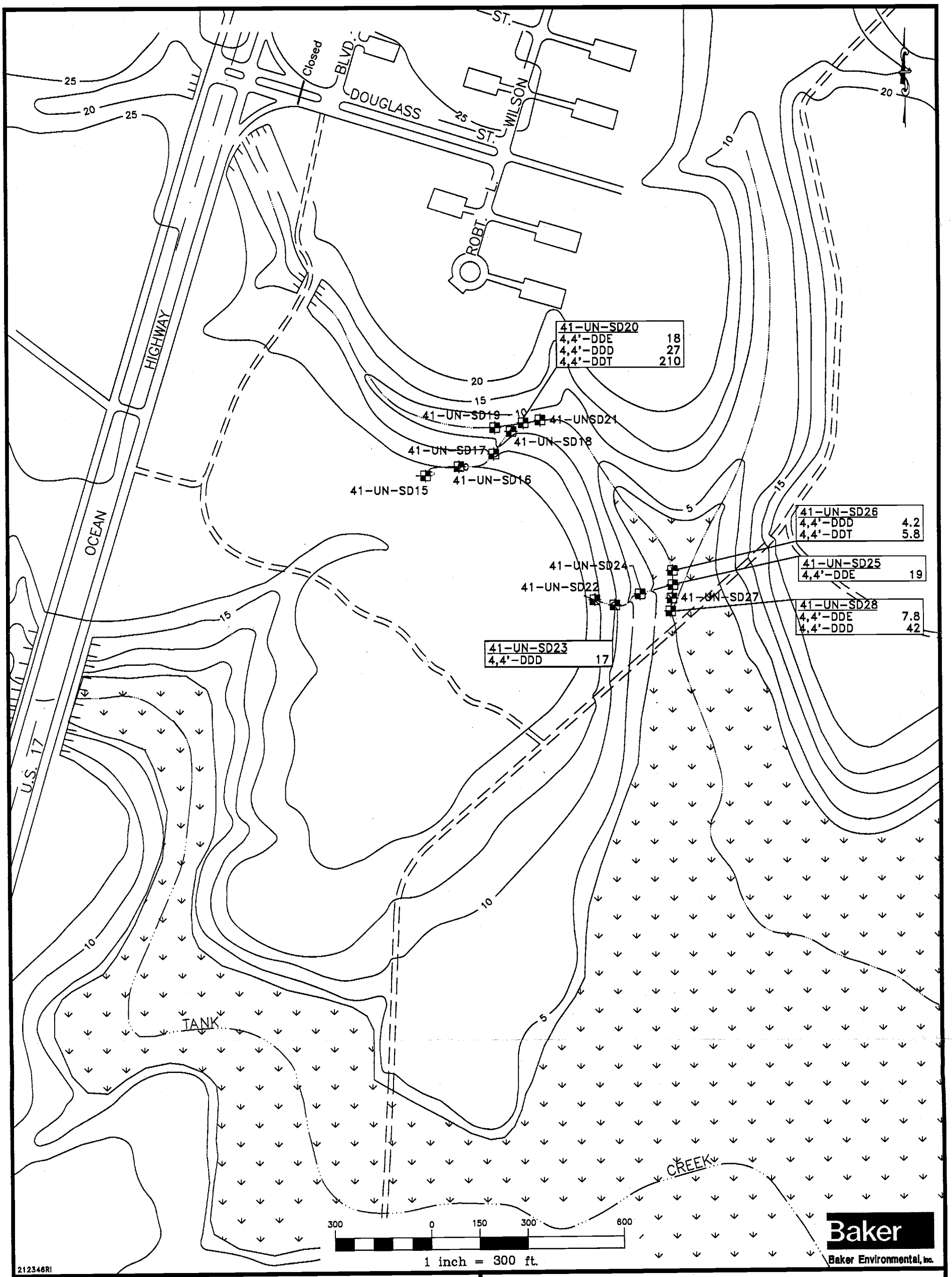
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

– MARSH

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

# FIGURE 4-25
# POSITIVE DETECTIONS OF PESTICIDES/ PCBs IN SEDIMENT - SITE 41
# CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
# REMEDIAL INVESTIGATION CTO-0212
## MARINE CORPS BASE, CAMP LEJEUNE
## NORTH CAROLINA




LEGEND

41-UN-SD15 – SURFACE WATER/SEDIMENT SAMPLE LOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

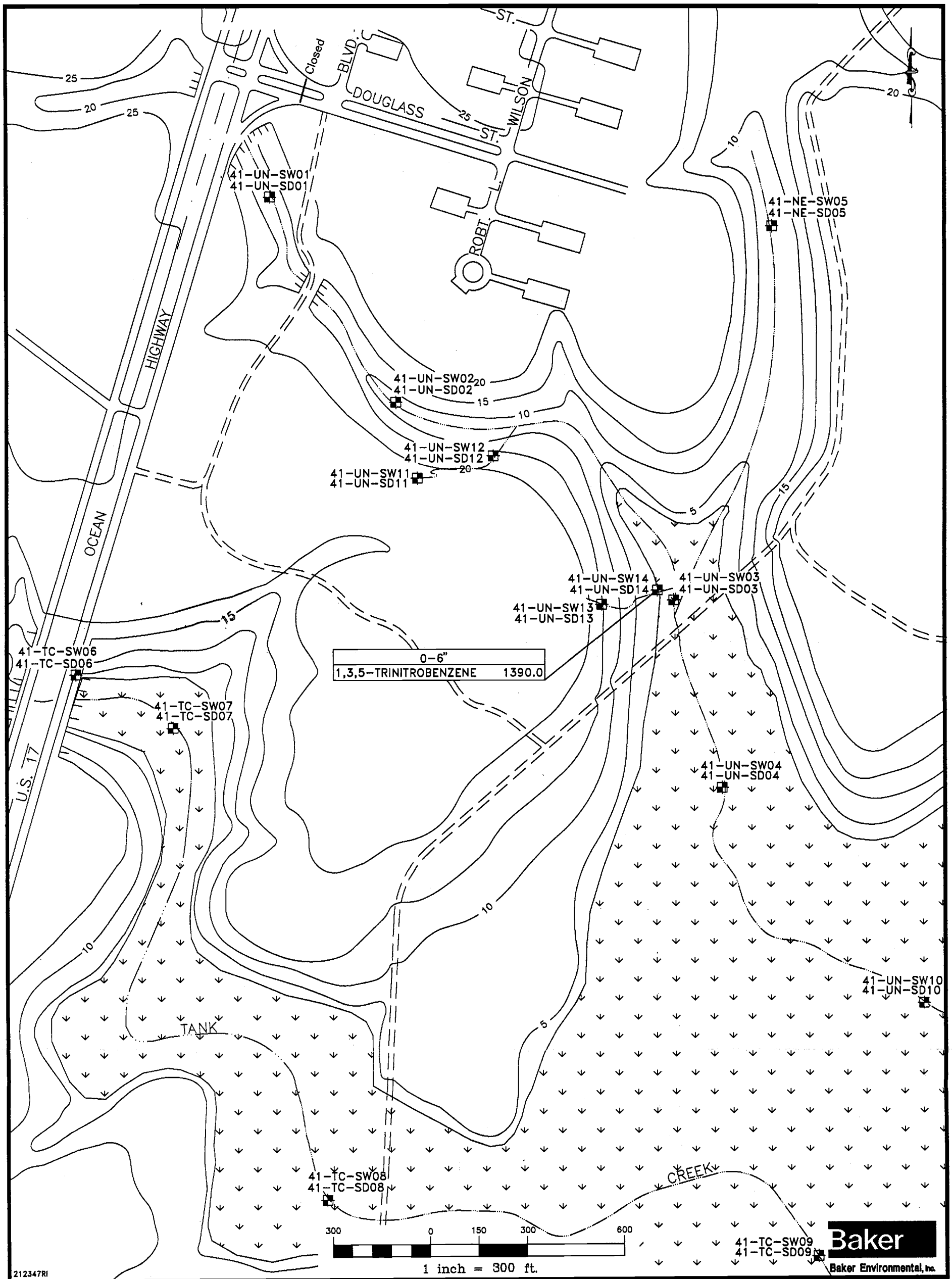
– ROAD (IMPROVED)

– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-26
POSITIVE DETECTIONS OF PESTICIDES FOR SECOND SAMPLING EVENT IN SEDIMENT – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




LEGEND

41-UN-SW01
41-UN-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

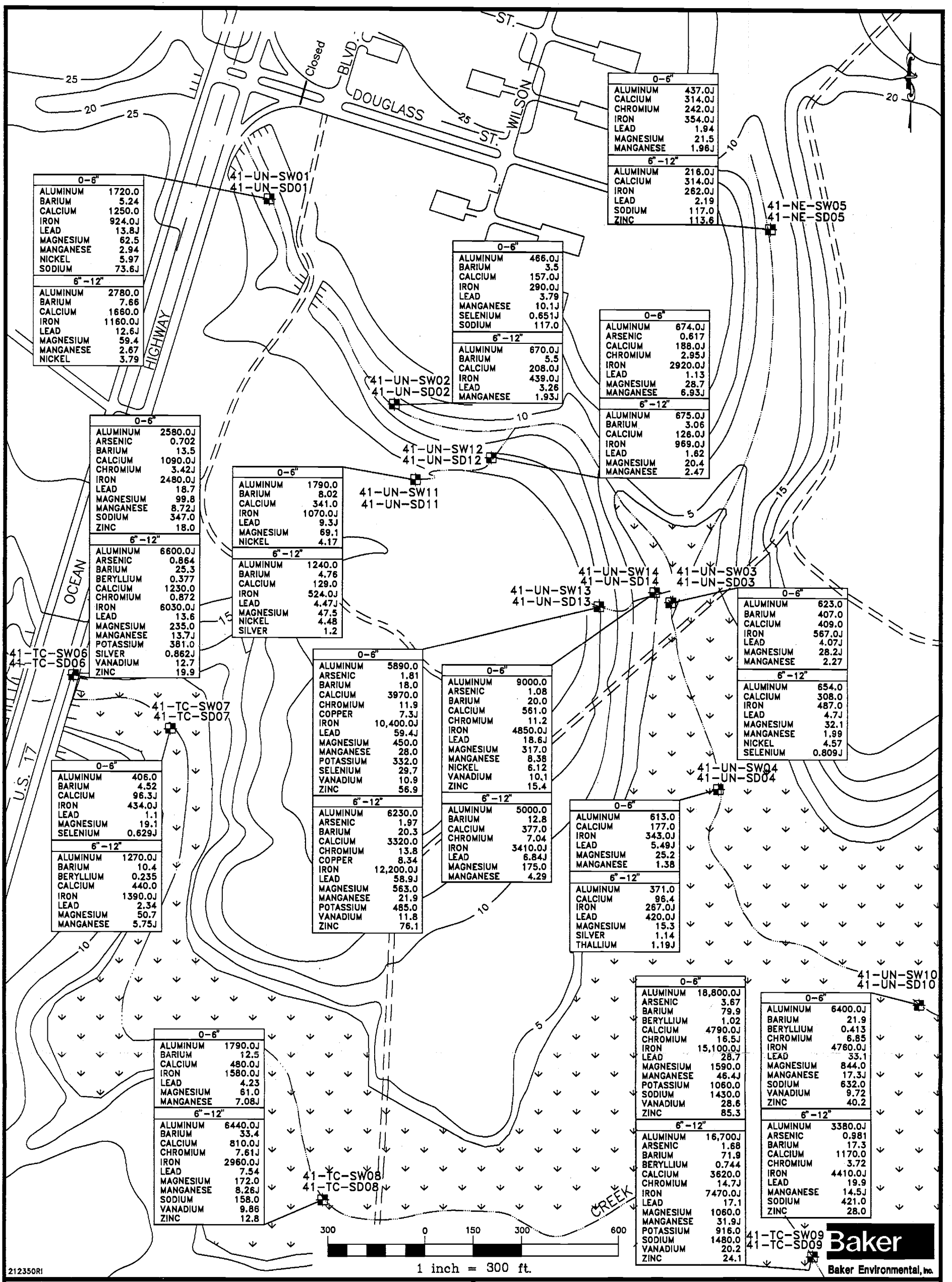
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

– MARSH

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

FIGURE 4-27
POSITIVE DETECTION OF ORDNANCE
IN SEDIMENT - SITE 41
CAMPGEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




## LEGEND

41-UN-SW01
41-UN-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

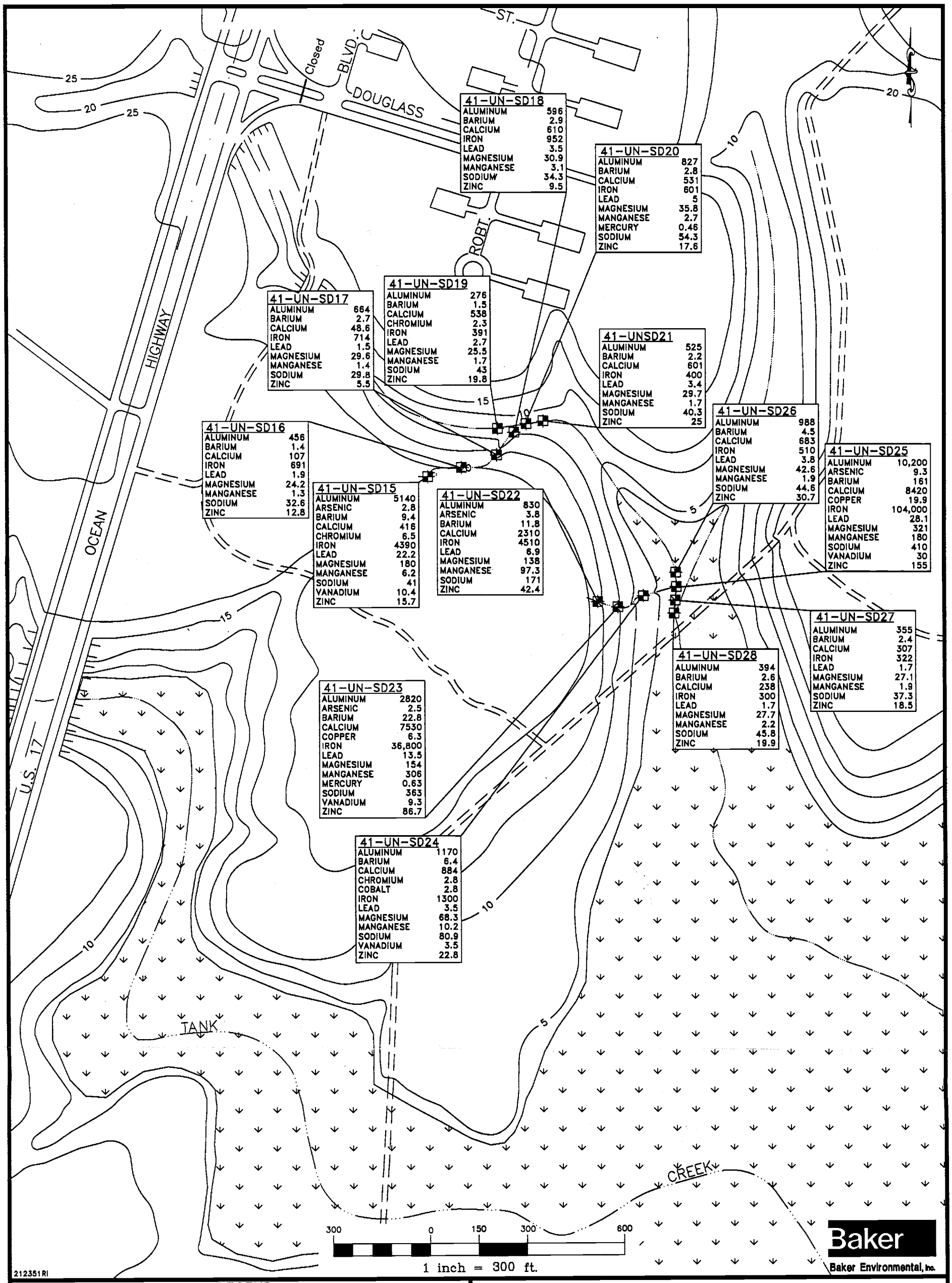
— 5 — – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED) = = – ROAD (UNIMPROVED)

– INTERMITTENT STREAM – MARSH

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, OCT. 1991

# FIGURE 4-28
# POSITIVE DETECTION OF TAL METALS IN SEDIMENT - SITE 41
# CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
# REMEDIAL INVESTIGATION CTO-0212
## MARINE CORPS BASE, CAMP LEJEUNE
## NORTH CAROLINA




LEGEND

41-UN-SD15 – SEDIMENT SAMPLE LOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

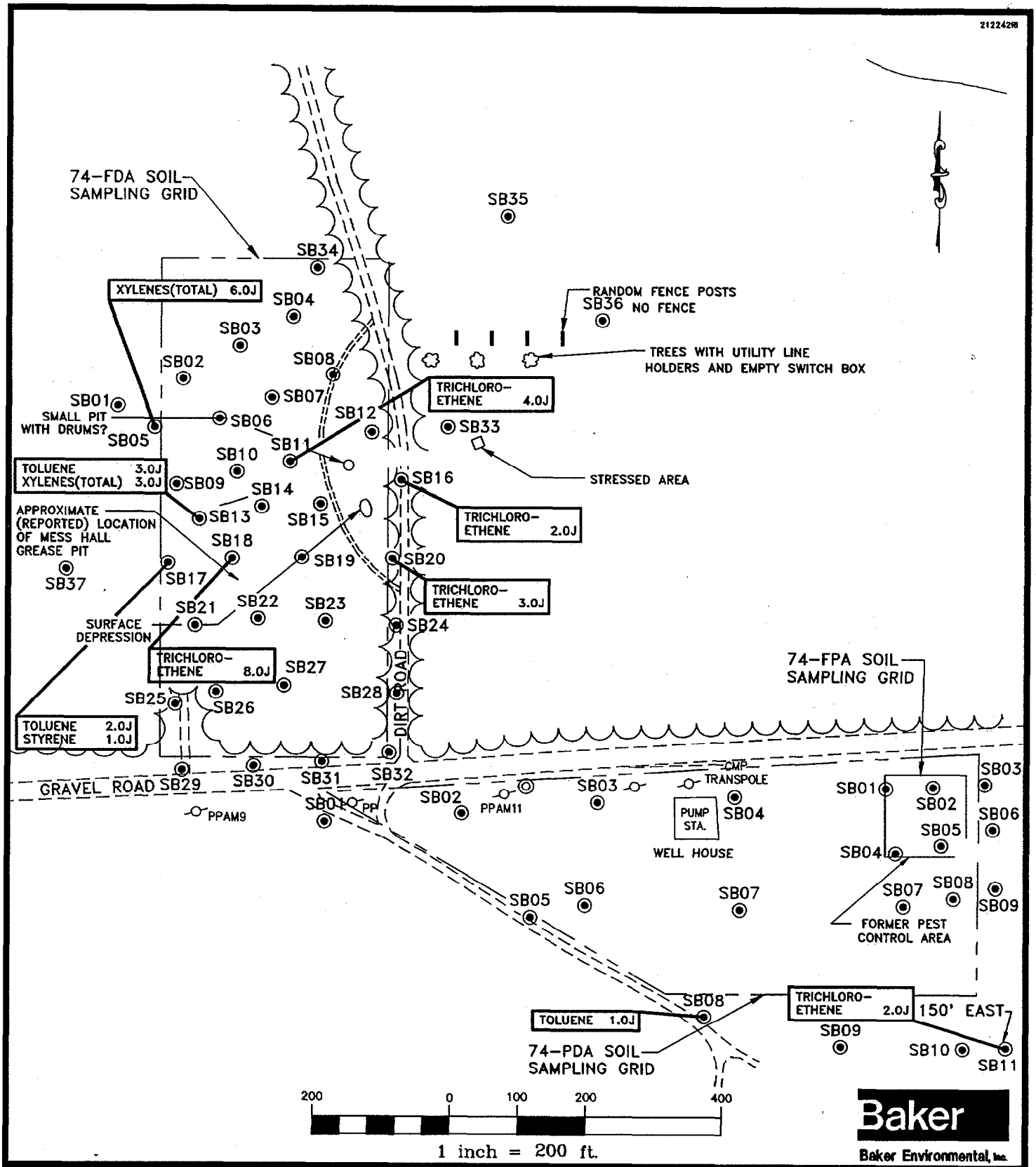
– ROAD (IMPROVED)

– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

SOURCE: LANTDIV, OCT. 1991

FIGURE 4-29
POSITIVE DETECTIONS OF TAL METALS FOR SECOND SAMPLING EVENT IN SEDIMENT – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

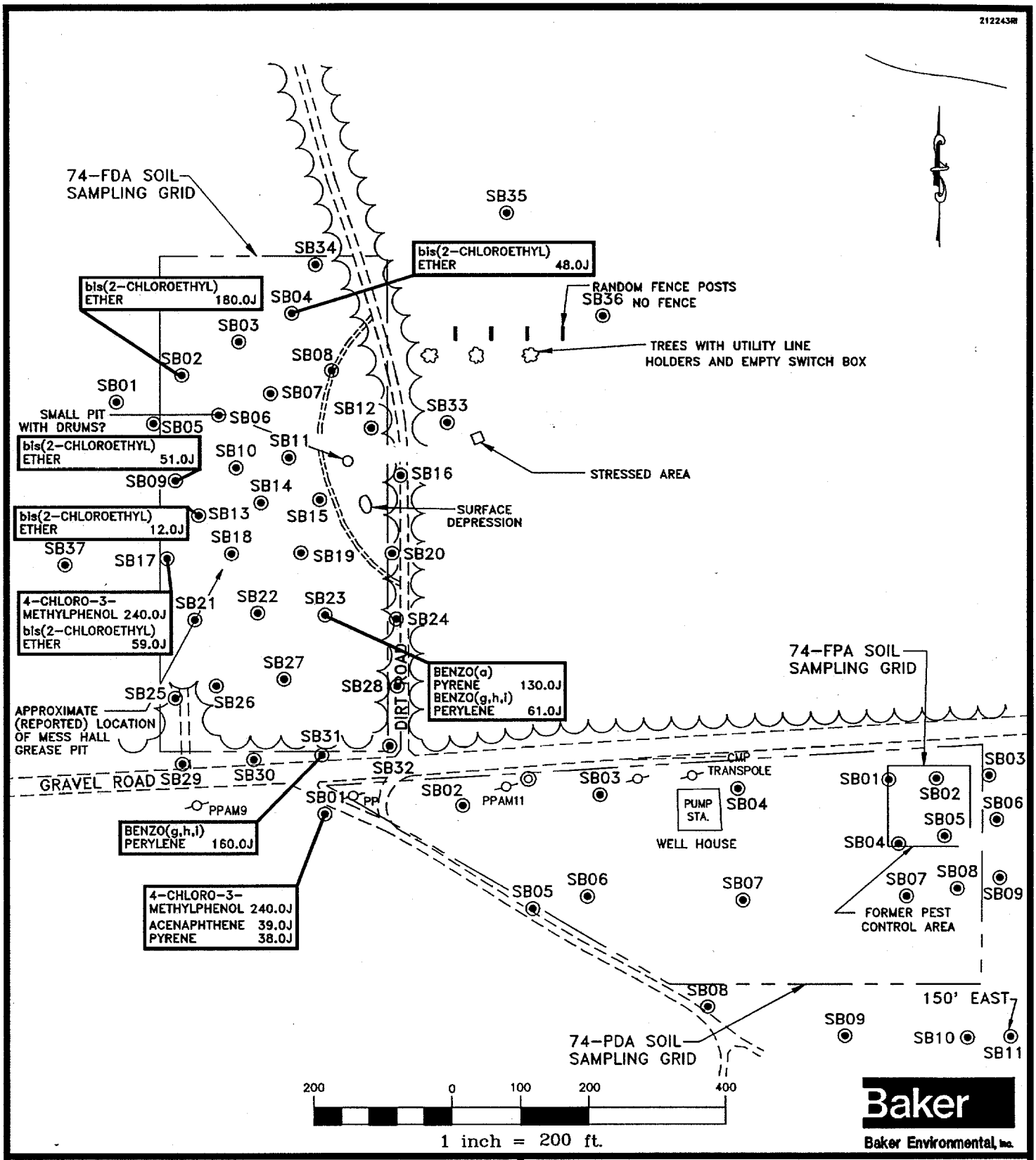



LEGEND

SB01 SOIL BORING LOCATION

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: REVISED FROM LANTDIV. OCT. 1991

FIGURE 4-30
POSITIVE DETECTIONS OF VOLATILES IN SURFACE SOILS - SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



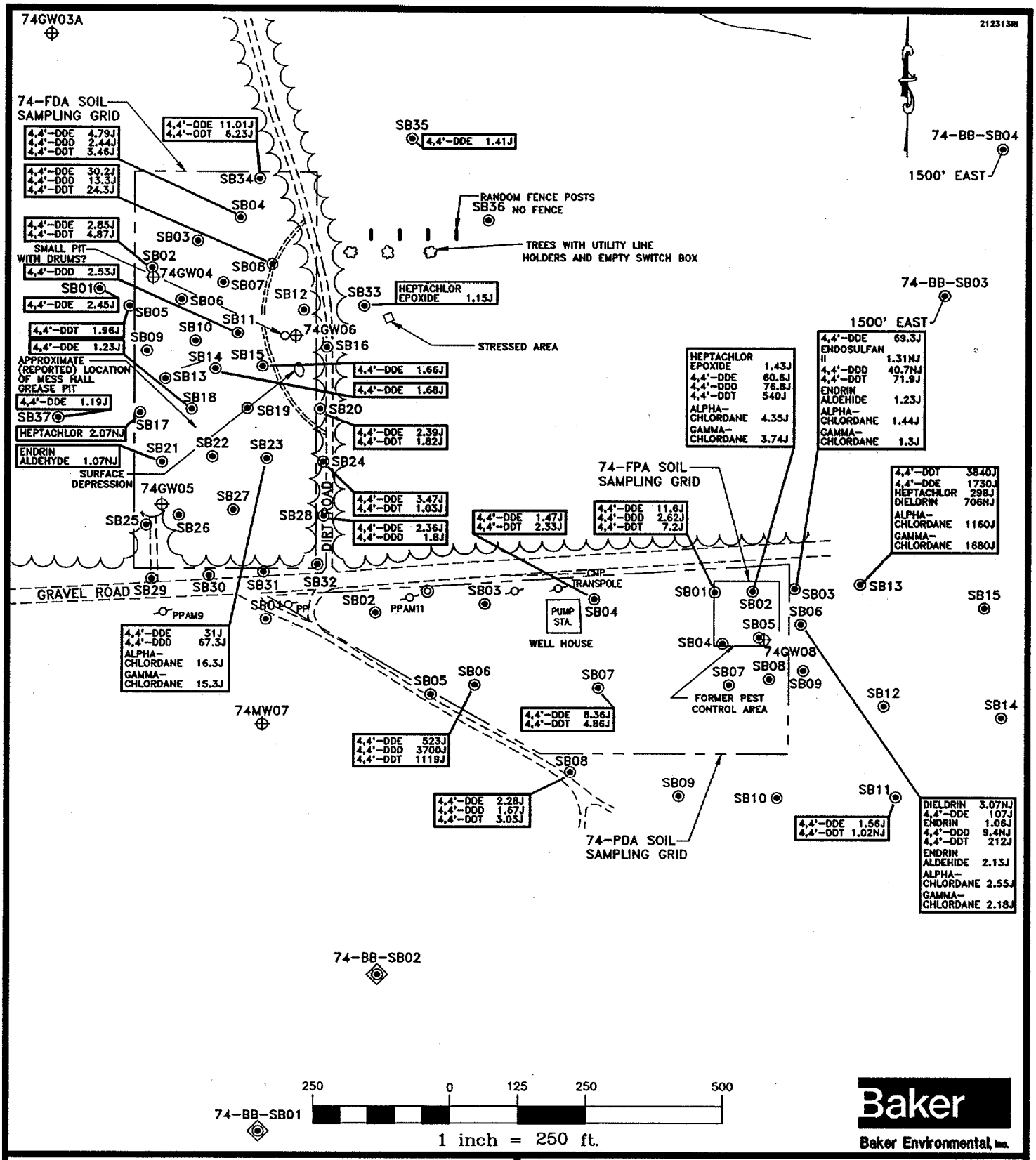

## LEGEND

SB01 SOIL BORING LOCATION

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

SOURCE: REVISED FROM LANTDIV. OCT. 1991

# FIGURE 4-31
## POSITIVE DETECTIONS OF SEMIVOLATILES IN SURFACE SOILS - SITE 74
## MESS HALL GREASE PIT DISPOSAL AREA
## REMEDIAL INVESTIGATION CTO-0212
## MARINE CORPS BASE, CAMP LEJEUNE
## NORTH CAROLINA



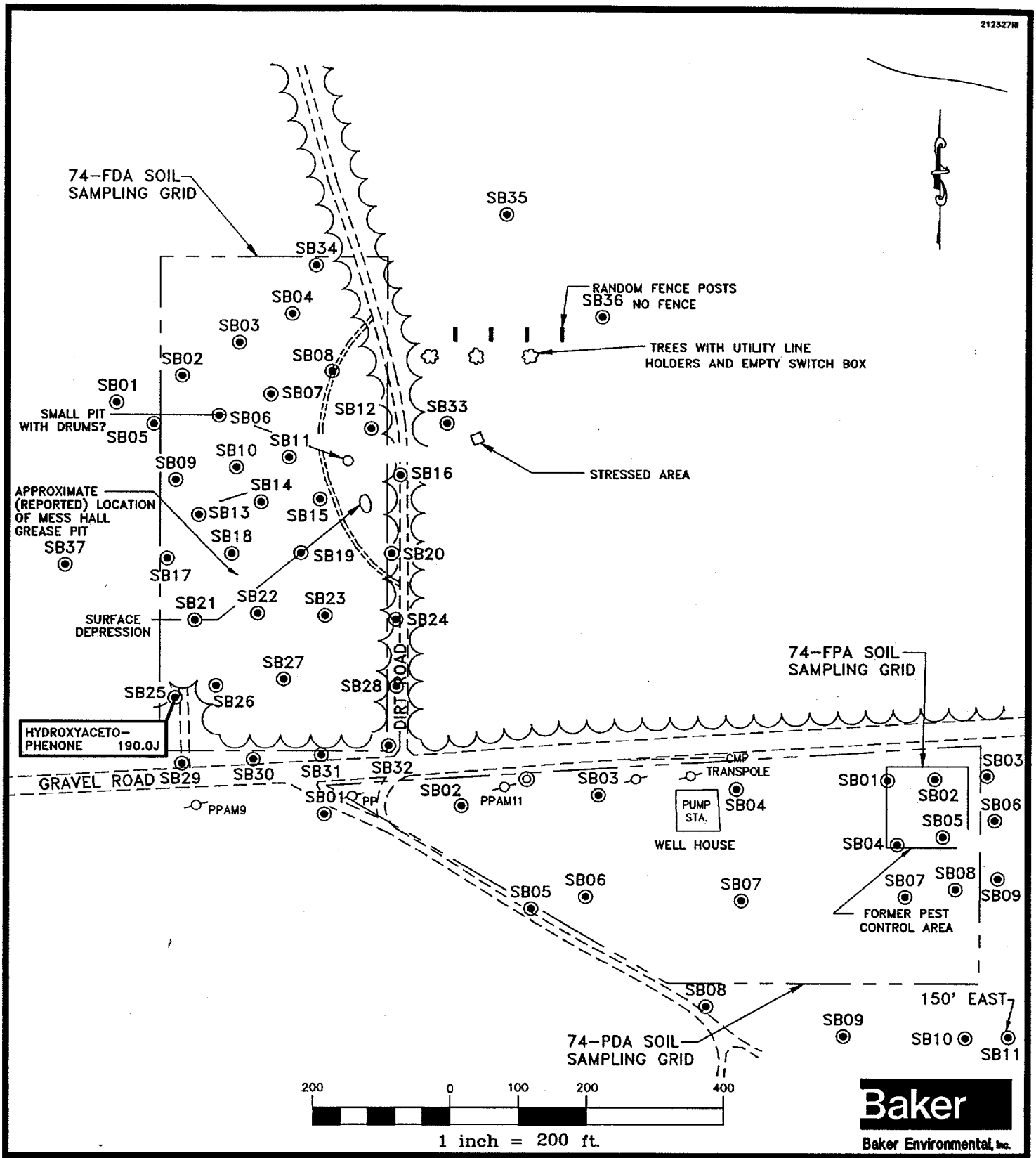

## LEGEND

| | |
|---|---|
| 74GW03A ⊕ | SHALLOW MONITORING WELL LOCATION |
| SB01 ◉ | SOIL BORING LOCATION |
| 74-BB-SB02 ◈ | BACKGROUND SOIL BORING LOCATION |

SOURCE: REVISED FROM LANTDIV. OCT. 1991

# FIGURE 4-32

POSITIVE DETECTIONS OF PESTICIDES ABOVE 1 ug/kg IN SURFACE SOILS – SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



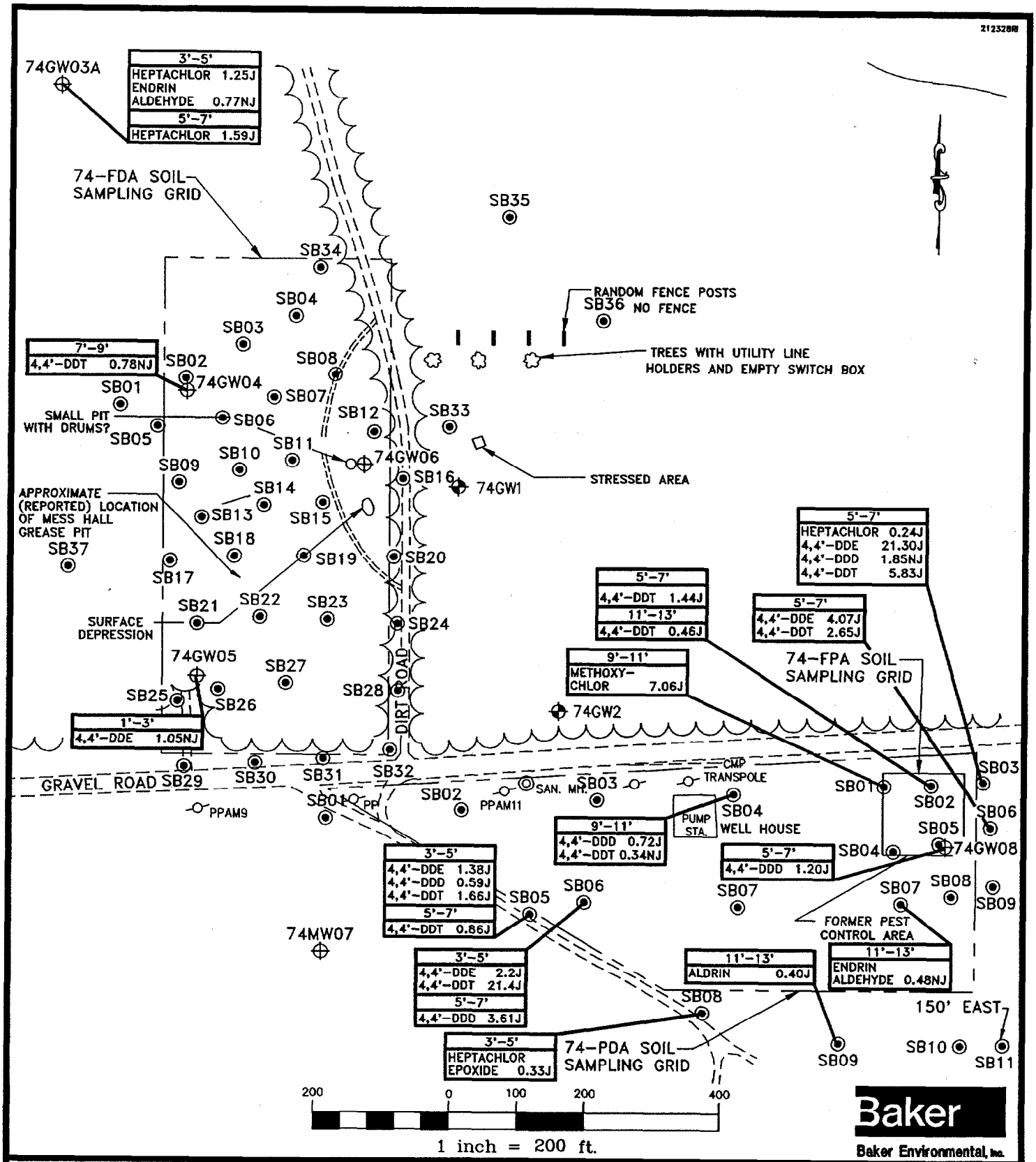

LEGEND

SB01 SOIL BORING LOCATION

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

SOURCE: REVISED FROM LANTDIV. OCT. 1991

FIGURE 4-33
POSITIVE DETECTIONS OF CHEMICAL SURETY MATERIALS IN SURFACE SOILS - SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




## LEGEND

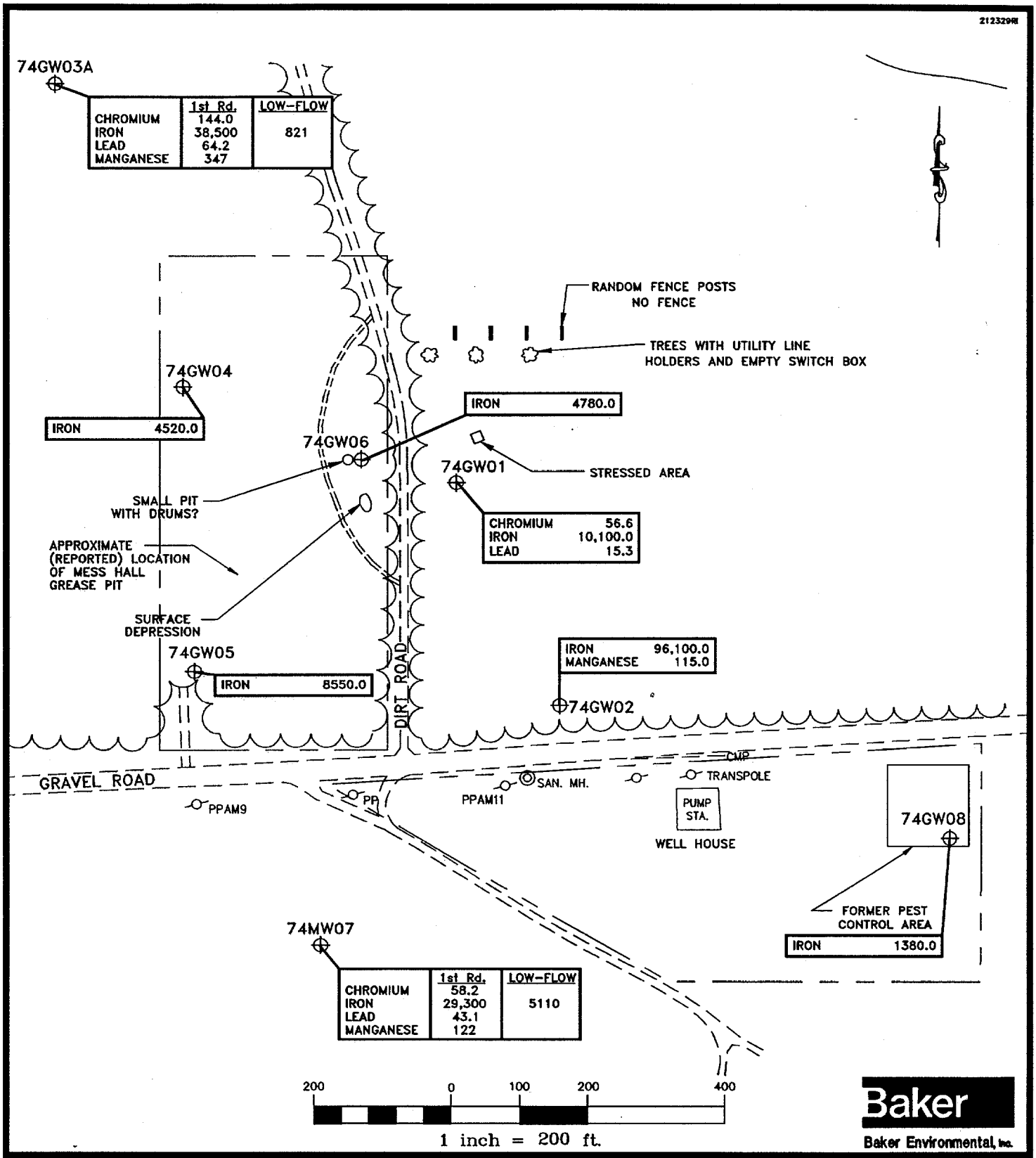
74GW03A ⊕ SHALLOW MONITORING WELL LOCATION

SB01 ⊙ SOIL BORING LOCATION

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

SOURCE: REVISED FROM LANTDIV. OCT. 1991

# FIGURE 4-34
## POSITIVE DETECTIONS OF PESTICIDES IN SUBSURFACE SOILS - SITE 74
## MESS HALL GREASE PIT DISPOSAL AREA
## REMEDIAL INVESTIGATION CTO-0212
## MARINE CORPS BASE, CAMP LEJEUNE
## NORTH CAROLINA



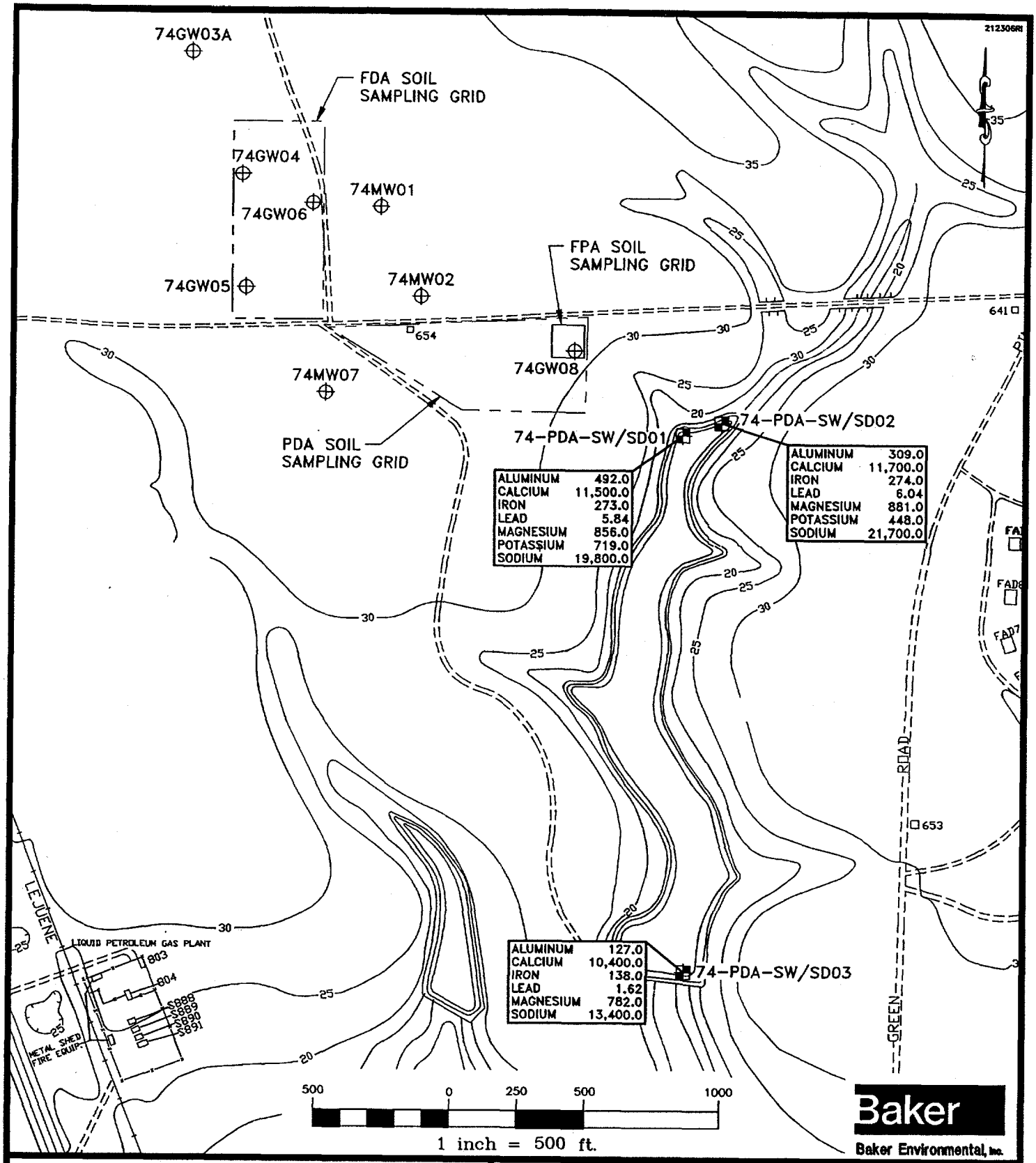

LEGEND

74GW03A ⊕ SHALLOW MONITORING WELL

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

SOURCE: REVISED FROM LANTDIV. OCT. 1991

FIGURE 4-35
POSITIVE DETECTIONS OF TAL METALS ABOVE FEDERAL MCLs AND/OR NCWQS IN SHALLOW WELLS
SITE 74 – MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

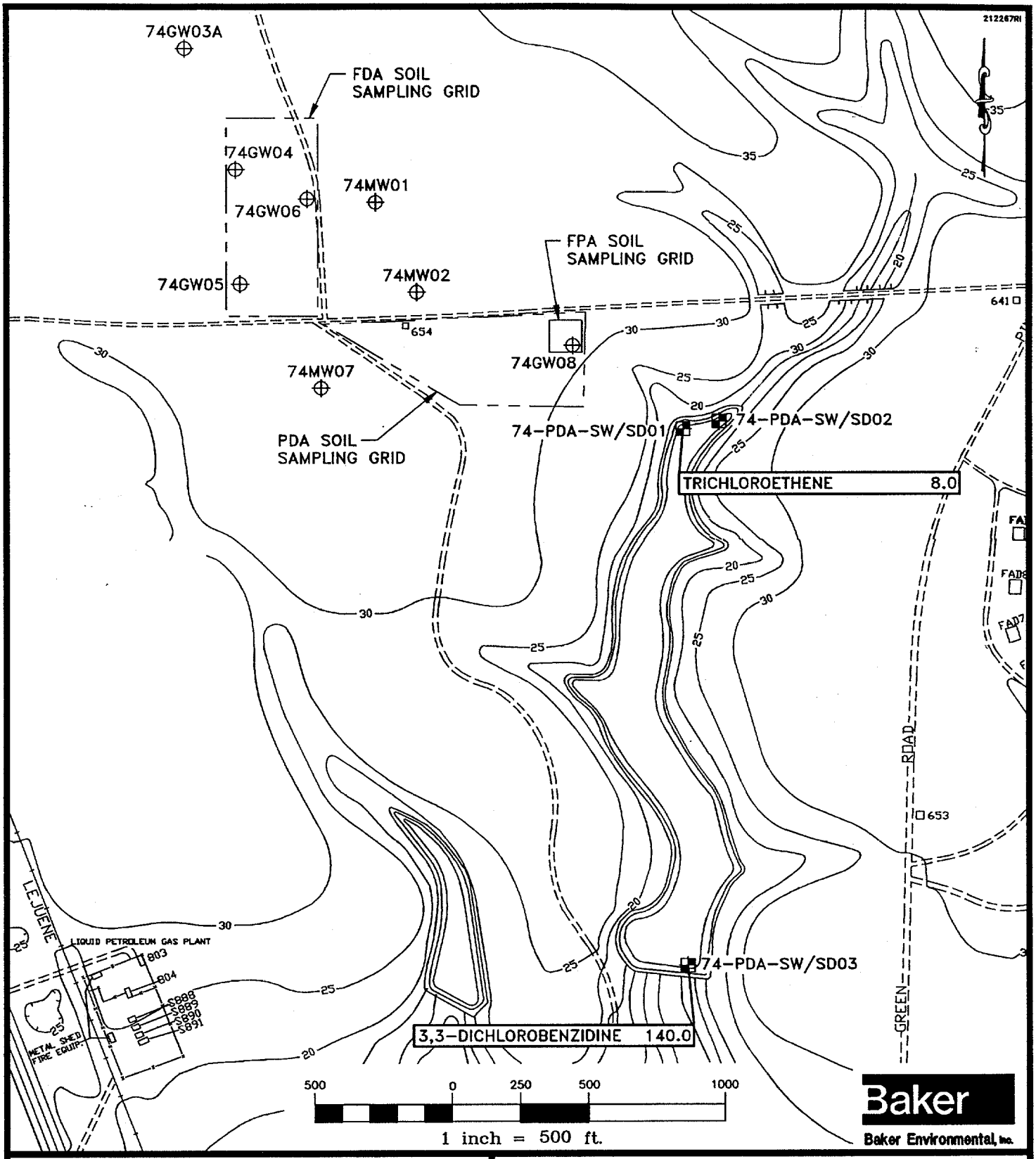



LEGEND

74-PDA-SW/SD01 SURFACE WATER/SEDIMENT SAMPLING STATION

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, FEB. 1994

FIGURE 4-36
POSITIVE DETECTIONS OF TAL METALS IN SURFACE WATER - SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

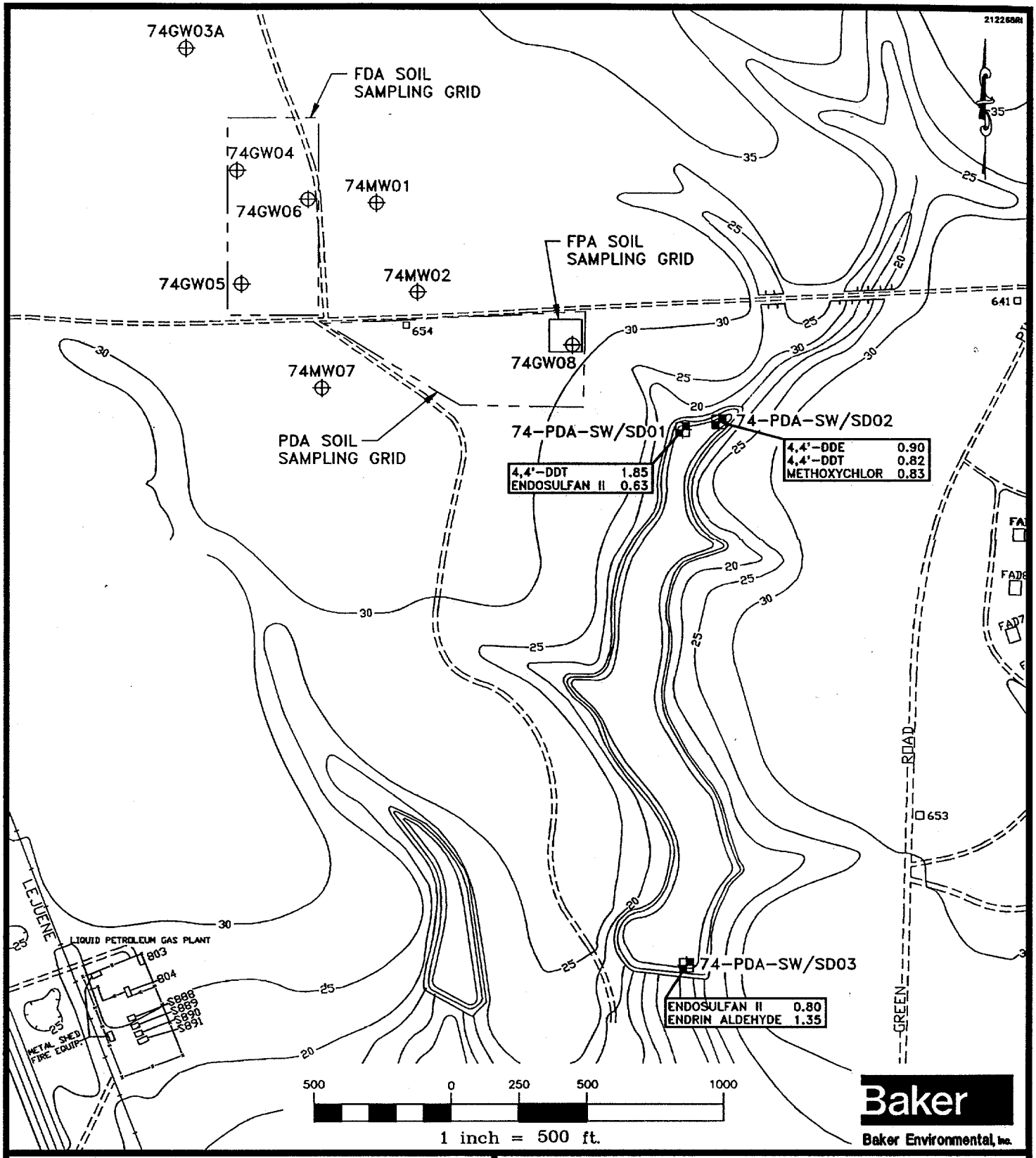



LEGEND

74-PDA-SW/SD01 SURFACE WATER/SEDIMENT SAMPLING STATION

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, FEB. 1994

FIGURE 4-37
POSITIVE DETECTIONS OF VOLATILES AND SEMIVOLATILES IN SEDIMENT - SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

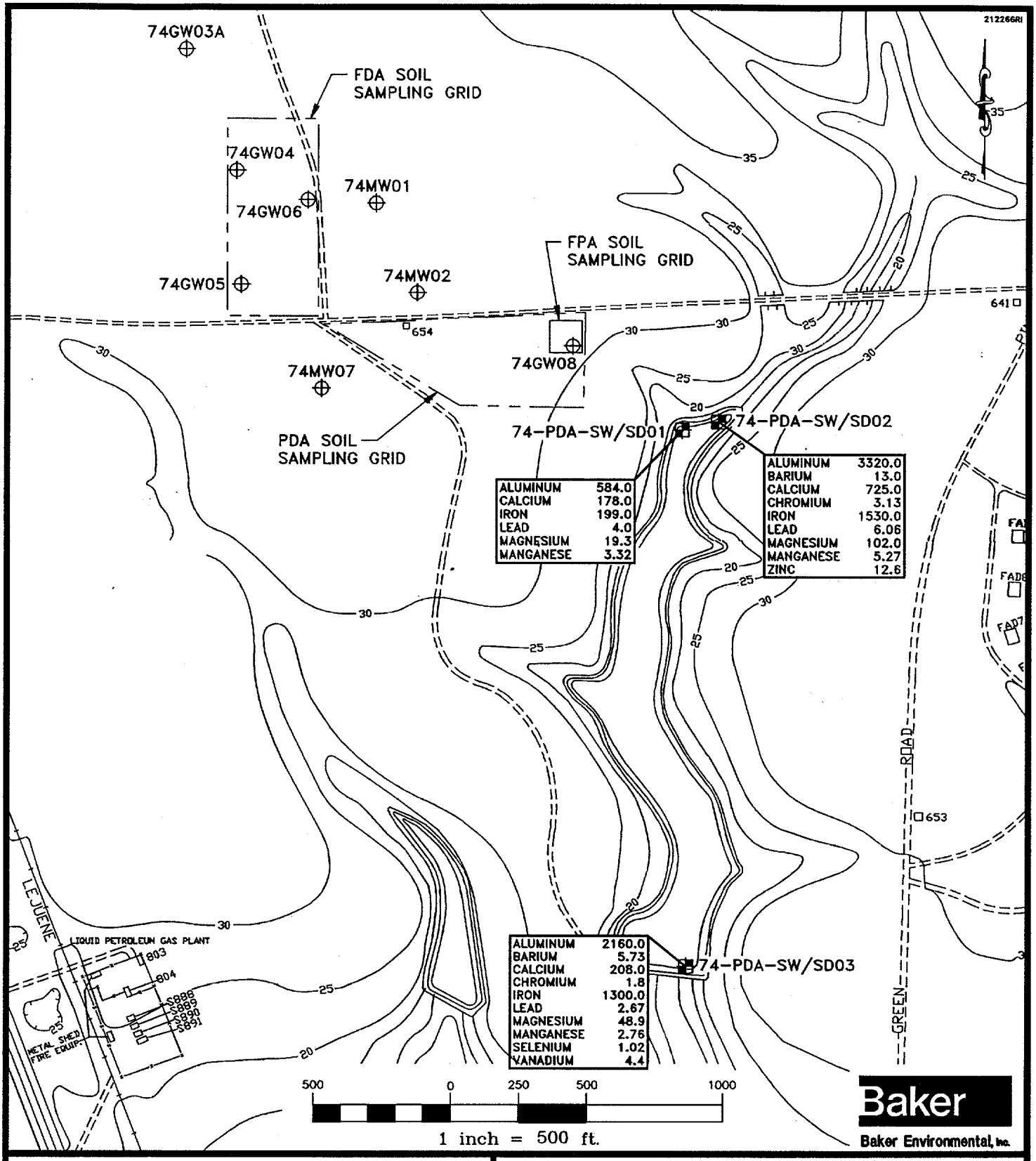



LEGEND

74-PDA-SW/SD01 SURFACE WATER/SEDIMENT SAMPLING STATION

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, FEB. 1994

FIGURE 4-38
POSITIVE DETECTIONS OF PESTICIDES IN SEDIMENT – SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA




LEGEND

74-PDA-SW/SD01 SURFACE WATER/SEDIMENT SAMPLING STATION

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER KILOGRAM (ug/kg).
SOURCE: LANTDIV, FEB. 1994

FIGURE 4-39
POSITIVE DETECTIONS OF TAL METALS IN SEDIMENT – SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

# 5.0 CONTAMINANT FATE AND TRANSPORT

The potential for a contaminant to migrate and persist in an environmental medium is critical when evaluating the potential for a chemical to elicit an adverse human health or ecological effect. The environmental mobility of a chemical is influenced by its physical and chemical properties, the physical characteristics of the site, and the site chemistry. This section presents a discussion of the various physical and chemical properties of contaminants detected at OU No. 4 that impact the fate and transport of the contaminants in the environment. The basis for this discussion of contaminant fate and transport is discussed in Section 4.0, Nature and Extent of Contamination.

## 5.1 Chemical and Physical Properties Impacting Fate and Transport

Table 5-1 presents the physical and chemical properties associated with the organic contaminants detected during this investigation. These properties determine the inherent environmental mobility and fate of a contaminant. These properties include:

- Vapor pressure
- Water solubility
- Octanol/water partition coefficient
- Organic carbon adsorption coefficient (sediment partition)
- Specific gravity
- Henry's Law constant
- Mobility index

A discussion of the environmental significance of each of these properties follows.

Vapor pressure provides an indication of the rate at which a chemical may volatilize. It is of primary significance at environmental interfaces such as surface soil/air and surface water/air. Volatilization is not as important when evaluating groundwater and subsurface soils. Vapor pressure for monocyclic aromatics are generally higher than vapor pressures for PAHs. Contaminants with higher vapor pressures will enter the atmosphere at a quicker rate than the contaminants with low vapor pressures.

The rate at which a contaminant is leached from soil by infiltrating precipitation is proportional to its water solubility. More soluble contaminants are usually more readily leached than less soluble contaminants. The water solubilities indicate that the volatile organic contaminants including monocyclic aromatics are usually several orders-of-magnitude more soluble than PAHs.

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

The organic carbon adsorption coefficient ($K_{oc}$) indicates the tendency of a chemical to adhere to soil particles organic carbon. Contaminants with high soil/sediment adsorption coefficients generally have low water solubilities and vice versa. For example, contaminants such as PAHs are relatively immobile in the environment and are preferentially bound to the soil. The compounds are not subject

to aqueous transport to the extent of compounds with higher water solubilities. Erosional properties of surface soils may, however, enhance the mobility of these bound soils contaminants.

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

Vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. These two parameters can be used to estimate an equilibrium concentration of a contaminant in the water phase and in the air directly above the water. This can be expressed as Henry's Law Constant.

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

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

A scale to evaluate MI is presented by Ford and Gurba (1894):

| Relative MI | Mobility Description |
|---|---|
| > 5 | extremely mobile |
| 0 to 5 | very mobile |
| -5 to 0 | slightly mobile |
| -10 to -5 | immobile |
| < -10 | very immobile |

## 5.2 Contaminant Transport Pathways

Based on the evaluation of existing conditions at Sites 41 and 74, the following potential contaminant transport pathways have been identified.

- On-site atmospheric deposition of windblown dust.
- Leaching of sediment contaminants to surface water.
- Migration of contaminants in surface water.
- Leaching of soil contaminants to groundwater.
- Migration of groundwater contaminants off site.
- Groundwater infiltration from the shallow aquifer to the deep aquifer.

Contaminants released to the environment could also undergo the following during transportation:

- Physical transformations: volatilization, precipitation
- Chemical transformations: photolysis, hydrolysis, oxidation, reduction
- Biological transformation: biodegradation
- Accumulation in one or more media

The following paragraphs describe the potential transport pathways listed above.

### 5.2.1 On-Site Deposition of Windblown Dust

Wind can act as a contaminant transport pathway agent by eroding exposed soil and exposed sediment and blowing it off site. This is influenced by: wind velocity, the grain size/density of the soil/sediment particles and the amount of vegetative cover over the soil or sediment.

A majority of the surface area of each site is vegetated (i.e., grass, trees), which would serve to retard airborne migration of site contaminants.

### 5.2.2 Leaching of Sediment Contaminants to Surface Water

When in contact with surface water, contaminants attached to sediment particles can disassociate from the sediment particle into surface water. This is primarily influenced by the physical and chemical properties of the contaminant, (i.e., water solubility, $K_{oc}$) and the physical and chemical properties of the sediment particle (i.e., grain size, $f_{oc}$).

Surface water sample analytical results indicate that there has not been significant leaching of sediment contaminants into surface water (Section 4.0), based on the infrequent occurrence and level of contamination.

### 5.2.3 Leaching of Soil Contaminants to Groundwater

Contaminants that adhere to soil particles or have accumulated in soil pore spaces can leach and migrate vertically to the groundwater. This is influenced by the depth to the water table, precipitation, infiltration, physical and chemical properties of the soil, and physical and chemical properties of the contaminant.

Groundwater samples were collected from shallow and deep monitoring wells at Site 41, and shallow wells only at Site 74. The groundwater analytical results can be compared to soil sample analytical results to determine if contaminants detected in soil have migrated or may migrate in the future, to underlying groundwater.

### 5.2.4 Migration of Groundwater Contaminants

Contaminants leaching from soils to underlying groundwater can migrate as dissolved constituents in groundwater in the direction of groundwater flow. Three general processes govern the migration of dissolved contaminants caused by the flow of water: (1) advection, movement caused by flow of groundwater; (2) dispersion, movement caused by irregular mixing of waters during advection; and (3) retardation, principally chemical mechanisms which occur during advection. Subsurface transport of the immiscible contaminants is governed by a set of factors different from those of dissolved contaminants. The potential movement of immiscible organic liquids (non-aqueous phase liquids) will not be discussed in this section.

Advection is the process which most strongly influences the migration of dissolved organic solutes. Groundwater, under water table aquifer conditions (i.e., unconfined aquifer), generally flows from regions of the subsurface where the water table is under a higher head to regions (i.e., recharge areas) of where the water table is under a lower head (i.e., discharge areas). Hydraulic gradient is the term used to describe the magnitude of this force (i.e., the slope of the water table). In general, the gradient usually follows the topography for shallow, uniform sandy aquifers which are commonly

found in coastal regions. In general, groundwater flow velocities, in sandy aquifers, under natural gradient conditions are probably between 10 meters/year to 100 meters/year (Lyman, et al., 1982).

Thus, when monitoring wells or potable supply wells in sand aquifers are located hundreds of meters downgradient of a contaminant source, the average travel time for the groundwater to flow from the source to the well point is typically on the order of years. In the zone of influence created by a high capacity production well or well field, however, the artificially increased gradient could substantially increase the local velocity, and the average travel times for groundwater flow are increased.

Dispersion results from two basic processes, molecular diffusion and mechanical mixing. The kinetic activity of dissolved solutes result in diffusion of solutes from a zone of high concentration to a lower concentration. Dispersion and spreading during transport result in the dilution of contaminants (maximum concentration of contaminant decreases with distance from the plume). For simple hydrogeological systems, the spreading is reported to be proportional to the flow rate. Furthermore, dispersion in the direction of flow is often observed to be markedly greater than dispersion in the directions transverse (perpendicular) to the flow. In the absence of detailed studies to determine dispersive characteristics at all the sites, longitudinal and transverse dispersivities are estimated based on similar hydrogeological systems (Mackay, et al., 1985).

Some dissolved contaminants may interact with the aquifer solids encountered along the flow path through adsorption, partitioning, ion exchange, and other processes. The interactions result in the contaminant distribution between aqueous phase and aquifer solids, diminution of concentrations in the aqueous phase, and retardation of the movement of the contaminant relative to groundwater flow. The higher the fraction of the contaminant sorbed, the more retarded its transport. Certain halogenated organic solvents sorption is affected by hydrophobility (antipathy for dissolving in water) and the fraction of solid organic matter in the aquifer solids (organic carbon content). If the aquifer below is homogeneous, sorption of hydrophobic organic solute should be constant in space and time. If the sorptive interaction is at equilibrium and completely reversible, the solute should move at a constant average velocity equal to the groundwaters average velocity divided by the retardation factor.

Organic contaminants can be transformed into other organic compounds by a complex set of chemical and biological mechanisms. The principal classes of chemical reactions that can affect organic contaminants in water are hydrolysis and oxidation. However, it is believed that most chemical reactions occurring in the groundwater zone are likely to be slow compared with transformations mediated by microorganisms. Certain organic groundwater contaminants can be biologically transformed by microorganisms attached to solid surfaces within the aquifer. Factors which affect the rates of biotransformation of organic compounds include: water temperature and pH, the number of species of microorganisms present, the concentration of substrate, and presence of microbial toxicants and nutrients, and the availability of electron acceptors. Transformation of a toxic organic solute is no assurance that it has been converted to harmless or even less harmless hazardous products. Biotransformation of common groundwater contaminants, such as TCE, TCA, and PCE, can result in the formation of such intermediates as vinyl chloride (Mackay, et al., 1985).

The interaction of non-ionic organic compounds with solid phases can also be used to predict the fate of the highly nonpolar organic contaminants (i.e., 4,4'-DDT, PCBs). Sorptive binding is proportional to the organic content of the sorbent. Sorption of non-ionic organic pesticides can be attributed to an active fraction of the soil organic matter (Lyman et al., 1982). The uptake of neutral organics by soils results from their partitioning to the solutes aqueous solubility and to its liquid-liquid (e.g.,

octanol-water) partition coefficient (Chiou, 1979). Currently, literature information is available on the interrelation of soil organic properties to the binding of pesticides, herbicides, and high molecular weight pollutants such as PCBs. Organic matrices in natural systems that have varying origins, degrees of humification, and degrees of association with inorganic matrices exhibit dissimilarities in their ability to sorb non-ionic organic contaminants.

The soils and sediments formed or deposited on the land surface can act as a reservoir for inorganic contaminants. Soils contain surface-active mineral and humic constituents involved in reactions that affect metal retention. The surfaces of fine-grained soil particles are very active chemically; surface sites are negatively or positively charged or they are electronically neutral. Oppositely charged metallic counterions from solutions in soils (i.e., groundwater) are attracted to these charged surfaces. The relative proportions of ions attracted to these various sites depends on the degree of acidity or alkalinity of the soil, on its mineralogical composition, and on its content of organic matter. The extent of adsorption depends on either the respective charges on the adsorbing surface and the metallic cation. In addition to these adsorption reactions, precipitation of new mineral phases also may occur if the chemical composition of the soil solution becomes supersaturated with respect to the insoluble precipitates. Of the probable precipitates, the most important of these phases are hydroxides, carbonates, and sulfides. The precipitation of hydroxide minerals is important for metals such as iron and aluminum, the precipitation of carbonate minerals is significant for calcium and barium, and the precipitation of sulfide minerals dominates the soil chemistry of zinc, cadmium, and mercury. A number of precipitates may form if metals are added to soils, the concentration of metal in solution, will be controlled, at equilibrium, by the solid phase that results in the lowest value of the activity of the metallic ion in solution (Evans, 1989).

Table 5-2 presents the general processes which influence the aquatic fate of contaminants at OU No. 4.

The following paragraphs summarize the site-specific fate and transport data for some potential contaminants of concern at OU No. 4.

## 5.3 Fate and Transport Summary

The following paragraphs summarize the contaminant group fate and transport data for contaminants detected in media collected at OU No. 4.

### 5.3.1 Volatile Organic Compounds

VOCs (i.e., vinyl chloride, TCE, and PCA) tend to be mobile in environmental media as indicated by their presence in groundwater and their corresponding MI values. Their environmental mobility is a function of high water solubilities, high vapor pressures, low $K_{ow}$ and $K_{oc}$ values, and high mobility indices.

Without a continuing source, VOCs do not generally tend to persist in environmental media because photolysis, oxidation, and biodegradation figure significantly in their removal.

### 5.3.2 Polycyclic Aromatic Hydrocarbons

Low water solubilities, high $K_{ow}$ and $K_{oc}$ indicate a strong tendency for PAHs to adsorb to soils. Of the PAHs, fluoranthene, is probably the best marker compound, since it is consistently the most

abundant of the PAHs measured and provides the strongest correlation with total PAH values. Benzo(g, h, i) perylene is usually the most abundant compound in soils with low PAH values but becomes less important with increasing total PAH values. Other PAH are benzo(a)anthracene, chrysene, pyrene, benzo(g,h,i) perylene, benzo(b)fluoranthene and phenanthrene. Their mobility indices indicate that they are relatively immobile from a physical-chemical standpoint. An exception is naphthalene, which is considered only slightly immobile because of somewhat higher water solubility (Jones, et al., 1989).

PAHs generally lack adequate vapor pressures to be transmitted via vaporization and subsequent airborne transport. However, surface and shallow surface soil particles containing PAHs could potentially be subject to airborne transport and subsequent deposition, especially during mechanical disturbances such as vehicle traffic or digging (Jones, et al., 1989).

PAHs are somewhat persistent in the environment. In general their persistence increases with increasing ring numbers. Photolysis and oxidation may be important removal mechanisms in surface waters and surficial soils, while biodegradation could be an important fate process in groundwater, surface soils or deeper soils. PAHs are ubiquitous in nature. The presence of PAHs in the soil may be the result of aerially deposited material, and the chemical and biological conditions in the soil which result in selective microbial degradation/breakdown.

### 5.3.3 Pesticides/Polychlorinated Biphenyls

Pesticides/PCBs are persistent and immobile contaminants in environmental media. Pesticides travel at varying rates through soil, mainly due to their affinity for soil surfaces. The soil sorption coefficient ($K_d$) is the distribution of a pesticide between soil and water. In general, the $K_d$ values are higher for high organic carbon soil than for low organic carbon soils. Therefore, soils with high $K_d$ values will retain pesticides (i.e., 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD). As evidenced by the ubiquitous nature of 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD, volatilization is an important transport process from soils and waters.

PCBs have low vapor pressures, low water solubilities, and high $K_{oc}$ and $K_{ow}$ values. Adsorption of these contaminants to soil and sediment is the major fate of these contaminants in the environment.

### 5.3.4 Inorganics

Inorganics can be found as solid complexes at ambient temperature and pressure in soils at the site. Inorganic ions exist in pure solutions as hydrated ions. Groundwater, as opposed to a pure solution, is a highly complex chemical system which is heavily influenced by the mineralogy of the substrate. Factors affecting the transport of inorganics in saturated soils are interactive and far more complex and numerous than those affecting the transport of organic contaminants.

The most complicated pathway for inorganic contaminants is migration in subsurface soils and groundwaters, where oxidation reduction potential (Eh) and pH play critical roles. Table 5-3 presents and assessment of relative inorganic environmental mobilities as a function of Eh and pH. Soils at MCB Camp Lejeune are relatively neutral, therefore, inorganics in the subsurface soil should be relatively immobile.

Transport of inorganic species in groundwater is mainly a function of the inorganic's solubility in solution under the chemical conditions of the soil-solution matrix. The inorganic must be dissolved

(i.e. in solution) for leaching and transport by advection with the groundwater to occur. Generally, dynamic and reversible processes control solubility and transport of the dissolved metal ions. Such process include precipitation/dissolution, adsorption/desorption, and ion exchange.

Inorganics could be sorbed onto colloidal materials, theoretically increasing their inherent mobility in saturated porous media. It is important to note, however, that colloids themselves are not mobile in most soil/water systems.

Inorganics such as arsenic and chromium depend upon speciation to influence their mobility. Speciation varies with the chemistry of the environmental medium and temporal factors. These variables make the site-specific mobility of an inorganic constituent difficult to assess.

# SECTION 5.0 TABLES

**TABLE 5-1**

**ORGANIC PHYSICAL AND CHEMICAL PROPERTIES**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Chemical | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Octanol/Water Coefficient (log $K_{ow}$) | Sediment Partition (log $K_{oc}$) | Specific Gravity ($g/cm^3$) | Henry's Law Constant ($atm\text{-}m^3/mole$) | Mobility Index | Comments |
|---|---|---|---|---|---|---|---|---|
| ***Volatiles:*** | | | | | | | | |
| Benzene | 76 | 1780 | 2.13 | 1.92 | 0.879 | 5.55E-03 | 3.2 | Very mobile |
| Bromodichloromethane | 50 | 4500 | 2.10 | 1.79 | -- | 2.41E-03 | 3.6 | Very mobile |
| Chlorobenzene | 8.8 | 500 | 2.84 | 2.64 | 1.1066 | 3.58E-03 | 1 | Very mobile |
| 1,1-Dichloroethene | 500 | 400 | 1.48 | 2.26 | 1.218 | 1.90E-01 | 3.0 | Very mobile |
| 1,2-Dichloroethene | 200 | 600 | 1.48 | 2.17 | 1.26 | 5.32E-03 | 2.9 | Very mobile |
| Ethylbenzene | 7 | 152 | 3.15 | 2.93 | 0.867 | 6.44E-03 | 0.1 | Very mobile |
| Tetrachloroethene | 14 | 150 | 2.6 | 2.6 | 1.626 | 2.87E-03 | 0.75 | Very mobile |
| Toluene | 22 | 515 | 2.69 | 2.54 | 0.867 | 5.90E-03 | 1.5 | Very mobile |
| 1,1,2,2-Trichloroethane | 5 | 2900 | 2.56 | 1.92 | 1.60 | 3.83E-04 | 2.2 | Very mobile |
| Trichloroethene | 60 | 1100 | 2.29 | 2.09 | 1.46 | 1.17E-03 | 2.7 | Very mobile |
| Vinyl chloride | 2660 | 1100 | 0.6 | 1.91 | 0.9121 | 8.14E-02 | 4.6 | Very mobile |
| Xylenes (total) | 6 | 180 | 3.02 | 2.84 | 0.87 | 4.64E-03 | 0.19 | Very mobile |
| ***Semivolatiles:*** | | | | | | | | |
| Benzo(a)anthracene | 5.0E-09 | 0.014 | 5.61 | 5.34 | NA | 1.0E-06 | -15.5 | Very Immobile |
| Benzo(b)fluoranthene | 10E-06 to 10E-07 | 0.009 | 6.57 | 6.26 | NA | 1.22E-05 | -14 | Very Immobile |
| Benzo(k)fluoranthene | 9.6E-11 | 0.0016 | 6.84 | 6.22 | NA | 3.87E-05 | -19 | Very Immobile |
| Benzo(a)pyrene | 5.0E-09 | 0.0038 | 6.04 | 5.72 | NA | 4.9E-07 | -16.4 | Very Immobile |
| Chrysene | 10E-06 to 10E-11 | 0.006 | 5.61 | 5.44 | 1.274 | 1.1E-06 | -13.7 | Very Immobile |
| 1,4-Dichlorobenzene | 6.0E-01 | 49 | 3.39 | 3.22 | 1.458 | 3.1E-03 | -1.8 | Slightly mobile |
| Fluoranthene | 10E-06 to 10E-04 | 0.265 | 5.33 | 4.84 | NA | 6.5E-06 | -9.4 | Immobile |

**TABLE 5-1 (Continued)**

**ORGANIC PHYSICAL AND CHEMICAL PROPERTIES**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Chemical | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Octanol/Water Coefficient (log $K_{ow}$) | Sediment Partition (log $K_{oc}$) | Specific Gravity ($g/cm^3$) | Henry's Law Constant ($atm\text{-}m^3/mole$) | Mobility Index | Comments |
|---|---|---|---|---|---|---|---|---|
| Ideno(1,2,3-cd)pyrene | 1E-10 | 5.3E-04 | 6.51 | 6.20 | 1.070 | 6.95E-08 | -19.5 | Very Immobile |
| Pyrene | 6.85 | 0.14 | 5.32 | 4.91 | NA | 5.1E-06 | -11.9 | Very Immobile |
| ***Pesticides/PCBs:*** | | | | | | | | |
| Aldrin | 2.31E-05 | 0.01 | 4.45 | 3.01 | NA | 1.6E-05 | -11 | Immobile |
| alpha-BHC | 2.5E-05 | 2.0 | 3.46 | 3.81 | NA | 6.0E-06 | -7.8 | Immobile |
| beta-BHC | 2.8E-07 | 0.70 | 3.35 | 3.80 | NA | 4.5E-07 | -10 | Immobile |
| Chlordane | 1.0E-05 | 1.85 | 3.19 | 2.78 | NA | 4.8E-05 | -7.9 | Immobile |
| delta-BHC | 1.7E-05 | 17 | 3.29 | 4.14 | 1.87 | 3.84E-07 | -6.8 | Immobile |
| Dieldrin | 1.87E-04 | 0.1 | 5.6 | 4.31 | 1.75 | 4.57E-10 | -12 | Very Immobile |
| 4,4-DDT | 1.9E-07 | 0.0034 | 6.19 | 4.89 | NA | 1.58E-05 | -14 | Very immobile |
| 4,4-DDD | 10.2E-07 | 0.09 | 5.99 | 4.47 | NA | 2.2E-08 | -12 | Very immobile |
| 4,4-DDE | 6.5E-06 | 0.04 | 4.28 | 3.66 | NA | 6.8E-05 | -10 | Immobile |
| Endosulfan I | 9.0E-03 | 0.10 | 3.47 | 3.62 | NA | 1.0E-05 | -6.5 | Immobile |
| Endrin | 2.0E-07 | 0.26 | 5.6 | 4.06 | NA | 4.0E-07 | -11 | Very Immobile |
| Heptachlor | 3.0E-04 | 0.18 | 4.15 | 5.3 | 1.57 | 4.0E-03 | -8.4 | Immobile |
| Heptachlor Epoxide | 3.0E-04 | 0.35 | 3.99 | 5.0 | NA | 3.9E-04 | -7.9 | Immobile |
| PCB-1254 | 7.7E-05 | 0.03 | 6.03 | 4.59 | 1.50 | 2.80E-03 | -10 | Immobile |
| PCB-1260 | 4.1E-05 | 0.003 | 4.87 | 6.11 | 1.58 | 7.1E-03 | -12 | Immobile |

Notes: NA - Not Applicable

Sources: 1. Verscheuren, K. 1983. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold Co., New York.
2. Lyman, et al. 1982. Handbook of Chemical Property Estimation Methods. Environmental Behavior of Organic Compounds.
3. USEPA. 1982. Aquatic Fate Process Data for Organic Priority Pollutants. Final Report.

**TABLE 5-2**

**PROCESSES INFLUENCING FATE OF ORGANIC POLLUTANTS**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Processes | | | | | |
|---|---|---|---|---|---|---|
| | Sorption | Volatilization | Biodegradation | Photolysis-Direct | Hydrolysis | Bioaccumulation |
| *Pesticides/PCBs* | | | | | | |
| Aldrin | + | + | ? | - | - | + |
| Chlordane | + | + | ? | - | - | + |
| DDD | + | + | - | - | - | + |
| DDE | + | + | - | + | - | + |
| DDT | + | + | - | - | + | + |
| Dieldrin | + | + | - | + | - | + |
| Endosulfan and Endosulfan Sulfate | + | + | + | ? | + | - |
| Endrin and Endrin Aldehyde | ? | ? | ? | + | - | + |
| Heptachlor | + | + | - | ? | ++ | + |
| Heptachlor Epoxide | + | - | ? | ? | - | + |
| *PCBs* | + | + | +[1] | ? | - | + |
| *Halogenated Aliphatic Hydrocarbons* | | | | | | |
| Chloromethane (methyl chloride) | - | + | - | - | - | - |
| Dichloromethane (methylene chloride) | - | + | ? | - | - | - |
| 1,1-Dichloroethane (ethylidene chloride) | - | + | ? | - | - | - |
| 1,2-Dichloroethane (ethylene dichloride) | - | + | ? | - | - | - |
| 1,1,2-Trichloroethane | ? | + | - | - | - | ? |
| Chloroethene (vinyl chloride) | + | - | - | - | - | - |
| 1,1,-Dichloroethene (vinylidene chloride) | ? | + | ? | - | - | ? |
| Trichloroethene | - | + | ? | - | - | - |
| Tetrachloroethene (perchloroethylene) | - | + | + | - | - | - |

**TABLE 5-2 (Continued)**

**PROCESSES INFLUENCING FATE OF ORGANIC POLLUTANTS**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Processes | | | | | |
|---|---|---|---|---|---|---|
| | Sorption | Volatilization | Biodegradation | Photolysis-Direct | Hydrolysis | Bioaccumulation |
| Bromodichloromethane | ? | ? | ? | ? | - | + |
| Dichlorodifluoromethane | ? | + | - | ? | - | ? |
| *Monocyclic Aromatics* | | | | | | |
| Benzene | + | + | - | - | - | - |
| Ethylbenzene | ? | + | ? | - | - | - |
| Toluene | + | + | ? | - | - | - |
| Phenol | - | + | + | - | - | - |
| 2,4-Dimethyl phenol (2,4-xylenol) | - | - | ? | + | - | - |
| *Phthalate Esters* | | | | | | |
| Dimethyl phthalate | + | - | + | - | - | + |
| Diethyl phthalate | + | - | + | - | - | + |
| Di-n-butyl phthalate | + | - | + | - | - | + |
| Di-n-octyl phthalate | + | - | + | - | - | + |
| Bis (2-ethylhexyl) phthalate | + | - | + | - | - | + |
| Butyl benzyl phthalate | + | - | + | - | - | + |
| *Polycyclic Aromatic Hydrocarbons* | | | | | | |
| Acenaphthene[3] | + | - | + | + | - | - |
| Acenaphthylene[3] | + | - | + | + | - | - |
| Fluorene[3] | + | - | + | + | - | - |
| Naphthalene | + | - | + | + | - | - |
| Anthracene | + | + | + | + | - | - |
| Fluoranthene[3] | + | + | + | + | - | - |

**TABLE 5-2 (Continued)**

**PROCESSES INFLUENCING FATE OF ORGANIC POLLUTANTS**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Processes | | | | | |
|---|---|---|---|---|---|---|
| | Sorption | Volatilization | Biodegradation | Photolysis-Direct | Hydrolysis | Bioaccumulation |
| Phenanthrene[3] | + | + | + | + | - | - |
| Benzo(a)anthracene | + | + | + | + | - | - |
| Benzo(b)fluoranthene[3] | + | - | + | + | - | - |
| Benzo(k)fluoranthene[3] | + | - | + | + | - | - |
| Chrysene[3] | + | - | + | + | - | - |
| Pyrene[3] | + | - | + | + | - | - |
| Benzo(g,h,i)perylene[3] | + | - | + | + | - | - |
| Benzo(a)pyrene | + | + | + | + | - | - |
| Dibenzo(a,h)anthracene[3] | + | - | + | + | - | - |
| Ideno(1,2,3-cd)pyrene[3] | + | - | + | + | - | - |

++ Predominate fate determining process
+ Could be an important fate process
- Not Likely to be an important process
? Importance of process uncertain or not known

Notes: (1) Biodegradation is the only process known to transform polychlorinated biphenyls under environmental conditions, and only the lighter compounds are measurably biodegraded. There is experimental evidence that the heavier polychlorinated biphenyls (five chlorine atoms or more per molecule) can be photolyzed by ultraviolet light, but there are no data to indicate that this process is operative in the environment.

(2) Based on information for 4-nitrophenol.

(3) Based on information for PAHs as a group. Little or no information for these compounds exists.

Source: USEPA. 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Groundwater - Part I.

**TABLE 5-3**

**RELATIVE MOBILITIES OF INORGANICS AS A FUNCTION OF ENVIRONMENTAL CONDITIONS (Eh, pH)**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

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

Notes:

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

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

# 6.0 BASELINE RISK ASSESSMENT

## 6.1 Introduction

The Baseline Risk Assessment (BRA) investigates the potential for contaminants of potential concern to affect human health and/or the environment, both now and in the future, under a "no further remedial action scenario." The BRA process evaluates the data generated during the sampling and analytical phase of the RI, identifying areas of interest and contaminants of concern with respect to geographical, demographic, and physical and biological characteristics of the study area. These, combined with the current understanding of physical and chemical properties of the site-associated constituents (with respect to environmental fate and transport processes), are then used to estimate the concentrations of contaminants at the end points of logical exposure pathways. Finally, contaminant intakes by hypothetical receptors are determined and combined with the toxicological properties of the contaminants to estimate (inferentially) the potential public health impacts posed by constituents detected at the sites.

This BRA is conducted in accordance with current USEPA Risk Assessment Guidance (USEPA, 1989a and USEPA, 1991a), and USEPA Region IV Supplemental Risk Guidance (USEPA, 1992d).

The components of the BRA include:

- Identification of contaminants of potential concern
- The exposure assessment
- The toxicity assessment
- Risk characterization
- Uncertainty analysis
- Conclusions of the BRA and potential site risk

The BRA is divided into seven sections, including the introduction. Section 6.2 establishes the criteria for the selection of contaminants of potential concern (COPCs). The COPCs are chosen, for each media at each site, from an overall list of contaminants detected at the site. Section 6.3 discusses the site characteristics, identifies potential human exposure pathways, and describes potential current and future exposure scenarios. Section 6.4 presents the estimation of potential exposure, discussing the estimation of daily intakes, incremental cancer risks and hazard indices. In addition, advisory criteria for the evaluation of human health is discussed. Section 6.5 discusses the risk characterization. Section 6.6 discusses the sources of uncertainty in the BRA. Section 6.7 provides the conclusion for the potential human health impacts in the form of total site risks. Referenced tables and figures are presented after the text portion of this section.

## 6.2 Contaminants of Potential Concern

COPCs are site-related contaminants used to quantitatively estimate human exposures and associated potential health effects. Five environmental media were investigated during this RI: surface soils, subsurface soils, groundwater, surface water, and sediments. This section presents the selection of COPCs for these media. The discussion of findings presented in Section 4.0, Nature and Extent of Contamination, was used as the basis for this section.

### 6.2.1 Criteria for Selecting Contaminants of Potential Concern

The criteria used in selecting the COPCs from the constituents detected during the field sampling and analytical phase of the investigation are:

- Historical information
- Prevalence
- Mobility
- Persistence
- Toxicity
- Examination of Federal and State criteria and standards
- Comparison to Risk-Based Concentrations (RBCs)
- Comparison to investigation associated field and laboratory blank data
- Comparison to background or naturally occurring levels
- Comparison to anthropogenic levels

The criteria chosen to establish the COPCs are based on the guidance in the USEPA's Risk Assessment Guidance for Superfund (USEPA, 1989a). A comparison to contaminant-specific criteria is also considered in the selection of COPCs. A brief description of the selection criteria used in choosing final COPCs is presented below. It is not required that a contaminant meet all criteria categories to be retained as a COPC.

#### 6.2.1.1 Historical Information

In order to estimate potential human health effects associated with contaminants identified at OU No. 4, the study area is divided into three areas of concern: Site 41 and Site 74. The OU is divided into these areas based upon their current accessibility and usage. The following is a description of these areas of concern:

- Site 41 was used as an open burn dump from 1946 to 1970. The dump received construction debris and several types of wastes including petroleum, oil and lubricants, solvents, batteries, mirex in bags, and ordnance. It is known that drums of chemical training agents, which may contain small quantities of blistering agents, were disposed at Site 41. The site area is heavily wooded and vegetated. The area of the former dump is approximately 30 acres.

- There are two areas of concern at Site 74: the Grease Pit Disposal Area and the Former Pest Control Area. The grease pit reportedly measures 135 feet long by 30 feet wide by 12 feet deep (ESE, 1991). However, this pit was not observed during the June 1992 site visit, nor was it detected by geophysical techniques. The second area of concern, the Former Pest Control Area, reportedly measures 100 feet by 100 feet; however, the area was not recognizable during the 1992 site visit. The general area is heavily overgrown with vegetation and looks similar to the surrounding area.

  There are presently no disposal activities on site. Drums containing either pesticides or transformer oil containing PCBs and pesticide-soaked bags were also reportedly disposed near the grease pit. Drums containing chemical surety materials may also be present since it was reported that drums that were supposed to be disposed at Site 69 were taken to Site 74.

The association of contaminants with site activities based on historical information is used along with the following procedures to determine retention or elimination of contaminants.

6.2.1.2 Prevalence

The frequency of positive detections in sample sets and the level at which a contaminant is detected in a given medium are factors that determine a chemical's prevalence. The judicious use of data is used in setting limits on the inclusion of infrequently detected contaminants. The occurrence of a chemical must be evaluated with respect to the number of samples taken to determine the frequency criterion which warrants the inclusion of a chemical as a COPC. Contaminants that are infrequently detected, (i.e., less than 5 percent, when at least 20 samples of a medium are available) may be artifacts in the data due to sampling or analytical practices. A contaminant may not be retained for quantitative evaluation in the BRA if: (1) it is detected infrequently in an environmental medium, (2) it is absent or detected at low concentrations in other media, or (3) site history does not provide evidence the contaminant to be present.

6.2.1.3 Mobility

The physical and chemical properties of a contaminant are responsible for its transport in the environment. These properties, in conjunction with site conditions, determine whether a contaminant will tend to volatilize into the air from surface soils or surface waters, or be transported via advection or diffusion through soils, groundwaters, and surface waters. Physical and chemical properties also describe a contaminant's tendency to adsorb onto soil/sediment particles. Environmental mobility can correspond to either an increased or decreased potential to affect human health and/or the environment.

6.2.1.4 Persistence

The persistence of a contaminant in the environment depends on factors such as the microbial content of soil and water, organic carbon content, the concentration of the contaminant, climate, and the ability of the microbes to degrade the contaminant under site conditions. In addition, chemical degradation (i.e., hydrolysis), photochemical degradation and certain fate processes such as sorption may contribute to the elimination or retention of a particular compound in a given medium.

6.2.1.5 Toxicity

The potential toxicity of a contaminant is an important consideration when selecting COPCs for further evaluation in the human health assessment. For example, the weight-of-evidence (WOE) classification should be considered in conjunction with concentrations detected at the site. Some effects considered in the selection of COPCs include carcinogenicity, mutagenicity, teratogenicity, systemic effects, and reproductive toxicity. Bioaccumulation and bioconcentration properties may affect the severity of the toxic response in an organism and/or subsequent receptors and are evaluated if relevant data exist.

Despite their inherent toxicity, certain inorganic contaminants are essential nutrients. Essential nutrients need not be considered for further consideration in the quantitative risk assessment if they are present in relatively low concentration (i.e., below 2 times the average base-specific background

levels or slightly elevated above naturally occurring levels), or if the contaminant is toxic at doses much higher than those which could be assimilated through exposures at the site.

6.2.1.6 State and Federal Criteria and Standards

Contaminant concentrations can be compared to contaminant-specific established State and Federal criteria and standards such as Maximum Contaminant Levels (MCLs) or Ambient Water Quality Criteria (AWQC).

The only enforceable Federal regulatory standards for water are the Federal MCLs. In addition to the Federal standards, the State of North Carolina has developed the North Carolina Water Quality Standards (NCWQS) for groundwater and surface water. Regulatory guidelines were used for comparative purposes to infer the potential health risks and environmental impacts when necessary. Relevant regulatory guidelines include AWQC and Health Advisories.

In general, chemical-specific criteria and standards are not available for soil. Therefore, base-specific background concentrations were compiled to evaluate background levels of organic and inorganic constituents in the surface and subsurface soil. Organic contaminants were not detected in the base-specific background samples. Therefore, it is likely that all organic contaminants detected in the surface and subsurface soil, are attributable to the practices which have or are currently taking place within the areas of concern. Additionally, in order to evaluate soil concentrations, the risk-based concentrations (RBCs) for residential soil ingestion developed by USEPA (Region III) were used as guidance criteria to evaluate soil concentrations. The RBCs were used as a benchmark for evaluating site investigation data and to assist in predicting single-contaminant health risks. These values were used in conjunction with other criteria in the selection of COPCs.

A brief explanation of the criteria and standards used for the evaluation of COPCs is presented below.

**Maximum Contaminant Levels** - MCLs are enforceable standards for public water supplies promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with a lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply.

**North Carolina Water Quality Standards (Groundwater)** - NCWQSs are the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the state, which may be tolerated without creating a threat to human health or which otherwise render the groundwater unsuitable for its intended purpose.

**Health Advisories** - HAs are guidelines developed by the USEPA Office of Drinking Water for nonregulated constituents in drinking water. These guidelines are designed to consider both acute and chronic toxic effects in children (assumed body weight 10 kg) who consume 1 liter of water per day or in adults (assumed body weight 70 kg) who consume 2 liters of water per day. HAs are generally available for acute (1 day), and subchronic (10 days), and chronic (longer-term) exposure

scenarios. These guidelines are designed to consider only threshold effects and, as such, are not used to set acceptable levels of potential human carcinogens.

**Ambient Water Quality Criteria** - AWQCs are non-enforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic systems. They may also be used for identifying the potential for human health risks. AWQCs consider acute and chronic effects in both freshwater and saltwater aquatic life, and potential carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day), or from ingestion of water alone (2 liters/day). The AWQCs for the protection of human health for potential carcinogenic substances are based on the USEPA's specified incremental cancer risk range of one additional case of cancer in an exposed population of 10,000,000 to 100,000 (i.e. the 10E-7 to 10E-5 range).

**North Carolina Water Quality Standards (Surface Water)** - The NCWQSs for surface water are the standard concentrations, that either alone or in combination with other wastes, in surface waters that will not render waters injurious to aquatic life or wildlife, recreational activities, public health, or impair the waters for any designated use.

**Region IV Sediment Screening Values** - Federal sediment quality criteria for the protection of aquatic life are being developed. In the interim, the EPA Region IV Waste Management Division recommends the use of sediment values compiled by the National Oceanic and Atmospheric Administration (NOAA) as screening values for evaluating the potential for chemical constituents in sediments to cause adverse biological effects. NOAA developed this screening method through evaluation of biological effects data for aquatic (marine and freshwater) organisms, obtained through equilibrium partitioning calculations, spiked-sediment bioassays, and concurrent biological and chemical field surveys. For each constituent having sufficient data available, the concentrations causing adverse biological effects were arrayed, and the lower 10 percentile (called an Effects Range-Low, or ER-L) and the median (called an Effects Range-Median, or ER-M) were determined.

If sediment contaminant concentrations are above the ER-M, adverse effects on the biota are considered probable. If contaminant concentrations are between the ER-L and the ER-M, adverse effects are considered possible, and EPA recommends conducting sediment toxicity tests as a follow-up. If contaminant concentrations are below the ER-L, adverse effects are considered unlikely.

6.2.1.7 Risk-Based Concentrations (RBCs)

The RBCs were developed by the USEPA, Region III as benchmark concentrations for evaluating site investigation data. RBCs are not intended as stand-alone decision-making tools, but as a screening tool to be used in conjunction with other information to help in the selection of COPCs. Selecting COPCs using RBCs is accomplished by the comparison of the maximum concentrations of each contaminant detected in each medium to its corresponding RBC. The RBCs were developed using conservative default exposure scenarios suggested by the USEPA, and the latest available toxicity indices for carcinogenic and systemic chemicals. The RBC corresponds to a Hazard Quotient of 0.1 and a lifetime cancer risk of 1E-6. The RBCs represent protective environmental concentrations at which the USEPA would not typically take action (USEPA, Region III, 1994a).

6.2.1.8 Contaminant Concentrations in Blanks

The association with contaminants detected in field related blanks (i.e., trip blanks, equipment rinsates and/or field blanks) or laboratory method blanks with the same contaminants detected in analytical samples may eliminate non-site-related contaminants from the list of COPCs. Blank data should be compared with results from samples with which the blanks are associated. However, due to the difficulty in determining this association between certain blanks and data, the maximum contaminant concentrations reported in the blanks will be compared to the entire sample data set to evaluate COPCs. In accordance with the National Functional Guidelines for Organics common lab contaminants (i.e., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters) should be considered attributable to site activities only if the concentrations in the sample exceed ten times the maximum amount detected in any blank. If a contaminant is not a common lab contaminant, then concentrations that are less than 5 times the concentration found in any blank are believed to be non-site-related. The elimination of a sample result will directly correlate to a reduction in the prevalence of the contaminant in that media. Consequently, a contaminant that may have been included on the basis of prevalencey would be eliminated as a COPC if elimination due to blank concentration reduces the prevalence of a contaminant to less than five percent.

The maximum concentrations of detected common laboratory contaminants in blanks are as follows:

- Acetone 190 µg/L
- Methylene Chloride 8.0 µg/L
- Toluene 1.0 µg/L
- Di-n-butylphthalate 2.0 µg/L
- bis(2-ethylhexyl)phthalate 4.0 µg/L

Blanks containing organic constituents that are not considered common laboratory contaminants (i.e., all other TCL compounds) are considered as positive results only when observed concentrations exceeded five times the maximum concentration detected in any blank (USEPA, 1989b). All TCL compounds at less than five times the maximum level of contamination noted in any blank are considered to be not detected in that sample. The maximum concentrations of all other detected blank contaminants are as follows:

- Chloroform 10 µg/L
- Bromodichloromethane 4.0 µg/L
- Dibromochloromethane 2.0 µg/L
- Total Xylenes 4.0 µg/L
- Heptachlor 0.03 µg/L

When assessing soil concentrations, the Contract Required Quantitation Limits (CRQL) and percent moisture were accounted for in order to correlate solid and aqueous quantitation limits. For example, when assessing semivolatile contaminants the CRQL for solid samples is 33 to 66 times (depending on the contaminant) that of aqueous samples. Therefore, in order to assess contaminant levels in soil samples using an aqueous blank concentration, the concentration must be multiplied by 5 or 10 (noncommon or common lab contaminant) and then multiplied by 33 or 66 to correct for the variance in the CRQL. This value is then divided by the percent moisture determined for the sample.

6.2.1.9 Background Naturally Occurring Levels

Naturally occurring levels of chemicals are present under ambient conditions. In general, comparison with naturally occurring levels is applicable only to inorganic analytes, because a majority of organic contaminants are not naturally occurring. Background samples were collected from areas that are known to be uninfluenced by site contamination. An inorganic concentration was considered site-related only if it exceeded two times the mean concentration estimated for the site-specific background samples. The mean for the surface soil inorganics was estimated using 17 data points. The mean for the subsurface soil inorganics was estimated using inorganic results from six sample locations. Consequently, a 95th U.C.L. cannot statistically be estimated for these sample sets.

6.2.1.10 Anthropogenic Levels

Ubiquitous anthropogenic background concentrations result from non-site related sources such as combustion of fossil fuels (i.e., automobiles), plant synthesis, natural fires and factories. A good example of ubiquitous, anthropogenic chemicals in environmental are the PAHs. In general, anthropogenic chemicals were not eliminated as COPCs without considering other selection criteria. It is difficult to determine that such chemicals are present at the site due to operations not related to the site or the surrounding area. Omitting anthropogenic background chemicals from the risk assessment could result in the loss of important information for those potentially exposed.

The remaining sections apply the aforementioned selection criteria beginning with the prevalence of detected analytical results in each medium of interest to establish a preliminary list of COPC for Sites 41 and 74. Once this task is completed, a final list of media-specific COPCs will be selected based on the remaining criteria (persistence, mobility, toxicity, ARARs, RBCs, blank concentrations, background concentrations, and anthropogenic concentrations).

### 6.2.2 Selection of Contaminants of Potential Concern

The following sections present an overview of the analytical data obtained for each medium and site during the RI and the subsequent retention or elimination of COPCs using the aforementioned criteria for selection of COPCs.

6.2.2.1 Site 41

Surface Soil

Forty six (46) surface soil samples were submitted for analysis of VOCs. Concentrations of methylene chloride (13 of 46 samples) and toluene (3 of 46 samples) are related to the levels of these contaminants reported in the investigation associated QA/QC blanks. Acetone was detected in 11 of 46 samples, however, the acetone levels in 10 of the 11 samples is attributed to QA/QC blanks. Consequently, the prevalence of this contaminant is less than five percent and is not warranted for retention as a COPC.

In the surface soil, the PAHs anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene are retained as COPCs based on prevalence (at least 3 detections in 46 samples). Additionally, the SVOC bis(2-chloroethyl)ether is retained due to prevalence. Other SVOCs including 1,4-

dichlorobenzene, 2-methylnaphthalene, acenaphthene, carbazole, dibenzofuran, dibenz(a,h)anthracene, fluorene, indeno(1,2,3-cd)pyrene, and naphthalene are not prevalent (detected in less than three samples) and are not retained as COPCs.

Several pesticides and PCBs were detected in the 46 surface soil samples. However, only the following are detected at a frequency that warranted retention as COPCs: heptachlor, heptachlor epoxide, dieldrin, 4,4'-DDE, endrin, endosulfan II, 4,4'-DDD, 4,4'-DDT, endrin aldehyde, alpha-chlordane, and gamma-chlordane.

Inorganic constituents arsenic, barium, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, vanadium, zinc, and cyanide are prevalent in the surface soil at concentrations greater than two times the average base-specific background concentration, therefore, are retained as COPCs.

Other inorganics (i.e., calcium, potassium, sodium) are not retained as COPCs. These inorganics are believed to nontoxic or are considered essential nutrients.

Presented in Table 6-1 are the surface soil concentration ranges and frequency for the positively detected organic compounds. Table 6-2 presents the surface soil inorganic ranges and frequency along with a comparison to the base-specific background concentrations.

Subsurface Soil

The VOCs trichloroethene, benzene, chloromethane, and ethylbenzene were infrequently detected (less than five percent) in the subsurface soil and did not warrant retention as COPCs. The concentrations of methylene chloride (maximum 26 µg/kg) are attributable to the blank concentrations (80 µg/L). Acetone was detected in 34 of 66 samples. However, the prevalence of this contaminant is less than five percent if concentrations due to blank contamination are eliminated. Consequently, this compound is not retained as a COPC.

SVOCs were detected in the 66 subsurface soil samples. Of the SVOCs detected only 2-methlynaphthalene, benzo(g,h,i)perylene, benzo(a)pyrene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene were detected at a frequency greater than five percent (at least 4 positive detects). Therefore, using prevalence as a criteria these contaminants are retained as COPCs. The phthalate esters, although prevalent, are not retained as COPCs due to their presence in investigation related QA/QC samples and knowledge of site history. Note that the variations in the analytical detection limits is taken into account when assessing the concentrations in the soil using aqueous blanks.

Several pesticides and PCBs were detected in the 66 subsurface soil samples. Of these contaminants, the following are detected at a frequency greater than five percent and retained as COPCs: heptachlor, aldrin, heptachlor epoxide, endosulfan I, dieldrin, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, endrin, endosulfan II, endrin aldehyde, alpha-chlordane, gamma-chlordane, PCB-1254 and PCB-1260. Other pesticide compounds which are not frequently detected (less than 3 of 66 samples) included delta-BHC, gamma-BHC, methoxychlor, and endrin ketone. These compounds are not retained as COPCs.

Inorganic constituents which are prevalent in the subsurface soil at concentrations greater than two times the average base-specific concentration, therefore, were retained as COPCs included antimony,

arsenic, barium, beryllium, chromium, copper, lead, manganese, mercury, vanadium, zinc, and cyanide.

Presented in Table 6-3 are the subsurface soil concentration ranges and frequency for the positively detected organic compounds. Table 6-4 presents the subsurface soil inorganic ranges and frequency along with a comparison to the base-specific background concentrations.

Groundwater

Eighteen (18) groundwater samples were collected for VOCs. VOC contaminants 1,1-trichloroethene, benzene, and chlorobenzene were detected at a concentration less than the CRQL in 1 of 18 groundwater samples. The infrequent detection at a concentration less than the CRQL does not warrant the retention of these contaminants as COPCs. The presence of acetone (maximum 12 µg/L) is attributable to the concentrations detected in the blanks (190 µg/L). Therefore, this contaminant is not retained as a COPC.

Eighteen (18) groundwater samples were submitted for analysis of SVOCs. SVOCs were absent in all of the groundwater samples. Therefore, no SVOCs are retained as COPCs.

Eighteen (18) groundwater samples were analyzed for pesticides and PCBs. Pesticide and PCB contaminants were determined to be absent in the groundwater. Therefore, no pesticides and PCBs warrant retention as COPCs.

Several total inorganic constituents including arsenic, barium, beryllium, cadmium, chromium, cobalt, lead, manganese, nickel, selenium, vanadium, and zinc are retained as COPCs using prevalence as a screening criteria.

Table 6-5 presents a comparison of the organic and inorganic groundwater findings to the applicable State and Federal groundwater criteria. Note that contaminants which may not warrant retention as COPCs for risk evaluation are included on the table for qualitative evaluation.

Surface Water

During the investigation surface water samples were obtained from the Unnamed Tributary and Tank Creek. These surface water body do not support recreational activities such as swimming which would present a human health exposure pathway. Consequently, COPCs are not selected to estimate human health risks. However, in order to qualitatively evaluate the potential environmental impact to surface water, analytical findings are compared to North Carolina and Federal surface water criteria. Tables 6-6 presents the qualitative evaluation of contaminants detected in the surface water to North Carolina and Federal standards and criteria.

Sediment

The sediment samples collected from the surface water bodies investigated at this site were not used to estimate potential human health risks. Presently, an exposure pathway does not exist for human exposure to these sediments. These samples were obtained in order to assess potential impact to the environment. Therefore, Table 6-7 presents a qualitative comparison of contaminant levels detected in the sediment to NOAA sediment quality criteria.

6.2.2.2 Site 74

Surface Soil

Sixty (60) surface soil samples were analyzed for VOCs. The prevalence of trichloroethene (5 of 60 samples) warrants the retention of this compound as a COPC. The presence of methylene chloride (maximum concentration 23 µg/kg), toluene (maximum concentration 3 µg/kg), and acetone (maximum concentration 210 µg/kg) are attributable to the investigation associated QA/QC blanks. Therefore, these compounds are not retained as COPCs. The prevalence of styrene (1 of 60 samples) and total xylenes (2 of 60 samples) is less than five percent. Consequently, these compounds are not retained as COPCs.

Sixty (60) surface soil samples were analyzed for SVOCs. Compounds which were detected but not prevalent include: 4-chloro-3-methylphenol, acenaphthene, benzo(a)pyrene, benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, diethylphthalate, and pyrene. These compounds were detected at a frequency of less than five percent and therefore are not warranted for retention as COPCs. Bis(2-chloroethyl)ether was prevalent in the surface soil, however, the maximum concentration of this contaminant (180 µg/kg) is less than the Region III RBC (580 µg/kg) for residential soil. Consequently, adopting Region IV guidance this compound is not retained as a COPC. Di-n-butylphthalate was detected in 13 of 60 samples. The prevalence of this contaminant warrants retention as a COPC. However, evaluation of sample contaminant levels to the investigation related QA/QC blanks reduces the prevalence of this contaminant to less than five percent. Therefore, this contaminant is not retained for evaluation in the risk assessment. Note that the variations in the analytical detection limits is taken into account when assessing the concentrations in the soil using aqueous blanks.

Several pesticides were detected in the 60 surface soil samples collected for pesticide/PCB analysis. The following pesticides are prevalent in the surface soil and warranted retention as COPCs: heptachlor, heptachlor epoxide, dieldrin, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, endrin aldehyde, alpha-chlordane, gamma-chlordane. Additionally, the following pesticides are not retained due to frequency of detection less than five percent: alpha-BHC, aldrin, endrin, endosulfan II, and methoxychlor.

Inorganic constituents arsenic, barium, chromium, manganese, nickel, selenium, vanadium, zinc, and cyanide are prevalent in the sixty (60) surface soil samples. Additionally, the maximum concentration of these metals is greater than two times the average base-specific concentration. Therefore, these metals are retained as COPCs. Other inorganics are not retained because they are either infrequently detected, less than two times the average base-specific background, are essential nutrients, or common salts not evaluated in a human health risk assessment.

Presented in Table 6-8 are the surface soil concentration ranges and frequency for the positively detected organic compounds. Table 6-9 presents the surface soil inorganic ranges and frequency along with a comparison to the base-specific background concentrations.

Subsurface Soil

The VOCs, acetone and methylene chloride, were detected in 1 of 47 and 32 of 47 subsurface soil samples, respectively. Methylene chloride was detected in less than five percent of the samples, therefore, it was not retained as a COPC. The concentrations of acetone (maximum 820 µg/kg) are

less than ten times the concentration (1900 µg/L) detected in the investigation associated QA/QC blanks, therefore, this compound is not retained as a COPC.

The SVOCs, bis(2-ethylhexyl)phthalate, diethylphthalate, and di-n-butylphthalate are prevalent, however, not at a concentration which could not be attributed to investigation related QA/QC samples. Evaluation of sample contaminant levels to the investigation related QA/QC blanks reduces the prevalence of these contaminants to less than five percent. Therefore, these contaminant are not retained for evaluation in the risk assessment. Note that the variations in the analytical detection limits is taken into account when assessing the concentrations in the soil using aqueous blanks. Additionally, these compounds are not present in other media and are not believed to be associated with past history of the site. Therefore, these compounds are not retained as COPCs.

The pesticides, heptachlor, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT were prevalent in the subsurface soil at greater than five percent. Due to their toxic potential and association with site history, these pesticides are retained as COPCs. Additional pesticides, aldrin, heptachlor epoxide, methoxychlor, and endrin aldehyde are not prevalent in the subsurface soil (less than five percent), therefore, they are not retained as COPCs.

Inorganic constituents arsenic, barium, chromium, manganese, vanadium, zinc, and cyanide are prevalent in subsurface soils at concentrations greater than two times the average base-specific background, therefore, they are retained as COPCs. Although prevalent in the subsurface soil, lead concentrations do not exceed two times the background concentration. Consequently, lead is not warranted for retention as a COPC.

Presented in Table 6-10 are the subsurface soil concentration ranges and frequency for the positively detected organic compounds. Table 6-11 presents the subsurface soil inorganic ranges and frequency along with a comparison to the base-specific background concentrations.

Groundwater

Acetone was the only VOC detected in the eight groundwater samples collected from this site. However, the concentration of acetone (maximum 2.04 µg/L) is less than 10 times the level of acetone detected in the investigation associated QA/QC samples. Consequently, acetone is not retained as a COPC.

Di-n-butylphthalate (2 µg/L) was the only SVOC detected in the eight groundwater samples collected from this site. However, this concentration was less than 10 times the concentration detected in the investigation related QA/QC samples (20 µg/L), therefore, this compound is not retained as a COPC.

The pesticides heptachlor, endosulfan II, alpha-chlordane, and gamma-BHC were detected at concentrations below the CRQL in one of seven samples. Therefore, based on frequency of detection and concentration, these compounds are not retained as COPCs.

Several total inorganic constituents including arsenic, barium, beryllium, chromium, lead, manganese, vanadium, and zinc are retained as COPCs, for the human health risk assessment, using prevalence as a selection criteria. Although, not retained for evaluation in the human health risk assessment, mercury and selenium are refined as COPCs for comparison to State and Federal criteria.

Table 6-12 presents a comparison of the organic and inorganic groundwater findings to the applicable State and Federal groundwater criteria.

Surface Water

Three surface water samples were collected from Henderson Pond, which is located in the approximate area of the site. This surface water body does not support recreational activities such as swimming which would present a human health exposure pathway. Consequently, COPCs are not selected to estimate human health risks. However, in order to qualitatively evaluate the potential environmental impact to surface water, analytical findings are compared to North Carolina and Federal surface water criteria. Table 6-13 presents the qualitative evaluation of contaminants detected in the surface water to North Carolina and Federal standards and criteria.

Sediment

The sediment samples collected from Henderson Pond were not used to estimate potential human health risks. Presently, an exposure pathway does not exist for human exposure to these sediments. These samples were obtained in order to assess potential impact to the environment. Therefore, Table 6-14 presents a qualitative comparison of contaminant levels detected in the sediment to NOAA sediment quality criteria.

#### 6.2.2.3 Summary of COPCs

Table 6-15 presents a detailed summary of the potential COPCs identified in each environmental medium sampled at OU No. 4 (Sites 41 and 74). Work sheets used in the selection of COPCs are presented in Appendix N.

## 6.3 Exposure Assessment

This section develops the potential human exposure pathways for each site and the rationale for their evaluation. Potential source areas and potential migration routes in conjunction with contaminant fate and transport information are combined to produce a site conceptual model. Exposure pathways to be retained for quantitative evaluation are subsequently selected, based on the conceptual site model.

### 6.3.1 Site Conceptual Model of Potential Exposure

A site conceptual model of potential sources, migration pathways and human receptors was developed to encompass all current and future potential routes of exposure at all three sites. Figure 6-1 presents the conceptual site model. Inputs to the site conceptual site model included qualitative descriptions of current and future land use patterns in the vicinity of each site. All available analytical data and meteorological data are considered in addition to a general understanding of the demographics of the surrounding habitats. For this information, the following list of potential receptors has been developed for inclusion in the quantitative health risk analysis:

- Current military personnel
- Future on-site residents (child and adult)
- Future construction worker

Contaminants detected in the surface and subsurface soils were discussed in Section 4.0 (Nature and Extent of Contamination) and in the selection of COPCs section. The migration of COPCs from these sources could potentially occur by the following routes:

- Vertical migration of potential contaminants from surficial soils to subsurface soils.
- Leaching of potential contaminants from subsurface soils to the water-bearing zones.
- Vertical migration from shallow water-bearing zones to deeper flow systems.
- Horizontal migration in groundwater in the direction of groundwater flow.
- Groundwater discharge into local streams.
- Wind erosion and subsequent deposition of windblown dust.

The potential for a contaminant to migrate spatially and persist in environmental media are important in the estimation of potential exposure.

### 6.3.2 Exposure Pathways

This section describes the potential exposure pathways presented on Figure 6-1 associated with each medium and each potential human receptor group, then qualitatively evaluates each pathway for further consideration in the quantitative risk analysis. Tables 6-16 and 6-17 present the matrices of potential human exposure scenarios for Sites 41 and 74, respectively.

#### 6.3.2.1 Surface Soils

Surface soil samples were collected on-site from Sites 41 and 74. Potential exposures for all current and future receptors identified above to these soils may possibly occur through incidental ingestion, absorption via dermal contact, and inhalation of airborne particulates of surface soil containing COPCs. Dermal intakes will also result following dermal contact with soils containing COPCs. Incidental ingestion of soil may also occur by oral contact with hands, arms, or food items which soil particles have adhered.

Receptors most likely to be exposed via dermal contact, incidental ingestion and inhalation of air-borne particulates are the same for each area of concern due to the current and future potential land use.

#### 6.3.2.2 Subsurface Soils

Potential exposure to subsurface soils is limited to potential site construction workers. In the event of construction in the areas of concern, workers may be exposed to subsurface soil. Therefore, future potential exposures via ingestion and dermal contact are retained for evaluation.

#### 6.3.2.3 Groundwater

Currently the shallow groundwater in the area of the sites is not used as a potable supply for residents or base personnel. However, under a future scenario (albeit unlikely due to poor transmissivity and insufficient flow) the major potential exposure pathways for the use of on-site groundwater are ingestion, dermal contact, and the inhalation of volatile contaminants by residents while showering.

6.3.2.4 Surface Water/Sediments

The general physical characteristics of the surface water bodies included in this investigation are currently not suitable for recreational activities (i.e., swimming and wading). If recreational activities were to occur in these surface water bodies, the activity patterns (reduced duration and frequency) would limit uptake. Additionally, the exposure duration will generally be less for recreational users of a surface water body, and workers are not expected to be exposed via this pathway (USEPA, 1989a). Therefore, current and future potential exposure to surface water and sediment via ingestion and dermal contact are not retained for evaluation.

6.3.2.5 Air

A potential human exposure pathway exists in air through the inhalation of airborne particulates from surface soils containing COPCs. Airborne particulate emissions may result from the wind erosion and the entrainment of soil particles in ambient air. COPCs adhering to these airborne soil particles may be inhaled by potential future on-site residents (i.e., child and adult) and current military personnel.

Therefore, inhalation of airborne particulate emissions by potential future residents and current military personnel is retained for quantitative evaluation. Off-site receptors would be exposed to concentrations much lower than those detected in on-site air samples as a result of the dilution characteristics of ambient air and the wooded areas which separate the facility from the nearby communities. Therefore, nearby residents are not evaluated.

### 6.3.3 Quantification of Exposure

The concentrations used in the estimation of chronic daily intakes (CDIs) must be representative of the type of exposure being considered.

Exposure to groundwaters, sediments and surface waters can occur discretely or at a number of sampling locations. These media are transitory in that concentrations change frequently over time. Averaging transitory data obtained from multiple locations is difficult and requires many more data points at discrete locations than exist within OU No. 4. As a result, the best way to represent groundwater, sediment, and surface water contaminants from an exposure standpoint is to use a representative exposure concentration.

Soils are less transitory than the aforementioned media and in most cases, exposure occurs over a wider area (i.e., residential exposure). Therefore, an upper confidence interval was used to represent a soil exposure concentration.

Soil data collected from each of these areas is used separately in estimating the potential human health risks under current and future exposure scenarios.

The human health assessment for future groundwater use considered groundwater data collected from all of the monitoring wells within a site and estimated risks to individuals per area of concern.

Since all the data sets originate from a skewed underlying distribution and since lognormal distribution best fits the majority of environmental data sets, the lognormal distribution was used to represent all facility media. This ensures conservatism in the estimation of chronic daily intake

associated with potential exposures. Ninety-five percent upper confidence levels (95 percent U.C.L.) derived for lognormal data sets produce concentrations in excess of the 95 percent confidence interval derived assuming normality. For the sake of conservatism, the 95 percent U.C.L. for the lognormal distribution was used for each contaminant in a given data set for quantifying potential exposure. For exposure areas with limited amounts of data or extreme variability in measured data, the 95 percent U.C.L. can be greater than the maximum measured concentration, therefore, in cases where the 95 percent U.C.L. for a contaminant exceeds the maximum detected value in a given data set, the maximum result was used in the estimate of exposure of the 95 percent U.C.L. However, the true mean may still be higher than this maximum value (i.e., the 95 percent U.C.L. indicates a higher mean is possible), especially if the most contaminated portion of the site has not been sampled.

Data and frequency summaries and statistical summaries are presented in Appendices O and P, respectively.

### 6.3.4 Calculation of Chronic Daily Intakes (CDI)

In order to numerically estimate the risks for current and future human receptors at each site, a CDI must be estimated for each COPC in every retained exposure pathway.

Appendix Q contains the specific CDI equations for each exposure scenario of interest. These equations were adopted from USEPA's Risk Assessment Guidance for Superfund, Volume I (USEPA, 1989a).

The following paragraphs present the general equations and input parameters used in the calculation of CDIs for each potential exposure pathway. Input parameters are taken from USEPA's default exposure factors guidelines where available and applicable. All inputs not defined by USEPA are derived from USEPA documents concerning exposure or best professional judgment. All exposure assessments incorporate the representative contaminant concentrations in the estimation of intakes. Therefore, only one exposure scenario is developed for each exposure route/receptor combination.

Carcinogenic risks were calculated as an incremental lifetime risk, and therefore incorporate terms describing the exposure duration (ED) in years over the course of a lifetime (70 years x 365 days/year, or 25,550 days).

Noncarcinogenic risks, on the other hand, are estimated using the concept of an average annual exposure. The intake incorporates terms describing the exposure time and/or frequency that represent the number of hours per day and the number of days per year that exposure occurs. In general, noncarcinogenic risks for many exposure routes (e.g., soil ingestion) are greater for children than adults because of the differences in body weights, similar exposure frequencies and higher ingestion rates.

Future residential exposure scenarios consider 1 to 6 year old children weighing 15 kg, and adults weighing 70 kg on average. For current/future military personnel an ED of 4 years is used to estimate a military residence. A one year ED is used for future construction worker scenarios.

6.3.4.1 Incidental Ingestion of Soil

The CDI for COPCs detected in soil is estimated for all potential human receptors and is expressed as:

$$CDI = \frac{C \times IR \times CF \times Fi \times EF \times ED}{BW \times AT}$$

Where:

| | | |
|---|---|---|
| C | = | Contaminant concentration in soil (mg/kg) |
| IR | = | Ingestion rate (mg/day) |
| CF | = | Conversion factor (1E-6 kg/mg) |
| Fi | = | Fraction ingested from source (dimensionless) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (days) |

The following paragraphs discuss the exposure assumptions used in the estimation of potential COPCs associated with the potential ingestion of soils.

*Military Personnel*

During the course of daily activities at each site, military personnel could potentially be exposed to potential COPCs by the incidental ingestion of surface soils.

The ingestion rate (IR) for residential adults (100 mg/day) is conservatively applied to evaluate ingestion of surface soils by military personnel.

An exposure frequency (EF) of 350 days/year is used to assess military personnel. It is conservatively assumed that military personnel are on base all year for the exception of two weeks (14 days vacation).

An averaging time (AT) of 70 years x 365 days/year or 25,550 days was used for exposure to potentially carcinogenic compounds while an averaging time of 1,460 days (4 years x 365 days/year) was used for noncarcinogenic exposures. An adult average body weight (BW) of 70 kg was used (USEPA, 1989a).

*Future On-Site Residents*

Future on-site residents could potentially be exposed to COPCs in the surficial soils during recreational activities or landscaping activities around their homes. Children and adults could potentially be exposed to COPCs in soils by incidental ingestion occurring through hand to mouth behavior.

The residential ED is divided in two parts. First, a six-year exposure duration is evaluated for young children which accounts for the period of highest soil ingestion (200 mg/day), and second a 24-year exposure is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) (USEPA, 1991a). The EFs for both receptor groups is assumed to be 350 days per year.

The BW, for a resident child is assumed to be 15 kg, representing younger individuals than those considered to be potential trespassers. The rationale is that the younger child (1 to 6 years), as a resident, will have access to affected on-site soils. The BW for the future resident adult is assumed to be 70 kg.

ATs of 25,550 days (70 years x 365 days/year) for potential carcinogens and 8,760 days (24 years x 365 days/year) for noncarcinogenic constituents is used for estimating potential CDIs for adults. An AT of 2,190 days (6 years x 365 days/year) is used to estimate potential CDIs for children potentially exposed to noncarcinogens.

*Future Construction Worker*

During the course of excavation activities construction workers could potentially be exposed to potential COPCs through the incidental ingestion of subsurface soil. The IR for future construction workers exposed to subsurface soils is assumed to be 480 mg/day (USEPA, 1991a). An EF of 90 days per year is used in conjunction with an ED of one year (USEPA, 1991a). An adult BW of 70 kg is used (USEPA, 1989a).

A summary of the exposure factors used in the estimation of soil CDIs associated with incidental ingestion are presented in Table 6-18.

6.3.4.2 Dermal Contact with Soil

Chronic daily intakes associated with potential dermal contact of soils containing COPCs is expressed using the following equation:

$$CDI = \frac{C \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

Where:

| | | |
|---|---|---|
| C | = | Contaminant concentration in soil (mg/kg) |
| CF | = | Conversion factor (kg/mg) |
| SA | = | Skin surface available for contact ($cm^2$) |
| AF | = | Soil to skin adherence factor ($mg/cm^2$) |
| ABS | = | Absorption factor (dimensionless) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (days) |

The following paragraphs discuss the exposure assumptions used in the estimation of potential COPCs with the potential dermal contact with soils.

*Military Personnel*

During the course of daily activities, there is a potential for base personnel to absorb COPCs by dermal contact.

It was assumed that military personnel have approximately 5,800 $cm^2$ (USEPA, 1992b) of skin surface (SA) available for dermal exposure with COPCs. Exposed body parts are the hands, head, forearms and lower legs are 25% of the total body surface area (23,000 $cm^2$). Thus, applying 25% to the upper-bound total body surface area results in a default of 5,800 $cm^2$ for military personnel.

Values for ED, EF, BW, and AT are the same as those used for the incidental ingestion of soil scenario.

*Future On-Site Residents*

Future on-site residents could also be potentially exposed to COPCs in on-site soil through dermal contact experienced during activities near their home.

Skin surface areas (SA) used in the on-site resident exposure scenario are developed for a reasonable worst case scenario for an individual wearing a short sleeve shirt, shorts, and shoes. The exposed skin surface area is limited to the head, hands, forearms, and lower legs. Thus, applying 25 percent of the total body surface area resulted in a default of 5,800 $cm^2$ for adults. The exposed skin surface for a child (2,300 $cm^2$) is estimated using an average of the 50th (0.866 $m^2$) and the 95th (1.06 $m^2$) percentile body surface for a six year old child multiplied by 25 percent. The child SA was calculated using information presented in Dermal Exposure Assessment: Principles and Applications (USEPA, 1992b).

Per USEPA Region IV guidance the absorption factors (ABS) factors for organics (1%) and inorganics (0.1%) were applied for this estimation of risk.

Values for ED, EF, BW, and AT are the same as those discussed for the incidental ingestion scenario presented previously.

Data on soil adherence factor (AF) are limited. A value of 1.0 $mg/cm^2$ (USEPA, Region IV, 1992d) is used in this assessment.

*Future Construction Worker*

Dermal contact with subsurface soil COPCs could potentially occur during excavation activities.

The SA used for the construction worker exposure scenario is developed for an individual wearing a short-sleeve shirt, long pants, and boots. The exposed skin surface area (4,300 $cm^2$) is limited to the head (1,180 $cm^2$), arms (2,280 $cm^2$), and hands (840 $cm^2$) (USEPA, 1992b).

The EF and ED are the same as those discussed for incidental ingestion of subsurface soil.

Data on soil AF are limited. A value of 1.0 $mg/cm^2$ (USEPA Region IV, 1992c) is used in this assessment.

A summary of the soil exposure assessment input parameters for dermal contact are presented in Table 6-19.

6.3.4.3 Inhalation of Fugitive Particulates

Exposure to fugitive particulates are estimated for future residents and civilian base personnel. These populations may be exposed during daily recreational or work-related activities. The chronic daily intake of contaminants associated with the inhalation of particulates is estimated using the following equation:

$$CDI = \frac{C \times IR \times EF \times ED \times 1/PEF}{BW \times AT}$$

Where:

| | | |
|---|---|---|
| C | = | Contaminant concentration in soil (mg/kg) |
| IR | = | Inhalation rate ($m^3$/hr) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| 1/PEF | = | Particulate emission factor ($m^3$/kg) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (days) |

The particulate emissions factor (PEF) relates the concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from surface contamination. This relationship is derived by Cowherd (1985). The particulate emissions from contaminated sites are due to wind erosion, and, therefore, depend on erodibility of the surface material. A default PEF obtained from USEPA, 1989a is used in this assessment.

The following paragraphs discuss the exposure assumptions used in the estimation of potential COPCs with the potential inhalation of particulates.

*Military Personnel*

During work related activities, there is a potential for military personnel to inhale COPCs emitted as fugitive dust. A conservative inhalation rate 20 $m^3$/day was used for military personnel (USEPA, 1991a). Values for ED, EF, BW, and AT are the same as those used for the incidental ingestion scenario.

*Future On-Site Residents*

Future on-site residents could also be potentially exposed to COPCs in on-site soil through inhalation of particulates during activities near their home.

An IR of 20 $m^3$/day is used to assess the on-site adult. An inhalation rate of 10 $m^3$/day is used to assess a child. This value was derived from a child conducting light (0.8 $m^3$/hr.) to moderate (2.0 $m^3$/hr.) activity for 8 hours per day (USEPA, 1989b). The EF, ED, BW, and AT are the same as those used for the incidental ingestion scenario.

Table 6-20 presents the exposure factors used to estimate CDIs associated with the particulate inhalation scenario.

6.3.4.4 Ingestion of Groundwater

Shallow groundwater is not currently being used as a potable supply at any of the sites. Development of the shallow aquifer for potable use is unlikely because of the general water quality in the shallow zone and poor flow rates. However, there remains the possibility that upon closure of this facility, residential housing could be constructed and deep groundwater used for potable purposes in the future. Deep groundwater from each of the sites is currently used for potable purposes. However, base supply wells are subject to routine operation, maintenance, and monitoring and those which have been determined to be contaminated have been permanently abandoned.

The CDI of contaminants associated with the future potential consumption of groundwater are estimated using the following general equation:

$$CDI = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where:

| | | |
|---|---|---|
| C | = | Contaminant concentration is groundwater (mg/L) |
| IR | = | Ingestion rate (L/day) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (days) |

The following paragraphs discuss the exposure assumptions used in the estimation of potential COPCs with the potential ingestion of groundwater.

*Future On-Site Residents*

Exposure to COPCs via ingestion of groundwater is retained as a potential future exposure pathway for both children and adults.

The IR of 1.0 L/day is used for the amount of water consumed by a 1 to 6 year old child with a BW of 15 kg. This ingestion rate provides a health conservative exposure estimate (for systemic, noncarcinogenic toxicants) designed to protect young children who could potentially be more affected than adolescents, or adults. This value assumes that children obtain all the tap water they drink from the same source for 350 days/year [which represents the exposure frequency (EF)]. AT of 2,190 days (6 years x 265 days/year) is used for noncarcinogenic compound exposure.

The IR for adults is 2 liters/day (USEPA, 1989a). The ED used for the estimation of adult CDIs is 30 years (USEPA, 1989b), which represents the national upper-bound (90th percentile) time at one residence. The averaging time for noncarcinogens is 10,950 days. An AT of 25,550 days (70 years x 365 days/year) is used to evaluate exposure for both children and adults to potential carcinogenic compounds.

Table 6-21 presents a summary of the input parameters for the ingestion of groundwater scenarios.

6.3.4.5 Dermal Contact with Groundwater

Shallow groundwater is not currently being used as a potable supply at any of the sites. However, there remains the possibility that upon closure of this facility residential housing could be constructed and groundwater used for residential purposes in the future.

The CDI associated with the dermal contact with groundwater is estimated using the following general equation:

$$CDI = \frac{C \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where:

| | | |
|---|---|---|
| C | = | Contaminant concentration is groundwater (mg/L) |
| SA | = | Surface area available for contact ($cm^2$) |
| PC | = | Dermal permeability constant (cm/hr) |
| ET | = | Exposure time (hour/day) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| CF | = | Conversion factor (1 L/1000 $cm^3$) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (days) |

The following paragraphs discuss the exposure assumptions used in the estimation of potential COPCs with potential dermal contact with groundwater.

*Future On-Site Residents*

Children and adults could contact COPCs through dermal contact with groundwater while bathing or showering.

An EF of 350 days/year is used assuming that site groundwater would be used as the sole-source for bathing. The whole body skin SA available for dermal absorption is estimated to be 10,000 $cm^2$ for children and 23,000 $cm^2$ for adults (USEPA, 1992b). The permeability constant (PC) reflects the movement of a chemical across the skin and into the blood stream. The permeability of a chemical is an important property in evaluating actual absorbed dose, yet many compounds do not have literature PC values. For contaminants in which a PC value are not established, the PC for water (1.55E-03 cm/hr), is used (USEPA, 1992b). This value may in fact be a realistic estimate of the absorption rate of a chemical when COPC concentrations are in the part-per-billion range.

An ET of 0.25 hour/day used to conservatively estimate the duration of bathing or showering. The ED, BW, and AT were the same as those used for the ingestion of groundwater scenario.

Table 6-22 presents the exposure factors used to estimate CDIs associated with the future dermal contact with COPCs in groundwater.

6.3.4.6 Inhalation of Volatile Organics While Showering

In order to quantitatively assess the inhalation of contaminants volatilized from shower water, the model developed by Foster and Chrostowski (1986) is utilized. Contaminant concentrations in air, due to VOCs while showering, are modeled by estimating the following: the rate of chemical releases into air (generation rate), the buildup of VOCs in the shower room air while the shower was on, the decay of VOCs in the shower room after the shower is turned off, and the quantity of airborne VOCs inhaled while the shower is both on and off. The contaminant concentrations calculated to be in the air are then used as the concentration term.

The CDI associated with the inhalation of airborne (vapor phase) VOCs from groundwater while showering is estimated using the following general equation:

$$CDI = \frac{C \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

| | | |
|---|---|---|
| C | = | Contaminant concentration in air ($mg/m^3$) |
| IR | = | Inhalation rate ($m^3/hr$) |
| ET | = | Exposure time (hr/day) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| BW | = | Body weight (kg) |
| $AT_c$ | = | Averaging time carcinogen (days) |
| $AT_{nc}$ | = | Averaging time noncarcinogen (days) |

*Future On-Site Residents*

Both children and adults could inhale vaporized volatile organic COPCs during showering. It is assumed that showering would take place over 350 days/year, using site groundwater as the sole source, for children weighing 15 kg, and adults weighing 70 kg (USEPA, 1989a). An inhalation rate (IR) of 0.6 $m^3/hr$ is used for both receptors (USEPA, 1989a). An exposure time (ET) of 0.25 hrs/day is used for both receptors (USEPA, 1989a). The ED and AT remained the same as for groundwater ingestion.

Table 6-23 presents the exposure factors used to estimate CDIs associated with the inhalation of VOCs from groundwater while showering.

Appendix Q contains the specific CDI equations for each exposure scenario of interest.

## 6.4 Toxicity Assessment

Section 6.3 identified potential exposure pathways and potentially affected populations for this BRA. This section will review the available toxicological information for the potential COPCs.

### 6.4.1 Toxicological Evaluation

The purpose of this section is to define the toxicological values used to evaluate the potential exposure to the potential COPCs identified in Section 6.2. A toxicological evaluation characterizes

the inherent toxicity of a compound. It consists of the review of scientific data to determine the nature and extent of the potential human health and environmental effects associated with potential exposure to various contaminants.

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

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

### 6.4.2 Dose-Response Evaluation

An important component of the risk assessment is the relationship between the dose of a compound (amount to which an individual or population is potentially exposed) and the potential for adverse health effects resulting from the exposure to that dose. Dose-response relationships provide a means by which potential public health impacts may be evaluated. The published information on doses and responses is used in conjunction with information on the nature and magnitude of exposure to develop an estimate of risk.

Standard carcinogenic slope factors (CSFs) and/or reference doses (RfDs) have been developed for many of the COPCs. This section provides a brief description of these parameters.

#### 6.4.2.1 Carcinogenic Slope Factor

CSFs are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen (USEPA, 1989a). This factor is generally reported in units of $(mg/kg/day)^{-1}$ and is derived through an assumed low-dosage linear multistage model and an extrapolation from high to low dose-responses determined from animal studies. The value used in reporting the slope factor is the upper 95th percent confidence limit.

These slope factors are also accompanied by USEPA WOE classifications which designate the strength of the evidence that the COPC is a potential human carcinogen.

In assessing the carcinogenic potential of a chemical, the Human Health Assessment Group (HHAG) of USEPA classifies the chemical into one of the following groups, according to the weight of evidence from epidemiologic and animal studies:

Group A - Human Carcinogen (sufficient evidence of carcinogenicity in humans)

Group B - Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)

Group C - Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)

Group D - Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)

Group E - Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

6.4.2.2 Reference Dose

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

UFs usually consist of multiples of 10, where each factor represents a specific area of uncertainty naturally present in the extrapolation process. These UFs are presented below and were taken from the "Risk Assessment Guidance Document for Superfund, Volume I, Human Health Evaluation Manual (Part A) (USEPA, 1989a):

- A UF of 10 is to account for variation in the general population and is intended to protect sensitive populations (e.g., elderly, children).
- A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.
- A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.
- A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

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

- A MF ranging from >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base

for the chemical not explicitly addressed by the preceding uncertainty factors. The default for the MF is 1.

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

Toxicity factors and the USEPA WOE classifications are presented in Table 6-24. The hierarchy (USEPA, 1989a) for choosing these values was as follows:

- Integrated Risk Information System (IRIS)
- Health Effects Assessment Summary Table (HEAST)

The IRIS data base is updated monthly and contains both verified CSFs and RfDs. The USEPA has formed the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Workgroup to review and validate toxicity values used in developing CSFs. Once the slope factors have been verified via extensive peer review, they appear in the IRIS data base. Like the CSF Workgroup, the USEPA has formed a RfD Workgroup to review existing data used to derive RfDs. Once the reference doses has been verified, they also appear in IRIS.

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

## 6.5 Risk Characterization

This section presents and discusses the estimated incremental lifetime cancer risks (ICRs) and hazard indices (HIs) for identified potential receptor groups which could be exposed to COPCs via the exposure pathways presented in Section 6.3.

These quantitative risk calculations for potentially carcinogenic compounds estimate ICRs levels for an individual in a specified population. This unit risk refers to the cancer risk that is over and above the background cancer risk in unexposed individuals. For example, an ICR of 1E-06 indicates that, for a lifetime exposure, one additional case of cancer may occur per one million exposed individuals.

The ICR to individuals is estimated from the following relationship:

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

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

In contrast to the above approach for potentially carcinogenic effects, quantitative risk calculations for noncarcinogenic compounds assume that a threshold toxicological effect exists. The total

noncarcinogenic acceptable risk level is a HI less than or equal to 1.0. This noncancer risk level indicates a level at or below which adverse systemic effects are not expected in the exposed population. Therefore, the potential for noncarcinogenic effects are calculated by comparing CDIs with threshold levels (reference doses).

Noncarcinogenic effects are estimated by calculating the hazard index (HI) which is defined as:

$$HI = HQ_1 + HQ_2 + ...HQ_n$$

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

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

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

### 6.5.1 Human Health Risks

The following paragraphs present the quantitative results of the human health evaluation for each medium and area of concern at Sites 41 and 74.

Estimated ICRs are compared to the USEPA's acceptable target risk range of 1E-04 to 1E-06. A value of 1.0 is used for examination of the HI. The HI is calculated by comparing estimated CDIs with threshold levels below which, noncarcinogenic health effects are not expected to occur. Any HI equal to or exceeding 1.0 suggests that noncarcinogenic health effects may be possible. If the HI is less than 1.0, then systemic human health effects are considered unlikely.

#### 6.5.1.1 Site 41

Soil

Table 6-25 presents the total ICR and HI values estimated for the exposure via incidental ingestion, dermal contact, and inhalation of particulates of on-site surface and subsurface soil. Potential risks via these routes of exposure are estimated for current military personnel and future residential (children and adults) receptors. Potential risks from subsurface soil contamination via ingestion and dermal contact are assessed for a future construction worker. Total ICR values estimated for each receptor are less than the lower bound target risk range, suggesting that the adverse health effects are unlikely to develop from exposure to surface or subsurface soil. Additionally, the total HI values estimated for each receptor are less than unity (1), therefore, it is unlikely that exposure to surface or subsurface contamination would produce and adverse systemic health effect.

Groundwater

The ICR and HI values estimated for potential future residential receptors (children and adults) from ingestion and dermal contact of groundwater and inhalation of vapors are presented on Table 6-26. The total ICR value for future residential children (6E-04) and adults (1E-03) exceeds the USEPA's upper bound risk range (1E-04). Therefore, adverse health effects to future residents from ingestion,

dermal contact, and inhalation are plausible. The total HI estimated for potential future residential children (16) and adults (8) exceeds unity (1.0), suggesting that adverse systemic health effects are likely. The ICR and HI values are driven by the presence of total metals arsenic, chromium, and manganese.

6.5.1.2 Site 74

Soil

Table 6-27 presents the total ICR and HI values estimated for exposure via incidental ingestion, dermal contact, and inhalation of particulates of on-site surface and subsurface soil. Potential risks via these routes of exposure are estimated for current military personnel and future residential (children and adults) receptors. Potential risks from subsurface soil contamination via ingestion and dermal contact are assessed for a future construction worker. Total ICR value estimated for each receptor is less than the lower bound target risk range, suggesting that the likelihood of adverse health effects is unlikely from exposure to surface or subsurface soil. Additionally, the total HI value estimated for each receptor is less than unity (1), therefore, it is unlikely that exposure to surface or subsurface contamination will produce and adverse systemic health effect.

Groundwater

The ICR and HI values estimated for potential future residential receptors (children and adults) from ingestion and dermal contact of groundwater and inhalation of vapors are presented on Table 6-28. The total ICR value for future residential children (2E-04) and adults (3E-04) exceeds the USEPA's upper bound risk range (1E-04). Therefore, adverse health effects to future residents from ingestion, dermal contact, and inhalation are plausible. The total HI estimated for potential future residential children (8) and adults (3) exceeds unity (1), suggesting that adverse systemic health effects are likely. The ICR and HI values are driven by the presence of total metals arsenic, beryllium, and manganese.

## 6.6 Sources of Uncertainty

Uncertainties may be encountered throughout the process of performing a BRA. This section discusses the sources of uncertainty involved with the following:

- Analytical data
- Exposure Assessment
- Toxicity Assessment
- Compounds Not Qualitatively Evaluated

### 6.6.1 Analytical Data

The development of a BRA depends on the reliability of and uncertainties with the analytical data available to the risk assessor. Analytical data are limited by the precision and accuracy of the analytical method of analysis. For example, Contract Laboratory Program (CLP) methods have, in general, a precision of approximately plus or minus 50 percent depending on the sample media and the presence of interfering compounds. A value of 100 µg/kg could be as high as 150 µg/kg or as low as 50 µg/kg. In addition, the statistical methods used to compile and analyze the data (mean

concentration, standard deviation, and detection frequencies) are subject to the uncertainty in the ability to acquire data.

Data validation serves to reduce some of the inherent uncertainty associated with the analytical data by establishing the usability of the data to the risk assessor who may or may not choose to include the data point in the estimation of risk. Data qualified as "J" (estimated) were retained for the estimation of risk at OU No. 4. Data can be qualified as estimated for many reasons including a slight exceedance of holding times, high or low surrogate recovery, or intra sample variability. Organic data qualified "B" (detected in blank) or "R" (unreliable) were not used in the estimation of risk due to the unusable nature of the data. Due to the comprehensive sampling and analytical program at OU No. 4, the loss of some data points qualified "B" or "R" did not significantly increase the uncertainty in the estimation of risk.

### 6.6.2 Exposure Assessment

In performing exposure assessments, uncertainties can arise from two main sources. First, the chemical concentration to which a receptor may be exposed must be estimated for every medium of interest. Second, uncertainties can arise in the estimation of contaminant intakes resulting from contact by a receptor with a particular medium.

Estimating the contaminant concentration in a given medium to which a human receptor could potentially be exposed can be as simple as deriving the 95th percent upper confidence limit of the mean for a data set. More complex methods of deriving the contaminant concentration are necessary when exposure to COPCs in a given medium occurs subsequent to release from another medium, or analytical data are not available to characterize the release. In this case, modeling is usually employed to estimate the potential human exposure.

The potential inhalation of fugitive dusts from affected soils was estimated in the BRA using USEPA's Rapid Assessment of Exposure to Particulate Emissions from Surface Contaminated Sites (Cowherd et al. 1985). The Cowherd model employs the use of a site-specific PEF for a wind erosion based on source area and vegetative cover. A conservative estimate of the PEF was derived for OU No. 4 by assuming that the entire area was not covered with vegetation and was unlimited in its erosion potential. Modeling results for fugitive dust emission exposure suggested that the potential risk associated with this pathway was not significant.

Groundwater samples were analyzed for total (unfiltered) and dissolved (filtered) inorganic contaminants. These samples were obtained from wells which were constructed using USEPA Region IV monitoring well design specifications. Groundwater taken from monitoring wells cannot be considered representative of potable groundwater or groundwater which is obtained from a domestic well "at the tap". The use of total inorganic analytical results overestimates the potential human health risks associated with potable use scenarios. However, for the sake of conservatism, total organic results were used to estimate the potential intake associated with groundwater use.

Currently, the shallow groundwater is not used as a potable source. Current receptors (military personnel, military dependents, and civilian base personnel) are exposed to groundwater drawn from the deep zone via ingestion, dermal contact, and inhalation. Therefore, assessing current risks to contaminants detected in the shallow aquifer for current receptors is unnecessary and if estimated may present an unlikely risk. Therefore, groundwater exposures to current receptors was not estimated for this investigation.

Current and/or future potential exposure via ingestion of surface water while swimming was not assessed. The surface water bodies included in this investigation are not sufficient in size or depth to support recreational swimming, therefore, the probability of exposure via this route is very small and estimation of risk, via this route, may unnecessarily produce an unacceptable risk.

To estimate an intake, certain assumptions must be made about exposure events, exposure durations, and the corresponding assimilation of contaminants by the receptor. Exposure factors, have been generated by the scientific community and have undergone review by the USEPA. Regardless of the validity of these exposure factors, they have been derived from a range of values generated by studies of limited number of individuals. In all instances, values used in the risk assessment, scientific judgments, and conservative assumptions agree with those of the USEPA. Conservative assumptions designed not to underestimate daily intakes were employed throughout the BRA and should error conservatively, thus adequately protecting human health and allowing the establishment of reasonable clean-up goals.

### 6.6.3 Sampling Strategy

Soil represents a medium of direct contact exposure and often is the main source of contaminants released into other media. The soil sampling depth should be applicable for the exposure pathways and contaminant transport routes of concern and should be chosen purposely within that depth interval. If a depth interval is chosen purposely, a random sample procedure to select a sampling point may be established. The assessment of surface exposure at all three sites is certain based on collection of samples from the shallowest depth, zero to one foot. Subsurface soil samples are important, however, if soil disturbance is likely or leaching of chemicals to groundwater is of concern.

Due to the nature of contaminants (i.e., chemical agents) at these sites, the soil investigation was limited to the surface soil. The surface soil samples at all sites were obtained directly or very near the suspected disposal areas. Therefore, these areas would be considered areas of very high concentration which would have a significant impact on exposures.

Due to the possible presence of buried chemical agents, the subsurface soil investigation did not consider potential hot spots through extensive sampling. The subsurface soil concentrations used in determining construction workers exposures were derived from subsurface soils which were considered around the site or off site. Consequently, the risk to future construction workers from ingestion and dermal contact with subsurface soils may be biased low. However, given the limited contaminants detected in the surface soil and groundwater, it does not appear as if this low bias creates a concern that needs to be addressed through additional subsurface soil sampling.

### 6.6.4 Toxicity Assessment

In making quantitative estimates of the toxicity of varying doses of a compound to human receptors, uncertainties arise from two sources. First, data on human exposure and the subsequent effects are usually insufficient, if they are available at all. Human exposure data usually lack adequate concentration estimations and suffer from inherent temporal variability. Therefore, animal studies are often used and therefore new uncertainties arise from the process of extrapolating animal results to humans. Second, to obtain observable effects with a manageable number of experimental animals, high doses of a compound are used over a relatively short time period. In this situation, a high dose means that experimental animal exposures are much greater than human environmental exposures.

Therefore, when applying the results of the animal experiment to the human condition, the effects at the high doses must be extrapolated to approximate effects at lower doses.

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

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

For compounds believed to cause threshold effects (i.e., noncarcinogens), safety factors are employed in the extrapolation of effects from animals to humans, and from high to low doses.

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

### 6.6.5 Compounds Not Quantitatively Evaluated

The following contaminants are not quantitatively evaluated in the BRA for OU No. 4 because toxicity information has not been promulgated by the USEPA:

- Copper
- Lead
- Vanadium
- Endosulfan II
- Endosulfan I
- Endrin Ketone
- 2-Methylnaphthalene

## 6.7 Conclusions of the BRA for OU No. 4

The BRA highlights the media of interest from the human health standpoint at OU No. 4 by identifying areas with elevated ICR and HI values. Current and future potential receptors at the site include current military personnel, future residents (i.e., children and adults), and future construction workers. The total risk from each site for the these receptors is estimated by logically summing the multiple pathways likely to affect the receptor during a given activity. The following algorithms defined the total site risk for the current and future potential receptor groups assessed in a quantitative manner. The risk associated with each site is derived using the estimated risk from multiple areas of interest.

1. Current Military Personnel

    a. Incidental ingestion of COPCs in surface soil + dermal contact with COPCs in surface soil + inhalation of airborne COPCs

2. Future Residents (Children and Adults)

    a. Incidental ingestion of COPCs in surface soil + dermal contact with COPCs in surface soil + inhalation of COPCs

    b. Ingestion of COPCs in groundwater + dermal contact with COPCs in groundwater + inhalation of volatile COPCs

3. Future Construction Worker

    a. Incidental ingestion of COPCs in on-site or off-site subsurface soil + dermal contact with COPCs in subsurface soil

### 6.7.1 Site 41

Presented on Table 6-29 are the total site ICR and HI values estimated for current and future receptors at this site. The total site ICR estimated for current military personnel (6E-07) is less than the USEPA's target risk range (1E-04 to 1E-06). Additionally, the total HI value estimated for this receptor is less than unity. The total site ICR estimated for future residential children (6E-04) and adults (1E-03) exceeds the USEPA's upper bound risk range (1E-04). The total site ICR estimated for future construction workers (9E-08) is less than the USEPA's target risk range of 1E-04 to 1E-06. Additionally, the total site HI for future residential children (16) and adults (8) exceeds unity. The total site HI estimated for the future construction worker (0.2) does not exceed unity. The total site risk receptors is driven by future potential exposure to shallow groundwater.

### 6.7.2 Site 74

Presented on Table 6-30 are the total site ICR and HI values estimated for current and future receptors at this site. The total site ICR estimated for current military personnel (8E-08) is less than the lower bound USEPA's target risk range (1E-06). Additionally, the total HI value estimated for this receptor is less than unity. The total site ICR estimated for future residential children (2E-04) and adults (3E-04) exceeds the USEPA's upper bound risk range (1E-04). The total site ICR estimated for future construction workers (2E-08) is less than the USEPA's target risk range of 1E-04 to 1E-06. Additionally, the total site HI for future residential children (8) and adults (3) exceeds unity. The total site HI estimated for the future construction worker (<0.01) does not exceed unity. The total site risk is driven by future potential exposure to shallow groundwater.

# SECTION 6.0 TABLES

**TABLE 6-1**

**ORGANIC DATA SUMMARY**
**DOWNSLOPE AND ON-SITE SURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Surface Soil | |
|---|---|---|
| | Range of Positive Detections | No. of Positive Detects/ No. of Samples |
| 1,4-Dichlorobenzene | 180J | 1/46 |
| 2-Methylnaphthalene | 55J | 1/46 |
| Acenaphthene | 91J - 380J | 2/46 |
| Anthracene | 41J - 510 | 3/46 |
| Benzo(a)anthracene | 130J - 2,400 | 4/46 |
| Benzo(a)pyrene | 40J - 2,000 | 5/46 |
| Benzo(b)fluoranthene | 38J - 2,500 | 6/46 |
| Benzo(g,h,i)perylene | 46J - 1,600 | 4/46 |
| Benzo(k)fluoranthene | 50J - 1,700 | 6/46 |
| bis(2-chloroethyl)ether | 57J - 220J | 6/46 |
| bis(2-ethylhexyl)phthalate | 42J - 580J | 12/46 |
| Carbazole | 44J - 330J | 2/46 |
| Chrysene | 49J - 2,300 | 6/46 |
| Dibenzofuran | 130J | 1/46 |
| Dibenz(a,h)anthracene | 57J | 1/46 |
| di-n-Butylphthalate | 42J - 230J | 13/46 |
| Fluoranthene | 40J - 200J | 6/46 |
| Fluorene | 79J - 280J | 2/46 |
| Indeno(1,2,3-cd)pyrene | 71J - 76J | 2/46 |
| Naphthalene | 70J | 1/46 |
| Phenanthrene | 72J - 2,600 | 6/46 |
| Pyrene | 50J - 2,300J | 7/46 |
| Methylene chloride | 2J - 5J | 13/46 |
| Acetone | 3J - 2,800 | 11/46 |
| Toluene | 1J - 4J | 3/46 |
| beta-BHC | 4.72NJ | 1/46 |

Note: Concentrations expressed in microgram per kilogram (µg/kg).
J - Estimated value
NJ - Estimated/tentative value

**TABLE 6-1 (Continued)**

**ORGANIC DATA SUMMARY**
**DOWNSLOPE AND ON-SITE SURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Surface Soil | |
|---|---|---|
| | Range of Positive Detections | No. of Positive Detects/ No. of Samples |
| delta-BHC | 0.03NJ | 1/46 |
| Lindane (gamma-BHC) | 0.22NJ | 1/46 |
| Heptachlor | 0.3NJ - 7.16J | 5/46 |
| Heptachlor epoxide | 0.56NJ - 9.6NJ | 5/46 |
| Dieldrin | 0.2NJ - 13.03NJ | 17/46 |
| 4,4-DDE | 0.12J - 87.6J | 34/46 |
| Endrin | 1.47NJ - 2.93J | 5/46 |
| Endosulfan II | 0.45NJ - 5.01J | 13/46 |
| 4,4-DDD | 0.37J - 92J | 19/46 |
| Endosulfan sulfate | 0.32J | 1/46 |
| 4,4-DDT | 0.37J - 277 | 29/46 |
| Methoxychlor | 1.41J - 3.28NJ | 3/46 |
| Endrin ketone | 0.44NJ | 1/46 |
| Endrin aldehyde | 0.61J - 1.37J | 7/46 |
| alpha-chlordane | 0.08J - 42.7J | 16/46 |
| gamma-chlordane | 0.06NJ - 93.5J | 16/46 |
| Aroclor 1242 | 82.9J | 1/46 |
| Aroclor 1260 | 58.4J | 1/46 |
| 1,3-Dinitrobenzene | 824NJ | 1/46 |

Note: Concentrations expressed in microgram per kilogram (µg/kg).
J - Estimated value
NJ - Estimated/tentative value

**TABLE 6-2**

**INORGANIC DATA SUMMARY**
**DOWNSLOPE AND ON-SITE SURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Inorganic | Surface Soil | | | | |
|---|---|---|---|---|---|
| | Average Base-Specific Background[(1)] Concentration Range | Twice the Average Base-Specific Maximum Concentration | Range of Positive Detections | No. of Positive Detects/ No. of Samples | No. of Times Exceeded Twice the Average Background Concentration |
| Aluminum | 2,435.66 | 4,871.32 | 878 - 17,400J | 46/46 | 13 |
| Arsenic | 0.38 | 0.76 | 0.671 - 4.42 | 19/46 | 16 |
| Barium | 8.79 | 17.58 | 3.14 - 82.2 | 46/46 | 11 |
| Beryllium | 0.114 | 0.228 | 0.187 - 0.344 | 12/46 | 4 |
| Cadmium | 0.325 | 0.655 | 0.854 - 7.44 | 5/46 | 5 |
| Calcium | 799 | 1,598 | 32.9 - 40,300 | 42/46 | 12 |
| Chromium | 2.49 | 4.97 | 2.19 - 41.4 | 41/46 | 24 |
| Cobalt | 1.728 | 3.455 | 6.46 | 1/46 | 1 |
| Copper | 7.04 | 14.08 | 4.17 - 132 | 15/46 | 4 |
| Iron | 1,583.12 | 3,166.24 | 397 - 91,600 | 46/46 | 20 |
| Lead | 18.55 | 37.09 | 2.57 - 341J | 46/46 | 9 |
| Magnesium | 105.52 | 211.05 | 28.1 - 1,100 | 46/46 | 10 |
| Manganese | 8.42 | 16.84 | 1.67 - 6,000J | 44/46 | 11 |
| Mercury | 0.043 | 0.087 | 0.074 - 0.768 | 22/46 | 13 |
| Nickel | 2.02 | 4.05 | 7.36 - 35.3 | 4/46 | 4 |
| Potassium | 99.26 | 198.52 | 184 - 547 | 14/46 | 11 |
| Selenium | 0.337 | 0.674 | 0.357 - 0.596 | 3/46 | 0 |
| Silver | 0.49 | 0.98 | 0.096 - 18.3J | 3/46 | 1 |
| Sodium | 42.706 | 85.412 | 84.7 - 230 | 8/46 | 7 |
| Vanadium | 3.38 | 6.76 | 4.62 - 39.8 | 31/46 | 24 |
| Zinc | 6.676 | 13.353 | 1.09 - 1.57 | 46/46 | 0 |

Notes: Concentrations expressed in milligram per kilogram (mg/kg).
(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.
ND - Not Detected
NA - Not Applicable
J - Estimated value

**TABLE 6-3**

**ORGANIC DATA SUMMARY**
**DOWNSLOPE AND ON-SITE SUBSURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Subsurface Soil | |
|---|---|---|
| | Range of Positive Detections | No. of Positive Detects/ No. of Samples |
| 1,4-Dichlorobenzene | 49J | 1/66 |
| 2-Methylnapthalene | 41J - 550 | 4/66 |
| 4-chloro-3-methylphenol | 61J | 1/66 |
| 4-Methylphenol | 53J | 1/66 |
| Acenaphthene | 52J - 130J | 3/66 |
| Benzo(a)anthracene | 71J - 160J | 2/66 |
| Benzo(b)fluoranthene | 75J - 150J | 2/66 |
| Benzo(a)pyrene | 74J - 4,700J | 6/66 |
| bis(2-chloroethyl)phthalate | 79J - 800 | 3/66 |
| bi(2-ethylhexyl)phthalate | 39J - 7,200J | 33/66 |
| Butylbenzyl phthalate | 88J | 1/66 |
| Carbazole | 66J | 1/66 |
| Chrysene | 43J - 170J | 4/66 |
| Dibenzofuran | 48J | 1/66 |
| Diethylphthalate | 110J | 1/66 |
| di-n-Butylphthalate | 40J - 230J | 26/66 |
| di-n-Octylphthalate | 40J - 1,600 | 9/66 |
| Fluoranthene | 46J - 260J | 5/66 |
| Fluorene | 44J - 120J | 4/66 |
| Indeno(1,2,3-cd)pyrene | 105J | 1/66 |
| Naphthalene | 45J - 130J | 5/66 |
| N-nitrosodiphenylamine | 240J | 1/66 |
| Phenanthrene | 39J - 260J | 5/66 |
| Pyrene | 52J - 290J | 6/66 |
| Benzo(g,h,i)perylene | 41J - 4,600J | 5/66 |
| Benzo(k)fluoranthene | 80J - 109J | 2/66 |

Note: Concentrations expressed in microgram per kilogram (µg/kg).
J - Estimated value
NJ - Estimated/tentative value

**TABLE 6-3 (Continued)**

**ORGANIC DATA SUMMARY**
**DOWNSLOPE AND ON-SITE SUBSURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Subsurface Soil | |
|---|---|---|
| | Range of Positive Detections | No. of Positive Detects/ No. of Samples |
| Chloromethane | 2J - 3J | 2/66 |
| Acetone | 4J - 6,000J | 34/66 |
| 2-Butanone | 1J - 15J | 8/66 |
| Trichloroethene | 1J | 1/66 |
| Benzene | 1J | 2/66 |
| Chlorobenzene | 4J - 100 | 5/66 |
| Ethylbenzene | 7J - 58 | 2/66 |
| delta-BHC | 0.91J | 2/66 |
| Lindane (gamma-BHC) | 11.9J | 1/66 |
| Heptachlor | 0.68J - 18 | 9/66 |
| Aldrin | 0.7J - 12.8J | 5/66 |
| Heptachlor epoxide | 0.4J - 11.5J | 5/66 |
| Endosulfan I | 0.78NJ - 2.92NJ | 5/66 |
| 4,4-DDE | 0.32NJ - 39.6J | 27/66 |
| Endrin | 0.35J - 28.3J | 11/66 |
| Endosulfan II | 0.5NJ - 25.2NJ | 24/66 |
| 4,4-DDD | 0.34NJ - 1,060J | 26/66 |
| 4,4-DDT | 0.68NJ - 302J | 10/66 |
| Methoxychlor | 5.47NJ | 1/66 |
| Endrin ketone | 0.86J | 1/66 |
| Endrin aldehyde | 0.85NJ - 4.38J | 9/66 |
| alpha-Chlordane | 0.28NJ - 160J | 17/66 |
| gamma-Chlordane | 0.31J - 170J | 13/66 |
| Aroclor 1254 | 36.7J - 214J | 5/66 |
| Aroclor 1260 | 34.6J - 317J | 5/66 |
| Acetophenone | 120J | 1/66 |
| Dieldrin | 0.32J - 60NJ | 17/66 |

Note: Concentrations expressed in microgram per kilogram (µg/kg).
J - Estimated value
NJ - Estimated/tentative value

**TABLE 6-4**

**INORGANIC DATA SUMMARY**
**DOWNSLOPE AND ON-SITE SUBSURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Inorganic | Subsurface Soil | | | | |
|---|---|---|---|---|---|
| | Average Base-Specific Background[1] Concentration Range | Twice the Average Base-Specific Maximum Concentration | Range of Positive Detections | No. of Positive Detects/ No. of Samples | No. of Times Exceeded Twice the Average Background Concentration |
| Aluminum | 672 - 10,200 | 8,946.3 | 486 - 13,500J | 66/66 | 6 |
| Arsenic | 0.03 - 0.47 | 0.6 | 0.518 - 3.02 | 33/66 | 29 |
| Barium | 2 - 11 | 11.9 | 3.15 - 186 | 63/66 | 37 |
| Beryllium | 0.03 - 0.23 | 0.2 | 0.187 - 0.31 | 10/66 | 8 |
| Cadmium | 0.17 - 1.2 | 1.0 | 1.32 - 4.73 | 3/66 | 3 |
| Calcium | 5 - 4,410 | 1,508.3 | 37.3 - 18,900 | 60/66 | 13 |
| Chromium | 2 - 9 | 8.7 | 2.1 - 40.5J | 64/66 | 18 |
| Cobalt | 0.175 - 2 | 1.6 | 4.53 | 1/66 | 1 |
| Copper | 0.47 - 2 | 1.6 | 3.77 - 39.8 | 15/66 | 15 |
| Iron | 126 - 2,840 | 1,778.0 | 115J - 41,100 | 66/66 | 21 |
| Lead | 1 - 12 | 9.1 | 0.894J - 829 | 66/66 | 27 |
| Magnesium | 13 - 260 | 231.2 | 18.4 - 567 | 65/6 | 14 |
| Manganese | 0.40 - 8 | 6.2 | 1.63 - 244 | 60/66 | 30 |
| Mercury | 0.01 - 0.11 | 0.1 | 0.057-0.312 | 17/66 | 11 |
| Nickel | 0.70 - 5 | 4.0 | 7.56 - 12.9 | 2/66 | 2 |
| Potassium | 41 - 187 | 228.8 | 123 - 562 | 26/66 | 16 |
| Selenium | 0.12 - 0.55 | 0.8 | 0.373J - 0.948 | 11/66 | 3 |
| Silver | 0.18 - 1 | 1.1 | 0.202 - 9.71J | 4/66 | 1 |
| Sodium | 7 - 45 | 40.6 | 59.3 - 486 | 10/66 | 10 |
| Vanadium | 0.75 - 13 | 10.1 | 4.79 - 25.7 | 44/66 | 20 |
| Zinc | 0.40 - 12 | 5.6 | 2.8J - 407 | 57/66 | 44 |

Notes: Concentrations expressed in milligram per kilogram (mg/kg).
[1] Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.
ND - Not Detected
NA - Not Applicable
J - Estimated

**TABLE 6-5**

**GROUNDWATER DATA SUMMARY**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| | Groundwater Criteria | | | | Frequency/Range | | Comparison to Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Federal Health Advisories[3] | | | | | | No. of Detects Above Health Advisories | |
| Contaminant | NCWQS[1] | MCL[2] | 10 kg Child | 70 kg Adult | No. of Positive Detects/ No. of Samples | Concentration Range | No. of Detects Above NCWQS | No. of Detects Above MCL | 10 kg Child | 70 kg Adult |
| Acetone | NE | NE | NE | NE | 3-18 | 4J - 12J | NA | NA | NA | NA |
| Benzene | 1.0 | 100[5] | NE | NC | 1/18 | 2J | 1 | 0 | NA | NA |
| Bromoform | 0.19 | 100 | 2,000 | 6,000 | 1/18 | 2J | 3 | 0 | 0 | 0 |
| Chlorobenzene | 50 | NE | NE | NE | 1/18 | 1.4J | 0 | 0 | NA | NA |
| Arsenic | 50 | 50 | NE | NE | 13/18 | 2.1 - 53.5 | 1 | 1 | NA | NA |
| Barium | 2,000 | 2,000 | NE | NE | 18/18 | 18.2 - 836 | 0 | 0 | NA | NA |
| Beryllium | NE | 4 | 30,000 | 20,000 | 11/18 | 0.954 - 37.4 | NA | 5 | 0 | 0 |
| Cadmium | 5 | 5 | 40 | 20 | 11/18 | 2.58 - 37.5 | 7 | 7 | 0 | 0 |
| Chromium | 50 | 100 | 1,000 | 800 | 12/18 | 12.1 - 166 | 8 | 4 | 0 | 0 |
| Cobalt | NE | NE | NE | NE | 6/18 | 15.6 - 106 | NA | NA | NA | NA |
| Lead | 15 | 15 | NE | NE | 13/18 | 2.3 - 145 | 10 | 10 | NA | NA |
| Manganese | 50 | 50[4] | NE | NE | 18/18 | 24.5 - 766 | 15 | 15 | NA | NA |
| Mercury | 1.1 | 2 | NE | NE | 2/18 | 0.264 - 0.33 | 0 | 0 | NA | NA |
| Nickel | 100 | 100 | 1,000 | 50 | 9/18 | 22.8 - 177 | 1 | 1 | 0 | 3 |
| Selenium | 50 | 50 | NE | NE | 1/18 | 10.3J | 0 | 0 | NA | NA |
| Vanadium | NE | NE | NE | NE | 14/18 | 10.6 - 179 | NA | NA | NA | NA |
| Zinc | 2,100 | 5,000[4] | 3,000 | 1,200 | 13/18 | 17.8 41.6 - 675 | 1 | 1 | 1 | 1 |

Notes: Concentrations expressed in microgram per liter (µg/L).

(1) NCWQS = North Carolina Water Quality Standard for Groundwater

(2) MCL = Safe Drinking Water Act Maximum Contaminant Level

(3) Longer Term Health Advisories for a 10 kg Child and 70 kg Adult

(4) SMCL = Secondary Maximum Contaminant Level

(5) Total trihalomethanes ($TTHM_3$)

NE - Not Established

NA - Not Applicable

NJ - Estimated/tentative value

Estimated value

**TABLE 6-6**

**SURFACE WATER DATA SUMMARY**
**UNNAMED TRIBUTARY AND TANK CREEK**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Surface Water Criteria | | | Contaminant Frequency/Range | | Comparison to Criteria | | |
|---|---|---|---|---|---|---|---|---|
| | | Federal Health AWQCs[2] | | | | Positive Detects Above NCWQS | Positive Detects Above AWQC | |
| | NCWQS[1] | Water & Organisms | Organisms Only | No. of Positive Detects/ No. of Samples | Contaminant Range | | Water & Organisms | Organisms Only |
| Chlorobenzene | 488 | 488 | NE | 2/14 | 1J - 4J | 0 | 0 | NA |
| Lindane (gamma-BHC) | NE | 0.0186 | 0.0625 | 1/28 | 0.02J | NA | 1 | 0 |
| 4,4-DDT | 0.000588 | 0.000024 | 0.000024 | 1/28 | 0.03J | NA | 1 | 1 |
| Barium | 1,000 | 1,000 | NE | 28/28 | 17.9 - 442 | 0 | 0 | 0 |
| Chromium | NE | 50 | NE | 1/28 | 8.52 | NA | 0 | NA |
| Lead | NE | 50 | NE | 19/28 | 1.13J - 36.8 | 0 | 0 | 0 |
| Manganese | 50 | 50 | 100 | 28/28 | 12.3 - 1700 | 1 | 1 | 1 |
| Mercury | NE | 0.144 | 0.146 | 9/28 | 0.101 - 0.56 | 0 | 0 | 0 |
| Zinc | NE | NE | NE | 23/28 | 16.3 - 235 | NA | NA | NA |

Notes: Concentrations expressed in microgram per liter ($\mu$g/L).
[1] NCWQS = North Carolina Water Quality Standards for Surface Water
[2] AWQC = Ambient Water Quality Standard
NE - Not Established
NA - Not Applicable
J - Estimated value

**TABLE 6-7**

**SEDIMENT DATA SUMMARY**
**UNNAMED TRIBUTARY AND TANK CREEK**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Sediment Criteria | | Range/Frequency | | Comparison to Criteria: Positive Detects Above NOAA | |
|---|---|---|---|---|---|---|
| | NOAA ER-L[1] Concentration | NOAA ER-M[2] Concentration | Range of Positive Detections | No. of Positive Detects/ No. of Samples | ER-L | ER-M |
| Benzo(a)pyrene | 430 | 1600 | 57J | 1/28 | NA | NA |
| Benzo(b)fluoranthene | NE | NE | 69J | 1/28 | NA | NA |
| Benzo(k)fluoranthene | NE | NE | 58J | 1/28 | NA | NA |
| di-n-Octylphthalate | NE | NE | 49J - 310J | 3/28 | NA | NA |
| di-n-Butylphthalate | NE | NE | 48J-370J | 6/28 | NA | NA |
| Methylene Chloride | NE | NE | 2J-7J | 8/28 | NA | NA |
| Acetone | NE | NE | 4J-190 | 11/28 | NA | NA |
| Trichloroethene | NE | NE | 2J | 1/28 | NA | NA |
| Toluene | NE | NE | 2J | 2/28 | NA | NA |
| Dieldrin | 0.02 | 8 | 0.46NJ - 6.39 | 10/41 | 10 | 0 |
| 4,4-DDE | 2 | 15 | 0.53J - 31.3J | 9/41 | 11 | 2 |
| Endosulfan II | NE | NE | 0.64NJ - 8.22 | 9/41 | NA | NA |
| 4,4-DDD | 2 | 20 | 0.38NJ - 73.9J | 22/41 | 13 | 3 |
| 4,4-DDT | 1 | 7 | 0.36NJ - 34.8J | 17/41 | 11 | 2 |
| Methoxychlor | NE | NE | 0.91J - 3.2 | 6/41 | NA | NA |
| Endrin ketone | NE | NE | 0.66NJ | 1/41 | NA | NA |
| alpha-Chlordane | NE | NE | 0.34J - 3.72 | 13/41 | NA | NA |
| gamma-Chlordane | NE | NE | 0.4J - 6.35J | 11/41 | NA | NA |
| Aroclor 1242 | 22.7 | 80[3] | 63J - 140J | 2/41 | 3 | 0 |
| Aroclor 1254 | 22.7 | 80[3] | 68J | 1/41 | 1 | 0 |
| 1,3,5-Trinitrobenzene | NE | NE | 1,390 | 1/28 | NA | NA |

**TABLE 6-7 (Continued)**

**SEDIMENT DATA SUMMARY**
**UNNAMED TRIBUTARY AND TANK CREEK**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Sediment Criteria | | Range/Frequency | | Comparison to Criteria: Positive Detects Above NOAA | |
|---|---|---|---|---|---|---|
| | NOAA ER-L[1] Concentration | NOAA ER-M[2] Concentration | Range of Positive Detections | No. of Positive Detects/ No. of Samples | ER-L | ER-M |
| Arsenic | 8.2 | 70 | 0.617 - 9.3 | 13/42 | 0 | 0 |
| Barium | NE | NE | 1.4 - 161 | 36/42 | NA | NA |
| Beryllium | NE | NE | 0.235 - 1.02 | 5/42 | NA | NA |
| Chromium | 81 | 370 | 2.32J - 16.5J | 16/42 | 0 | 0 |
| Copper | 34 | 270 | 6.13 - 19.9 | 4/42 | 0 | 0 |
| Lead | 46.7 | 218 | 1.1 - 59.4J | 42/42 | 2 | 0 |
| Manganese | NE | NE | 1.3 - 3.6 | 37/42 | NA | NA |
| Mercury | 0.15 | 0.71 | 0.46-0.63 | 2/40 | 2 | 0 |
| Nickel | 20.9 | 51.6 | 3.79 - 6.12 | 6/42 | 0 | 0 |
| Selenium | NE | NE | 0.629J - 0.862J | 4/42 | NA | NA |
| Thallium | NE | NE | 1.19J | 1/42 | NA | NA |
| Vanadium | NE | NE | 3.5 - 30 | 12/42 | NA | NA |
| Zinc | 150 | 410 | 5.5 - 155 | 25/42 | 0 | 0 |

Notes: Organic concentrations expressed in microgram per Kilogram (µg/Kg).
Inorganic concentrations expressed in milligram per Kilogram (mg/Kg).
(1) ER-L - Effective Range-Lower
(2) ER-M - Effective Range-Medium
(3) Total PCBs.
NE - Not Established
NA - Not Applicable
J - Estimated Value
NJ - Estimated/tentative value

**TABLE 6-8**

**ORGANIC DATA SUMMARY**
**PESTICIDE DISPOSAL AREA SURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Surface Soil | |
|---|---|---|
| | Range of Positive Detections | No. of Positive Detects/ No. of Samples |
| 4-chloro-3-methylphenol | 54J - 240J | 2/60 |
| Acenaphthene | 39J | 1/60 |
| Benzo(a)pyrene | 130J | 1/60 |
| Benzo(g,h,i)pyrene | 61J - 160J | 2/60 |
| bis(2-chloroethyl)ether | 12J - 180J | 5/60 |
| Diethylphthalate | 86J - 866 | 2/60 |
| di-n-Butylphthalate | 39J - 126J | 13/60 |
| Pyrene | 38J | 1/60 |
| Methylene chloride | 4J - 23J | 20/60 |
| Acetone | 4J - 210J | 22/60 |
| Trichloroethene | 2J - 8J | 5/60 |
| Toluene | 1J - 3J | 3/60 |
| Styrene | 1J | 1/60 |
| Xylenes (total) | 3J - 6J | 2/60 |
| alpha-BHC | 0.45 | 1/60 |
| Heptachlor | 0.2 NJ - 298J | 8/60 |
| Aldrin | 0.41NJ | 1/60 |
| Heptachlor epoxide | 0.21NJ - 1.43J | 4/60 |
| Dieldrin | 0.32J - 706NJ | 5/60 |
| 4,4-DDE | 0.31J - 1,730J | 31/60 |
| Endrin | 0.42J - 1.06J | 3/60 |
| Endosulfan II | 0.44NJ - 1.31NJ | 3/60 |
| 4,4-DDT | 0.81J - 3,840J | 22/60 |
| Methoxychlor | 166J | 1/60 |
| Endrin aldehyde | 0.5NJ - 2.29NJ | 5/60 |
| alpha-chlordane | 0.39J - 1,160J | 8/60 |
| gamma-chlordane | 0.45J - 1,680J | 8/60 |
| Hydroxyacetophenone | 190J | 1/37 |
| 4,4'-DDD | 0.37 - 3,700J | 17/60 |

Note: Concentrations expressed in microgram per kilogram (µg/kg).
J - Estimated value
NJ - Estimated/tentative value

**TABLE 6-9**

**INORGANIC DATA SUMMARY**
**PESTICIDE DISPOSAL AREA SURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Inorganic | Surface Soil | | | | |
|---|---|---|---|---|---|
| | Average Base-Specific Background[(1)] Concentration Range | Twice the Average Base-Specific Maximum Concentration | Range of Positive Detections | No. of Positive Detects/ No. of Samples | No. of Times Exceeded Twice the Average Background Concentration |
| Aluminum | 2,435.66 | 4,871.32 | 36.3 - 10,900 | 60/60 | 20 |
| Arsenic | 0.38 | 0.76 | 0.62J - 1.16 | 9/60 | 9 |
| Barium | 8.79 | 17.58 | 2.89 - 54.7 | 54/60 | 1 |
| Beryllium | 0.114 | 0.228 | ND | 0/60 | NA |
| Cadmium | 0.325 | 0.655 | 0.543 - 0.686 | 4/60 | 1 |
| Calcium | 799 | 1,598 | 34. 9 - 175,000 | 53/60 | 7 |
| Chromium | 2.49 | 4.97 | 1.89 - 10.6 | 50/60 | 17 |
| Cobalt | 1.728 | 3.455 | ND | 0/60 | NA |
| Copper | 7.04 | 14.08 | 5.07 - 22 | 4/60 | 1 |
| Iron | 1,583.12 | 3,166.24 | 31.21J - 34,200 | 60/60 | 6 |
| Lead | 18.55 | 37.09 | 0.878J - 15.4 | 60/60 | 0 |
| Magnesium | 105.52 | 211.05 | 16.3 - 2,790 | 52/60 | 5 |
| Manganese | 8.42 | 16.84 | 1.44 - 96.2 | 58/60 | 4 |
| Mercury | 0.043 | 0.087 | 0.015 - 0.092 | 8/60 | 2 |
| Nickel | 2.02 | 4.05 | 3.15 - 4.78 | 6/60 | 2 |
| Potassium | 99.26 | 198.52 | 80.7 - 351 | 16/60 | 3 |
| Selenium | 0.337 | 0.674 | 0.609 - 1.2 | 14/60 | 12 |
| Silver | 0.49 | 0.98 | 0.116J | 1/60 | 1 |
| Sodium | 42.706 | 85.412 | 105J - 860 | 10/60 | 10 |
| Vanadium | 3.38 | 6.76 | 4.03 - 15.1 | 34/60 | 0 |
| Zinc | 6.676 | 13.353 | 2.27 - 33.9 | 33/60 | 2 |

Notes: Concentrations expressed in milligram per kilogram (mg/kg).
(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.
ND - Not Detected
NA - Not Applicable
J - Estimated value

**TABLE 6-10**

**ORGANIC DATA SUMMARY**
**PESTICIDE DISPOSAL AREA SUBSURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Subsurface Soil | |
|---|---|---|
| | Range of Positive Detections | No. of Positive Detects/ No. of Samples |
| bis(2-ethylhexyl)phthalate | 37J - 240J | 8/47 |
| Diethylphthalate | 874 | 1/47 |
| di-n-Butylphthalate | 43J - 155J | 10/47 |
| Methylene chloride | 190 | 1/47 |
| Acetone | 6J - 820 | 32/47 |
| Heptachlor | 0.24J - 1.59J | 3/47 |
| Aldrin | 0.4J | 1/47 |
| Heptachlor epoxide | 0.33J | 1/47 |
| 4,4-DDE | 1.05NJ - 21.3J | 5/47 |
| 4,4-DDD | 0.59J - 3.61J | 5/47 |
| 4,4-DDT | 0.34NJ - 21.37J | 9/47 |
| Methoxychlor | 7.06J | 1/47 |
| Endrin aldehyde | 0.48NJ - 0.77NJ | 2/47 |

Note: Concentrations expressed in microgram per kilogram (µg/kg).
J - Estimated value
NJ - Estimated/tentative value

**TABLE 6-11**

**INORGANIC DATA SUMMARY**
**PESTICIDE DISPOSAL AREA SUBSURFACE SOIL**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Inorganic | Subsurface Soil | | | | |
|---|---|---|---|---|---|
| | Average Base-Specific Background[1] Concentration Range | Twice the Average Base-Specific Maximum Concentration | Range of Positive Detections | No. of Positive Detects/ No. of Samples | No. of Times Exceeded Twice the Average Background Concentration |
| Aluminum | 672 - 10,200 | 8,946.3 | 349 - 9,380 | 47/47 | 1 |
| Arsenic | 0.03 - 0.47 | 0.6 | 0.538J - 2.76 | 10/47 | 8 |
| Barium | 2 - 11 | 11.9 | 2.77 - 17.5 | 29/47 | 3 |
| Beryllium | 0.03 - 0.23 | 0.2 | ND | 0/47 | NA |
| Cadmium | 0.17 - 1.2 | 1.0 | ND | 0/47 | NA |
| Calcium | 5 - 4,410 | 1,508.3 | 34 - 2,250 | 23/47 | 1 |
| Chromium | 2 - 9 | 8.7 | 1.92 - 9.91 | 41/47 | 2 |
| Cobalt | 0.175 - 2 | 1.6 | ND | 0/47 | NA |
| Copper | 0.47 - 2 | 1.6 | ND | 0/47 | NA |
| Iron | 126 - 2,840 | 1,778.0 | 123 - 4,940 | 47/47 | 6 |
| Lead | 1 - 12 | 9.1 | 0.751 - 7.42 | 47/47 | 0 |
| Magnesium | 13 - 260 | 231.2 | 15.4 - 250 | 45/47 | 1 |
| Manganese | 0.40 - 8 | 6.2 | 1.55 - 21.7 | 32/47 | 2 |
| Mercury | 0.01 - 0.11 | 0.1 | 0.056 | 1/47 | 0 |
| Nickel | 0.70 - 5 | 4.0 | ND | 0/47 | NA |
| Potassium | 41 - 187 | 228.8 | 191 - 302 | 4/47 | 1 |
| Selenium | 0.12 - 0.55 | 0.8 | 0.818 | 1/47 | 1 |
| Silver | 0.18 - 1 | 1.1 | ND | 0/47 | NA |
| Sodium | 7 - 45 | 40 | ND | 0/47 | NA |
| Vanadium | 0.75 - 13 | 10.1 | 3.93 - 14.2 | 16/47 | 3 |
| Zinc | 0.40 - 12 | 5.6 | 2.51 - 11.9 | 18/47 | 2 |

Notes: Concentrations expressed in milligram per kilogram (mg/kg).
(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.
ND - Not Detected
NA - Not Applicable
J - Estimated value

**TABLE 6-12**

**GROUNDWATER DATA SUMMARY**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| | Groundwater Criteria | | | | Frequency/Range | | Comparison to Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Federal Health Advisories[3] | | | | | | No. of Detects Above Health Advisories | |
| Contaminant | NCWQS[1] | MCL[2] | 10 kg Child | 70 kg Adult | No. of Positive Detects/ No. of Samples | Concentration Range | No. of Detects Above NCWQS | No. of Detects Above MCL | 10 kg Child | 70 kg Adult |
| di-n-butylphthalate | 700 | NE | NE | NE | 1/8 | 2J | 0 | NA | NA | NA |
| Acetone | 700 | NE | NE | NE | 2/8 | 2J - 2.04J | 0 | NA | NA | NA |
| Lindane (gamma-BHC) | 0.2 | 0.2 | 30 | 100 | 1/7 | 0.04J | 0 | 0 | 0 | 0 |
| Heptachlor | 0.008 | 0.4 | 5 | 5 | 1/7 | 0.01NJ | 1 | 0 | 0 | 0 |
| Endosulfan II | NE | NE | NE | NE | 1/7 | 0.02J | NA | NA | NA | NA |
| alpha-Chlordane | 0.027 | 2 | NE | NE | 1/7 | 0.02NJ | 0 | 0 | NA | NA |
| Arsenic | 50 | 50 | NE | NE | 5/8 | 2.86J - 18.1 | 0 | 0 | NA | NA |
| Barium | 2,000 | 2,000 | NE | NE | 8/8 | 28.2-117 | 0 | 0 | NA | NA |
| Beryllium | NE | 4 | 4,000 | 20,000 | 3/8 | 0.842 - 2.25 | NA | 0 | 0 | 0 |
| Chromium | 50 | 100 | 200 | 800 | 5/8 | 15.9-56.6 | 1 | 1 | 0 | 0 |
| Lead | 15 | 15 | NE | NE | 7/8 | 3.1J - 15.3 | 1 | 1 | NA | NA |
| Manganese | 50 | 50[4] | NE | NE | 8/8 | 8.47 - 115 | 1 | 1 | NA | NA |
| Mercury | 1.1 | 2 | NE | 2 | 1/8 | 0.244 | 0 | 0 | NA | 0 |
| Selenium | 50 | 50 | NE | NE | 1/8 | 1.8J | 0 | 0 | NA | NA |
| Vanadium | NE | NE | NE | NE | 4/8 | 4.3 - 301 | NA | NA | NA | NA |
| Zinc | 2,100 | 5,000[4] | 3,000 | 12,000 | 5/5 | 19.1 - 417J | 0 | 0 | 0 | 0 |

Notes: Concentrations expressed in microgram per liter (µg/L).

[1] NCWQS = North Carolina Water Quality Standards for Groundwater

[2] MCL = Safe Drinking Water Act Maximum Contaminant Level

[3] Longer Term Health Advisories for a 10 kg Child and 70 kg Adult

[4] SMCL = Secondary Maximum Contaminant Level

NE - Not Established

NA - Not Applicable

NJ - Estimated/tentative value

J - Estimated value

**TABLE 6-13**

**SURFACE WATER DATA SUMMARY**
**PESTICIDE DISPOSAL AREA**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Surface Water Criteria | | | Contaminant Frequency/Range | | Comparison to Criteria | | |
|---|---|---|---|---|---|---|---|---|
| | | Federal Health AWQCs[2] | | | | Positive Detects Above AWQC | | |
| | NCWQS[1] | Water & Organisms | Organisms Only | No. of Positive Detects/ No. of Samples | Contaminant Range | Positive Detects Above NCWQS | Water & Organisms | Organisms Only |
| Lead | NE | 50 | NE | 3/3 | 1.62J - 6.04J | NA | 0 | NA |

Notes: Concentrations expressed in microgram per liter ($\mu$g/L).
[1] NCWQS = North Carolina Water Quality Standards for Surface Water
[2] AWQC = Ambient Water Quality Standard
NE - Not Established
NA - Not Applicable
J - Estimated value

**TABLE 6-14**

**SEDIMENT DATA SUMMARY**
**PESTICIDE DISPOSAL AREA**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Sediment Criteria | | Range/Frequency | | Comparison to Criteria: Positive Detects Above NOAA | |
|---|---|---|---|---|---|---|
| | NOAA ER-L[1] Concentration | NOAA ER-M[2] Concentration | Range of Positive Detections | No. of Positive Detects/ No. of Samples | ER-L | ER-M |
| 3,3-Dichlorobenzidine | NE | NE | 140J | 1/3 | NA | NA |
| Trichloroethene | NE | NE | 8J | 1/3 | NA | NA |
| 4,4-DDE | 2 | 15 | 0.9J - 1.85J | 2/3 | 0 | 0 |
| Endosulfan II | NE | NE | 0.63J - 0.8JB | 2/3 | NA | NA |
| 4,4-DDT | 1.58 | 46.1 | 0.82NJ | 1/3 | 0 | 0 |
| Methoxychlor | NE | NE | 0.83J | 1/3 | NA | NA |
| Endrin aldehyde | NE | NE | 1.35NJ | 1/3 | NA | NA |
| Barium | NE | NE | 5.73 - 13 | 2/3 | NA | NA |
| Chromium | 5 | 9 | 1.8 - 3.13 | 2/3 | 0 | 0 |
| Lead | 46.7 | 218 | 2.67J - 6.06 | 3/3 | 0 | 0 |
| Manganese | NE | NE | 2.67 - 5.27 | 3/3 | NA | NA |
| Vanadium | NE | NE | 4.4 | 1/3 | NA | NA |
| Zinc | 150 | 410 | 12.6 | 1/3 | 0 | 0 |

Notes: Organic concentrations expressed in microgram per Kilogram (µg/Kg).
Inorganic concentrations expressed in milligram per Kilogram (mg/Kg).
[1] ER-L - Effective Range-Low
[2] ER-M - Effective Range-Medium
J - Estimated value
NJ - Estimated/tentative value
JB - Value estimated is greater than the Instrument Detection Limit (IDL).

## TABLE 6-15

## SUMMARY OF RISK-BASED AND CRITERIA-BASED COPCs
## OPERABLE UNIT NO. 4 (SITES 41 AND 74)
## REMEDIAL INVESTIGATION, CTO-0212
## MCB CAMP LEJEUNE, NORTH CAROLINA

| Contaminant | Surface Soil | | Subsurface Soil | | Groundwater | | Surface Water | | Sediment | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 41 | 74 | 41 | 74 | 41 | 74 | 41 | 74 | 41 | 74 |
| Total 1,2-Dichloroethene | | | | | ● | | | | | |
| Trichloroethene | | X | | | | | | | ● | ● |
| Toluene | | X | | | | | | | ● | |
| Chlorobenzene | | | | | ● | | ● | | | |
| Anthracene | X | | | | | | | | | |
| Benzo(a)anthracene | X | | | | | | | | | |
| Benzo(a)pyrene | X | | X | | | | | | ● | |
| Benzo(b)fluoranthene | X | | | | | | | | ● | |
| Benzo(g,h,i)perylene | X | | X | | | | | | | |
| Benzo(k)fluoranthene | X | | | | | | | | ● | |
| Bis(2-chloroethyl)ether | X | | | | | | | | | |
| Chrysene | X | | | | | | | | | |
| Fluoranthene | X | | X | | | | | | ● | |
| Phenanthrene | X | | X | | | | | | | |
| Pyrene | X | | X | | | | | | ● | |
| Fluorene | | | X | | | | | | | |
| Naphthalene | | | X | | | | | | | |
| 2-Methylnaphthalene | | | X | | | | | | | |
| Heptachlor | X | X | X | X | | X● | | | | |
| Heptachlor Epoxide | X | X | X | | | | | | | |
| Dieldrin | X | X | X | | | | | | ● | |
| 4,4-DDE | X | X | X | X | | | | | ● | ● |
| 4,4-DDT | X | X | X | X | | | ● | | ● | ● |
| 4,4-DDD | X | X | X | X | X | | | | ● | |
| Endrin Aldehyde | X | X | X | | | | | | | ● |
| alpha-Chlordane | X | X | X | | | X● | | | ● | |
| gamma-Chlordane | X | X | X | | | | | | ● | |
| Endosulfan II | X | | X | | | X● | | | ● | ● |
| Aldrin | | | X | | | | | | | |
| Endrin | | | X | | | | | | | |
| Endosulfan I | | | X | | | | | | | |
| PCB-1254 | | | X | | | | | | ● | |
| PCB-1260 | | | X | | | | | | | |
| alpha-BHC | | | | | ● | | | | | |
| beta-BHC | | | | | X | | | | | |

**TABLE 6-15 (Continued)**

**SUMMARY OF RISK-BASED AND CRITERIA-BASED COPCs**
**OPERABLE UNIT NO. 4 (SITES 41 AND 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant | Surface Soil | | Subsurface Soil | | Groundwater | | Surface Water | | Sediment | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 41 | 74 | 41 | 74 | 41 | 74 | 41 | 74 | 41 | 74 |
| Methoxychlor | | | | | | | | | ● | ● |
| PCB-1242 | | | | | | | | | ● | |
| Endrin Ketone | | | | | | | | | ● | |
| Arsenic | X | X | X | X | X● | X● | | | ● | |
| Barium | X | X | X | X | X● | X● | ● | | ● | ● |
| Beryllium | X | | X | | X● | X● | | | ● | |
| Cadmium | X | | | | X● | | ● | | | |
| Chromium | X | X | X | X | X● | X● | ● | | ● | ● |
| Copper | X | | X | | | | | | ● | |
| Lead | X | | X | | X● | X● | ● | ● | ● | ● |
| Nickel | X | X | | | X● | X● | | | ● | |
| Manganese | X | X | X | | X● | X● | ● | | ● | ● |
| Mercury | | | X | | | | ● | | | |
| Selenium | X | X | | | X● | | | | | |
| Vanadium | X | X | X | X | X● | X● | ● | | ● | ● |
| Zinc | X | X | X | X | X● | X● | ● | | ● | ● |
| Cyanide | X | X | X | X | | | | | | |

X - Selected as risk-based COPC
● - Selected as criteria-based COPC

**TABLE 6-16**

**MATRIX OF POTENTIAL HUMAN EXPOSURE**
**SITE 41**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Exposure Medium/ Exposure Route | Current Military Personnel | Future Construction Worker | Future Residential Population |
|---|---|---|---|
| **Soil** | | | |
| Incidental Ingestion | M | W | A, C |
| Dermal Contact | M | W | A, C |
| **Groundwater** | | | |
| Ingestion | NE | NE | A, C |
| Dermal Contact | NE | NE | A, C |
| **Surface Water** | | | |
| Ingestion | NE | NE | A, C |
| Dermal Contact | NE | NE | A, C |
| **Sediment** | | | |
| Incidental Ingestion | NE | NE | A, C |
| Dermal Contact | NE | NE | A, C |
| **Air** | | | |
| Inhalation of Vapor Phase Chemicals Indoor | NE | NE | A, C |
| Inhalation of Particulates Outdoor | M | NE | A, C |

M = Military lifetime exposure
W = Construction duration exposure
NE = Not Exposed
A = Adult lifetime exposure
C = Exposure in children may be significantly greater than in adults

**TABLE 6-17**

**MATRIX OF POTENTIAL HUMAN EXPOSURE**
**SITE 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Exposure Medium/ Exposure Route | Current Military Personnel | Future Construction Worker | Future Residential Population |
|---|---|---|---|
| **Soil** | | | |
| Incidental Ingestion | M | W | A, C |
| Dermal Contact | M | W | A, C |
| **Groundwater** | | | |
| Ingestion | NE | NE | A, C |
| Dermal Contact | NE | NE | A, C |
| **Surface Water** | | | |
| Ingestion | NE | NE | A, C |
| Dermal Contact | NE | NE | A, C |
| **Sediment** | | | |
| Incidental Ingestion | NE | NE | A, C |
| Dermal Contact | NE | NE | A, C |
| **Air** | | | |
| Inhalation of Vapor Phase Chemicals Indoor | NE | NE | A, C |
| Inhalation of Particulates Outdoor | M | NE | A, C |

M = Military lifetime exposure
W = Construction duration exposure
NE = Not Exposed
A = Adult lifetime exposure
C = Exposure in children may be significantly greater than in adults

**TABLE 6-18**

**EXPOSURE ASSESSMENT SUMMARY**
**INCIDENTAL INGESTION OF SOIL CONTAMINANTS**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Future Residential Child and Adult, Current Military Personnel, Future Construction Worker | | | | |
|---|---|---|---|---|
| Input Parameter | Description | Value | | Reference |
| C | Exposure Concentration | 95% UCL | (mg/kg) | USEPA, May 1992 |
| IR | Ingestion Rate | Child<br>Adult<br>Military Personnel<br>Construction Worker | 200 mg/day<br>100 mg/day<br>100 mg/day<br>480 mg/day | USEPA, December 1989<br>USEPA, March 1991 |
| CF | Conversion Factor | 1E-6 kg/mg | | USEPA, December 1989 |
| Fi | Fraction Ingested from Contaminated Source | 100% | | Conservative Professional Judgement |
| EF | Exposure Frequency | Child<br>Adult<br>Military Personnel<br>Construction Worker | 350 days/yr<br>350 days/yr<br>350 days/yr<br>90 days/yr | USEPA, December 1989<br>USEPA, March 1991 |
| ED | Exposure Duration | Child<br>Adult<br>Military Personnel<br>Construction Worker | 6 years<br>24 years<br>4 years<br>1 year | USEPA, March 1991<br>USEPA, December 1989 |
| BW | Body Weight | Child<br>Adult<br>Military Personnel<br>Construction Worker | 15 kg<br>70 kg<br>70 kg<br>70 kg | USEPA, December 1989 |
| $AT_c$ | Averaging Time Carcinogen | All | 25,550 days | USEPA, December 1989 |
| $AT_{nc}$ | Averaging Time Noncarcinogen | Child<br>Adult<br>Military Personnel<br>Construction Worker | 2,190 days<br>8,760 days<br>1,460 days<br>365 days | USEPA, December 1989 |

**TABLE 6-19**

**EXPOSURE ASSESSMENT SUMMARY**
**DERMAL CONTACT WITH SOIL CONTAMINANTS**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Future Residential Child and Adult, Current Military Personnel, Future Construction Worker | | | | |
|---|---|---|---|---|
| Input Parameter | Description | Value | | Reference |
| C | Exposure Concentration | 95% UCL | (mg/kg) | USEPA, May 1992 |
| CF | Conversion Factor | 1E-6 kg/mg | | USEPA, December 1989 |
| SA | Exposed Surface Area of Skin Available for Contact | Child<br>Adult<br>Military Personnel<br>Construction Worker | 2,300 $cm^2$<br>5,800 $cm^2$<br>5,800 $cm^2$<br>4,300 $cm^2$ | USEPA, January 1992<br>Reasonable worst case: individual skin area limited to head, hands, forearms, lower legs |
| AF | Soil-to-Skin Adherence Factor | 1.0 $mg/cm^2$ | | USEPA, Region IV, 1992 |
| ABS | Absorption Factor (dimensionless) | Organics<br>Inorganics | 1.0<br>0.1 | USEPA, Region IV, 1992 |
| EF | Exposure Frequency | Child<br>Adult<br>Military Personnel<br>Construction Worker | 350 days/yr<br>350 days/yr<br>350 days/yr<br>90 days/yr | USEPA, December 1989<br>USEPA, March 1991 |
| ED | Exposure Duration | Child<br>Adult<br>Military Personnel<br>Construction Worker | 6 years<br>24 years<br>4 years<br>1 year | USEPA, March 1991<br>USEPA, December 1989 |
| BW | Body Weight | Child<br>Adult<br>Military Personnel<br>Construction Worker | 15 kg<br>70 kg<br>70 kg<br>70 kg | USEPA, December 1989 |
| $AT_c$ | Averaging Time Carcinogen | All | 25,550 days | USEPA, December 1989 |
| $AT_{nc}$ | Averaging Time Noncarcinogen | Child<br>Adult<br>Military Personnel<br>Construction Worker | 2,190 days<br>8,760 days<br>1,460 days<br>365 days | USEPA, December 1989 |

**TABLE 6-20**

**EXPOSURE ASSESSMENT SUMMARY**
**INHALATION OF FUGITIVE PARTICULATES**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Future Residential Child and Adult, Current Military Personnel | | | | |
|---|---|---|---|---|
| Input Parameter | Description | Value | | Reference |
| C | Exposure Concentration | 95% UCL | (mg/kg) | USEPA, May 1992 |
| EF | Exposure Frequency | Child<br>Adult<br>Military Personnel | 350 days/yr<br>350 days/yr<br>350 days/yr | USEPA, December 1989 |
| ED | Exposure Duration | Child<br>Adult<br>Military Personnel | 6 years<br>24 years<br>4 years | USEPA, March 1991 |
| IR | Inhalation Rate | Child<br>Adult<br>Military Personnel | 10 $m^3$<br>20 $m^3$<br>20 $m^3$ | USEPA, March 1991<br>USEPA, May 1989 |
| BW | Body Weight | Child<br>Adult<br>Military Personnel | 15 kg<br>70 kg<br>70 kg | USEPA, December 1989 |
| $AT_c$ | Averaging Time Carcinogen | All | 25,550 days | USEPA, December 1989 |
| $AT_{nc}$ | Averaging Time Noncarcinogens | Child<br>Adult<br>Military Personnel | 2,190 days<br>8,760 days<br>1,460 days | USEPA, December 1989 |
| PEF | Site-Specific Particulate Emission Factor | $4.63 \times 10^9$ $m^3/kg$ | | USEPA, December 1989<br>Cowherd, 1985 |

**TABLE 6-21**

**EXPOSURE ASSESSMENT SUMMARY**
**INGESTION OF GROUNDWATER CONTAMINANTS**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Future Residential Child and Adult | | | |
|---|---|---|---|
| Input Parameter | Description | Value | Reference |
| C | Exposure Concentration | 95% UCL (mg/L) | USEPA, May 1992 |
| IR | Ingestion Rate | Child 1 L/day<br>Adult 2 L/day | USEPA, March 1991<br>USEPA, December 1989 |
| EF | Exposure Frequency | Child 350 days/yr<br>Adult 350 days/yr | USEPA, December 1989 |
| ED | Exposure Duration | Child 6 years<br>Adult 30 years | USEPA, March 1991 |
| BW | Body Weight | Child 15 kg<br>Adult 70 kg | USEPA, December 1989 |
| $AT_c$ | Averaging Time Carcinogen | All 25,550 days | USEPA, December 1989 |
| $AT_{nc}$ | Averaging Time Noncarcinogen | Child 2,190 days<br>Adult 10,950 days | USEPA, December 1989 |

**TABLE 6-22**

**EXPOSURE ASSESSMENT SUMMARY**
**DERMAL CONTACT WITH GROUNDWATER CONTAMINANTS**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Future Residential Child and Adult | | | |
|---|---|---|---|
| Input Parameter | Description | Value | Reference |
| C | Exposure Concentration | 95% UCL (mg/L) | USEPA, May 1992 |
| SA | Exposed Surface Area of Skin Available for Contact | Child 10,000 $cm^2$<br>Adult 23,000 $cm^2$ | USEPA, January 1992 |
| PC | Permeability Constant | Chemical Specific | USEPA, January 1992 |
| ET | Exposure Time | All 0.25 hr/day | USEPA, January 1992 |
| EF | Exposure Frequency | Child 350 days/yr<br>Adult 350 days/yr | USEPA, March 25, 1991 |
| ED | Exposure Duration | Child 6 years<br>Adult 30 years | USEPA, December 1989 |
| CF | Conversion Factor | 1 L/1000 $cm^3$ | USEPA, December 1989 |
| BW | Body Weight | Child 15 kg<br>Adult 70 kg | USEPA, December 1989 |
| $AT_c$ | Averaging Time Carcinogen | All 25,550 days | USEPA, December 1989 |
| $AT_{nc}$ | Averaging Time Noncarcinogen | Child 2,190 days<br>Adult 10,950 days | USEPA, December 1989 |

**TABLE 6-23**

**EXPOSURE ASSESSMENT SUMMARY**
**INHALATION OF GROUNDWATER VOLATILE CONTAMINANTS**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Future Residential Child and Adult | | | | |
|---|---|---|---|---|
| Input Parameter | Description | Value | | Reference |
| C | Exposure Concentration | 95% UCL ($mg/m^3$) | | USEPA, May 1992 |
| IR | Inhalation Rate | Child<br>Adult | 0.6 $m^3/hr$<br>0.6 $m^3/hr$ | USEPA, December 1989 |
| ET | Exposure Time | All | 0.25 hr/day | USEPA, January 1992 |
| EF | Exposure Frequency | All | 350 day/yr | USEPA, December 1989 |
| ED | Exposure Duration | Child<br>Adult | 6 years<br>30 years | USEPA, December 1989 |
| BW | Body Weight | Child<br>Adult | 15 kg<br>70 kg | USEPA, December 1989 |
| $AT_c$ | Averaging Time Carcinogen | All | 25,550 days | USEPA, December 1989 |
| $AT_{nc}$ | Averaging Time Noncarcinogens | Child<br>Adult | 2,190 days<br>10,950 days | USEPA, December 1989 |

## TABLE 6-24

## TOXICITY FACTORS
## REMEDIAL INVESTIGATION, CTO-0212
## MCB CAMP LEJEUNE, NORTH CAROLINA

| | RfD | RfC | CSF | CSFI | WOE | Reference |
|---|---|---|---|---|---|---|
| **Volatiles:** | | | | | | |
| Benzene | PDG | PDG | 2.9E-02 | 2.9E-02 | A | IRIS, 1994 |
| Chlorobenzene | 2.0E-02 | 2.0E-02 | – | – | D | IRIS, 1994; HEAST 1994 |
| Toluene | 2.0E-01 | 4.0E-01 | – | – | D | IRIS, 1994 |
| Trichloroethene | 6E-03 | PDG | 1.1E-02 | 6.0E-03 | B2 | IRIS, 1994; USEPA 1992 |
| **Semivolatiles:** | | | | | | |
| 1,4-Dichlorobenzene | – | 8.0E-01 | 2.4E-02 | – | B2 | IRIS, 1994, HEAST, 1994 |
| Benzo(a)anthracene | – | – | 7.3E-01 | – | B2 | USEPA - Region IV, 1992 |
| Benzo(b)fluoranehtne | – | – | 7.3E-01 | – | B2 | USEPA - Region IV, 1992 |
| Benzo(k)fluoranthene | – | – | 7.3E-01 | – | B2 | USEPA - Region IV, 1992 |
| Benzo(a)pyrene | – | – | 7.3E+00 | – | B2 | USEPA - Region IV, 1992 |
| Chrysene | – | – | 7.3E-02 | – | B2 | USEPA - Region IV, 1992 |
| Fluoranthene | 4.0E-02 | ND | – | – | D | IRIS, 1994 |
| Indeno(1,2,3-cd)pyrene | – | – | 7.3E-01 | – | B2 | USEPA - Region IV, 1992 |
| Phenanthrene | 3E-02[1] | ND | ND | ND | D | IRIS, 1994 |
| Phenol | 6.0E-01 | – | – | – | D | IRIS, 1994 |
| Pyrene | 3.0E-02 | ND | – | – | D | IRIS, 1994 |
| **Pesticides/PCBs:** | | | | | | |
| 4,4-DDD | ND | ND | 2.4E-01 | – | B2 | IRIS, 1994 |
| 4,4-DDE | ND | ND | 3.4E-01 | – | B2 | IRIS, 1994 |
| 4,4-DDT | 5.0E-04 | ND | 3.4E-01 | 3.4E-01 | B2 | IRIS, 1994 |
| Dieldrin | 5.0E-05 | – | 1.6E+01 | 1.6E+01 | B2 | IRIS, 1994 |
| Heptachlor | 5.0E-04 | ND | 4.5E+00 | 4.5E+00 | B2 | IRIS, 1994 |
| Heptachlor Epoxide | 1.3E-05 | ND | 9.1E+00 | 9.1E+00 | B2 | IRIS, 1994 |
| Total Chlordane | 6.0E-05 | UR | 1.3E+00 | 1.3E+00 | B2 | IRIS, 1994 |

## TABLE 6-24 (Continued)

## TOXICITY FACTORS
## REMEDIAL INVESTIGATION, CTO-0212
## MCB CAMP LEJEUNE, NORTH CAROLINA

| | RfD | RfC | CSF | CSFI | WOE | Reference |
|---|---|---|---|---|---|---|
| **Inorganics:** | | | | | | |
| Arsenic | 3.0E-04 | ND | 1.75+00 | 5.0E+01 | $A_I$ | IRIS, 1994 |
| Barium | 7.0E-02 | – | – | – | – | IRIS, 1994 |
| Beryllium | 5.0E-03 | ND | 4.3E+00 | 8.4E+00 | B2 | IRIS, 1994 |
| Cadmium | 5.0E-04(2)<br>1.0E-03(3) | PDG | – | 6.3E+00 | B1 | IRIS, 1994 |
| Chromium VI | 5.0E-03 | PDG | – | 4.2E+01 | $A_I$ | IRIS, 1994 |
| Cyanide | 2.0E-02 | ND | – | – | – | IRIS, 1994 |
| Manganese | 5.0E-03(2)<br>1.4E-01(3) | 5.0E-05 | – | – | D | IRIS, 1994 |
| Mercury | 3.0E-04 | 3.0E-04 | – | – | D | HEAST, 1994 |
| Nickel | 2.0E-02 | PDG | – | – | – | IRIS, 1994 |
| Selenium | 5.0E-03 | ND | – | – | D | IRIS, 1994 |
| Vanadium | 7.0E-03 | – | – | – | – | HEAST, 1994 |
| Zinc | 3.0E-01 | – | – | – | D | IRIS, 1994 |

Notes:

| | |
|---|---|
| RfD | Oral Reference Dose (mg/kg - day) |
| RfC | Inhalation Reference Concentration (mg/cu m) |
| CSF | Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$ |
| CSFI | Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$ |
| WOE | Weight of Evidence |
| IRIS | Integrated Risk Information System |
| HEAST | Health Effects Assessment Summary Tables |
| USEPA | United States Environmental Protection Agency |
| ND | Not Determined |
| PDG | Pending |
| WOE | Weight of Evidence |
| PDG | Pending |
| UR | Under Review by USEPA |
| A | Human Carcinogen |
| B1 | Probable Human Carcinogen - Limited Evidence |
| B2 | Probable Human Carcinogen - Sufficient Evidence |
| C | Possible Human Carcinogen |
| D | Not Classifiable as to Human Carcinogenicity |
| I | Ingestion |

(1) Pyrene RfD used as a surrogate
(2) RfD for evaluation in water
(3) RfD for evaluation in soil/sediment

**TABLE 6-25**

**INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)**
**OPERABLE UNIT NO. 4 (SITE 41)**
**SOIL**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Exposure Route | Receptor Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Current Military Personnel | | Future Residential Child | | Future Residential Adult | | Future Construction Worker | |
| | ICR | HI | ICR | HI | ICR | HI | ICR | HI |
| Incidental Ingestion | 4E-07 | 0.02 | 6E-06 | 0.2 | 3E-06 | 0.02 | 9E-08 | 0.2 |
| Dermal Contact | 2E-07 | <0.01 | 5E-07 | <0.01 | 9E-07 | <0.01 | 5E-09 | <0.01 |
| Inhalation of Particulates | 1E-09 | 0.01 | 5E-09 | <0.01 | 9E-09 | <0.01 | NA | NA |
| Total | 6E-07 | 0.02 | 7E-06 | 0.2 | 4E-06 | 0.02 | 9E-08 | 0.2 |

NA - Not Applicable

**TABLE 6-26**

**INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)**
**OPERABLE UNIT NO. 4 (SITE 41)**
**GROUNDWATER**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Exposure Route | Receptor Group | | | |
|---|---|---|---|---|
| | Future Residential Child | | Future Residential Adult | |
| | ICR | HI | ICR | HI |
| Ingestion | 6E-04 | 16 | 1E-03 | 8 |
| Dermal Contact | 6E-06 | 0.03 | 4E-06 | 0.03 |
| Inhalation of Vapors | NA | NA | NA | NA |
| Total | 6E-04 | 16.03 | 1E-03 | 8.03 |

NA - Not Applicable

**TABLE 6-27**

**INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)**
**OPERABLE UNIT NO. 4 (SITE 74)**
**SOIL**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Exposure Route | Receptor Group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Current Military Personnel | | Future Residential Child | | Future Residential Adult | | Future Construction Worker | |
| | ICR | HI | ICR | HI | ICR | HI | ICR | HI |
| Incidental Ingestion | 7E-08 | <0.01 | 9E-07 | 0.05 | 4E-07 | <0.01 | 2E-08 | <0.01 |
| Dermal Contact | 9E-09 | <0.01 | 2E-08 | <0.01 | 5E-08 | <0.01 | 2E-10 | <0.01 |
| Inhalation of Particulates | 7E-11 | <0.01 | 3E-10 | <0.01 | 4E-10 | <0.01 | NA | NA |
| Total | 8E-08 | <0.01 | 9E-07 | 0.05 | 5E-07 | <0.01 | 2E-08 | <0.01 |

NA - Not Applicable

**TABLE 6-28**

**INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)**
**OPERABLE UNIT NO. 4 (SITE 74)**
**GROUNDWATER**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Exposure Route | Receptor Group | | | |
|---|---|---|---|---|
| | Future Residential Child | | Future Residential Adult | |
| | ICR | HI | ICR | HI |
| Ingestion | 2E-04 | 8 | 3E-04 | 3 |
| Dermal Contact | 7E-07 | 0.03 | 2E-07 | 0.02 |
| Inhalation of Vapors | NA | NA | NA | NA |
| Total | 2E-04 | 8.03 | 3E-04 | 3.02 |

NA - Not Applicable

**TABLE 6-29**

**TOTAL SITE RISK**
**OPERABLE UNIT NO. 4 (SITE 41)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Receptors | Soil | | Groundwater | | Total | |
|---|---|---|---|---|---|---|
| | ICR | HI | ICR | HI | ICR | HI |
| Current Military Personnel | 6E-07 (100) | 0.02 (100) | NA | NA | 6E-07 | 0.02 |
| Future Child Resident | 7E-06 (<1) | 0.2 (<1) | 6E-04 (100) | 16 (99) | 6E-04 | 16 |
| Future Adult Resident | 4E-06 (<1) | 0.02 (<1) | 1E-03 (100) | 8 (99) | 1E-03 | 8 |
| Future Construction Worker | 9E-08 (100) | 0.2 (100) | NA | NA | 9E-08 | 0.2 |

Notes: ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
( ) = Approximate percent contribution to the total ICR or HI values
Total = Soil + Groundwater
NA = Not Applicable

**TABLE 6-30**

**TOTAL SITE RISK**
**OPERABLE UNIT NO. 4 (SITE 74)**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

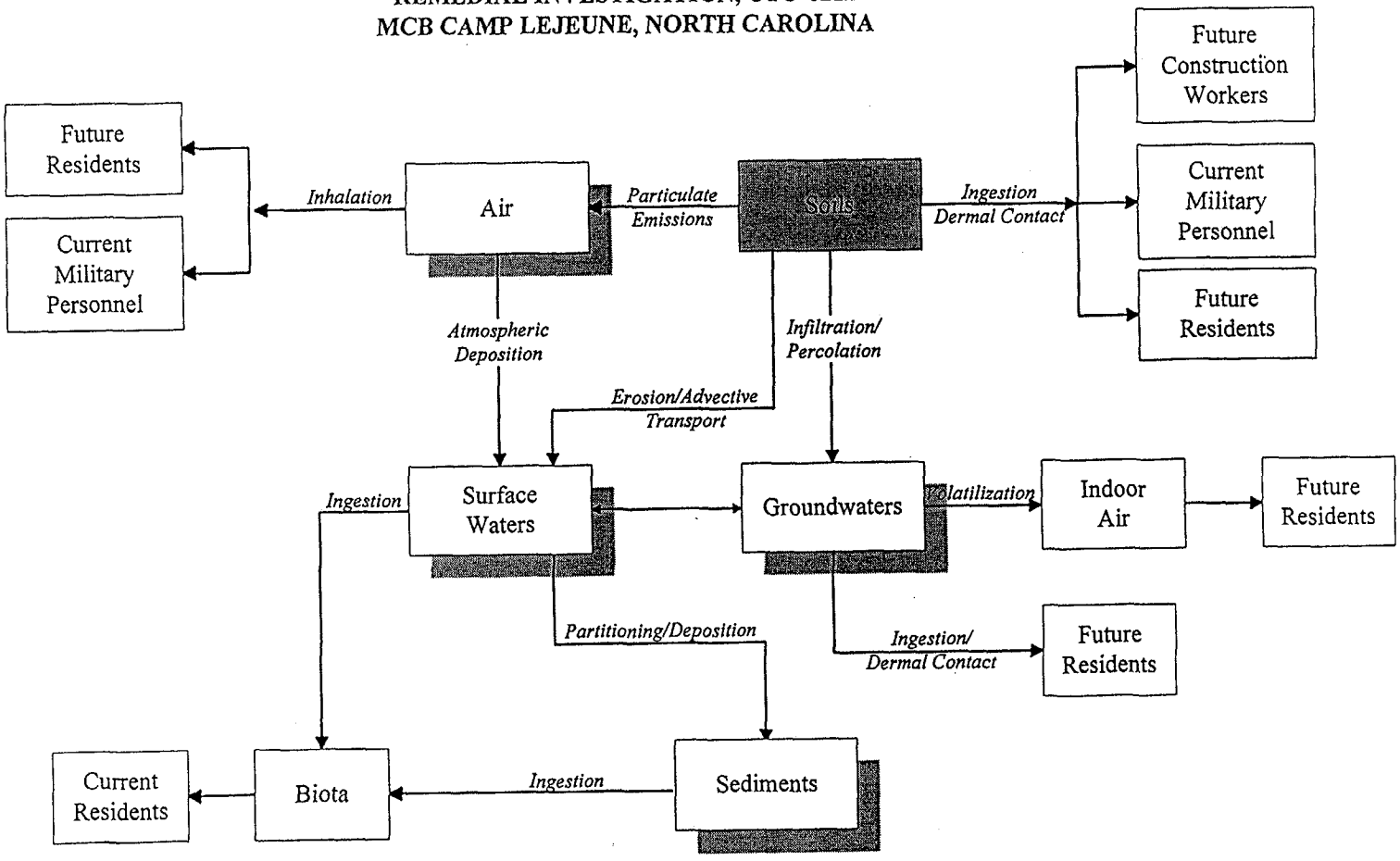
| Receptors | Soil | | Groundwater | | Total | |
|---|---|---|---|---|---|---|
| | ICR | HI | ICR | HI | ICR | HI |
| Current Military Personnel | 8E-08 (100) | <0.01 (100) | NA | NA | 8E-08 | <0.01 |
| Future Child Resident | 9E-07 (<1) | 0.05 (<1) | 2E-04 (99.7) | 8.03 (99.7) | 2E-04 | 8.08 |
| Future Adult Resident | 5E-07 (<1) | <0.01 (<1) | 3E-04 (100) | 3.02 (100) | 3E-04 | 3.0 |
| Future Construction Worker | 2E-08 (100) | <0.01 (100) | NA | NA | 2E-08 | <0.01 |

Notes: ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
( ) = Approximate percent contribution to the total ICR or HI values
Total = Soil + Groundwater
NA = Not Applicable

# SECTION 6.0 FIGURES

**FIGURE 6-1**

**CONCEPTUAL SITE MODEL**
**OPERABLE UNIT NO. 4**
**SITES 69, 74, AND 41**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**



# 7.0 ECOLOGICAL RISK ASSESSMENT

## 7.1 Introduction

This section presents the ecological risk assessment (ERA) conducted at Operable Unit (OU) No. 4 that assesses the potential impacts to ecological receptors from contaminants detected at the site. The sites included at OU No. 4 are Site 41, Site 69 and Site 74 (Site 69 will be discussed in a separate risk assessment).

### 7.1.1 Objectives of the Ecological Risk Assessment

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 directs EPA to protect human health and the environment with respect to releases or potential releases of contaminants from abandoned hazardous waste sites (USEPA, 1989a). In addition, there are various Federal and State laws and regulations concerning environmental protection that are considered applicable or relevant and appropriate requirements or to be considered (ARARs/TBC) criteria. For example, these ARARs/TBCs include comparisons of contaminant concentrations in surface water to State Water Quality Standards.

The objective of this ERA was to evaluate if past reported disposal practices at OU No. 4 potentially are adversely impacting the ecological integrity of the terrestrial and aquatic habitats on, or adjacent to the sites. This assessment also evaluated the potential effects of contaminants at OU No. 4 on sensitive environments including wetlands and protected species. The conclusions of the ERA will be used in conjunction with the human health risk assessment to evaluate the appropriate remedial action for this site for the overall protection of public health and the environment.

### 7.1.2 Scope of the Ecological Risk Assessment

This ERA evaluated and analyzed the results from the RI and historical data collected during other studies. The RI included sampling and chemical analysis of the surface water, sediments, soil, and groundwater at the sites, as applicable. Information used to evaluate sensitive environments was obtained from historical data and previous studies conducted at Marine Corps Base (MCB) Camp Lejeune, North Carolina. In addition, a qualitative habitat evaluation was conducted at each of the two sites to identify potential terrestrial receptors (Figures 7-1 and 7-2, Biohabitat Maps). The media of concern for this ERA were the surface water, sediment, and surface soil.

This ERA focused on adverse impacts to aquatic and terrestrial receptors. If potential risks are characterized for the ecological receptors, further ecological evaluation of the site and surrounding areas may be warranted.

The risk assessment methodologies used in this evaluation were consistent with those outlined in the Framework for Ecological Risk Assessment (USEPA, 1992a). In addition, information found in the following documents was used to supplement the USEPA guidance document:

- U.S. EPA Supplemental Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (USEPA, 1989a)

- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA, 1989b)

- Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters (USEPA, 1990)

- Fish Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters (USEPA, 1993b)

### 7.1.3 Organization of The Ecological Risk Assessment

Based on the USEPA Framework for Ecological Risk Assessment, an ERA consists of three main components: (1) Problem Formulation, (2) Analysis, and (3) Risk Characterization (USEPA, 1992a). The Problem Formulation section includes a preliminary characterization of exposure and effects of the stressors to the ecological receptors. During the Analysis, the data is evaluated to determine the exposure and potential effects on the ecological receptors from the stressors. Finally, in the Risk Characterization, the likelihood of adverse effects occurring as a result of exposure to a stressor are evaluated. This section evaluates the potential impact on the ecological integrity at the site from the contaminants detected in the media.

## 7.2 Problem Formulation

Problem formulation is the first step of an ERA and includes a preliminary characterization of exposure and effects, as well as scientific data needs, policy and regulatory issues, and site-specific factors to define the feasibility, scope, and objectives for the ERA (USEPA, 1992a).

The results of the various site investigations indicated the presence of contaminants in the surface water, sediment and surface soil. As discussed above, CERCLA directs USEPA to protect the environment with respect to releases of contaminants. Due to the potential for ecological receptors to be exposed to the contaminants detected at OU No. 4, it was decided that an ERA should be performed.

Three types of information are needed to evaluate potential links between the contaminants of potential concern (COPCs) and the ecological endpoints. First, chemical analyses of the appropriate media are necessary to establish the presence, concentrations, and variabilities of the COPCs. Second, ecological surveys are necessary to establish if adverse ecological effects have occurred. Finally, toxicological information is necessary to evaluate the potential effects of the COPCs on the ecological receptors. The combination of all three types of data allows the assessment of the relative contribution of other potential causes of the observed effects (as measured by the ecological endpoints) that may be unrelated to the toxic effects of the contaminants of concern (e.g., habitat alterations and natural variability). Therefore, confidence in cleanup and monitoring decisions is greatly enhanced when based on a combination of chemical, ecological, and toxicological data.

Chemical analyses were performed on samples collected from the surface water, sediment, and surface soil to evaluate the presence, concentrations, and variabilities of the COPCs. Ecological surveys also were conducted as part of the Baker's field activities during the RI. Based on observations and available habitats, potential ecological receptors were identified. Finally, toxicological information for the COPCs detected in the media were obtained from available

references and literature and used to evaluate the potential adverse ecological effects to the ecological receptors.

The components of the problem formulation include stressor characteristics, ecosystems potentially at risk, ecological effects, endpoint selection, and a conceptual model. The following sections discuss each of these components, and how they were evaluated in this ERA.

### 7.2.1 Stressor Characteristics

One of the initial steps in the problem formulation stage of an ERA is identifying the stressor characteristics. For this ERA, the stressors that were evaluated include the contaminants detected in the surface water, sediment, biota, and surface soils. Contaminants in the subsurface soils and groundwater were not evaluated in this ERA.

The nature and extent of these contaminants were discussed in Section 4.0 of this report. Table 7-1 lists the contaminants that were detected in each media at Sites 41 and 74. The location of samples was based on historical information available for the site and a site visit to evaluate potential ecosystems and ecological receptors.

#### 7.2.1.1 Contaminants of Potential Concern (COPCs)

The COPCs for the ERA were selected following the same procedures and criteria (i.e., frequency of detection, toxicity, etc.) used for selecting the COPCs for the Human Health Risk Assessment (HHRA). Some of the COPCs included in the ERA were different than those included in the HHRA. This is because some of the COPCs, which may adversely impact the ecological integrity at the site, may not pose a significant risk to humans and vice-versa. The frequency of detection and statistical summary tables are presented in Appendices O and P, respectively.

##### *7.2.1.1.1 COPCs - Surface Water*

Surface water samples were collected at OU No. 4 from Sites 41 and 74. The ERA addressed the surface water samples from Tank Creek and the associated tributary at Site 41 and the surface water at Site 74. Sample locations are illustrated on Figures 7-1, 7-2 and 7-4.

Site 41

The following organics and inorganics detected in the surface water samples were not addressed in the ERA because they are common naturally occurring chemicals and/or were not expected to be ecologically significant at the detected concentrations or at the frequency of detection or were infrequently detected: gamma-BHC, heptachlor, 4,4'-DDT, chlorobenzene, cadmium, calcium, chromium, magnesium, nickel, potassium, and sodium.

There were no semivolatile organic compounds (SVOCs) or polychlorinated biphenyls (PCBs) detected in the surface water samples.

The following inorganics were detected in the surface water samples at Site 41 and were included in the ERA: aluminum, arsenic, barium, cobalt, copper, iron, lead, manganese, mercury, and zinc.

Site 74

The following inorganics detected in the surface water samples were not addressed in the ERA because they are common naturally occurring chemicals and were not expected to be ecologically significant at the detected concentration: calcium, magnesium, potassium and sodium.

There were no VOCs, SVOCs, pesticides, or PCBs detected in the surface water sample.

The following inorganics detected in the surface water samples at Site 74 were included in the ERA: aluminum, iron, and lead.

*7.2.1.1.2 COPCs - Sediments*

Sediment samples were collected at OU No. 4 from Sites 41 and Site 74. The ERA will address the sediment samples collected from Site 41 and Site 74. Sample locations are illustrated on Figures 7-1, 7-2 and 7-4.

Site 41

The following detected VOCs, SVOCs, pesticides, PCBs, and ordnance in the sediment samples were not addressed in the ERA because they are common laboratory and/or decontamination contaminants, or were detected infrequently: acetone, methylene chloride, trichloroethene, toluene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, di-n-octyl phthalate, fluoranthene, pyrene, endrin ketone, Aroclor - 1248, Aroclor - 1254 and 1,3,5-trinitrobenzene.

The following inorganics detected in the sediment samples were not addressed in the ERA because they are common naturally occurring chemicals, they were not expected to be ecologically significant at the detected concentrations, or they were infrequently detected: calcium, cobalt, magnesium, mercury, potassium, sodium, and thallium.

The following chemicals detected in the sediment samples were addressed in the ERA: dieldrin, endosulfan II, 4-4'-DDD, 4-4'-DDE, 4-4'-DDT, methoxychlor, alpha-chlordane, gamma-chlordane, aluminum, arsenic, barium, beryllium, chromium, copper, iron, lead, manganese, nickel, selenium, silver, vanadium, and zinc.

Site 74

The following VOC, SVOC, and pesticides detected in the sediment samples were not addressed in the ERA because they are common laboratory and/or decontamination contaminants or were detected infrequently: trichloroethene, 3,3'-dichlorobenzidine, methoxychlor, and endrin aldehyde.

The following inorganics detected in the sediment samples were not addressed in the ERA because they are naturally occurring chemicals, they were not expected to be ecologically significant at the detected concentrations, or they were infrequently detected: calcium, magnesium, selenium, vanadium, and zinc.

The following chemicals detected in the sediment samples were addressed in the ERA: endosulfan II, 4-4'-DDE, 4-4'-DDT, aluminum, barium, chromium, iron, lead, and manganese.

*7.2.1.1.3 COPCs - Surface Soils*

Surface soil samples were collected at Sites 41 and 74. Sample locations are illustrated on Figures 2-2 and 2-11 found in Section 2 of this report.

Site 41

The following VOCs, SVOCs, pesticides, PCBs, and ordnance detected in the surface soil samples were not addressed in the ERA because they are common laboratory and/or decontamination contaminants; they were detected in and attributed to the laboratory or field blanks (the concentrations were compared to five or ten times the concentration of the maximum detect in blanks collected site-wide) or were infrequently detected: acetone, methylene chloride, bis(2-ethylhexyl)phthalate, 1,4-dichlorobenzene, 2-methylnaphthalene, acenaphthalene, carbazole, dibenzofuran, dibenz(a,h)anthracene, di-n-butyl phthalate, di-n-octyl phthalate, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, beta-BHC, delta-BHC, gamma-BHC, endrin, endosulfan sulfate, methoxychlor, endrin ketone, Aroclor-1242, Aroclor-1260, and 1,3-dinitrobenzene.

The following inorganics detected in the surface soil were not addressed in the ERA because they are common naturally occurring chemicals, they were not expected to be ecologically significant at the detected concentrations, they were infrequently detected or they were within typical background concentration found at the site: antimony, calcium, cobalt, magnesium, potassium, selenium, and sodium.

The following chemicals detected in the surface soil samples were addressed in the ERA: toluene, anthracene, bis(2-chloroethyl)ether, phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, 4-4'-DDE, 4-4'-DDD, 4-4'-DDT, alpha-chlordane, gamma-chlordane, heptachlor, heptachlor epoxide, dieldrin, endosulfan II, endrin aldehyde, aluminum, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, vanadium, zinc, and total cyanide.

Site 74

The following VOCs, SVOCs, and pesticides detected in the surface soil samples were not addressed in the ERA because they are common laboratory and/or decontamination contaminants; they were detected infrequently; or were attributed to blank contamination: acetone, methylene chloride, styrene, xylenes (total), di-n-butyl phthalate and bis(2-ethylhexyl)phthalate, 4-chloro-3-methylphenol, acenaphthalene, benzo(a)pyrene, benzo(g,h,i)perylene, bis(2-chloroethyl)ether, diethylphthalate, pyrene, alpha-BHC, aldrin, endrin, endosulfan II, methoxychlor, and hydroxyacetophenone.

The following inorganics detected in the surface soil were not addressed in the ERA because they are common naturally occurring chemicals, they were not expected to be ecologically significant at the detected concentrations, they were infrequently detected, or were within typical background concentrations found at the site: antimony, cadmium, calcium, copper, magnesium, potassium, silver, and sodium.

The following chemicals detected in the surface soil samples were addressed in the ERA: trichloroethene, toluene, heptachlor, heptachlor epoxide, endrin aldehyde, dieldrin, 4-4'-DDE, 4-4'-

DDD, 4-4'-DDT, alpha-chlordane, gamma-chlordane, aluminum, arsenic, barium, chromium, iron, lead, manganese, mercury, nickel, selenium, vanadium, zinc, and total cyanide.

7.2.1.2 Physical/Chemical Characteristics of COPCs

Table 7-2 contains values for bioconcentration factors (BCFs, freshwater), water solubility, organic carbon partition coefficient, octanol water partition coefficient, and vapor pressure for the potential contaminants of concern identified in the sediments, surface water, surface soil, and biota samples for each site. Information from these tables were used in the risk characterization to assess the fate and transport of the constituents and the potential risks to the environmental receptors at each site. The following paragraphs discuss the significance of each parameter included in the table.

Bioconcentration factors measure the tendency for a chemical to partition from the water column or sediment and concentrate in aquatic organisms. Bioconcentration is important for ecological receptors because chemicals with high BCFs could accumulate in lower-order species and subsequently accumulate to toxic levels in species higher up the food chain. The BCF is the concentration of the chemical in the organism at equilibrium divided by the concentration of the chemical in the water. Therefore, the BCF is unitless. Bioconcentration factors among the metals range from 1 for chromium to 350,000 for manganese (SCDM, 1991). The bioconcentration factors among the organics range from 17 for trichloroethene to 180,000 for 4-4'-DDE (SCDM, 1991). The pesticides have the highest potential to concentrate in the tissue of organisms exposed to the contaminants. Published BCF data were not available for some of the COPCs at OU No. 4.

Water solubility is important in the ecological environment because it measures the tendency for a chemical to remain dissolved in the water column, partition to soil or sediment, or bioconcentrate in aquatic organisms. Chemicals with high water solubilities tend to be more bioavailable to aquatic organisms. However, they will not significantly bioconcentrate in the organisms. On the other hand, chemicals with a low water solubility will remain bound to the sediment and soils but may bioconcentrate in organisms to a significant degree. Water solubility for metals is negligible because they are practically insoluble in water. The water solubility of the organics ranged from less than 0.025 mg/L for 4,4' DDT to 17,000 mg/L for bis(2-chloroethyl ether) (SCDM, 1991).

The organic carbon partition coefficient (Koc) measures the tendency for a chemical to partition between soil or sediment particles containing organic carbon and water. This coefficient is important in the ecological environment because it determines how strongly an organic chemical will be bound to the organics in the sediments. The Koc is highest for benzo(a)pyrene at $5.5 \times 10^6$ mL/g and lowest for trichloroethene at 126 mL/g.

The octanol/water partition coefficient (Kow) is the ratio of a chemical concentration in octanol divided by the concentration in water. The octanol/water partition coefficient has been shown to correlate well with bioconcentration factors in aquatic organisms and adsorption to soil or sediment. The log Kow is presented in Table 7-2. The log Kow is highest for benzo(b)fluoranthene at 6.6 and lowest for bis(2-chloroethyl) ether at 1.3.

The vapor pressure measures the tendency for a chemical to partition into air. This parameter is important for the ecological environment because it can be used to determine the concentrations of the constituents in air. The vapor pressure is highest for cobalt, 1,300 mm Hg (SCDM, 1991). The vapor pressure for most of the other contaminants of concern are low or negligible.

### 7.2.2 Ecosystems Potentially at Risk

Based on the site-specific and regional ecology, several ecological receptors are potentially at risk from contaminants at the sites. Contaminants were identified in the surface water, sediment, soil, and groundwater samples at the sites. Potential receptors of contaminants in surface water and sediment include fish, oysters, blue crabs, benthic macroinvertebrates, other aquatic flora and fauna and some terrestrial faunal species. Potential receptors of contaminants in soils include: deer, rabbits, foxes, raccoons, birds and other terrestrial flora and fauna.

### 7.2.3 Ecological Effects

The ecological effects data that were used to assess potential risks to aquatic and/or terrestrial receptors in this ERA include: aquatic reference values including North Carolina Water Quality Standards (NCWQS), USEPA Region IV Water Quality Screening Values (WQSV), USEPA Ambient Water Quality Criteria Documents (AWQC), the Aquatic Information Retrieval Database, and Sediment Screening Values (SSVs), and terrestrial reference values. The following paragraphs discuss each of the above data sources.

The North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR) has promulgated Water Quality Standards (WQS). These WQS meet the requirements of both federal and state law. These standards are regulatory values and are enforceable. They are used to evaluate the quality of waters in North Carolina.

The USEPA Region IV Waste Management Division (Region IV) has adopted Water Quality Screening Values (WQSV) for chemicals detected at hazardous waste sites (USEPA, 1992b). These values are intended as preliminary screening tools to review chemical data from hazardous waste sites. Exceedances of the screening level values indicate that there may be a need for further investigation of the site.

Section 304(a)(1) of the Clean Water Act of 1977 (P.L. 95-217) requires the Administrator of the USEPA to publish criteria for water quality accurately reflecting the latest scientific knowledge on the type and extent of all identifiable effects on health and welfare which may be expected from the presence of pollutants in any body of water, including groundwater. In accordance with the Clean Water Act, the USEPA Office of Water Regulations and Standards, Criteria and Standards Division have published Ambient Water Quality Criteria (AWQC) documents for several chemicals. These documents can be used to evaluate potential risks to aquatic organisms. In addition, potential risks to aquatic plants from contaminants also can be evaluated using these documents.

The Aquatic Information Retrieval Database (AQUIRE) database is an on-line system that contains information on acute, chronic, bioaccumulative, and sublethal effects data from tests performed on freshwater and saltwater organisms excluding bacteria, birds, and aquatic mammals. This database can be accessed to evaluate potential risks to aquatic organisms.

Currently, promulgated sediment quality criteria do not exist. Until these criteria are developed, USEPA Region IV is using Sediment Screening Values (SSV) compiled by National Oceanic and Atmospheric Administration for evaluating the potential for chemical constituents in sediments to cause adverse biological effects (USEPA, 1992b). The lower ten percentile (Effects Range-Low [ER-L]) and the median percentile (Effects Range-Median [ER-M]) of biological effects have been developed for several of the chemicals identified during the sediment investigations at OU No. 4.

If sediment contaminant concentrations are above the ER-M, adverse effects on the biota are considered probable. If contaminant concentrations are between the ER-M and ER-L, adverse effects on the biota are considered possible. Finally, if contaminant concentrations are below the ER-L, adverse effects on the biota are considered unlikely (USEPA, 1992b).

There are no standards, criteria, or other screening values for assessing potential impacts to terrestrial ecological receptors from contaminants in soils. A literature search was conducted to identify levels of contaminants in the soil that could cause adverse effects to terrestrial flora and invertebrates. However, these data cannot be used to evaluate potential risks to other terrestrial fauna (e.g., birds, deer, rabbits), since the exposure doses for these species are different than exposure doses for invertebrates and plants, which are in constant direct contact with the contaminants in the soil. In addition, the sensitivity of the organisms to the COPCs are not similar.

Terrestrial reference values (TRVs) for evaluating estimated chronic daily intakes (CDIs) were calculated from available toxicity data. TRVs were developed from No-Observed-Adverse-Effect-Levels (NOAELs) or Lowest-Observed-Adverse-Effect-Levels (LOAELs) obtained from the Integrated Risk Information System (IRIS), toxicological profiles for specific chemicals and information from other reference books. These values were used to assess the potential effects of contaminants on terrestrial fauna.

### 7.2.4 Ecological Endpoints

The information compiled during the first stage of problem formulation (stressor characteristics, ecosystems potentially at risk, and ecological effects) was used to select the ecological endpoints for this ERA. The following section of this report contains a description of the ecological endpoints selected for this ERA, and the reason they were selected.

There are two primary types of ecological endpoints: assessment endpoints and measurement endpoints. Assessment endpoints are environmental characteristics, which, if they were found to be significantly affected, would indicate a need for remediation (e.g., decrease in sports/fisheries). Measurement endpoints are quantitative expressions of an observed or measured effect of the contamination of concern. Measurement endpoints may be identical to assessment endpoints (e.g., measurement of abundance of fish), or they may be used as surrogates for assessment endpoints (e.g., toxicity test endpoints). Both types of endpoints were used in the ecological risk evaluation and are discussed in the following sections.

#### 7.2.4.1 Assessment Endpoints

Assessment endpoints are the ultimate focus of risk characterization and link the measurement endpoints to the risk management process (USEPA, 1992a). There are five criteria that an assessment endpoint should satisfy (Suter, 1993):

- Societal relevance
- Biological relevance
- Unambiguous operational definition
- Accessibility to prediction and measurement
- Susceptibility to the hazardous agent

Societal relevance is important because risk to ecological receptors of little intrinsic interest to the public (e.g., nematodes, zooplankton) are unlikely to influence decisions unless they can be shown to indicate risks to biota of direct human interest (e.g., fish, wildlife) (Suter, 1993). The biological significance of a property is determined by its importance to a higher level of the biological hierarchy (Suter, 1993). The endpoint should be well defined and operational with a subject (e.g., benthic macroinvertebrates) and a characteristic of the subject (e.g., decrease in numbers of benthic macroinvertebrate) (USEPA, 1989b). The endpoint should be measurable (e.g., numbers of individuals) or predictable from measurements (e.g., toxicity tests). Finally, the endpoint must be susceptible to the contaminant being assessed. The assessment endpoints in this ERA were exceedances of Aquatic Reference Values (ARVs) and decreased integrity of populations of terrestrial floral and faunal species.

Aquatic organisms (e.g., fish, benthic macroinvertebrates) are socially relevant because humans enjoy the sport of fishing and they also are a food source for many people. The organisms are biologically relevant because they serve as food sources for other aquatic and terrestrial organisms. The endpoint is defined with a subject (aquatic organisms), and a characteristic of the subject (decreased integrity to aquatic organisms). The risk may be predicted by contaminant concentrations in media exceeding published aquatic reference values. Finally, aquatic organisms are susceptible to the COPCs at OU No. 4.

Terrestrial organisms (e.g., rabbits, deer, fox, raccoon, quail) are socially relevant because humans enjoy the sport of hunting and they also are a food source for many people. The organisms are biologically relevant because they serve as food sources for other terrestrial organisms and some also consume smaller mammals and plants which potentially have been contaminated. The endpoint is defined with a subject (rabbits, deer, fox, raccoon, and quail), and a characteristic of the subject (decreased integrity to rabbits, deer, fox, raccoon, and quail). The TRVs can be used to predict risks to terrestrial organisms. Finally, terrestrial organisms are susceptible to the COPCs at OU No. 4.

7.2.4.2 Measurement Endpoints

A measurement endpoint, or "ecological effects indicator" as it is sometimes referred, is used to evaluate the assessment endpoint. Therefore, measurement endpoints must correspond to, or be predictive of, assessment endpoints. In addition, they must be readily measurable, preferably quickly and inexpensively, using existing techniques. Measurement endpoints must take into consideration the magnitude of the contamination and the exposure pathway. The measurement endpoint should be an indicator of effects that are temporally distributed. Low natural variability in the endpoint is preferred to aid in attributing the variability in the endpoint to the contaminant. Measurement endpoints should be diagnostic of the pollutants of interest, as well as broadly applicable to allow comparison among sites and regions. Also, measurement endpoints should be standardized (e.g., standard procedures for toxicity tests). Finally, it is desirable to use endpoints that already are being measured (if they exist) to determine baseline conditions.

Endpoints are divided into four primary ecological groups: individual, population, community, and ecosystem endpoints. Individual endpoints (e.g., death, growth, tissue concentrations) are evaluated through toxicity tests, models, and other methods used to assess the effects on individual organisms. Population endpoints (e.g., occurrence, abundance, reproductive performance) are evaluated to determine presence and absence of species through field studies. Community endpoints (e.g., number of species, species diversity) are used to describe the complexity of the community. Finally, ecosystem endpoints (e.g., biomass, productivity, nutrient dynamics) are used to determine the

effects between groups of organisms, and between organisms and the environment. Individual, population, and community endpoints were evaluated in this assessment.

The primary goal in deciding upon which ecological endpoints to evaluate was to determine the current effects that the contamination is having on the environment. The following sections discuss the measurement endpoints that were chosen for the ERA.

*7.2.4.2.1 Aquatic Endpoints*

Aquatic biota samples (e.g., fish, shellfish, and benthic macroinvertebrates) were not collected as part of the field activities at Sites 41 and 74. Aquatic species are expected to inhabit Sites 41 and 74 and be exposed to the COPCs. Potential effects from contaminants detected at Sites 41 and 74 on these species were evaluated by comparing exposure levels of COPCs in the surface water and sediments to aquatic reference values (i.e., NCWQS, WQSV, AWQC and SSVs).

*7.2.4.2.2 Terrestrial Endpoints*

As discussed earlier in this report, several terrestrial faunal species inhabit MCB Camp Lejeune including deer, birds, and small mammals, and potentially are exposed to the COPCs at OU No. 4. Potential effects from contaminants detected at OU No. 4 to these species were evaluated by comparing the CDIs to TRVs. In addition, comparisons of COPC concentrations in the soil to published plant and earthworm toxicity information was used to evaluate potential effects to some terrestrial species.

### 7.2.5 The Conceptional Model

This section of the report contains a list of hypotheses regarding how the stressors might affect ecological components of the natural environment:

- Aquatic receptors potentially may be adversely affected by exposure to contaminated water, sediment, and contaminated biota they ingest.
- Terrestrial receptors potentially may be adversely affected by exposure to contaminants in the surface water and surface soil.
- Terrestrial receptors potentially may be adversely affected by exposure to contaminated organisms and vegetation they ingest.

## 7.3 Analysis Phase

The next phase after the problem formulation is the analysis which consists of the technical evaluation of data on the potential effects and exposure of the stressor. This phase includes the ecological exposure characterization and the ecological effects characterization.

### 7.3.1 Characterization of Exposure

Characterization of exposure evaluates the interaction of the stressor with the ecological component. The following sections characterize the exposure in accordance with the stressors, ecosystem, exposure analysis, and exposure profile.

7.3.1.1 Stressor Characterization: Distribution or Pattern of Change

The remedial investigations involved collecting samples from four media; surface water, sediment, soil, and groundwater. The analytical results of these investigations are presented in Section 4.0 of this report. In addition, the source identification also is presented in Section 4.0 of the report, while the extent of contamination is discussed in Section 4.3 of this report.

7.3.1.2 Ecosystem Characterization

This section describes the regional ecology of the coastal plain and the habitats present at Sites 41 and 74. Information on sensitive environments and endangered species is also included.

*Site Description*

Site 41 is heavily wooded and vegetated. The areas along the eastern and southern boundaries are classified as wooded (Palustrine) wetlands (United State Fish and Wildlife Service, National Wetland Inventory, 1986). These areas are downslope of the former disposal area. No ecological surveys (i.e., biota sampling) were conducted at this site.

Site 74 is located in a stand of woods approximately one-half mile east of Holcomb Boulevard in the northeast portion of MCB Camp Lejeune. The general area is heavily overgrown with vegetation. The site is relatively flat. There are no significant surface water drainage features (i.e., ditches, streams, etc.) on site.

Deer, rabbits, and birds were the only terrestrial faunal species observed at OU No. 4. Based on the regional ecology, and due to the wooded areas around OU No. 4, there is the potential for other terrestrial fauna to periodically visit the site.

*Regional Ecology*

Camp Lejeune covers approximately 108,800 acres, 84 percent of which is forested (USMC, 1987). Approximately 45.1 percent of this is pine forest, 22 percent is mixed pine/hardwood forest, and 16.8 percent is hardwood forest. Nine percent of the base, a total of 3,587 acres, is wetland and includes pure pond pine stands, mixed pond pine/hardwood, marshes, pocosins, and wooded swamps. The base also contains 80 miles of tidal streams, 21 miles of marine shoreline, and 12 freshwater ponds.

The base drains primarily to the New River or its tributaries. These tributaries include Northeast Creek, Southwest Creek, Wallace Creek, French Creek, Bear Head Creek, and Duck Creek.

Because of the natural resources on the base, forested areas are actively managed for timber. Game species are also managed for hunting and ponds are maintained for fishing. Game species managed include wild turkey, white-tailed deer, black bear, grey and fox squirrels, bobwhite quail, eastern cottontail and marsh rabbits, raccoons, and wood ducks.

MCB Camp Lejeune is located in the Coastal Plain. The ecology of the region is influenced by climate, which is characterized by hot, humid summers and cool winters. Some subfreezing cold spells occur during the winters, and there are occasional accumulations of snow that rarely persist. The average precipitation is 55.96 inches and the mean temperature is 60.9°F. The area exhibits a

long growing season, typically more than 230 days. Soils in the region range from very poorly drained muck to well-drained sandy loam.

A number of natural communities are present in the Coastal Plain. Subcommunities and variations of these major community types are also present and alterations of natural communities have occurred in response to disturbance and intervention (i.e., forest cleared to become pasture). The natural communities found in the area are summarized as follows:

- Mixed Hardwood Forest - Found generally on slopes of ravines. Beech is an indicator species with white oak, tulip, sweetgum, and holly.

- Southeastern Evergreen Forest - Dominated by pines, especially longleaf pine.

- Loblolly Pine/Hardwoods Community - Second growth forest that includes loblolly pine with a mix of hardwoods -- oak, hickory, sweetgum, sour gum, red maple, and holly.

- Southern Floodplain Forest - Occurs on the floodplains of rivers. Hardwoods dominate with a variety of species present. Composition of species varies with the amount of moisture present.

- Maritime Forest - Develop on the lee side stable sand dunes protected from the ocean. Live oak is an indicator species with pine, cedar, youpon, holly, and laurel oak. Deciduous hardwoods may be present where forest is mature.

- Pocosins - Lowland forest community that develop on highly organic soils that are seasonally flooded. Characterized by plants adapted to drought and acidic soils low in nutrients. Pond pine is dominant tree with dense layer of evergreen shrubs. Strongly influenced by fire.

- Cypress Tupelo Swamp Forest - Occurs in the lowest and wettest areas of floodplains. Dominated by bold cypress and tupelo.

- Freshwater Marsh - Occurs upstream from tidal marshes and downstream from non-tidal freshwater wetlands. Cattails, sedges, and rushes are present. On the coast of North Carolina swamps are more common than marshes.

- Salt Marsh - Regularly flooded, tidally influenced areas dominated by salt-tolerant grasses. Saltwater cordgrass is a characteristic species. Tidal mud flats may be present during low tide.

- Salt Shrub Thicket - High areas of salt marshes and beach areas behind dunes. Subjected to salt spray and periodic saltwater flooding. Dominated by salt resistant shrubs.

- Dunes/Beaches - Zones from the ocean shore to the maritime forest. Subjected to sand, salt, wind, and water.

- Ponds and Lakes - Low depressional areas where water table reaches the surface or where ground is impermeable. In ponds rooted plants can grow across the bottom. Fish populations managed in these ponds include redear, bluegill, largemouth bass, and channel catfish (USMC, 1987).

- Open Water - Marine and estuarine waters as well as all underlying bottoms below the intertidal zone.

*Water Body Description*

The unnamed tributary from the New River is classified by the NC DEHNR as SC HQW. The SC classifies the water body as tidal saltwater, which allows for aquatic life propagation and survival, fishing, wildlife and secondary recreation. The HQW means high quality waters, which are waters rated as excellent based on biological and physical/chemical characteristics obtained by monitoring, special studies or special designations made by the Wildlife Resources Commission, the Marine Fisheries Commission and/or the Department of Agriculture. These special designations include trout fishing areas, primary and functional nursing areas, and critical habitat areas (NC DEHNR, 1993).

Tank Creek and an unnamed tributary water body system is classified by NC DEHNR as C NSW, which indicates that it is a freshwater source available for aquatic life propagation and survival, fishing, wildlife, secondary recreation and agriculture. The NSW stands for Nutrient Sensitive Waters, which require limitations on nutrient inputs (NC DEHNR, 1993).

*Site-Specific Ecology*

During April 1993, Baker conducted a qualitative habitat evaluation of the terrestrial environment at Sites 41 and 74. Table 7-3 summarizes the habitats identified at each site and Appendix S includes data sheets that provide more detailed information.

Site 41

Site 41 and the surrounding area is primarily wooded with the age and composition of the forest varying with the amount of past disturbance in the area. The former landfill area is covered by a young pine forest dominated by loblolly pine (Pinus taeda). Secondary vegetation includes sweetgum (Liquidambar styraciflua). Saplings of sweetgum are mixed with red cedar (Juniperus virginiana) and wax myrtle (Myrica cerifera) in the understory. Vines are common in the understory and included poison ivy (Rhus radicans), trumpet creeper (Campsis radicans), Virginia creeper (Parthenocissus quinquefolia), and bullbriar (Smilax bona-nox). Grasses are the dominant groundcover in some areas and slender bush clover (Lespedeza virginica) is dominant in other areas. Forbs present on the forest floor also include the following species:

- Ebony spleenwort - Asplenium ebeneum
- Wood Sorrel - Oxalis europaea
- Barren False Strawberry - Duchesnea indica
- Lyre-leaved Sage - Salvia lyrata
- Bladder Sedge - Carex intermescens
- Bog Rush - Juncus effusus

- Corn Salad - Valerianella radiata
- Broom Sedge - Andropogon virginicus

Along a drainage swale to the north of the landfill a small freshwater wetland is present. Dominant vegetation varies within the wetland, depending on the amount of moisture present and the nature of the soil. Loblolly and longleaf pine (P. taeda and P. palustris), red cedar (Juniperus virginiana), sweetgum saplings (Liquidambar styraciflua), holly (Ilex opaca), and sweet myrtle (Myrica cerifera) are growing along the edges of the drainage swale. Several species of blueberries (Vaccinium spp.) are also present. Lichens and mosses are dominant on areas of open, sandy ground where they are interspersed with round-leaved sundew (Drosera rotundifolia), horned bladderwort (Utricularia cornuta), and rock spikemoss (Selaginella rupestris). Along the drainage way cattails (Typha latifolia), broom sedge (Andropogon virginicus), dwarf iris (Iris verna), and water pennywort (Hydrocotyle americana) are growing with grasses, sedges, and rushes. This drainage swale appears to lead to a large wetland identified on the NWI map as a palustrine, forested, deciduous wetland, which was also studied during the habitat evaluation.

South of the landfill, a loblolly pine\hardwood forest is present. Trees are the dominant vegetation in this habitat, although no species is clearly dominant. Tree species identified in the canopy include the following:

- Red Maple - Acer rubrum
- Tulip - Liriodendron tulipifera
- Loblolly Pine - Pinus taeda
- Sweetgum - Liquidambar styraciflua
- Beech - Fagus grandifolia
- Sugar Maple - Acer saccharum
- White Oak - Quercus alba
- Water Oak - Q. nigra
- Mockernut Hickory - Carya tomentosa
- Ironwood - Carpinus caroliniana
- River Birch - Betula nigra
- Sweetbay - Magnolia virginiana

Trees in the understory are also well mixed and no species is clearly dominant. Understory species identified include red cedar (Juniperus virginiana), wax myrtle (Myrica cerifera), dogwood (Cornus florida), holly (Ilex opaca), umbrella magnolia (Magnolia tripetala), and American snowbell (Styrax americana). Vines are common in the understory and seven different species were identified. They include poison ivy (Rhus radicans), Japanese honeysuckle (Lonicera japonica), wild grape (Vitis sp.), greenbriar (Smilax rotundifolia), Virginia creeper (Parthenocissus quinquefolia), trumpet creeper (Campsis radicans), and sand grape (Vitis rupestris).

Ferns are common on the forest floor; four species were identified including ebony spleenwort (Asplenium ebeneum), marsh fern (Aspidium thelypteris), royal fern (Osmunda regalis) and sensitive fern (Onoclea sensibilis). Cane (Arumdinaria tecta), grasses, and blue-eyed grass (Sisyrinchium sp.) are also found in the loblolly pine\hardwood forest.

Areas of mature hardwood forest were identified to the north, east, and west of the landfill, particularly in areas bordering the palustrine wetland. Again, trees are clearly dominant, although no individual species is dominant. Species present include tulip (Liriodendron tulipifera), red maple

(Acer rubrum), sweetgum (Liquidambar styraciflua), beech (Fagus grandifolia), white oak (Quercus alba), and mockernut hickory (Carya tomentosa). The understory is limited and consists of scattered dogwood (Cornus florida) and holly (Ilex opaca) trees. Vegetation is sparse on the forest floor and includes partridgeberry (Michella repens) and heartleaf (Hexastylis virginica ).

To the south, east, and west of the site, a palustrine, forested, deciduous wetland is present along Tank and Southwest Creeks and along an unnamed tributary that flows roughly parallel to Tank Creek. This wetland area is often referred to as a swamp. (A swamp is defined as a forested wetland.) Trees are dominant in this area, but no species is clearly dominant. Some of the trees standing in deeper water are dead or dying and it appears that the water level may increased in the past. Trees identified in this wetland include black gum (Nyssa sylvatica), red maple (Acer rubrum), tulip (Liriodendron tulipifera), elm (Ulmus sp.), and swamp chestnut oak (Quercus michauxii). Ironwood (Carpinus caroliniana) and Leucothoe axillaris are present in the understory. Grasses, blue-eyed grass (Sisyrinchium sp.), and violets (Viola sp.) are present along the drier areas at the edge of the wetland and wetland vegetation, including sensitive fern (Onoclea sensibilis), marsh fern (Aspidium thelypteris), switch cane (Arundinaria tecta), sedges, and water pennywort (Hydrocotyle americana, is present in wetter areas, Lizards tail (Saururus cernus) is the dominant forb on the wetland floor in some areas.

A number of birds were observed at Site 41. Species identified include both resident birds and neotropical migrants. They are as follows:

- Downy Woodpecker - Picoides pubescens
- Red-eyed Vireo - Vireo oliveaceus
- Fish Crow - Corvus ossifragus
- Carolina Chickadee - Parus carolinensis
- Mourning Dove - Zenaida macroura
- Carolina Wren - Thryothorus ludovicianus
- Barn Swallow - Hirundo rustica
- Cardinal - Richmondena cardinalis
- Wood Thrush - Hylocichla mustelina
- Mockingbird - Mimus polyglottos
- Yellow Warbler - Dendroica petechia
- Blue-grey Gnatcatcher - Polioptila caerula
- Myrtle Warbler - Dendroica coronata
- Magnolia Warbler - Dendroica magnolia

Several species of reptiles and amphibians were observed at Site 41. Black racers (Coluber constrictor constrictor) were seen in the young pine forest and in the wooded wetland and a pair of box turtles (Terrepene carolina) were mating in the drainage swale. Several small pond-like areas are present along the access roads; these appeared to be large ruts that had collected surface water runoff. Tadpoles of at least two different species of frogs or toads were observed in the ponds. An adult southern toad (Bufo terrestris) was also found in this area of the site. Anoles (Anolis carolinensis carolinensis) were observed climbing trees in the pine\hardwood forest.

From direct observations and from signs found at Site 41 during the habitat evaluation, several species of mammals are present. These include white-tailed deer (Odocoileus virginianus), fox (Vulpes sp.), raccoon (Procylon lotor), and squirrel (Sciurus carolinensis). While beavers have dammed areas of the wooded wetland in the past, no current sign of beavers was observed.

Site 74

Site 74 and its environs are covered with pine forest. Loblolly pine (Pinus taeda) is dominant in the Former Mess Hall Grease Pit Area and longleaf pine (Pinus palustris) is dominant in the Former Pest Control Area. The understory of this pine forest is a shrub layer ranging in height from 1 to 15 feet. Scattered deciduous trees are also present and represent the following species:

- Sweetgum - Liquidambar styraciflua
- Post Oak - Quescus stellata
- Red Oak - Q. falcata
- White Oak- Q. alba
- Laurel Oak - Q. laurifolia
- Water Oak - Q. nigra
- Tulip - Liriodendron tulipifera
- Mockernut Hickory - Carya tomentosa

A variety of shrubs is present in the understory of the pine forest. In some areas of the site they formed dense thickets; in others they carpeted the ground. The following species were identified:

- Myrtle - Myrica cerifera
- Fetterbush - Lyonia lucida
- Slender Blueberry - Vaccinium tenellum
- Staggerbush - Lyonia mariana
- Sweet Pepperbush - Clethra alnifolia
- Winged Sumac- Rhus copallina
- Chinkapin - Castanea pumila
- Coastal Highbush Blueberry - Vaccinium caesariense
- Elliott's Blueberry - V. elliottii

In several areas of the Former Pesticide Control Area slender blueberry was dominant and carpeted the ground. Pine seedlings and deciduous tree seedlings were mixed with the shrubs throughout the site. Woody vines are also present and include greenbriar (Smilax rotundifolia), bullbriar (Smilax bona-nox), sand grape (Vitis rupestris), poison ivy (Rhus radicans), and Virginia creeper (Parthenocissus quinquefolia).

Ferns are also present. In the damper areas of the Former Mess Hall Grease Pit Area four species of ferns were identified -- cinnamon fern (Osmunda cinnamomea), royal fern (Osmunda regalis), sensitive fern (Onoclea sensibilis), and marsh fern (Aspidium thelypteris). These ferns are growing with switch cane (Arundinaria tecta). In other areas mosses, lichens, and various grasses are found with broom sedge (Andropogon virginicus), slender bush clover (Lespedeza virginica), bracken (Pteris aquilina), and partridgeberry (Mitchella repens).

A variety of birds were observed at Site 74. They include the following species:

- Mourning Dove - Zenaida macroura
- Wood Peewee - Contopus virens
- Carolina Chickadee - Parus
- Fish Crow - Corvus ossifragus
- Blue Jay - Cyanocitta cristata

- Whippoorwill - Caprimulgus vociferus
- Red-eyed Vireo - Vireo olivaceus
- Cardinal - Richmondena cardinalis
- Robin - Turdus migratorius
- Downy Woodpecker - Picoides pubescens
- White-eyed Towhee - Pipilo erythrophthalmus
- Blue-grey Gnatcatcher - Polioptila caerulea
- Carolina Wren - Thryothorus ludovicianus
- Great-crested Flycatcher - Myiarchus crinitus
- Red-bellied Woodpecker - Melanerpes carolinus
- Summer Tanager - Piranga rubra

No reptiles or amphibians were observed at Site 74. Tracks of mice and rabbits were noted, as were tracks of white-tailed deer. Regular deer trails through the forest were also observed and deer were apparently feeding on ferns in the Former Mess Hall Grease Pit Area.

*Sensitive Environments*

This section describes the sensitive environments that were evaluated at Sites 41 and 74. These sensitive environments include wetlands, threatened and endangered species, and other potentially sensitive environments.

*Wetlands*

The NC DEHNR's Division of Environmental Management (DEM) has developed guidance pertaining to activities that may impact wetlands (NC DEHNR, 1992a). In addition, certain activities affecting wetlands also are regulated by the U.S. Corps of Engineers.

The U.S. Fish and Wildlife Service (FWS) has prepared National Wetlands Inventory (NWI) maps for the Camp Lejeune, North Carolina area by stereoscopic analysis of high altitude aerial photographs (USDI, 1982). Sites 41 and 74 are included on these maps. The wetlands were identified on the photographs based on vegetation, visible hydrology, and geography in accordance with Classification of Wetland and Deep-Water Habitats of the United States (Cowardin, et al, 1979). NWI maps are intended for an initial identification of wetland areas. They cannot be substituted for an actual wetland delineation that may be required by Federal, State and/or local regulatory agencies. Information from the wetlands maps was transferred to the site-specific biohabitat maps (Figures 7-1and 7-2).

Site-specific wetland delineations were not conducted at Sites 41 and 74, although potential wetland areas were noted during the habitat evaluation. These wetlands are illustrated on the biohabitat maps.

At Site 41, a drainage swale that supports wetland vegetation (sedges, rushes, cattails) is present, although it does not appear on NWI wetlands maps. This swale leads to a large palustrine, forested, deciduous wetland along the banks of Tank Creek, Southwest Creek, and an unnamed creek that is parallel to Tank Creek. Portions of this wetland were investigated during the habitat evaluation.

Two ponds, classified as palustrine open-water wetlands, are located within a half-mile radius of Site 74. Both of these ponds are managed for fish. South of the smaller pond a palustrine, forested,

broad-leaved deciduous wetland is present. This wetland grades to a larger palustrine, forested, deciduous wetland. East of Piney Green Road, this wetland becomes a palustrine, forested, needle-leaved deciduous wetland.

*Threatened and Endangered Species*

Certain species have been granted protection by the FWS under the Federal Endangered Species Act (16 U. S. C. 1531-1543), and/or by the North Carolina Wildlife Resources Commission, under the North Carolina Endangered Species Act (G. S. 113-331 to 113-337). The protected species fall into one of the following status classifications: Federal or State endangered, threatened or candidate species; State special concern; State significantly rare; or State watch list. While only the Federal or State threatened or endangered and State special concern species are protected from certain actions, the other classified species have the potential for protection in the future.

Surveys have been conducted to identify threatened and endangered species at Camp Lejeune and several programs are underway to manage and protect them. Table 7-4 lists protected species present at the base and their protected classification. Of these species, the red-cockaded woodpecker, American alligator, and sea turtles are covered by specific protection programs.

The red-cockaded woodpecker requires a specific habitat in mature, living longleaf or loblolly pine trees. The birds live in family groups and young are raised cooperatively. At Camp Lejeune, 2,512 acres of habitat have been identified and marked for protection. Research on the bird at Camp Lejeune began in 1985 and information has been collected to determine home ranges, population size and composition, reproductive success, and habitat use. An annual roost survey is conducted and 36 colonies of birds have been located.

The American alligator is considered endangered in the northern-most part of its range, which includes North Carolina. It is found in freshwater, estuarine, and saltwater wetlands in Camp Lejeune and base wetlands are maintained and protected to protect alligators. Signs have been erected where alligators are known to live. Annual surveys of Wallace, Southwest, French, Duck, Mill, and Stone Creeks have been conducted since 1977 to identify alligators and their habitats on base.

Two protected sea turtles, the Atlantic loggerhead and Atlantic green turtle, nest on Onslow Beach at Camp Lejeune. The green turtle was found nesting in 1980; the sighting was the first time the species was observed nesting north of Georgia. The turtle returned to nest in 1985. Turtle nests on the beach are surveyed and protected, turtles are tagged, and annual turtle status reports are issued.

Four bird species, black skimmer, piping plover, Bachmans sparrow, and Peregrine falcon have also been identified during surveys at Camp Lejeune. The black skimmer and piping plover are sea and shore birds, respectively. Skimmers nest on low sandy islands and sand bars along the coast and piping plovers prefer beaches with broad open sandy flats above the high tide line. Skimmers feed above open water and piping plovers feed along the edge of incoming waves. Like the black skimmer and piping plover, Bachmans sparrows are very specific in their habitat requirements. They live in open stretches of pines with grasses and scattered shrubs for ground cover. Bachmans sparrows were observed at numerous locations throughout southern Camp Lejeune. A Peregrine falcon was observed approximately three miles east of OU No. 4 and may have been feeding in the area since the birds have a large foraging range.

In addition to the protected species that breed or forage at Camp Lejeune, several protected whales migrate through the coastal waters off the base during spring and fall. These include the Atlantic right whale, finback whale, sei whale, and sperm whale. Before artillery or bombing practice is conducted in the area, aerial surveys are made to assure that whales are not present in the impact areas.

No protected species were observed at Sites 41 and 74 during the habitat evaluation nor would they be expected to occur. Protected species at Camp Lejeune require specific habitats that do not correspond to the habitats identified at the sites. Previous survey results and maps of locations were protected species have been identified were consulted to produce biohabitat maps. No protected species have been identified within half-mile radii of Sites 41 or 74.

A natural heritage resources was conducted at Camp Lejeune (LeBlond, 1991) to identify threatened or endangered plants and areas of significant natural interest. From this list, the Rough-leaf loosestrife was the only Federally threatened or endangered plant species found on the Marine Corps Base. In addition, several State endangered or threatened and Federal and State candidate species were found on the MCB. The results of this survey are included in Appendix R.

*Other Sensitive Environments*

In addition to wetlands and protected species, other sensitive environments, including those listed in 40 CFR Part 300, were evaluated during Hazard Ranking System evaluations. These sensitive environments and their presence or absence at Sites 41 and 74 are discussed below.

- Marine Sanctuary - Sites 41 and 74 are not located within a Marine Sanctuary (NCMFC, 1992).

- National Park - Sites 41 and 74 are not located within a National Park (NPS, 1991).

- Designated Federal Wilderness Area - Sites 41 and 74 are not located within a Designated Federal Wilderness Area (WS, 1989).

- Areas Identified under the Coastal Zone Management Act - The North Carolina Coastal Area Management Act (CAMA) regulates various types of Areas of Environmental Concern including estuarine waters, coastal wetlands, public trust areas, and estuarine shoreline through the establishment of unified policies, criteria, standards, methods, and processes (CAMA, 1974).

- Sensitive Areas Identified under the National Estuary Program (NEP) or Near Coastal Waters Program (NCWP) - Sites 41 and 74 are not located within a Sensitive Area identified under the NEP or NCWP (NCMFC, 1992).

- Critical Areas Identified under the Clean Lakes Program - Sites 41 and 74 are not located within a Critical Area identified under the Clean Lakes Program (NPS, 1991).

- National Monument - Sites 41 and 74 are not located near a National Monument (NPS, 1991).

- National Seashore Recreational Area - Sites 41 and 74 are not located within a National Seashore Recreational Area (NPS, 1991).

- National Lakeshore Recreational Area - Sites 41 and 74 are not located within a National Lakeshore Recreational Area (NPS, 1991).

- National Preserve - Sites 41 and 74 are not located within a National Preserve (NPS, 1991).

- National or State Wildlife Refuge - Sites 41 and 74 are not located within a National or State Wildlife Refuge (NCWRC, 1992).

- Unit of the Coastal Barrier Resource Program - Sites 41 and 74 are not located within a unit of the Coastal Barrier Resource Program (USDI, 1993).

- Administratively Proposed Federal Wilderness Area - Sites 41 and 74 are not located within an Administratively Proposed Federal Wilderness Area (WS, 1989, 1993).

- Spawning Areas Critical for the maintenance of fish/shellfish species within river, lake, or coastal tidal waters - Due to size restrictions, no critical spawning areas have been identified within Tank Creek (USMC, 1993). No specific spawning areas critical for the maintenance of fish/shellfish species in Tank Creek have been designated as such by state agencies (NC DEHNR, 1992).

- Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which fish spend extended periods of time - Surface waters associated with Sites 41 and 74 are not migratory pathways or feeding areas critical for the maintenance of an anadromous fish species because there is not a significant population of anadromous fish in Tank Creek (USMC, 1993).

- National river reach designated as Recreational - Tank Creek is not designated as a National Recreational River (NPS, 1990, 1993).

- Federal designated Scenic or Wild River - Tank Creek is not a Federally designated Scenic or Wild River (NPS, 1990, 1993).

- State land designated for wildlife or game management - Sites 41 and 74 are not located within a State game land (NCWRC, 1992).

- State designated Scenic or Wild River - Tank Creek is not a State designated Scenic or Wild River (NCMFC, 1992).

- State designated Natural Area - Sites 41 and 74 are not located within a State designated Natural Area or Area of Significant Value (LeBlond, 1991).

- State designated areas for protection or maintenance of aquatic life - No areas within the boundaries of Sites 41 and 74 are designated as primary nursery areas or

are unique or special waters of exceptional state or national recreational or ecological significance which require special protection to maintain existing uses (NC DEHNR, 1992).

- Areas of Significant Value - Sites 41 and 74 are not located within a State Area of Significant Value (LeBlond, 1991).

- State Registered Natural Resource Area - Sites 41 and 74 are not located within a State Registered Natural Resource Area (LeBlond, 1991).

7.3.1.3 Exposure Analysis/Profile

The next step in the characterization of exposure is to combine the spatial and temporal distributions of both the ecological component and the stressor to evaluate exposure. This section of the ERA addresses and quantifies each exposure pathway via surface water, sediment, air, soil, and groundwater.

To determine if ecological exposure via these pathways may occur in the absence of remedial actions, an analysis was conducted including the identification and characterization of the exposure pathways. The following four elements were examined to determine if a complete exposure pathway was present:

- A source and mechanism of chemical release
- An environmental transport medium
- A feasible receptor exposure route
- A receptor exposure point

*7.3.1.3.1 Potential Exposure Scenarios*

This section discusses the potential exposure scenarios at OU No. 4 including surface water, sediments, soil, groundwater and air. The location of samples was based on historical information available for the site and a site visit to evaluate potential ecosystems and ecological receptors (see Figures 7-1 and 7-2, Biohabitat Maps).

Surface Water Exposure Pathway

Potential release sources to be considered in evaluating the surface water pathway are contaminated surface soils and groundwater. The release mechanisms to be considered are groundwater seepage and surface runoff. The potential routes to be considered for ecological exposure to the contaminated surface waters are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the surface water on site or off site and downgradient relative to tidal influence.

COPCs were detected in the surface water demonstrating a release from a source to the surface water transport medium. Potential receptors that may be exposed to contaminants in surface waters in/or around surface water include: fish, benthic macroinvertebrates, deer, birds, and other aquatic and terrestrial life.

Aquatic organisms (i.e., fish, benthic macroinvertebrates) are exposed to contaminants in the surface water by ingesting water while feeding and by direct contact. In addition, aquatic organisms may ingest other aquatic flora and fauna that have bioconcentrated chemicals from the surface water. Overall, aquatic organisms have a high exposure to contaminants in the surface water. Potential decreased integrity of aquatic receptors from contaminants in the surface water were evaluated in this ERA by direct comparisons of contaminant concentrations in the surface water to published water quality standards and criteria.

Terrestrial faunal receptors potentially are exposed to contaminants in the surface water through ingestion and dermal contact. The magnitude of the exposure depends on their feeding habits and the amount of time they reside in the contaminated waters. In addition, terrestrial species may ingest organisms (e.g., fish, insects, plants) that have bioconcentrated contaminates from the surface water. Potential decreased integrity of terrestrial receptors from contaminants in the surface water was evaluated in this ERA by comparing CDI to TRVs. Total exposure of the terrestrial receptors to the COPCs in the surface waters was determined by estimating the CDI dose and comparing this dose to TRVs representing acceptable daily doses in mg/kg/day.

Sediment Exposure Pathway

The potential release sources to be considered in evaluating the sediment pathway are contaminated surface soils and groundwater. The release mechanisms to be considered are groundwater seepage and surface runoff. The potential routes to be considered for ecological exposure to the contaminated sediments are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the sediments.

COPCs were detected in the sediment demonstrating a release from a source to the sediment transport medium. Potential receptors that may be exposed to contaminants in sediments include benthic macroinvertebrates, bottom feeding fish, aquatic vegetation and other aquatic life,

Aquatic organisms (i.e. fish, benthic macroinvertebrates) are exposed to contaminants in the sediments by ingesting sediments while feeding and by direct contact. In addition, aquatic organisms may ingest other aquatic flora and fauna that have bioconcentrated chemicals from the sediments. Overall, aquatic organisms have a high exposure to contaminants in the sediment. Potential decreased integrity of aquatic receptors from contaminants in the sediment were evaluated in this ERA by direct comparisons of contaminant concentrations in the sediments to SSVs.

Terrestrial faunal receptors potentially are exposed to contaminants in the sediments through ingestion and dermal contact. The magnitude of the exposure depends on their feeding habits and the amount of time they reside in the contaminated sediments. In addition, terrestrial species may ingest organisms (e.g., fish, insects, small mammals, plants) that have bioconcentrated contaminates from the sediments. Potential decreased integrity of terrestrial receptors from contaminants in the sediments was qualitatively evaluated in this ERA.

Soil Exposure Pathway

Potential release sources to be considered in evaluating the soil pathway are surface or buried wastes and contaminated soil. The release mechanisms to be considered are fugitive dust, leaching, tracking, and surface runoff. The transport medium is the soil. The potential routes to be considered for ecological exposure to the contaminated soils are ingestion and dermal contact. Potential

exposure points for ecological receptors include species living in, or coming in contact with, the soils.

COPCs were detected in the surface soil demonstrating a release from a source to the surface soil transport medium. Potential receptors that may be exposed to contaminants in surface soil at/or around surface soil in the areas of detected COPCs including: deer, fox, raccoon, rabbits, birds, plants, and other terrestrial life.

Terrestrial receptors potentially are exposed to contaminants in the soils through ingestion, dermal contact, and/or direct uptake (for flora). The magnitude of the exposure depends on their feeding habits and the amount of time they reside in the contaminated soils. In addition, terrestrial species may ingest organisms (e.g., insects, small mammals, plants) that have bioconcentrated contaminates from the soils. Potential decreased integrity of terrestrial receptors from contaminants in the surface soils was evaluated in this ERA by comparison of CDIs to TRVs, and direct comparisons of soil concentrations to literature toxicity value for plants and invertebrates.

Groundwater Exposure Pathway

The potential release source to be considered in evaluating the groundwater pathway is contaminated soils. The release mechanism to be considered is leaching. The routes to be considered for ecological exposure to the contaminated groundwater are ingestion and dermal contact. Groundwater discharge to area surface waters may represent a pathway for contaminant migration. Since organisms are not directly exposed to groundwater at OU No. 4, the groundwater to surface water exposure is accounted for in the surface water section of the ERA.

Air Exposure Pathway

There are two potential release mechanisms to be considered in evaluating the atmospheric pathway: release of contaminated particulates and volatilization from surface soil, groundwater and surface water. The potential exposure points for receptors are areas on or adjacent to the site.

No data has been collected to document exposure to receptors via the air pathway. However, based on the low concentrations of VOCs detected in the soils, sediments, and surface water, and the negligible vapor pressure of pesticides and metals, the air concentration of the COPCs is not expected to cause a decrease in integrity of the terrestrial receptors. Therefore, this pathway was not evaluated as part of the ERA.

### 7.3.2 Ecological Effects Characterization

The potential ecological effects to aquatic receptors were evaluated by direct comparisons of contaminant concentrations in surface water and sediment to ARVs and other available criteria or TBCs. Potential ecological effects to terrestrial receptors were evaluated by comparison to literature values and by comparing the CDIs to TRVs. The following sections further discuss the Aquatic Reference Values (ARV) comparisons and the CDI to TRV comparisons to evaluate the potential ecological effects to aquatic and terrestrial receptors from the COPCs.

Contaminant concentrations detected in the surface water at OU No. 4 were compared to the NC DEHNR WQS, USEPA WQSV, USEPA AWQC and other toxicity values obtained from the USEPA AWQC documents and AQUIRE to determine if there were any exceedances of the published

values. In addition, the log normal upper 95 percent confidence limit or the maximum value detected were compared to the WQS, the acute and chronic WQSVs, and the acute and chronic AWQC using the quotient ratio method. If the variability in measured concentration values is great and the log normal upper 95 percent confidence limit was greater than the maximum detected value, the maximum detected value was used in the quotient ratio. This yields a value termed the Quotient Index (QI). A QI greater than unity indicates a potential for adverse effects to aquatic life. The log normal upper 95 percent confidence limit were used to represent a conservative estimate of exposure at the site. The ratio of the upper 95 percent confidence limit (or maximum detected value) and the ARVs were calculated for each COPC.

Contaminant concentrations detected in the sediments at Site OU No. 4 were compared to the SSVs to determine if there were any exceedances in the established values. In addition, the upper 95 percent confidence limit or the maximum value detected was compared to the Region IV lower 10 percentile (ER-L) and median percentile (ER-M) using the quotient ratio method. Because the screening values are set to be protective of the aquatic environment, any exceedances of these values indicate a potentially toxic environment for the aquatic organisms inhabitating the water body.

7.3.2.1 Surface Water Quality

Tables 7-5 and 7-6 contain the freshwater North Carolina WQS, the Region IV USEPA WQSV, and the USEPA AWQC for the COPCs detected at Site 41and Site 74, respectively.

The freshwater water quality values for the following metals are water hardness dependent: cadmium, chromium III, copper, lead, nickel, silver, and zinc. In general, the higher the water hardness (in mg/L of $CaCO_3$) the higher the water quality value. A hardness concentration of 50 mg/L $CaCO_3$ was used to calculate these values since actual hardness data was not available.

The following COPCs detected in the surface water samples do not have WQS, WQSV, or AWQC values: aluminum, barium, cobalt, manganese, and vanadium. The potential impact to aquatic species from these chemicals in the surface water was evaluated using the results of acute and chronic tests obtained from the AQUIRE database (AQUIRE, 1993). The maximum detected concentration of these chemicals in the surface water were below the adverse effects levels obtained from the database. Therefore, no decrease in integrity of ecological receptors from these chemicals is expected.

7.3.2.2 Sediment Quality

Tables 7-7 and 7-8 contain the sediment SSVs for hazardous waste sites for the COPCs detected in Site 41 and Site 74. Sediment samples were collected from zero to six inches, and six to twelve inches at most of the sediment stations. Some sediment stations were sampled at a depth of zero to six inches only, due to sampler refusal or other difficulties in collecting the 6 to 12-inch sample.

The following COPCs detected in the sediments do not have SSVs for them: aluminum, barium, beryllium, iron, manganese, selenium, vanadium, endosulfan II and methoxychlor. There is limited, if any, data assessing the effects on aquatic organism exposed to these chemicals in sediment samples. Therefore, the effects of these chemicals on aquatic organisms were not determined.

7.3.2.3 Surface Soil Quality

There are no standards, criteria, or other screening values for assessing potential impacts to terrestrial ecological receptors from contaminants in soils. In addition, the amount of literature data evaluating adverse ecological effects on terrestrial species exposed to contaminants in surface soils is limited. However, toxicological effects on plants and/or invertebrates inhabiting soils contaminated by the following chemicals were obtained from various studies in the literature: arsenic, barium, beryllium, chromium, copper, lead, manganese, mercury, silver, vanadium, and zinc. This data was used to evaluate decreased integrity of terrestrial flora and invertebrates from COPCs in the soil.

No toxicological effects of plants and/or invertebrates inhabiting soils contaminated by the following chemicals were obtained from various studies in the literature: aluminum, cobalt, iron, nickel, selenium, and thallium. Therefore, these contaminants were not evaluated in the ERA.

No information was found which evaluate the toxicological affects on plants and/or invertebrates inhabiting soils contaminated with TCL organics, therefore, the evaluation was limited to TAL inorganics.

7.3.2.4 Terrestrial Chronic Daily Intake

As discussed above, there are no standards, criteria, or other screening values for assessing potential impacts to terrestrial receptors from contaminants in soils. However, there are some models that exist to estimate the exposure to terrestrial receptors. The following describes the procedures used to evaluate the potential soil exposure to terrestrial fauna at OU No. 4 by both direct and indirect exposure to COPCs via water (surface water), soil, and foodchain transfer.

Contaminants of concern at OU No. 4 are identified in Section 7.2.1.1 for each media. Based on the regional ecology and potential habitat at the site, the indicator species used in this analysis are the white-tailed deer, cottontail rabbit, red fox, raccoon, and the bobwhite quail. The exposure points for these receptors are the surface soils, surface water, and vegetation. The routes for terrestrial exposure to the COPCs in the soil and water are incidental soil ingestion, drinking water, vegetation (leafy plants, seeds and berries) ingestion, fish ingestion, and ingestion of small mammal ingestion.

Total exposure of the terrestrial receptors to the COPCs in the soil and surface waters was determined by estimating the Chronic Daily Intake (CDI) dose and comparing this dose to TRVs representing acceptable daily doses in mg/kg/day. For this analysis, TRVs were developed from NOAELs or LOAELs obtained from the Integrated Risk Information System (IRIS, 1993), or other toxicological data in the literature (Table 7-9).

## 7.4 Risk Characterization

The risk characterization is the final phase of a risk assessment. It is at this phase that the likelihood of adverse effects occurring as a result of exposure to a stressor are evaluated. This section evaluates the potential adverse effects on the ecological integrity at Sites 41 and 74 from contaminants identified at the site.

A Quotient Index (QI) approach was used to characterize the risk to aquatic receptors from exposure to surface water and sediments. This approach characterizes the potential effects by comparing

exposure levels of COPCs in the surface water and sediments to the aquatic reference values presented in Section 7.2.3, Ecological Effects. The QI is calculated as follows:

$$QI = \frac{EL}{ARV}$$

Where: QI = Quotient Index
EL = Exposure Level, mg/L or mg/kg
ARV = Aquatic Reference Value, mg/L or mg/kg

### 7.4.1 Surface Water Quality

Table 7-10 contains a comparison of the COPCs identified in the surface water at Sites 41 and 74 to the ARVs to determine if they exceeded the published values. A QI ratio of the detected value at each sampling station, and WQS, WQSVs, and AWQC were calculated for each COPC. A QI ratio greater than unity indicates a potential for decreased integrity of aquatic life. Table 7-10 presents only the ratios that are greater than unity for the COPCs at each site. Figures 7-3, 7-4 and 7-5 presents the QI exceedances per sampling station.

The following sections discuss the surface water quality results at Sites 41 and 74. These sections contain comparisons of the contaminants detected in the surface water and sediments at the sites to their ARVs and comparisons to base-wide background (inorganics only) concentrations (see Section 4.4 for base-wide concentration tables).

#### 7.4.1.1 Site 41

Twenty-eight surface water samples collected at Site 41 in the unnamed tributary and Tank Creek were analyzed for TCL organics, TCL pesticides and PCBs, and TAL inorganics. Aluminum had QI ratios greater than unity when compared to the acute AWQC in six samples and the chronic AWQC in twenty-five samples. Aluminum was detected at concentrations greater than the base-wide background average concentration in six samples. Copper had QI ratios greater than unity when compared to NCWQS in four samples, the acute WQSV and AWQC in three samples, and the chronic WQSV and AWQC in four samples. Copper was detected at concentrations greater than the base-wide background average concentration in four samples. Iron had QI ratios greater than unity when compared to the NCWQS and the chronic AWQC in nineteen samples. Iron was detected at concentrations above the base-wide background average concentration in twenty samples. Lead had QI ratios greater than unity when compared to the NCWQS in three samples and the chronic WQSV and AWQC in eleven samples. Lead was detected in twelve samples at concentrations above the base-wide background average concentration. Mercury also had QIs greater than one when compared to the NCWQS, chronic WQSV and the chronic AWQC in nine samples. Mercury was detected at concentrations above the base-wide background average concentration in nine samples. Zinc had QI ratios greater than unity when compared to the NCWQS in six samples, and the acute and chronic WQSVs and AWQC in three samples. Zinc was detected at concentrations greater than the base-wide background average in twenty samples. The locations of these exceedances also are present in Table 7-10 and Figures 7-3 and 7-4. No other inorganics detected at Site 41 exceeded any of the surface water ARVs.

No organics or pesticides detected at Site 41 had QI ratios greater than unity.

7.4.1.2 Site 74

Three surface water samples collected at Site 74 were analyzed for TCL organics, TCL pesticides and PCBs, and TAL inorganics. Aluminum had QI ratios greater than unity when compared to the chronic AWQC in three samples; however, all three samples were detected at concentrations below both the base-wide background average concentration. Lead had QIs greater than unity when compared to the chronic WQSV and the chronic AWQC in three samples. Lead was detected at concentration above both the base-wide background average concentration in two samples. The locations of these exceedances are presented in Table 7-18 and Figure 7-5.

No TCL organics or TCL pesticides and PCBs detected at Site 74 had QIs greater than unity when compared to the surface water ARVs.

### 7.4.2 Sediment Quality

Table 7-11 contains a comparison of the COPCs identified in the sediment to the ARVs to determine if exceedances of published values occurred. The QI ratio of the detected values at each sampling station and the ER-L and ER-M were calculated for each COPC. A ratio greater than unity indicates a possibility for adverse effects to aquatic life. Table 7-19 presents only the ratios that are greater than unity for the COPCs. Figures 7-3 and 7-4 presents the ratios that are greater than unity per sampling location.

The following sections discuss the sediment quality results at the sites. These sections contain a comparison of the contaminants detected in the sediments to their ARVs and base-wide background concentrations (see Section 4.4 for base-wide inorganic concentration tables).

7.4.2.1 Site 41

Forty-two sediment samples collected from twenty-eight stations were analyzed for TCL organics, TCL pesticides and PCBs, and TAL inorganics. Lead exceeded the ER-L in two samples and silver exceeded the ER-L in three samples and the ER-M in one sample. Lead was detected at concentrations above the base-wide average background in five samples. Silver was detected at concentration above the base-wide average background in these three samples. Zinc exceeded the ER-L in one sample and was detected at concentrations above the base-wide average background concentration in twenty samples. No other inorganics detected in the sediments exceeded the ER-L or ER-M values.

Among the pesticides and PCBs, 4-4'-DDD exceeded the ER-L in seventeen samples and the ER-M in five samples; 4-4'-DDT exceeded the ER-L in fourteen samples and the ER-M in three samples; 4,4'-DDE exceeded the ER-L in fifteen samples and the ER-M in four samples; dieldrin exceeded the ER-L in ten samples; alpha-chlordane exceeded the ER-L in eleven samples; and gamma-chlordane exceeded the ER-L in nine samples and the ER-M in one sample. No other organics, pesticides or PCBs exceeded the ER-L or ER-M values in any of the sediment samples.

The following COPCs in the sediments had QIs greater than unity when compared to the ER-L: lead, silver, zinc, 4-4'-DDD, 4-4'-DDT, 4,4'-DDE, dieldrin, and alpha and gamma-chlordane. The following COPCs had QIs greater than unity when compared with the ER-Ms: silver, 4,4'-DDD, 4,4'-DDE, 4-4'-DDT, and gamma-chlordane.

7.4.2.2 Site 74

Three sediment samples collected from three stations at Site 74 were analyzed for TCL organics, TCL pesticides and PCBs, and TAL inorganics.

No TCL organics, TCL pesticides, TCL PCBs, or TAL inorganics were detected in Site 74 sediments exceeded the ER-L or ER-M values.

### 7.4.3 Surface Soils

The following sections discuss the results of the risk characterization of surface soils at OU No. 4. These sections contain a comparison of the contaminants detected in the surface soils to the concentrations of the contaminants in soil that caused adverse effects to plants, terrestrial invertebrates, and terrestrial vertebrates. This data was obtained from various sources in the literature.

7.4.3.1 Site 41

Arsenic concentrations ranged from 0.617 to 3.67 mg/kg in the surface soils at Site 41, which are below the 25 mg/kg that depressed crop yields (USDI, 1988). Barium concentrations ranged from 3.14 to 82.2 mg/kg, which are below the 2,000 mg/kg that induced plant toxicity (Adriano, 1986). Beryllium concentrations of 0.187 to 0.344 mg/kg were found in the surface soils which were below the 0.500 mg/kg limit for neutral to alkaline fine-textured soils (Adriano, 1986). Some of the chromium concentrations found in the surface soils (2.42J to 41.4 mg/kg) are greater than the 10 kg/mg in surface soils that caused mortality in the earthworm species Pheretima pesthuma, (Hopkin, 1989).

Copper concentrations ranged from 4.17 to 132 mg/kg, some of which are above the 50 mg/kg level that interfered with the reproduction activity of the earthworm species Allolobuphora caliginosa (Hopkin, 1989). The phytotoxicity of lead was reported to be lower than that of copper (which would be greater than 50 mg/kg). Lead concentrations ranged from 2.57 to 341 mg/kg, which are less than the 670 mg/kg, which is considered hazardous to earthworms (Beyer, 1993). Manganese concentrations ranged from 1.67 to 6,000 mg/kg some of which were greater than the mean U.S. soil concentration of 560 mg/kg and vanadium concentrations ranged from 4.62 to 39.8 mg/kg which are lower than the mean U.S. soil concentration of 58 mg/kg (Adriano, 1986). Mercury concentrations ranged from 0.073 to 0.768 mg/kg, which are less than the 3 mg/kg which has been shown to interfere with reproduction in mallard ducks and produce brain lesions in their ducklings (Beyer, 1993). Zinc concentrations ranged from 3.77 to 14,600 mg/kg, which are greater than the 450 to 1400 mg/kg that caused plant toxicity (Adriano, 1986).

7.4.3.2 Site 74

Arsenic concentrations ranged from 0.621J to 1.16 mg/kg in the surface soils, which are below the 25 mg/kg that depressed crop yields (USDI, 1988). Barium concentrations ranged from 2.89 to 54.7 mg/kg, which are below the 2,000 mg/kg that induced plant toxicity (Adriano, 1986). Chromium concentrations of 1.89 to 10.6 mg/kg were found in the surface soils, which are greater than the 10 kg/mg in surface soils that caused mortality in the earthworm species Pheretima pesthuma, (Hopkin, 1989). Copper concentrations ranged from 5.07 to 22 mg/kg, which are below

the 50 mg/kg level that interfered with the reproduction activity of the earthworm species Allolobuphora caliginosa (Hopkin, 1989).

Lead concentrations ranged from 0.878J to 15.4 mg/kg, which are less than the 670 mg/kg which is considered hazardous to earthworms (Beyer, 1993). Manganese concentrations ranged from 1.44 to 96.2 mg/kg, which are lower than the mean U.S. soil concentration of 560 mg/kg (Adriano, 1986). Mercury concentrations ranged from 0.015 to 0.092 mg/kg, which are less than the 3 mg/kg which has been shown to interfere with reproduction in mallard ducks and produce brain lesions in their ducklings (Beyer, 1993). Vanadium concentrations ranged from 4.03 to 15.1 mg/kg, which are below the mean U.S. soil concentrations of 58 mg/kg (Adriano, 1986). Zinc concentrations ranged from 2.27 to 33.9 mg/kg which are below the 450 to 1400 mg/kg that caused plant toxicity (Adriano, 1986). Selenium concentrations ranged from 0.609 to 1.2 mg/kg, which were below the 5 to 15 mg/kg range that is highly toxic to animals (Arthur, 1992).

### 7.4.4 Terrestrial Chronic Daily Intake Model

The following sections discuss the CDIs and QIs calculated for the terrestrial receptors.

#### 7.4.4.1 CDI Calculations

Total exposure of the terrestrial receptors at Sites 41 and 74 to the COPCs in the soil and surface waters was determined by estimating the CDI dose and comparing this dose to TRVs representing acceptable daily doses in mg/kg/day. CDIs were estimated for the white-tailed deer, cottontail rabbit, bobwhite quail, and red fox at Sites 41 and 74. The CDI for the raccoon was only estimated at Site 41. There were no streams or rivers that run traverse Site 74, therefore it was assumed that there were no fish, and therefore no raccoons feeding on site. The estimated CDI dose of the receptors (bobwhite quail, cottontail rabbit, and white-tailed deer) to soils, surface water, and vegetation was determined using the following equation:

$$E = \frac{(Cw)(Iw)+[(Cs)(Bv \text{ or } Br)(Iv)+(Cs)(Is)][H]}{BW}$$

where:

| | | |
|---|---|---|
| E | = | Total Exposure, mg/kg/d |
| Cw | = | Constituent concentration in the surface water, mg/L |
| Iw | = | Rate of drinking water ingestion, L/d |
| Cs | = | Constituent concentration in soil, mg/kg |
| Bv | = | Soil to plant transfer coefficient (leaves, stems, straw, etc.), unitless |
| Br | = | Soil to plant transfer coefficient (fruits, seeds, tubers, etc.), unitless |
| Iv | = | Rate of vegetation ingestion, kg/d |
| Is | = | Incidental soil ingestion, kg/d |
| H | = | Contaminated area/Home area range area ratio, unitless |
| BW | = | Body weight, kg |

The estimated CDI dose of the raccoon was determined using the following equation.

$$E = \frac{(Cw)(Iw)+[(Cs)(Br)(Iv)+(Cs)(Is)+(Cf)(If)][H]}{BW}$$

where:

| | | |
|---|---|---|
| E | = | Total Exposure, mg/kg/d |
| Cw | = | Constituent concentration in the surface water, mg/L |
| Iw | = | Rate of drinking water ingestion, L/d |
| Cs | = | Constituent concentration in soil, mg/kg |
| Br | = | Soil to plant transfer coefficient (fruit, seeds, tubers, etc.), unitless |
| Iv | = | Rate of vegetation ingestion, kg/d |
| Is | = | Incidental soil ingestion, kg/d |
| If | = | Rate of fish ingestion, kg/d |
| Cf | = | Constituent concentration in the fish, mg/kg (whole body concentrations) |
| H | = | Contaminated area/Home area range area ratio, unitless |
| BW | = | Body weight, kg |

The estimated CDI dose of the red fox was determined using the following equation:

$$E = \frac{(Cw)(Iw)+[(Cs)(Br)(Iv)+(Cs)(Is)+(Cm)(Im)][H]}{BW}$$

where:

| | | |
|---|---|---|
| E | = | Total Exposure, mg/kg/d |
| Cw | = | Constituent concentration in the surface water, mg/L |
| Iw | = | Rate of drinking water ingestion, L/d |
| Br | = | Soil to plant transfer coefficient (fruit, seeds, tubers, etc.), unitless |
| Iv | = | Rate of vegetation ingestion, kg/d |
| Cs | = | Constituent concentration in soil, mg/kg |
| Is | = | Incidental soil ingestion, kg/d |
| Im | = | Rate of small mammal ingestion, kg/d |
| Cm | = | Constituent concentrations in small mammals, mg/kg<br>where: Cm = (Cs)(Bv) + (Cs)(Is) |
| Bv | = | Soil to plant transfer coefficient (leaves, stems, straw, etc.), unitless |
| H | = | Contaminated area/Home area range area ratio, unitless |
| BW | = | Body weight, kg |

Bioconcentration of the COPCs to plants was calculated using the soil to plant transfer coefficient (Bv or Br) for organics (Travis, 1988) and metals (Baes, 1984). Concentrations of COPCs in the fish were calculated for Site 41. This was accomplished by multiplying the freshwater BCF by the surface water concentration of a specific chemical. Freshwater BCFs could not be located in the literature for aluminum, barium, cobalt, iron, and manganese. These concentrations were assumed to be zero. If a chemical was not detected in the surface water, it was also assumed to be a nondetect in the fish. The concentrations of the COPCs in the soil (Cs) used in the model were the upper 95 percent confidence limit or the maximum concentration detected of each COPC at each site. The upper 95 percent confidence limit or the maximum concentration detected for each constituent was

also used as the concentration of each COPC in the surface water. The exposure parameters used in the CDI calculations are presented in Table 7-12 and are summarized for each receptor below.

For the white-tailed deer, the feeding rate is 1.6 kg/d (Dee, 1991). The incidental soil ingestion rate is 0.019 kg/d (Scarano, 1993). The rate of drinking water ingestion is 1.1 L/d (Dee, 1991). The rate of vegetation ingestion is 1.6 kg/d. The body weight is 45.4 kg (Dee, 1991), and the home range is 454 acres (Dee, 1991). The deer's diet was assumed to be 100 percent vegetation (leaves, stems, straw).

For the eastern cottontail rabbit, the feeding rate is 0.1 kg/d (Newell, 1987). The incidental soil ingestion rate is 0.002 kg/d (Newell, 1987). The rate of drinking water ingestion is 0.119 L/d (USEPA, 1993). The rate of vegetation ingestion is 0.1 kg/d. The body weight is 1.229 kg (USEPA, 1993), and the home range is 9.29 acres (USEPA, 1993). The rabbit's diet was assumed to be 100 percent vegetation (leaves, stems, straw).

For the bobwhite quail, the feeding rate is 0.014 kg/d (USEPA, 1993). The quail's diet was assumed to be 100 percent vegetation (leaves, stems, straw). The incidental soil ingestion rate is 0.001 kg/d (Newell, 1987). The rate of drinking water ingestion is 0.019 L/d (USEPA, 1993). The rate of vegetation ingestion is 0.014 kg/d. The body weight is 0.177 kg (USEPA, 1993), and the home range is 8.89 acres (USEPA, 1993).

For the red fox, the feeding rate is 0.446 kg/d (USEPA, 1993). The fox's diet was assumed to be 20 percent vegetation (seed, berries) and 80 percent small mammals. The incidental soil ingestion rate is 0.012 kg/d (USEPA, 1993). The rate of drinking water ingestion is 0.399 L/d (USEPA, 1993). The rate of vegetation ingestion is 0.089 kg/d, the rate of small mammal ingestion is 0.356 kg/d. The body weight is 4.69 kg (USEPA, 1993), and the home range is 1,771 acres (USEPA, 1993).

For the raccoon, the feeding rate is 0.319 kg/d (USEPA, 1993). The raccoon's diet was assumed to be 40 percent vegetation (nuts, seeds, berries) and 60 percent fish. The incidental soil ingestion rate is 0.030 kg/d (USEPA, 1993). The rate of drinking water ingestion is 0.331 L/d (USEPA, 1993). The rate of vegetation ingestion is 0.128 Kg/d and the rate of fish ingestion is 0.192 kg/d. The body weight is 3.99 kg (USEPA, 1993), and the home range is 385 acres (USEPA, 1993).

7.4.4.2 QI Calculations

As was used to characterize the risk to aquatic receptors, the QI approach was used to characterize the risk to terrestrial receptors. In this use of the QI, the risk are characterized by comparing the CDIs for each COPCs to the TRVs and is calculated as follows:

$$QI = \frac{E}{TRV}$$

Where: QI = Quotient Index
E = Total Exposure, mg/kg/day
TRV = Terrestrial Reference Value, mg/kg/day

Tables 7-13 and 7-14 contain the QI for the COPCs in each of the areas. A QI of greater than "unity" is considered to be indicative of potential risk. Such values do not necessarily indicate that

an effect will occur but only that a lower threshold has been exceeded. The evaluation of the significance of the QI has been judged as follows: (Menzie, 1993)

- QI exceeds "1" but less than "10": some small potential for environmental effects;
- QI exceeds "10": significant potential that greater exposures could result in effects based on experimental evidence;
- QI exceeds "100": effects may be expected since this represents an exposure level at which effects have been observed in other species.

The risks characterized above provide insight into general effects upon animals in the local population. However, depending on the endpoint selected, they may not indicate if population-level effects will occur.

There are some differences of opinion found in the literature as to the effectiveness of using models to predict concentrations of contaminants found in terrestrial species. According to one source, the food chain models currently used incorporate simplistic assumption that may not represent conditions at the site, bioavailability of contaminants, or site-specific behavior of the receptors. Simple food chain models can provide an effective means of initial characterization of risk, however, residue analyses, toxicity tests, and the use of biomarkers provide a better approach for assessing exposure (Menzie, 1993).

The following sections discuss the results of the terrestrial CDI compared to the TRVs, the COPCs in the soils compared to published soil toxicity data, and an evaluation of the potential impacts to threatened and endangered species, wetlands, and other sensitive environments. TRVs could not be located for bis(2-chloroethylether, 4-methyl-2-pentanone, aluminum, cobalt, and iron. Therefore, these COPCs could not be included in this comparison.

The CDI model was used to assess decreased integrity in terrestrial species from exposure to contaminants in surface water and surface soils. The surface soil data were grouped into two areas, Site 41 and Site 74 for the statistics. Therefore, a QI was calculated for each area (Note: the surface water samples were included in the calculations for each area).

At Site 41, the QIs of the CDI to the TRVs were less than unity for all COPCs except manganese. The QIs for manganese were calculated to be 10.6 for the quail, 9.0 for the rabbit, 1.2 for the fox, and 1.3 for the raccoon. Therefore, the total QI for the quail, rabbit fox, and raccoon were greater than unity. The QIs were greater than unity, but less than ten for all the contaminants except manganese in the quail, indicating only a small potential that the animals are being adversely affected by the contaminants at Site 41. The QI for manganese for the quail was greater than 10 (10.6) but much less than 100 indicating a significant potential that greater exposures could result in adverse affects.

At Site 74, the QIs of the CDI to the TRVs were less than unity for all the COPCs except manganese. The QIs for manganese were calculated to be 1.19 for the quail and 1.04 for the rabbit. Therefore, the total QIs for the quail (1.26) and the rabbit (1.09) were greater than unity. The QIs were greater than unity, but less than 10 for all contaminants indicating only a small potential that the animals are being adversely affected.

### 7.4.5 Threatened and/or Endangered Species

Several threatened and/or endangered species inhabit MCB Camp Lejeune. However, these threatened and/or endangered species are not known to regularly frequent or breed at OU No. 4 (USMC, 1993). In addition, no protected species were observed at Sites 41 and 74 during the habitat evaluation nor would they be expected to occur. Protected species at Camp Lejeune require specific habitats that do not correspond to the habitats identified at the sites. Previous survey results and maps of locations where protected species have been identified were consulted to produce biohabitat maps. No protected species have been identified within half-mile radii of Sites 41 or 74. Therefore, potential adverse impacts to these protected species from contaminants at OU No. 4 appear to be low.

### 7.4.6 Flora/Wetlands

Site-specific wetland delineations were not conducted at Sites 41 and 74, although potential wetland areas were noted during the habitat evaluation. Generally, wetlands were not identified on each of the sites, although wetlands were present within a half mile radius of each site. These wetlands are illustrated on the biohabitat maps (Figures 7-1 and 7-2) potential impacts to wetlands are addressed in the surface water and sediment sections.

### 7.4.7 Other Sensitive Environments

No areas within the boundaries of OU No. 4 are designated as unique or special waters of exceptional state or national recreational or ecological significance which require special protection to maintain existing uses. There are no known spawning and nursery areas for resident fish species within Site 41 or 74. There is no potential for decreased integrity of fish spawning or nursing in those areas.

Several threatened and/or endangered species are known to inhabit Camp Lejeune as discussed in Section 7.3. No known threatened and/or endangered species are known to inhabit Sites 41 or 74.

The potential impact to terrestrial organisms that are present at OU No. 4 is discussed in earlier sections of this report. The terrestrial organisms that may be breeding in contaminated areas at OU No. 4 may be more susceptible to chemical stresses due to the higher sensitivity of the reproductive life stages of organisms to these types of stresses.

## 7.5 Ecological Significance

This section essentially summarizes the overall risks to the ecology at the site. It addresses impacts to the ecological integrity at the Operable Unit from the COPCs detected in the media, and to determine which COPCs are impacting the site to the greatest degree. This information, to be used in conjunction with the human health RA, supports the selection of remedial action(s) for the Operable Unit that are protective of public health and the environment.

### 7.5.1 Aquatic Endpoints

The measurement endpoint used to assess the aquatic environment is decreased integrity of aquatic organisms.

7.5.1.1 Surface Water and Sediments

Overall, metals and pesticides appear to be the most significant site related COPCs that have the potential for decreasing the integrity of aquatic organisms at OU No. 4. Pesticides are not only potentially toxic to aquatic life through a direct exposure pathway, but as indicated by their high BCF value, they have a high potential to bioconcentrate pesticides in organisms. Therefore, other fauna that feed upon these organisms will be exposed to pesticides via this indirect exposure pathway. Following is a summary of other findings within OU No. 4.

Based on the potential habitat, and other physical characteristics, the most significant populations of aquatic organisms at the site, including fish, bentho macroinvertebrates, and some terrestrial vertebrates, potentially are in or surrounding Site 41. Aluminum, copper, iron, lead, mercury, silver, and zinc were the only inorganic COPCs detected in the surface water at concentrations that exceeded any of the ARVs. Copper, iron, lead, mercury, silver, and zinc exceeded the ARVs at Site 41; and, lead and aluminum exceeded the ARVs at Site 74.

Lead, silver, zinc, 4,4'-DDD, 4,4'-DDT, 4,4'-DDE, dieldrin, alpha-chlordane, and gamma-chlordane were the only COPCs detected in sediment samples at Site 41 that exceeded the sediment ARVs. There were no COPCs detected at Site 74 that exceeded any sediment ARVs.

### 7.5.2 Terrestrial Endpoints

During the habitat evaluation, no areas of vegetation stress or gross impacts from site contaminants were noted. Habitats surrounding all three sites appeared to be diverse and the community and ecosystem structure appeared to be intact.

The measurement endpoints used to assess the terrestrial environment is decreased integrity of terrestrial organisms. Overall, metals appear to be the most significant site-related COPCs that have the potential for decreasing the integrity of terrestrial organisms at OU No. 4. Other site-specific comments follow.

Based on the soil toxicity data for plants and terrestrial invertebrates (earthworms), beryllium, chromium, copper, iron, lead, manganese, and zinc were detected in concentrations that potentially may decrease the integrity of terrestrial invertebrates and floral species at Site 41.

At Site 74, chromium was detected at concentrations that potentially may decrease the integrity of terrestrial invertebrates and floral species.

Other terrestrial organisms (e.g., rabbits, birds, deer) may be exposed to contaminants in the surface soils and surface water by ingestion. Based on the comparison of the CDI to the TRVs, there is a small potential that terrestrial receptors are being adversely affected.

### 7.5.3 Threatened and Endangered Species

Potential adverse impacts to these threatened or endangered species from contaminants at OU No. 4 appear to be low. There are no areas where protected, threatened, or endangered species have been observed on OU No. 4.

### 7.5.4 Wetlands

Site-specific wetland delineations were not conducted at Sites 41 and 74, although potential wetland areas were noted during the habitat evaluation. Generally, wetlands were not identified on each of the sites, although wetlands were present within a half mile radius of each site. These wetlands are illustrated on the biohabitat maps (Figures 7-1 and 7-2) potential impacts to wetlands are addressed in the surface water and sediment sections.

### 7.5.5 Other Sensitive Environments

There are no known spawning and nursery areas for resident fish species within Sites 41 or 74. Therefore, there is no potential for decreased integrity of fish spawning or nursing at Sites 41 or 74.

## 7.6 Uncertainty Analysis

The procedures used in this evaluation to assess risks to ecological receptors, as in all such assessments, are subject to uncertainties. The following discusses the uncertainty in the ERA.

The chemical sampling program at OU No. 4 consisted of surface water, sediments, soil, and groundwater. The concentrations of chemicals in the surface water will vary with the tides; the concentrations are expected to be lower at higher tides (more dilution) and higher at low tides (less dilution).

The ecological investigation consisted of one sampling effort. The results of this sampling will only provide a "snapshot in time" of the ecological environment. Because the biotic community can have a high amount of natural variability, the "snapshot in time" may not be an accurate representation of actual site conditions.

There also is uncertainty in the use of toxicological data in ecological risk assessments. The surface water and sediment values established by North Carolina and Region IV are set to be protective of a majority of the potential receptors. There will be some species, however, that will not be protected by the values because of their increased sensitivity to the chemicals. Also, the toxicity of chemicals mixtures is not well understood. All the toxicity information used in the ERA for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals.

There is uncertainty in the ecological endpoint comparison. The values used in the ecological endpoint comparison (either the WQS of the SSV) are set to be protective of a majority of the potential receptors. There will be some species, however, that will not be protected by the values because of their increased sensitivity to the chemicals. Also, the toxicity of chemical mixtures is not well understood. All the toxicity information used in the ecological risk assessment for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals. In addition, there were several contaminants that did not have WQS or SSVs. Therefore, potential effects to ecological receptors from these chemicals cannot be determined.

The SSVs were developed using data obtained from freshwater, estuarine and marine environments. Therefore, their applicability for use to evaluate potential effects to aquatic organisms from contaminants in estuarine habitats must be evaluated on a chemical specific basis because of

differences in both the toxicity of individual contaminants to freshwater and saltwater organisms, and the bioavailability of contaminants in the two aquatic systems. In addition, the toxicity of several of the metals (cadmium, chromium, copper, lead, nickel, and zinc) to aquatic organisms increases or decreases based on water hardness. Because water hardness was not available, a default value of 50 mg/L of $CaCO_3$ was used.
Several contaminants in the surface water and sediment exceeded applicable ARVs values. Although the ARVs may have been exceeded in these samples, the potential for them to impact aquatic life may not be significant.

Finally, there is also uncertainty in the chronic daily intake models used to evaluate decreased integrity to terrestrial receptors. Many of the input parameters are based on default values (i.e., ingestion rate) that may or may not adequately represent the actual values of the parameters. In addition, there is uncertainty in the amount that the indicator species will represent other species potentially exposed to COPCs at the site. Finally, terrestrial species will also be exposed to contaminants by ingesting fauna that have accumulated contaminants. This additional exposure route was not evaluated in this ERA because the high uncertainty associated with this exposure route.

## 7.7 Conclusions

Overall, metals and pesticides appear to be the most significant site related COPCs that have the potential to affect the integrity of the aquatic ecosystems at OU No. 4. For the terrestrial ecosystems, metals appear to be the most significant site related COPCs that have the potential to affect terrestrial receptors at OU No. 4.

Potential adverse impacts to threatened or endangered species are low due to the absence of critical habitats or noted observations at the three sites. Biohabitats maps did not indicate a significant impact to ecological resources on or near the three sites.

### 7.7.1 Site 41

Aluminum, copper, iron, lead, mercury, and zinc exceeded surface water ARVs and lead, silver, zinc, 4,4'-DDD, 4,4'-DDT, 4,4'-DDE, dieldrin, alpha-chlordane, and gamma-chlordane exceeded the sediment ARVs. The surface water and sediments with the greatest potential impact to aquatic receptors are associated with the two seeps and their drainage channels to the unnamed tributary to Tank Creek. The surface waters of the unnamed tributary and Tank Creek do not show significant potential for impact to aquatic receptors from COPC concentrations except for aluminum and iron. However, these COPCs lacked an upstream to downstream concentration gradient in the tributary and the creek. The sediments of the unnamed tributary and Tank Creek do not show a significant potential for impact to aquatic receptors from COPC concentrations due to the lack of upstream to downstream concentration gradients that would indicate a source area for COPCs on site.

The seeps and drainage channels to the unnamed tributary do not represent a significant habitat for aquatic receptors. Although the seeps were flowing during various site visits, extended drought conditions could result in more ephermal conditions. While it is recognized that these systems will support some tolerant species, the natural conditions that exist in both the seeps and the drainage channel are not conducive to attainment of a diverse and stable aquatic community. The populations that would occur in both the seeps and the drainage channel at the site would exhibit high temporal and spatial variability in both diversity and densities due to the natural conditions that exist. This

type of natural variability has been recognized as one of the most significant components of the uncertainty associated with ecological risk assessments. Because there is no point of departure (e.g., 1 x $10^{-6}$ for human health carcinogenic risk) for determining when a ecosystem has been impacted by site conditions verses when a ecosystem is exhibiting natural temporal and spatial fluctuations, the high natural variability of ecosystems that exist in drainage channels and seeps makes it difficult to quantify site impacts to the ecological integrity of these systems.

However, the potential for impacts to the integrity of aquatic receptors in the seeps and drainage channels warranted additional investigation of these ecosystems. Subsequently, additional surface water and sediment analysis for metals in the seeps was initiated and were reported and discussed in this version of the report. In addition to total metal analyses, dissolved metal analyses were conducted on surface water samples. It has been established that the dissolved fraction of the sample represents the most bioavailable form of the metal and is a more accurate indication of potential risks. Mercury and aluminum were not detected in the dissolved analysis, and dissolved lead was detected only once at a concentration below the surface water ARV. Based on the additional investigations, these results support the conclusion that the seeps are not adversely impacting the aquatic ecosystems of the unnamed tributary and Tank Creek and potential impacts from sediments are limited to the seeps and drainage channels to the unnamed tributary to Tank Creek.

Comparison of surface soils and soil toxicity studies indicate that beryllium, chromium, copper, iron, lead, manganese, and zinc were detected in concentrations that potentially may decrease the integrity of terrestrial invertebrates and floral species at Site 41. However, based on the comparison of chronic daily intakes and terrestrial reference values, there does not appear to be an impact to terrestrial organisms including rabbits, deer, quail, fox, and raccoon from the site. This analysis included exposure to surface waters of the seeps, unnamed tributary, and Tank Creek, which supports the conclusion that any potential impacts from the seeps are limited to only aquatic receptors in the seeps itself.

### 7.7.2 Site 74

Aluminum and lead exceeded the ARVs in surface water. There were no COPCs detected that exceeded any sediment ARVs. Aluminum was detected at concentrations below both the median and average base-wide concentrations, while lead was detected at concentrations above both the base-wide average and median concentrations, but the quotient ratio was not indicative of a significant potential for impact to surface water aquatic receptors. For surface soils, chromium at the site exceeded soil toxicity reference levels. Based on the comparison of chronic daily intakes and terrestrial reference values, there appears to be a small potential for adverse affect to terrestrial organisms due to manganese for the quail and rabbit. There does not appear to be an impact to terrestrial organisms based on the comparison of chronic daily intakes and terrestrial reference values for the fox and deer receptors.

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# SECTION 7.0 TABLES

**TABLE 7-1**

**LIST OF CONTAMINANTS DETECTED IN THE SURFACE WATER, SEDIMENT, SURFACE SOIL AND BIOTA SAMPLES**
**OPERABLE UNIT NO. 4**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| | Site 41 | | | | Site 74 | | |
|---|---|---|---|---|---|---|---|
| | Surface Water | | Sediment | Surface Soil | Surface Water | Sediment | Surface Soil |
| | Unnamed Tributary and Tank Creek | | Unnamed Tributary and Tank Creek | Unnamed Tributary and Tank Creek | Pesticide Disposal Area | Pesticide Disposal Area | Former Disposal Potential Disposal Former Pest Control Area |
| Analyte | Total | Dissolved | | | | | |
| **Volatiles** | | | | | | | |
| Acetone | | | X | X | | | X |
| Chlorobenzene | X | | | | | | |
| Methylene Chloride | | | X | X | | | X |
| Toluene | | | X | X | | | X |
| Trichloroethene | | | X | | | X | X |
| Styrene | | | | | | | X |
| Xylenes (total) | | | | | | | X |
| **Semivolatiles** | | | | | | | |
| Acenaphthene | | | | X | | | X |
| Anthracene | | | | X | | | |
| Diethyl phthalate | | | | | | | X |
| Di-n-butyl phthalate | | | X | X | | | X |
| 1,4-Dichlorobenzene | | | | X | | | |
| Bis(2-chloroethyl)ether | | | | X | | | X |
| Bis(2-ethylhexyl)phthalate | | | X | X | | | X |
| Benzo(a)anthracene | | | | X | | | |
| Dibenz(a,h)anthracene | | | | X | | | |
| Benzo(a)pyrene | | | X | X | | | X |
| Benzo(b)fluoranthene | | | X | X | | | |
| Benzo(k)fluoranthene | | | X | X | | | |
| Benzo(g,h,i)perylene | | | | X | | | X |
| Indeno(1,2,3-cd)pyrene | | | | X | | | |
| Carbazole | | | | X | | | |
| Chrysene | | | | X | | | |
| Dibenzofuran | | | | X | | | |
| Di-n-octyl phthalate | | | X | X | | | |
| 3,3-Dichlorobenzidine | | | | | | X | |
| Fluoranthene | | | X | X | | | |

**TABLE 7-1 (Continued)**

**LIST OF CONTAMINANTS DETECTED IN THE SURFACE WATER, SEDIMENT, SURFACE SOIL AND BIOTA SAMPLES**
**OPERABLE UNIT NO. 4**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| | Site 41 | | | | Site 74 | | |
|---|---|---|---|---|---|---|---|
| | Surface Water | | Sediment | Surface Soil | Surface Water | Sediment | Surface Soil |
| | Unnamed Tributary and Tank Creek | | Unnamed Tributary and Tank Creek | Unnamed Tributary and Tank Creek | Pesticide Disposal Area | Pesticide Disposal Area | Former Disposal Potential Disposal Former Pest Control Area |
| Analyte | Total | Dissolved | | | | | |
| Fluorene | | | | X | | | |
| 4-Chloro-3-methylphenol | | | | | | | X |
| 2-Methylnaphthalene | | | | X | | | |
| Naphthalene | | | | X | | | |
| Phenanthrene | | | | X | | | |
| Pyrene | | | X | X | | | X |
| **Pesticides** | | | | | | | |
| 4,4-DDE | | | X | X | | X | X |
| 4,4-DDD | | | X | X | | | X |
| 4,4-DDT | X | | X | X | | X | X |
| alpha-Chlordane | | | X | X | | | X |
| gamma-Chlordane | | | X | X | | | X |
| Aldrin | | | | | | | X |
| Dieldrin | | | X | X | | | X |
| Endrin | | | | X | | | X |
| Endrin aldehyde | | | | X | | X | X |
| Endrin ketone | | | X | X | | | |
| Endosulfan II | | | X | X | | X | X |
| Endosulfan sulfate | | | | X | | | |
| alpha-BHC | | | | | | | X |
| beta-BHC | | | | X | | | |
| delta-BHC | | | | X | | | |
| gamma-BHC (Lindane) | X | | | X | | | |
| Heptachlor | X | | | X | | | X |
| Heptachlor epoxide | | | | X | | | X |
| Methoxychlor | | | X | X | | X | X |

**TABLE 7-1 (Continued)**

**LIST OF CONTAMINANTS DETECTED IN THE SURFACE WATER, SEDIMENT, SURFACE SOIL AND BIOTA SAMPLES**
**OPERABLE UNIT NO. 4**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | Site 41 | | | | Site 74 | | |
|---|---|---|---|---|---|---|---|
| | Surface Water | | Sediment | Surface Soil | Surface Water | Sediment | Surface Soil |
| | Unnamed Tributary and Tank Creek | | Unnamed Tributary and Tank Creek | Unnamed Tributary and Tank Creek | Pesticide Disposal Area | Pesticide Disposal Area | Former Disposal Potential Disposal Former Pest Control Area |
| | Total | Dissolved | | | | | |
| **PCBs** | | | | | | | |
| PCB-1242 | | | | X | | | |
| PCB-1248 | | | X | | | | |
| PCB-1254 | | | X | | | | |
| PCB-1260 | | | | X | | | |
| **Ordanance** | | | | | | | |
| 1,3,5-Trinitrobenzene | | | X | | | | |
| 1,3-Dinitrobenzene | | | | X | | | |
| **Chemical Surety** | | | | | | | |
| Thiodiglycol | | | | | | | X |
| Hydroxyacetophone | | | | | | | X |
| **Inorganics** | | | | | | | |
| Aluminum | X | | X | X | X | X | X |
| Antimony | | | | X | | | X |
| Arsenic | X | X | X | X | | | X |
| Barium | X | X | X | X | | X | X |
| Beryllium | | | X | X | | | |
| Cadmium | X | | | X | | | X |
| Calcium | X | X | X | X | X | X | X |
| Chromium | X | | X | X | | X | X |
| Cobalt | X | X | X | X | | | |
| Copper | X | X | X | X | | | X |
| Iron | X | X | X | X | X | X | X |
| Lead | X | X | X | X | X | X | X |
| Magnesium | X | X | X | X | X | X | X |
| Manganese | X | X | X | X | | X | X |
| Mercury | X | | X | X | | | X |
| Nickel | X | | X | X | | | X |
| Potassium | X | X | X | X | X | | X |

**TABLE 7-1 (Continued)**

**LIST OF CONTAMINANTS DETECTED IN THE SURFACE WATER, SEDIMENT, SURFACE SOIL AND BIOTA SAMPLES**
**OPERABLE UNIT NO. 4**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| | Site 41 | | | | Site 74 | | |
|---|---|---|---|---|---|---|---|
| | Surface Water | | Sediment | Surface Soil | Surface Water | Sediment | Surface Soil |
| | Unnamed Tributary and Tank Creek | | Unnamed Tributary and Tank Creek | Unnamed Tributary and Tank Creek | Pesticide Disposal Area | Pesticide Disposal Area | Former Disposal Potential Disposal Former Pest Control Area |
| Analyte | Total | Dissolved | | | | | |
| Selenium | | | X | X | | X | X |
| Silver | | | X | X | | | X |
| Sodium | X | X | X | X | X | | X |
| Thallium | | | X | | | | |
| Vanadium | X | | X | X | | X | X |
| Zinc | X | X | X | X | | X | X |
| Total Cyanide | | | | X | | | X |

**TABLE 7-2**

**PHYSICAL/CHEMICAL CHARACTERISTICS OF THE COPCs**
**OPERABLE UNIT NO. 4**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | BCF | Water Solubility (mg/L) | Organic Carbon Partition Coefficient (mL/g) | Vapor Pressure (mm Hg) | Log Octanol/ Water Coefficient |
|---|---|---|---|---|---|
| **Inorganics** | | | | | |
| Aluminum | ND[1,3] | ND[1,3] | ND[1] | ND[1,3] | ND[1,3,4] |
| Arsenic | 4[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Barium | ND[1,3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Beryllium | 19[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Cadmium | 3,800[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Chromium | 1[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Cobalt | ND[3] | ND[1,3] | ND[1] | 1,300[3] | ND[1,3,4] |
| Copper | 23,000[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Cyanide, total | ND | Miscible | ND | 264.3[3] | 0.66[3] |
| Iron | ND[3] | ND[1,3] | ND[1] | ND[1,3] | ND[1,3,4] |
| Lead | 45[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Manganese | 350,000[3] | ND[1,3] | ND[1] | ND[1,3] | ND[1,3,4] |
| Mercury | 52,175[8] | ND[1,3] | ND[1] | 0.002[3] | ND[1,3,4] |
| Nickel | 8[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Selenium | 5,700[3] | ND[1,2] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Silver | 28[3] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| Vanadium | ND[3] | ND[1,3] | ND[1] | ND[3] | ND[1,3,4] |
| Zinc | 4.4[8] | ND[1,3] | ND[1] | ND[1,2,3] | ND[1,3,4] |
| **VOCs** | | | | | |
| Toluene | 90[5] | 530[5] | 300 | 28 | 2.73 |
| Trichloroethene | 17[3] | 1,100[3] | 126[1] | 69[3] | 2.4[3] |
| **SVOCs** | | | | | |
| Anthracene | 9,200[3] | 0.043[3] | 14,000[1] | ND[1,2,3] | 4.5[3] |
| Benzo(a)anthracene | ND[3] | ND[1,2,3] | 1,380,000[1] | ND[1,2,3] | 5.7[3] |
| Benzo(a)pyrene | 83,000[3] | ND[1,2,3] | 5,500,000[1] | ND[1,2,3] | 6.0[3] |
| Benzo(b)fluoranthene | ND | ND[1,2] | 550,000[1] | ND[2,3] | 6.6[3] |
| Benzo(k)fluoranthene | ND[3] | ND[1,2,3] | 550,000 | ND[1,2,3] | 6.1[1] |
| Benzo(g,h,i)perylene | ND | ND[1,2] | 1,600,000[1] | ND[1,2] | 6.5[1] |
| Chrysene | ND[3] | ND[1,2,3] | 200,000[1] | ND[1,2,3] | 5.7[3] |
| Bis(2-chloroethyl)ether | $1.1 \times 10^{1}$[3] | $1.7 \times 10^{4}$[3] | ND | 1.6[3] | 1.3[3] |
| Fluoranthene | 1,150[1] (L/kg) | 0.206[1] | 38,000[1] | ND[1,2] | 4.9[1] |
| Phenanthrene | 2,630[1] (L/kg) | 1.2[3] | 14,000[1] | ND[1,2,3] | 4.5[1] |
| Pyrene | 69[3] | ND[1,2,3] | 38,000[1] | ND[1,2,3] | 4.88[1] |

**TABLE 7-2 (Continued)**

**PHYSICAL/CHEMICAL CHARACTERISTICS OF THE COPCs**
**OPERABLE UNIT NO. 4**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | BCF | Water Solubility (mg/L) | Organic Carbon Partition Coefficient (mL/g) | Vapor Pressure (mm Hg) | Log Octanol/ Water Coefficient |
|---|---|---|---|---|---|
| **Pesticides/PCBs** | | | | | |
| Chlordane, total | 11,500[6] | 0.056[3] | 140,000[1] | ND[1,2,3] | 5.5[6] |
| Dieldrin | 6,800[3] | 0.2[3] | 1,700[1] | ND[1,2,3] | 4.3[6] |
| Methyoxychlor | ND | ND | ND | ND | ND |
| Endrin Aldehyde** | 7,000[7] | $2.5 \times 10^{-7}$ | ND[1,3,4,5,6,7] | $3.0 \times 10^{-6}$ | 4.56[7] |
| 4,4-DDE | 180,000[3] | 0.12[3] | 4,400,000[1] | ND[1,2,3] | 5.7[3] |
| 4,4-DDD | ND[3] | 0.09[3] | 770,000[1] | ND[1,2,3] | 6.0[3] |
| 4,4-DDT | 31,477[7] | 0.025[3] | 243,000[1] | ND[1,2,3] | 6.4[3] |
| Endosulfan II* | ND | 0.51 | 2,042 | $1 \times 10^{-5}$ | 3.83 |
| Heptachlor | ND | 0.18 | ND | $4 \times 10^{-4}$ | 5.27 |
| Heptachlor Epoxide | ND | 0.2 | ND | $1.95 \times 10^{-5}$ | 5.40 |

(1) USEPA, 1986.
(2) Negligible (less than 0.1).
(3) SCDM, 1991.
(4) USEPA, 1985.
(5) Howard, 1990.
(6) Howard, 1991.
(7) USEPA, 1993a.

ND = No data
BCF = Bioconcentration Factor
VOCs = Volatile Organic Compounds
SVOCs = Semivolatile Organic Compounds
* Values for Endosulfan
** Values for Endrin

**TABLE 7-3**

**SUMMARY OF HABITAT TYPES**
**SITES 41, 69, AND 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Area Designation | Habitat Type | Dominant Vegetation | Secondary Vegetation | Fauna Present |
|---|---|---|---|---|
| 41A | Young Pine Forest | Loblolly Pine | Sweetgum, red cedar, wax myrtle, vines (poison ivy, trumpet creeper, virginia creeper, bullbriar) grasses, bush clover, ebony spleenwort, sedges, rushes, corn salad | Mourning dove, resident and migratory songbirds including neotropical migrants, black racer, southern toad, frog and toad tadpoles |
| 41B | Freshwater Wetland | No vegetation clearly dominant vegetation types (trees, shrubs, forbs) varied in dominance depending on area (saplings, grasses, lichens) | Loblolly pine, longleaf pine, red cedar, sweetgum, wax myrtle, holly, blueberry, lichens/mosses, round-leaved sundew, horned bladderwort, rock spikemoss, broom sedge, cattail, dwarf iris, grasses, sedges, rushes | Mourning dove, resident and migratory songbirds including neotropical migrants, fox, white-tailed deer, box turtles |
| 41C | Loblolly Pine/ Hardwood Forest | Trees are dominant but no species clearly dominant | Loblolly pine, tulip, red maple, beech, sweetgum oak (white, water), hickory, red cedar, wax myrtle, dogwood, holly, umbrella magnolia vines (Japanese honeysuckle, poison ivy, greenbriars, Virginia creeper, grapes), ferns (marsh, royal, sensitive, ebony spleenwort), grasses, cane | Mourning dove, resident and migratory songbirds including neotropical migrants, white-tailed deer, raccoon, squirrel, anole |
| 41D | Wooded Wetland (Swamp) | Trees dominant but no species clearly dominant. Species include tulip, black gum, red maple, elm, swamp chestnut oak | Ironwood, Leucothoe axillaris, lizards tail, cane, grasses, sedges, water pennywort, violet, ferns (marsh, sensitive) | Mourning dove, resident and migratory songbirds including neotropical migrants, white-tailed deer, raccoon, black racer, crayfish |

**TABLE 7-3 (Continued)**

**SUMMARY OF HABITAT TYPES**
**SITES 41, 69, AND 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Area Designation | Habitat Type | Dominant Vegetation | Secondary Vegetation | Fauna Present |
|---|---|---|---|---|
| 41E | Hardwood Forest | Tress dominant but no species clearly dominant. Species include tulip, red maple, sweetgum, beech, white oak, mockernut hickory | Dogwood, holly, partridgeberry, wild ginger | Mourning dove, resident and migratory songbirds including neotropical migrants, white-tailed deer |
| 74 | Pine Forest with Shrub Understory | Loblolly pine, longleaf pine | Scattered deciduous trees, wax myrtle, fetterbush, staggerbush, sweet pepperbush blueberries (slender, coastal highbush, Elliott's) greenbriars, broom sedge and other grasses, ferns (cinnamon, marsh, royal, sensitive, braken) | White-tailed deer, rabbit, small rodents, mourning dove, whippoorwill, resident and migratory songbirds |

**TABLE 7-4**

**OPERABLE UNIT NO. 4**
**PROTECTED SPECIES WITHIN MCB CAMP LEJEUNE**
**REMEDIAL INVESTIGATION CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Species | Protected Classification |
|---|---|
| American alligator (Alligator mississippienis) [2] | T(f), T(s) |
| Bachmans sparrow (Aimophilia aestivalis)[1] | SC |
| Black skimmer (Rhynochops niger)[1] | SC |
| Green (Atlantic) turtle (Chelonia m. mydas) [2] | T(f), T(s) |
| Loggerhead turtle (Caretta caretta) [2] | T(f), T(s) |
| Peregrine falcon (*)[1] | (*) |
| Piping plover (Charadrius melodus)[1] | T(f), T(s) |
| Red-cockaded woodpecker (Picoides borealis)[3] | E(f), E(s) |
| Rough-leaf loosestrife (Lysimachia asperulifolia)[4] | E(f), E(s) |

Legend: SC= State Special Concern
E(f) = Federal Endangered
E(s) = State Endangered
T(f) = Federal Threatened
T(s) = State Threatened

* The observer did not differentiate between the American eastern peregrine falcon [E(f), E(s)] or the Arctic peregrine falcon [T(f), T(s)].

Source: [1] Fussell, 1991
[2] USMC, 1991
[3] Walters, 1991
[4] LeBlond, 1991

**TABLE 7-5**

**SITE 41 - UNNAMED TRIBUTARY AND TANK CREEK**
**FREQUENCY AND RANGE OF DETECTION COMPARED TO FRESHWATER NORTH CAROLINA WQSs, AND USEPA WQSVs**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | Surface Water | | | | | Contaminant Frequency/Range | | No. of Positive Detects Above NCWQS | No. of Positive Detects Above Screening Values | | No. of Positive Detects Above USEPA AWQC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Carolina (NCWQS) | Region IV Screening Values (USEPA WQSVs) | | USEPA Water Quality Criteria (USEPA AWQC) | | No. of Positive Detects/No. of Samples | Range of Positive Detections | | | | | |
| | | Acute | Chronic | Acute | Chronic | | | | Acute | Chronic | Acute | Chronic |
| **Inorganics (µg/L)** | | | | | | | | | | | | |
| Aluminum | NE | NE | NE | 750 | 87 | 24/28 | 76.6 - 17,800 | NA | NA | NA | 6/28 | 25/28 |
| Arsenic | 50 | 360 | 190 | 360 | 190 | 9/28 | 2.2 - 30.2 | 0/9 | 0/9 | 0/9 | 0/9 | 0/9 |
| Barium | NE | NE | NE | NE | NE | 28/28 | 17.9 - 442 | NA | NA | NA | NA | NA |
| Cobalt | NE | NE | NE | NE | NE | 3/28 | 19.6 - 43.9 | NA | NA | NA | NA | NA |
| Copper | 7 | 18* | 12* | 18* | 12* | 4/28 | 13.3 - 41.2 | 4/4 | 3/4 | 4/4 | 3/4 | 4/4 |
| Iron | 1000 | NE | NE | NE | 1000 | 28/28 | 469 - 278,000 | 19/28 | NA | NA | NA | 19/28 |
| Lead | 25 | 82* | 3.2* | 82* | 3.2* | 19/28 | 1.13 - 36.8 | 3/19 | 0/19 | 11/9 | 0/19 | 11/19 |
| Manganese | NE | NE | NE | NE | NE | 28/28 | 12.3 - 1,700 | NA | NA | NA | NA | NA |
| Mercury | 0.012 | 2.4 | 0.012 | 2.4 | 0.012 | 9/28 | 0.101 - 0.56 | 9/9 | 0/9 | 9/9 | 0/9 | 9/9 |
| Vanadium | NE | NE | NE | NE | NE | 3/28 | 35.4 - 51.5 | NA | NA | NA | NA | NA |
| Zinc | 50 | 120* | 110* | 120* | 110* | 23/28 | 16.3 - 235 | 6/23 | 3/23 | 3/23 | 3/23 | 3/23 |

* = Criteria are hardness dependent (calculated using a hardness of 100 mg/L CaCO3)
NE = Not established
NA = Not applicable

**TABLE 7-6**

**SITE 74 - PESTICIDE DISPOSAL AREA**
**FREQUENCY AND RANGE OF DETECTION COMPARED TO FRESHWATER NORTH CAROLINA WQSs, USEPA WQSVs, AND USEPA AWQC**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | Surface Water ARARs | | | | | Contaminant Frequency/Range | | Comparison to ARARs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Carolina (NCWQS) | Region IV Screening Values (USEPA WQSVs) | | USEPA Water Quality Criteria (USEPA AWQC) | | No. of Positive Detects/ No. of Samples | Range of Positive Detections | No. of Positive Detects Above NCWQS | No. of Positive Detects Above Screening Values | | No. of Positive Detects Above USEPA AWQC | |
| | | Acute | Chronic | Acute | Chronic | | | | Acute | Chronic | Acute | Chronic |
| **Inorganics (µg/L)** | | | | | | | | | | | | |
| Aluminum | NE | NE | NE | 750 | 87 | 3/3 | 12J - 492J | NA | NA | NA | 0/3 | 3/3 |
| Iron | 1000 | NE | NE | NE | 1,000 | 3/3 | 138 - 274 | 0/3 | NA | NA | NA | 0/3 |
| Lead | 25 | 82[1] | 3.2[1] | 82[1] | 3.2[1] | 3/3 | 1.62J - 6.04J | 0/3 | 0/3 | 2/3 | 0/3 | 2/3 |

NE = Not Established
NA = Not Applicable
[1] Criteria are hardness dependent

**TABLE 7-7**

**SITE 41 - UNNAMED TRIBUTARY AND TANK CREEK**
**FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING VALUES**
**REMEDIAL INVESTIGATION CTO - 0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | Sediment Screening Values (SSVs) | | Contaminant Frequency/Range | | Comparison to Screening Values | |
|---|---|---|---|---|---|---|
| | ER-L | ER-M | No. of Positive Detects/No. of Samples | Range of Positive Detections | No. of Positive Detects Above ER-L | No. of Positive Detects Above ER-M |
| **Inorganics (mg/kg)** | | | | | | |
| Aluminum | NE | NE | 42/42 | 276 - 18,800 | NA | NA |
| Arsenic | 33 | 85 | 13/42 | 0.617 - 9.3 | 0/13 | 0/13 |
| Barium | NE | NE | 36/42 | 1.4 - 161 | NA | NA |
| Beryllium | NE | NE | 5/42 | 0.235 - 1.02 | NA | NA |
| Chromium | 80 | 145 | 16/42 | 2.3 - 16.5 | 0/16 | 0/16 |
| Copper | 70 | 390 | 4/42 | 6.3 - 19.9 | 0/4 | 0/4 |
| Iron | NE | NE | 42/42 | 262 - 104,000 | NA | NA |
| Lead | 35 | 110 | 42/42 | 1.1 - 59.4 | 2/42 | 0/42 |
| Manganese | NE | NE | 37/42 | 1.3 - 306 | NA | NA |
| Nickel | 30 | 50 | 6/42 | 3.79 - 6.12 | 0/6 | 0/6 |
| Selenium | NE | NE | 4/42 | 0.629 - 08.862 | NA | NA |
| Silver | 1 | 2.2 | 3/42 | 1.14 - 29.7 | 3/3 | 1/3 |
| Vanadium | NE | NE | 12/42 | 3.5 - 3.0 | NA | NA |
| Zinc | 120 | 270 | 25/42 | 5.5 - 155 | 1/25 | 0/25 |

**TABLE 7-7 (Continued)**

**SITE 41 - UNNAMED TRIBUTARY AND TANK CREEK**
**FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING VALUES**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | Sediment Screening Values (SSVs) | | Contaminant Frequency/Range | | Comparison to Screening Values | |
|---|---|---|---|---|---|---|
| | ER-L | ER-M | No. of Positive Detects/No. of Samples | Range of Positive Detections | No. of Positive Detects Above ER-L | No. of Positive Detects Above ER-M |
| **Pesticides/PCBs (µg/k)** | | | | | | |
| Endosulfan II | NE | NE | 9/41 | 0.64 - 8.22 | NA | NA |
| 4,4-DDD | 2 | 20 | 22/41 | 0.38 - 73.9 | 17/22 | 5/22 |
| 4,4-DDT | 1 | 7 | 17/41 | 0.36 - 210 | 14/17 | 3/17 |
| 4,4-DDE | 2 | 15 | 19/41 | 0.53 - 31.3 | 15/19 | 4/19 |
| Dieldrin | 0.02 | 8 | 10/41 | 0.46 - 6.39 | 10/10 | 0/10 |
| Methoxychlor | NE | NE | 6/41 | 0.91 - 21.7 | NA | NA |
| alpha-Chlordane | 0.5* | 6* | 13/41 | 0.34 - 3.72 | 11/13 | 0/13 |
| gamma-Chlordane | 0.5* | 6* | 11/41 | 0.4 - 6.35 | 9/11 | 9/11 |

NE = Not Established
NA = Not Applicable
(1) Values for Total PCBs.

**TABLE 7-8**

**SITE 74 - PESTICIDE DISPOSAL AREA**
**FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING VALUES**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Analyte | Sediment Screening Values (SSVs) | | Contaminant Frequency/Range | | Comparison to Screening Values | |
|---|---|---|---|---|---|---|
| | ER-L | ER-M | No. of Positive Detects/No. of Samples | Range of Positive Detections | No. of Positive Detects Above ER-L | No. of Positive Detects Above ER-M |
| **Inorganics (mg/kg)** | | | | | | |
| Aluminum | NE | NE | 3/3 | 584-3,320 | NA | NA |
| Barium | NE | NE | 2/3 | 5.73-13 | NA | NA |
| Chromium | 80 | 145 | 2/3 | 1.8-3.13 | 0/2 | 0/2 |
| Iron | NE | NE | 3/3 | 199-1,530 | NA | NA |
| Lead | 35 | 110 | 3/3 | 2.67J-6.06J | 0/3 | 0/3 |
| Manganese | NE | NE | 3/3 | 2.76-5.27 | NA | NA |
| **Pesticides (µg/kg)** | | | | | | |
| Endosulfan II | NE | NE | 2/3 | 0.63J-0.8JP | NA | NA |
| 4,4-DDE | 2 | 15 | 2/3 | 0.9J-1.85J | 0/2 | 0/2 |
| 4,4-DDT | 1 | 7 | 1/3 | 0.82NJ | 0/1 | 0/1 |

NE = Not Established
NA = Not Applicable

**TABLE 7-9**

**TERRESTRIAL REFERENCE VALUES AND SOIL TO PLANT TRANSFER COEFFICIENTS**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant of Concern | Soil to Plant Transfer Coefficient (Bv) | Soil-to-Plant Coefficient (Br)* | Terrestrial Reference Value (TRV) mg/kg/day |
|---|---|---|---|
| Phenanthrene | 0.097 (1,2) | 0.097 | 150 (7)+++ |
| Anthracene | 0.097 (1,2) | 0.097 | 150 (7)+++ |
| Fluoranthene | 0.057 (1,2) | 0.057 | 125 (8) |
| Pyrene | 0.059 (1,2) | 0.059 | 75 (8) |
| Benzo(a)anthracene | 0.020 (1,2) | 0.020 | 150 (7)+++ |
| Chrysene | 0.020 (1,2) | 0.020 | 150 (7)+++ |
| Benzo(b)fluoranthene | 0.006 (1,2) | 0.006 | 150 (7)+++ |
| Benzo(k)fluoranthene | 0.012 (1,2) | 0.012 | 150 (7)+++ |
| Benzo(a)pryene | 0.013 (1,2) | 0.013 | 150 (7)+++ |
| Benzo(g,h,i)perylene | 0.007 (1,2) | 0.007 | 150 (7)+++ |
| Bis(2-chloroethyl)ether | 6.86 (1,3) | 6.86 | NA |
| Trichloroethene | 1.58 (1,4) | 1.58 | 750 (9) |
| Toluene | 1.02 (1,2) | 1.02 | 223 (10) |
| Dieldrin | 0.126 (1,4) | 0.126 | 0.005 (10) |
| 4,4-DDE | 0.019 (1,4) | 0.019 | 0.05 (10) |
| 4,4-DDD | 0.013 (1,4) | 0.013 | 0.05 (10) |
| 4,4-DDT | 0.008 (1,4) | 0.008 | 0.05 (10) |
| Chlordane, alpha | 0.026 (1,4) | 0.026 | 0.055 (10) |
| Chlordane, gamma | 0.026 (1,4) | 0.026 | 0.055 (10) |
| Heptachlor | 0.035 (1,3) | 0.035 | 0.15 (10) |
| Heptachlor Epoxide | 0.029 (1,3) | 0.029 | 0.15 (10)++++ |
| Endosulfan II | 0.237 +(1,5) | 0.237 | 0.15 (8)+ |
| gamma-BHC | 0.331 (1,5) | 0.331 | 0.33 (8) |
| Endrin aldehyde ++ | 0.0896++(1,3) | 0.090 | 0.065 (10)++ |
| Aluminum | 0.004 (6) | 0.007 (6) | NA |
| Arsenic | 0.040 (6) | 0.006 (6) | 16 (11) |
| Barium | 0.150 (6) | 0.015 (6) | 30 (10) |
| Chromium | 0.008 (6) | 0.005 (6) | 2.7 (12) |
| Cobalt | NA | NA | NA |
| Copper | 0.400 (6) | 0.250 (6) | 300 (10) |
| Iron | 0.004 (6) | 0.001 (6) | NA |

**TABLE 7-9 (Continued)**

**TERRESTRIAL REFERENCE VALUES AND SOIL TO PLANT TRANSFER COEFFICIENTS**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant of Concern | Soil to Plant Transfer Coefficient (Bv) | Soil-to-Plant Coefficient (Br)* | Terrestrial Reference Value (TRV) mg/kg/day |
|---|---|---|---|
| Lead | 0.045 (6) | 0.009 (6) | 27.4 (10) |
| Manganese | 0.250 (6) | 0.050 (6) | 0.14 (13) |
| Mercury | 0.900 (6) | 0.200 (6) | 7.4 (14) |
| Nickel | 0.060 (6) | 0.060 (6) | 5 (10) |
| Selenium | 0.025 (6) | 0.853 (6) | 0.025 (8) |
| Vanadium | 0.006 (6) | 0.003 (6) | 5 (8) |
| Zinc | 1.500 (6) | 0.900 (6) | 38 (15) |
| Cyanide, total | NA | NA | 10.8 (10) |

NA - Information not available
* - Br is assumed to be the same as Bv for organics
+ Value is for Endosulfan
++ Value is for Endrin
+++ Value is for total PAHs
++++ Value is for Heptachlor

(1) Travis, 1988
(2) Montgomery, 1990
(3) SCDM, 1991
(4) USEPA, 1986
(5) Howard, 1991
(6) Baes, 1984
(7) ATSDR, 1990
(8) HEAST, 1993
(9) ATSDR, 1991
(10) IRIS, 1993
(11) USDH, 1992
(12) USDH, 1991
(13) IRIS, 1990
(14) ATSDR, 1988
(15) ATSDR, 1989

**TABLE 7-10**

**SURFACE WATER QUOTIENT INDEX FOR SITES 41 AND 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Parameter | Sample Number | Sample Concentration ($\mu g/L$)[3] | North Carolina (NCWQS)[1] Quotient Ratio | Region IV Screening Values (USEPA WQSV)[2] Quotient Ratio | | USEPA Ambient Water Quality Criteria (USEPA AWQC) Quotient Ratio | |
|---|---|---|---|---|---|---|---|
| | | | | Acute | Chronic | Acute | Chronic |
| **Site 41 - Tank Creek and Unnamed Tributary** | | | | | | | |
| Aluminum | | | | | | | |
| | 41-TC-SW06 | 390 | NA | NA | NA | 0.52 | 4.5 |
| | 41-TC-SW07 | 395 | NA | NA | NA | 0.53 | 4.5 |
| | 41-TC-SW08 | 411 | NA | NA | NA | 0.55 | 4.7 |
| | 41-TC-SW09 | 397 | NA | NA | NA | 0.53 | 4.6 |
| | 41-NE-SW05 | 178 | NA | NA | NA | 0.24 | 2.0 |
| | 41-UN-SW01 | 447 | NA | NA | NA | 0.60 | 5.7 |
| | 41-UN-SW02 | 303 | NA | NA | NA | 0.40 | 3.5 |
| | 41-UN-SW03 | 437 | NA | NA | NA | 0.58 | 5.0 |
| | 41-UN-SW04 | 442 | NA | NA | NA | 0.59 | 5.1 |
| | 41-UN-SW10 | 460 | NA | NA | NA | 0.61 | 5.3 |
| | 41-UN-SW11 | 3,380 | NA | NA | NA | 4.5 | 388.5 |
| | 41-UN-SW12 | 139 | NA | NA | NA | 0.19 | 1.6 |
| | 41-UN-SW13 | 3,390 | NA | NA | NA | 4.5 | 39.0 |
| | 41-UN-SW14 | 139 | NA | NA | NA | 0.19 | 1.6 |
| | 41-UN-SW15 | 260 | NA | NA | NA | 0.35 | 3.0 |
| | 41-UN-SW16 | 183 | NA | NA | NA | 0.24 | 2.1 |
| | 41-UN-SW17 | 988 | NA | NA | NA | 1.3 | 11.4 |
| | 41-UN-SW18 | 356 | NA | NA | NA | 0.47 | 4.1 |
| | 41-UN-SW19 | 245 | NA | NA | NA | 0.33 | 2.8 |
| | 41-UN-SW20 | 110 | NA | NA | NA | 0.15 | 1.3 |
| | 41-UN-SW23 | 11,000 | NA | NA | NA | 14.7 | 126.4 |
| | 41-UN-SW24 | 17,800 | NA | NA | NA | 23.7 | 204.6 |

**TABLE 7-10 (Continued)**

**SURFACE WATER QUOTIENT INDEX FOR SITES 41 AND 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Parameter | Sample Number | Sample Concentration ($\mu g/L$)[3] | North Carolina (NCWQS)[1] Quotient Ratio | Region IV Screening Values (USEPA WQSV)[2] Quotient Ratio | | USEPA Ambient Water Quality Criteria (USEPA AWQC) Quotient Ratio | |
|---|---|---|---|---|---|---|---|
| | | | | Acute | Chronic | Acute | Chronic |
| Aluminum (Continued) | 41-UN-SW25 | 7,060 | NA | NA | NA | 9.4 | 81.1 |
| | 41-UN-SW26 | 102 | NA | NA | NA | 0.14 | 1.2 |
| | 41-UN-SW28 | 585 | NA | NA | NA | 0.78 | 6.7 |
| Copper | 41-UN-SW23 | 34.1 | 4.9 | 1.9 | 2.8 | 1.9 | 2.8 |
| | 41-UN-SW24 | 41.2 | 5.9 | 2.3 | 3.4 | 2.3 | 3.4 |
| | 41-UN-SW25 | 20.1 | 2.9 | 1.1 | 1.7 | 1.1 | 1.7 |
| | 41-UN-SW26 | 13.3 | 1.9 | 0.74 | 1.1 | 0.74 | 1.1 |
| Iron | | | | | | | |
| | 41-TC-SW01 | 1,300 | 1.3 | NA | NA | NA | 1.3 |
| | 41-TC-SW06 | 1,460 | 1.5 | NA | NA | NA | 1.5 |
| | 41-TC-SW07 | 1,540 | 1.5 | NA | NA | NA | 1.5 |
| | 41-TC-SW08 | 1,490 | 1.5 | NA | NA | NA | 1.5 |
| | 41-TC-SW09 | 1,510 | 1.5 | NA | NA | NA | 1.5 |
| | 41-TC-SW011 | 2,690 | 2.7 | NA | NA | NA | 2.7 |
| | 41-TC-SW012 | 6,260 | 6.3 | NA | NA | NA | 6.3 |
| | 41-TC-SW013 | 14,100 | 14.1 | NA | NA | NA | 14.1 |
| | 41-TC-SW014 | 2,810 | 2.8 | NA | NA | NA | 2.8 |
| | 41-UN-SW15 | 39,600 | 39.6 | NA | NA | NA | 39.6 |
| | 41-UN-SW16 | 33,400 | 33.4 | NA | NA | NA | 33.4 |
| | 41-UN-SW17 | 17,600 | 17.6 | NA | NA | NA | 17.6 |
| | 41-UN-SW18 | 10,600 | 10.6 | NA | NA | NA | 10.6 |
| | 41-UN-SW22 | 15,700 | 15.7 | NA | NA | NA | 15.7 |
| | 41-UN-SW23 | 245,000 | 245.0 | NA | NA | NA | 245.0 |
| | 41-UN-SW24 | 278,000 | 278.0 | NA | NA | NA | 278.0 |

**TABLE 7-10 (Continued)**

**SURFACE WATER QUOTIENT INDEX FOR SITES 41 AND 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Parameter | Sample Number | Sample Concentration ($\mu$g/L)[3] | North Carolina (NCWQS)[1] Quotient Ratio | Region IV Screening Values (USEPA WQSV)[2] Quotient Ratio | | USEPA Ambient Water Quality Criteria (USEPA AWQC) Quotient Ratio | |
|---|---|---|---|---|---|---|---|
| | | | | Acute | Chronic | Acute | Chronic |
| Iron (Continued) | 41-UN-SW25 | 238,000 | 238.0 | NA | NA | NA | 238.0 |
| | 41-UN-SW27 | 1,340 | 1.3 | NA | NA | NA | 1.3 |
| | 41-UN-SW28 | 2,940 | 2.9 | NA | NA | NA | 2.9 |
| Lead | 41-TC-SW011 | 8.1 | 0.32 | 0.1 | 2.6 | 0.1 | 2.6 |
| | 41-TC-SW013 | 12.1 | 0.48 | 0.15 | 3.8 | 0.15 | 3.8 |
| | 41-UN-SW16 | 7.7 | 0.31 | 0.09 | 2.4 | 0.09 | 2.4 |
| | 41-UN-SW17 | 3.6 | 0.14 | 0.04 | 1.1 | 0.04 | 1.1 |
| | 41-UN-SW18 | 4.3 | 0.17 | 0.05 | 1.3 | 0.05 | 1.3 |
| | 41-UN-SW23 | 36.2 | 1.4 | 0.44 | 11.3 | 0.44 | 11.3 |
| | 41-UN-SW24 | 36 | 1.4 | 0.44 | 11.3 | 0.44 | 11.3 |
| | 41-UN-SW25 | 36.8 | 1.5 | 0.45 | 11.5 | 0.45 | 11.5 |
| | 41-UN-SW26 | 7.2 | 0.29 | 0.09 | 2.3 | 0.09 | 2.3 |
| | 41-UN-SW27 | 17 | 0.68 | 0.21 | 5.3 | 0.21 | 5.3 |
| | 41-UN-SW28 | 4.8 | 0.19 | 0.06 | 1.5 | 0.06 | 1.5 |
| Mercury | 41-TC-SW013 | 0.101 | 8.4 | 0.04 | 8.4 | 0.04 | 8.4 |
| | 41-UN-SW15 | 0.28 | 23.3 | 0.12 | 23.3 | 0.12 | 23.3 |
| | 41-UN-SW17 | 0.36 | 30.0 | 0.15 | 30.0 | 0.15 | 30.0 |
| | 41-UN-SW18 | 0.28 | 23.3 | 0.12 | 23.3 | 0.12 | 23.3 |
| | 41-UN-SW19 | 0.21 | 17.5 | 0.09 | 17.5 | 0.09 | 17.5 |
| | 41-UN-SW23 | 0.56 | 46.7 | 0.23 | 46.7 | 0.23 | 46.7 |
| | 41-UN-SW24 | 0.46 | 38.3 | 0.19 | 38.3 | 0.19 | 38.3 |
| | 41-UN-SW25 | 0.26 | 21.7 | 0.11 | 21.7 | 0.11 | 21.7 |
| | 41-UN-SW26 | 0.23 | 19.2 | 0.10 | 19.2 | 0.10 | 19.2 |

**TABLE 7-10 (Continued)**

**SURFACE WATER QUOTIENT INDEX FOR SITES 41 AND 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Parameter | Sample Number | Sample Concentration ($\mu g/L$)[3] | North Carolina (NCWQS)[1] Quotient Ratio | Region IV Screening Values (USEPA WQSV)[2] Quotient Ratio | | USEPA Ambient Water Quality Criteria (USEPA AWQC) Quotient Ratio | |
|---|---|---|---|---|---|---|---|
| | | | | Acute | Chronic | Acute | Chronic |
| Zinc | 41-UN-SW15 | 59.2 | 1.2 | 0.49 | 0.54 | 0.49 | 0.54 |
| | 41-UN-SW16 | 68.7 | 1.4 | 0.57 | 0.62 | 0.57 | 0.62 |
| | 41-UN-SW17 | 80.7 | 1.6 | 0.67 | 0.73 | 0.67 | 0.73 |
| | 41-UN-SW23 | 231 | 4.6 | 1.9 | 2.1 | 1.9 | 2.1 |
| | 41-UN-SW24 | 235 | 4.7 | 2.0 | 2.1 | 2.0 | 2.1 |
| | 41-UN-SW25 | 133 | 2.7 | 1.1 | 1.2 | 1.1 | 1.2 |
| **Site 74** | | | | | | | |
| Aluminum | 74-PDA-SW01 | 492 | NA | NA | NA | 0.66 | 5.7 |
| | 74-PDA-SW02 | 309 | NA | NA | NA | 0.41 | 3.6 |
| | 74-PDA-SW03 | 127 | NA | NA | NA | 0.17 | 1.6 |
| Lead | 74-PDA-SW01 | 5.84 | 0.23 | 0.07 | 1.8 | 0.07 | 1.8 |
| | 74-PDA-SW02 | 6.04 | 0.24 | 0.07 | 1.9 | 0.07 | 1.9 |

(1) NCWQS = North Carolina Water Quality Standards
(2) USEPA WQSV = U.S. Environmental Protection Agency Water Quality Screening Values
(3) µg/L = micrograms per liter
NA = Not Available
NOTE: Shaded areas are for Quotient Ratios that exceed one.

**TABLE 7-11**

**SEDIMENT SCREENING VALUES QUOTIENT INDEX FOR SITE 41**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Parameter | Sample Number | Sample Concentration ($\mu$g/kg)[2] | SSV[1] QUOTIENT RATIO | |
|---|---|---|---|---|
| | | | ER-L[3] | ER-M[4] |
| **SITE 41 - Tank Creek and Unnamed Tributary** | | | | |
| Lead | 41-UN-SD13-06 | 59,400 | 1.7 | 0.5 |
| | 41-UN-SD13-612 | 58,900 | 1.7 | 0.5 |
| Silver | 41-UN-SD04-612 | 1,140 | 1.1 | 0.5 |
| | 41-UN-SD11-612 | 1,200 | 1.2 | 0.5 |
| | 41-UN-SD13-06 | 29,700 | 29.7 | 13.5 |
| Zinc | 41-UN-SD25 | 155 | 1.3 | 0.57 |
| 4,4-DDD | 41-UN-SD01-06 | 2.77 | 1.4 | 0.14 |
| | 41-UN-SD01-612 | 12.7 | 6.4 | 0.64 |
| | 41-UN-SD03-06 | 3.73 | 1.9 | 0.19 |
| | 41-UN-SD03-612 | 15.3 | 7.7 | 0.77 |
| | 41-UN-SD04-06 | 3.95 | 2 | 0.19 |
| | 41-TC-SD06-612 | 12.6 | 6.3 | 0.63 |
| | 41-TC-SD09-06 | 63.3 | 31.7 | 3.1 |
| | 41-UN-SD10-06 | 23.1 | 11.6 | 1.16 |
| | 41-UN-SD10-612 | 73.9 | 37 | 3.7 |
| | 41-UN-SD13-06 | 7.69 | 3.8 | 0.38 |
| | 41-UN-SD13-612 | 10.5 | 5.3 | 0.53 |
| 4,4-DDD | 41-UN-SD14-06 | 5.9 | 3 | 0.3 |
| | 41-UN-SD14-612 | 6.68 | 3.34 | 0.33 |
| | 41-UN-SD20 | 27 | 13.5 | 1.35 |
| | 41-UN-SD23 | 17 | 8.5 | 0.85 |
| | 41-UN-SD26 | 4.2 | 2.1 | 0.21 |
| | 41-UN-SD28 | 42 | 21 | 2.1 |

**TABLE 7-11 (Continued)**

**SCREENING VALUES QUOTIENT INDEX FOR SITE 41**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Parameter | Sample Number | Sample Concentration ($\mu$g/kg)[2] | SSV[1] QUOTIENT RATIO | |
|---|---|---|---|---|
| | | | ER-L[3] | ER-M[4] |
| 4,4-DDT | 41-UN-SD02-06 | 1.36 | 1.4 | 0.19 |
| | 41-UN-SD02-612 | 2.58 | 2.6 | 0.37 |
| | 41-UN-SD03-06 | 1.26 | 1.3 | 0.18 |
| | 41-UN-SD03-612 | 1.25 | 1.3 | 0.18 |
| | 41-TC-SD06-06 | 2 | 2 | 0.29 |
| | 41-TC-SD06-612 | 34.8 | 34.8 | 5 |
| | 41-UN-SD10-06 | 4.51 | 4.5 | 0.64 |
| | 41-UN-SD10-612 | 5.96 | 6 | 0.85 |
| | 41-UN-SD13-06 | 4.78 | 4.8 | 0.68 |
| | 41-UN-SD13-612 | 9.64 | 9.6 | 1.4 |
| | 41-UN-SD14-06 | 2.29 | 2.3 | 0.33 |
| | 41-UN-SD14-612 | 1.58 | 1.6 | 0.23 |
| | 41-UN-SD20 | 210 | 210 | 30 |
| | 41-UN-SD26 | 5.8 | 5.8 | 0.83 |
| 4,4-DDE | 41-UN-SD01-06 | 4.66 | 2.3 | 0.31 |
| | 41-UN-SD01-612 | 4.9 | 2.5 | 0.33 |
| | 41-UN-SD03-06 | 3.05 | 1.5 | 0.2 |
| | 41-UN-SD03-612 | 3.98 | 2 | 0.27 |
| | 41-UN-SD04-06 | 2.07 | 1.03 | 0.14 |
| | 41-UN-SD10-06 | 29 | 14.5 | 1.93 |
| | 41-UN-SD10-612 | 31.3 | 15.7 | 2.09 |
| | 41-UN-SD13-06 | 14.3 | 7.2 | 0.95 |
| | 41-UN-SD13-612 | 14.9 | 7.5 | 0.99 |
| | 41-UN-SD14-06 | 4.04 | 2.02 | 0.27 |
| | 41-UN-SD14-612 | 2.91 | 1.46 | 0.19 |
| | 41-TC-SD09-06 | 11.2 | 5.6 | 0.75 |
| | 41-UN-SD20 | 18 | 9 | 1.2 |
| | 41-UN-SD25 | 19 | 9.5 | 1.3 |
| | 41-UN-SD28 | 7.8 | 3.9 | 0.52 |

**TABLE 7-11 (Continued)**

**SCREENING VALUES QUOTIENT INDEX FOR SITE 41**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Parameter | Sample Number | Sample Concentration ($\mu$g/kg)[2] | SSV[1] QUOTIENT RATIO | |
|---|---|---|---|---|
| | | | ER-L[3] | ER-M[4] |
| Dieldrin | 41-UN-SD01-06 | 1.35 | 67.5 | 0.17 |
| | 41-UN-SD01-612 | 1.08 | 54 | 0.14 |
| | 41-UN-SD02-06 | 1.21 | 60.5 | 0.15 |
| | 41-UN-SD03-06 | 0.83 | 41.5 | 0.1 |
| | 41-UN-SD04-06 | 0.46 | 23 | 0.06 |
| | 41-UN-SD13-06 | 6.39 | 319.5 | 0.79 |
| | 41-UN-SD13-612 | 5.19 | 259.5 | 0.65 |
| | 41-UN-SD14-06 | 2.07 | 103.5 | 0.26 |
| | 41-UN-SD14-612 | 1.57 | 78.5 | 0.19 |
| | 41-TC-SD06-06 | 2.5 | 125 | 0.31 |
| alpha-Chlordane | 41-UN-SD01-06 | 1.38 | 2.8 | 0.23 |
| | 41-UN-SD01-612 | 1.15 | 2.3 | 0.19 |
| | 41-UN-SD03-06 | 0.82 | 1.6 | 0.14 |
| | 41-UN-SD10-06 | 3.72 | 7.4 | 0.62 |
| | 41-UN-SD10-612 | 1.81 | 3.6 | 0.3 |
| | 41-UN-SD13-06 | 2.56 | 5.1 | 0.43 |
| | 41-UN-SD13-612 | 3.09 | 6.2 | 0.52 |
| | 41-UN-SD14-06 | 1.39 | 2.8 | 0.23 |
| | 41-UN-SD14-612 | 0.98 | 2 | 0.16 |
| | 41-TC-SD06-612 | 2.01 | 1 | 0.34 |
| | 41-TC-SD09-06 | 3.48 | 1.7 | 0.58 |
| gamma-Chlordane | 41-UN-SD01-06 | 1.43 | 2.9 | 0.24 |
| | 41-UN-SD01-612 | 1.35 | 2.7 | 0.23 |
| | 41-UN-SD03-06 | 0.92 | 1.8 | 0.15 |
| | 41-UN-SD10-06 | 6.35 | 12.7 | 1.1 |
| | 41-UN-SD10-612 | 1.45 | 2.9 | 0.24 |
| | 41-UN-SD13-06 | 2 | 4 | 0.67 |
| | 41-UN-SD13-612 | 2.44 | 4.9 | 0.41 |
| | 41-UN-SD14-06 | 1 | 2 | 0.17 |
| | 41-TC-SD06-612 | 0.99 | 2 | 0.17 |

(1) Sediment Screening Values
(2) µg/kg = micrograms per kilogram
(3) ER-L = Effects Range-Low
(4) ER-M = Effects Range-Median

Notes: Shaded areas are for Quotient Ratios that exceed one.
There were no QI ratios greater than one at Site 74.

**TABLE 7-12**

**TERRESTRIAL CHRONIC DAILY INTAKE MODEL EXPOSURE PARAMETERS[1]**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Exposure Parameter | Units | White-Tailed Deer | Eastern Cottontail Rabbit | Bobwhite Quail | Red Fox | Raccoon |
|---|---|---|---|---|---|---|
| Food Source Ingestion | NA | Vegetation 100% | Vegetation 100% | Vegetation 100% | Small Mammals 80% Vegetation 20% | Vegetation 40% Fish 60% |
| Feeding Rate | kg/d | 1.6[2] | 0.1[3] | 0.014[4] | 0.446[4] | 0.319[4] |
| Incident Soil Ingestion | kg/d | 0.019[1] | 0.002[3] | 0.001[3] | 0.012[4] | 0.030[4] |
| Rate of Drinking Water Ingestion | L/d | 1.1[2] | 0.119[4] | 0.019[4] | 0.399[4] | 0.331[4] |
| Rate of Vegetation Ingestion | kg/d | 1.6 | 0.1 | 0.014 | 0.089 | 0.128 |
| Body Weight | kg | 45.4[2] | 1.229[4] | 0.177[4] | 4.69[4] | 3.99[4] |
| Rate of Small Mammal Ingestion | kg/d | NA | NA | NA | 0.356 | NA |
| Rate of Fish Ingestion | kg/d | NA | NA | NA | NA | 0.192 |
| Home Range Size | acres | 454[2] | 9.29[4] | 8.89[4] | 1,771[4] | 385[4] |

NA - Not Applicable
[1] Scarano, 1993
[2] Dee, 1991
[3] Newell, 1987
[4] USEPA, 1993

**TABLE 7-13**

**QUOTIENT INDEX RATIO - SITE 41**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB, CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant of Concern | Bobwhite Quail | Eastern Cottontail | Red Fox | Whitetailed Deer | Raccoon |
|---|---|---|---|---|---|
| Phenanthrene | 2.61e-05 | 1.82e-05 | 3.97e-07 | 1.50e-07 | 1.63e-06 |
| Anthracene | 2.69e-05 | 1.88e-05 | 4.10e-07 | 1.55e-07 | 1.69e-06 |
| Fluoranthene | 2.21e-05 | 1.33e-05 | 3.00e-07 | 1.05e-07 | 1.59e-06 |
| Pyrene | 3.60e-05 | 2.18e-05 | 4.91e-07 | 1.73e-07 | 2.58e-06 |
| Benzo(a)anthracene | 1.65e-05 | 7.18e-06 | 1.76e-07 | 5.01e-08 | 1.46e-06 |
| Chrysene | 1.70e-05 | 7.38e-06 | 1.81e-07 | 5.15e-08 | 1.50e-06 |
| Benzo(b)fluoranthene | 1.45e-05 | 4.84e-06 | 1.29e-07 | 2.89e-08 | 1.42e-06 |
| Benzo(k)fluoranthene | 1.48e-05 | 5.61e-06 | 1.44e-07 | 3.64e-08 | 1.39e-06 |
| Benzo(a)pryene | 1.53e-05 | 5.99e-06 | 1.52e-07 | 3.96e-08 | 1.42e-06 |
| Benzo(g,h,i)perylene | 1.37e-05 | 4.67e-06 | 1.24e-07 | 2.83e-08 | 1.34e-06 |
| Bis(2-chloroethyl)ether | NA | NA | NA | NA | NA |
| Toluene | 1.53e-06 | 1.47e-06 | 3.03e-08 | 1.29e-08 | 5.61e-08 |
| Dieldrin | 9.59e-03 | 7.13e-03 | 1.54e-04 | 5.96e-05 | 5.57e-04 |
| 4,4'-DDE | 2.97e-03 | 1.28e-03 | 3.15e-05 | 8.88e-06 | 2.63e-04 |
| 4,4'-DDD | 1.44e-03 | 5.62e-04 | 1.42e-05 | 3.71e-06 | 1.33e-04 |
| 4,4'-DDT | 1.74e-03 | 6.43e-04 | 6.64e-05 | 1.81e-05 | 7.08e-02 |
| Chlordane, alpha | 3.48e-04 | 1.63e-04 | 3.92e-06 | 1.18e-06 | 3.24e-05 |
| Chlordane, gamma | 3.34e-04 | 1.57e-04 | 3.76e-06 | 1.13e-06 | 3.12e-05 |
| Heptachlor | 1.24e-04 | 7.89e-05 | 3.22e-05 | 9.21e-06 | 3.71e-05 |
| Heptachlor Epoxide | 7.91e-05 | 3.86e-05 | 9.17e-07 | 2.83e-07 | 6.57e-06 |
| Endosulfan II | 4.83e-04 | 4.05e-04 | 8.53e-06 | 3.47e-06 | 2.35e-05 |
| gamma-BHC (lindane) | 1.31e-04 | 1.15e-04 | 7.43e-06 | 2.41e-06 | 8.61e-05 |
| Endrin aldehyde | 4.86e-04 | 3.32e-04 | 7.28e-06 | 2.72e-06 | 3.11e-05 |
| Aluminum | NA | NA | NA | NA | NA |
| Arsenic | 7.83e-04 | 4.93e-04 | 1.67e-04 | 4.81e-05 | 1.95e-04 |
| Barium | 1.20e-02 | 9.42e-03 | 1.40e-03 | 4.24e-04 | 1.59e-03 |
| Cobalt | NA | NA | NA | NA | NA |
| Copper | 1.14e-03 | 1.03e-03 | 3.13e-05 | 1.21e-05 | 4.84e-05 |
| Iron | NA | NA | NA | NA | NA |
| Lead | 1.63e-02 | 9.16e-03 | 3.01e-04 | 1.02e-04 | 1.22e-03 |
| Manganese | 1.06e+01 | 9.03e+00 | 1.17e+00 | 3.62e-01 | 1.27e+00 |

**TABLE 7-13 (Continued)**

**QUOTIENT INDEX RATIO - SITE 41**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB, CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant of Concern | Bobwhite Quail | Eastern Cottontail | Red Fox | Whitetailed Deer | Raccoon |
|---|---|---|---|---|---|
| Mercury | 1.14e-03 | 1.09e-03 | 2.53e-05 | 1.13e-05 | 7.17e-04 |
| Vanadium | 1.49e-02 | 5.54e-03 | 9.96e-04 | 2.77e-04 | 2.19e-03 |
| Zinc | 4.12e-01 | 4.03e-01 | 8.13e-03 | 3.69e-03 | 1.00e-02 |
| Total | 1.11e+01 | 9.46e+00 | 1.19e+00 | 3.66e-01 | 1.36e+00 |

NA - Terrestrial reference value not available, therefore a quotient index ration could not be calculated.

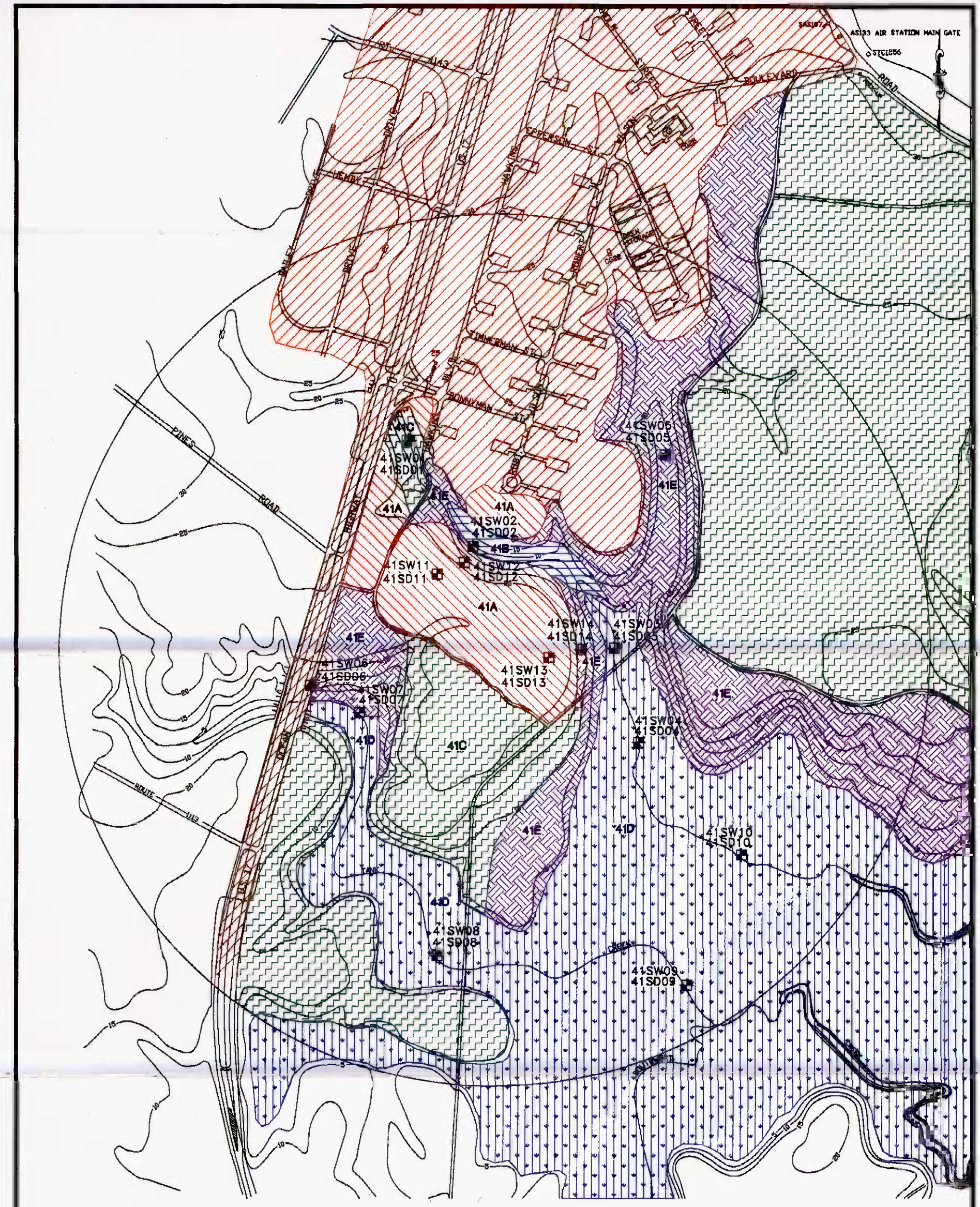
**TABLE 7-14**

**QUOTIENT INDEX RATIOS - SITE 74**
**REMEDIAL INVESTIGATION, CTO-0212**
**MCB CAMP LEJEUNE, NORTH CAROLINA**

| Contaminant of Concern | Bobwhite Quail | Eastern Cottontail | Red Fox | Whitetailed Deer |
|---|---|---|---|---|
| Trichloroethene | 1.01E-06 | 1.02E-06 | 6.11E-09 | 1.36E-08 |
| Toluene | 1.15E-06 | 1.14E-06 | 6.81E-09 | 1.51E-08 |
| Dieldrin | 1.24E-02 | 9.50E-03 | 5.95E-05 | 1.20E-04 |
| 4,4'-DDE | 3.02E-03 | 1.35E-03 | 9.62E-06 | 1.41E-05 |
| 4,4'-DDD | 1.56E-03 | 6.28E-04 | 4.63E-06 | 6.25E-06 |
| 4,4'-DDT | 3.81E-03 | 1.37E-03 | 1.05E-05 | 1.28E-05 |
| Chlordane, alpha | 4.31E-04 | 2.09E-04 | 1.46E-06 | 2.28E-06 |
| Chlordane, gamma | 4.45E-04 | 2.16E-04 | 1.51E-06 | 2.35E-06 |
| Heptachlor | 1.95E-04 | 1.04E-04 | 7.10E-07 | 1.18E-06 |
| Hepachlor Epoxide | 7.54E-05 | 3.80E-05 | 2.62E-07 | 4.20E-07 |
| Endrin Aldehyde | 4.45E-04 | 3.14E-04 | 2.00E-06 | 3.87E-06 |
| Aluminum | NA | NA | NA | NA |
| Arsenic | 2.30E-04 | 1.28E-04 | 7.76E-07 | 1.47E-06 |
| Barium | 4.86E-03 | 3.87E-03 | 2.04E-05 | 4.92E-05 |
| Chromium | 1.22E-02 | 4.39E-03 | 3.31E-05 | 4.07E-05 |
| Iron | NA | NA | NA | NA |
| Lead | 1.76E-03 | 1.03E-03 | 2.48E-05 | 1.70E-05 |
| Manganese | 1.19E+00 | 1.04E+00 | 5.42E-03 | 1.34E-02 |
| Mercury | 5.12E-04 | 5.06E-04 | 2.57E-06 | 6.69E-06 |
| Nickel | 5.16E-03 | 3.25E-03 | 2.12E-05 | 3.89E-05 |
| Selenium | 4.01E-03 | 1.93E-03 | 1.35E-05 | 2.10E-05 |
| Vanadium | 7.54E-03 | 2.57E-03 | 1.97E-05 | 2.30E-05 |
| Zinc | 2.00E-02 | 2.02E-02 | 1.11E-04 | 2.68E-04 |
| Cyanide, total | 6.28E-04 | 1.81E-04 | 1.50E-06 | 1.40E-06 |
| Total | 1.26E+00 | 1.09E+00 | 5.76E-03 | 1.40E-02 |

NA - Terrestrial reference value not available, therefore, a quotient index ratio could not be calculated.

# SECTION 7.0 FIGURES




NOTES:
1. HABITAT AREAS APPROXIMATE AND NOT TO SCALE.
2. THIS ENTIRE AREA IS LOCATED WITHIN A DEER MANAGEMENT UNIT.

212309RI

600 0 300 600 1200

1 inch = 600 ft.

Baker Environmental, Inc.

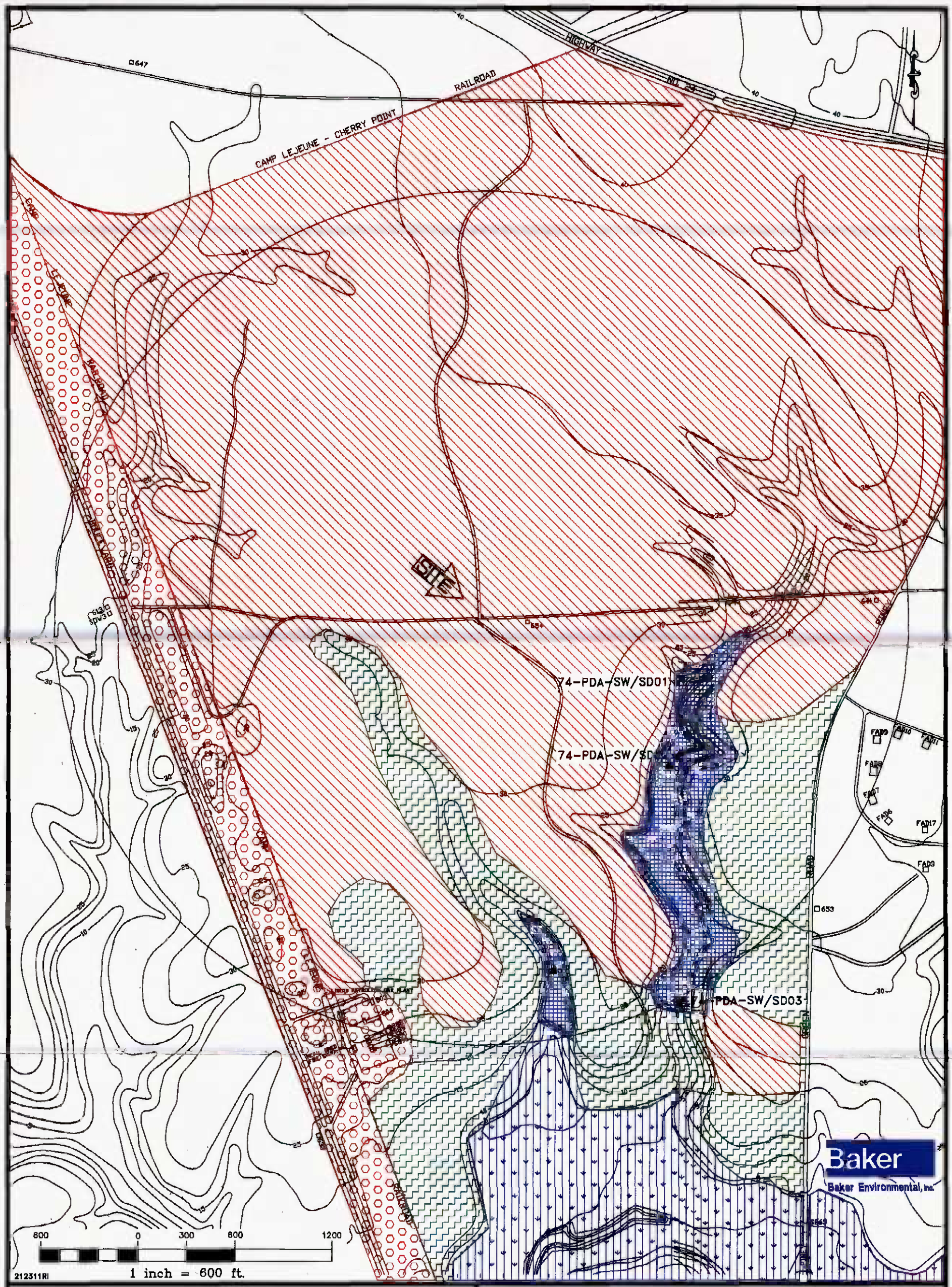
LEGEND

- WETLAND PF06(PALUSTRINE,FORESTED,DECIDUOUS)
- PINE FOREST (VARIOUS AGES)
- PINE/HARDWOOD FOREST
- HARDWOOD FOREST
- OPEN AREA WITH DRAINAGE SWALE
- BUILTUP AREA

SOURCE: LANTDIV, FEB. 1992

FIGURE 7-1
BIOHABITAT MAP - 1/2 MILE RADIUS
SITE 41 - CAMP GEIGER
DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01544T01Y




LEGEND

- WETLAND–PALUSTRINE, OPEN WATER, PERMANENTLY FLOODED
- WETLAND–PALUSTRINE, FORESTED, DECIDUOUS
- HARDWOOD FOREST
- PINE FOREST
- ROADWAY BUFFER ZONE AND INDUSTRIAL AREAS
- ▲ PONDS MANAGED FOR FISH

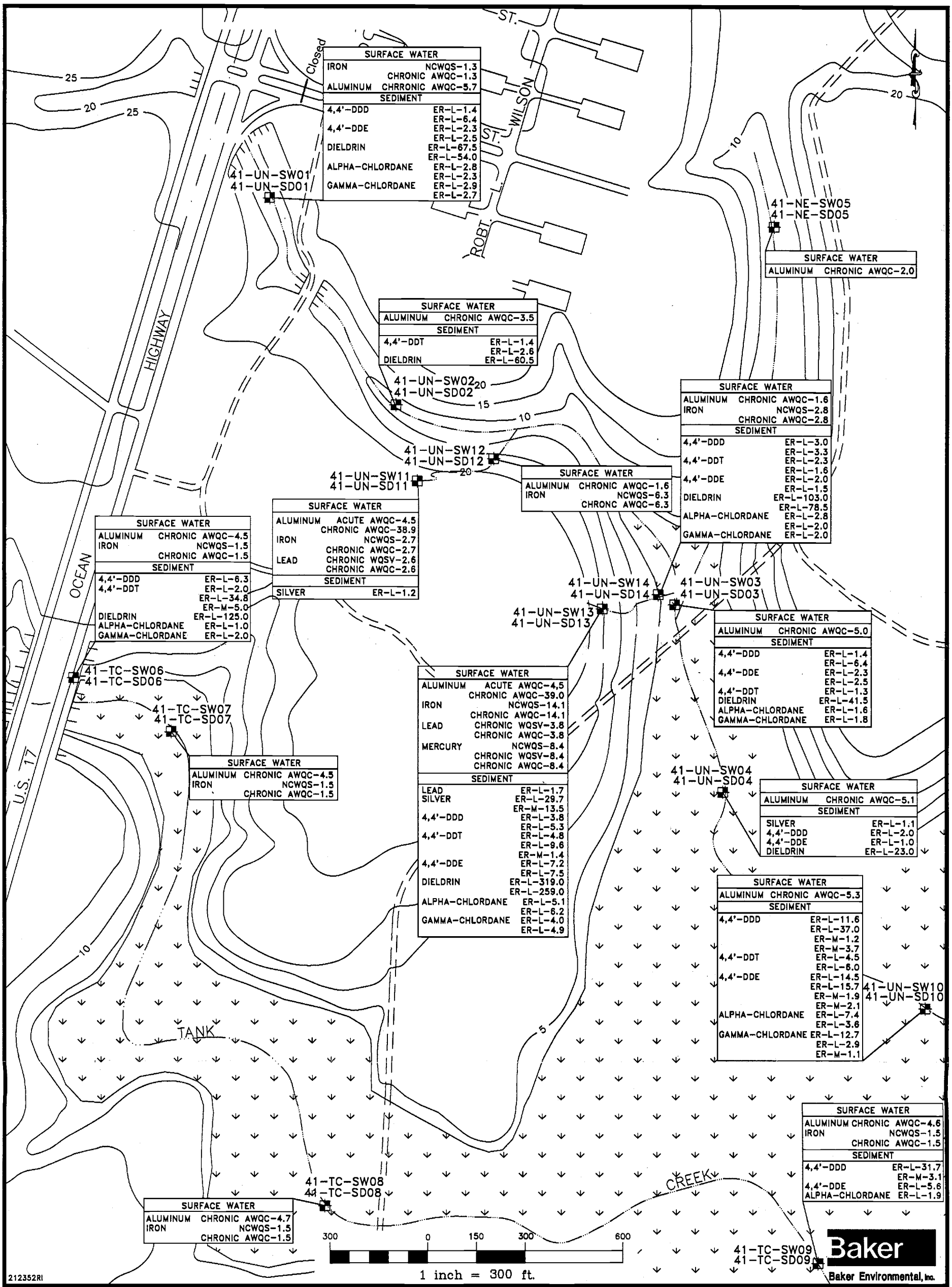
SOURCE: LANTDIV, FEB. 1992

NOTE:
1. HABITAT AREAS ARE APPROXIMATE AND NOT TO SCALE.
2. THIS ENTIRE AREA IS LOCATED WITHIN A DEER MANAGEMENT UNIT.

FIGURE 7–2
BIOHABITAT MAP – 1/2 MILE RADIUS
SITE 74 – MESS HALL GREASE
PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO–0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

Baker
Baker Environmental, Inc.

01544T02Y




LEGEND

41-UN-SW01
41-UN-SD01 SURFACE WATER/SEDIMENT SAMPLING STATIONS

— 5 — TOPOGRAPHIC ELEVATION LINES

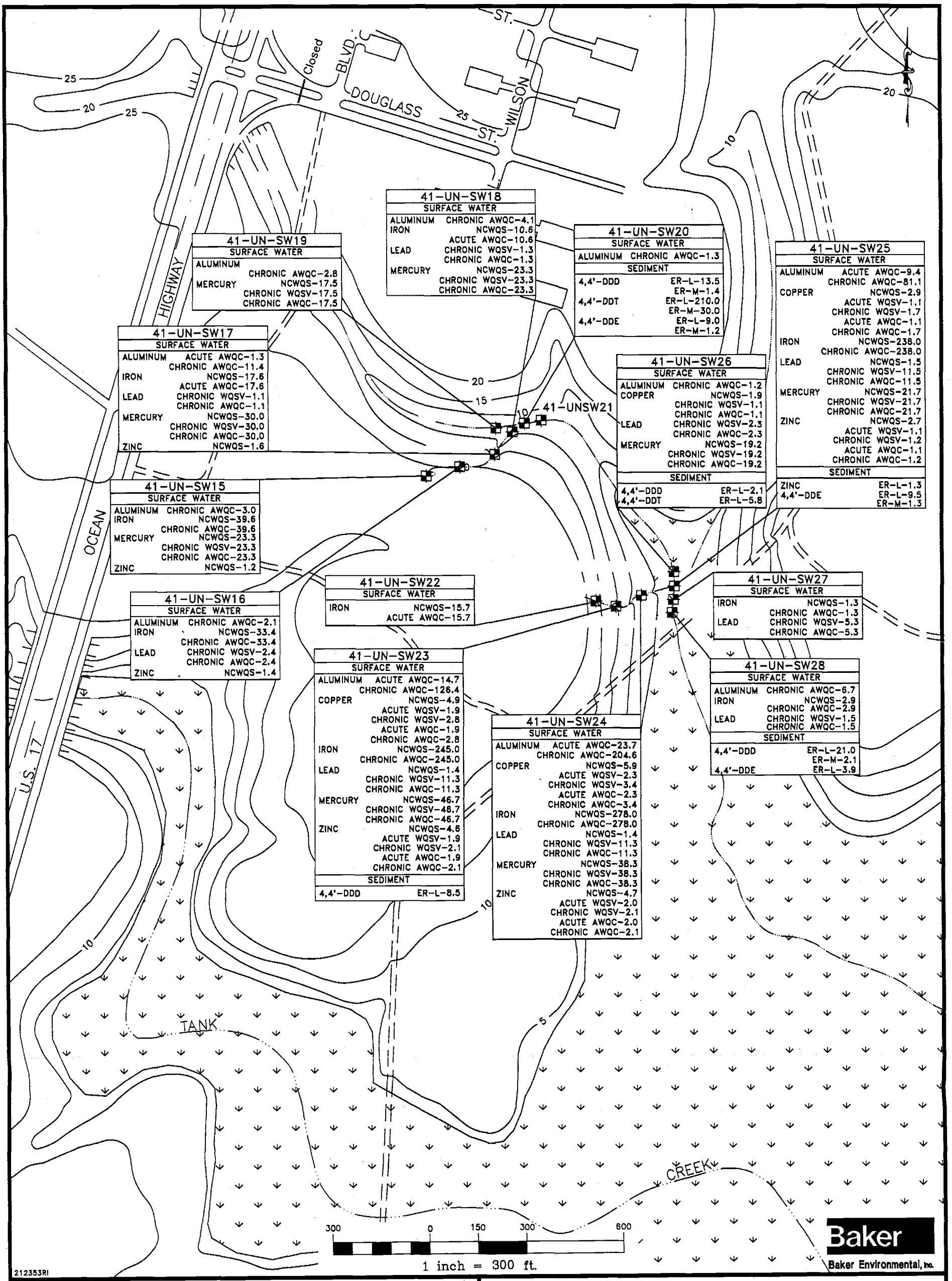
ROAD (IMPROVED) — ROAD (UNIMPROVED)

INTERMITTENT STREAM — MARSH

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).
SOURCE: LANTDIV, OCT. 1991

# FIGURE 7-3
## QUOTIENT INDEX RATIO EXCEEDANCES IN SURFACE WATER AND SEDIMENT - SITE 41
## CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
## REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01544 T03Z




## LEGEND

41-UN-SW15 – SURFACE WATER/SEDIMENT SAMPLE LLOCATION

– MARSH

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

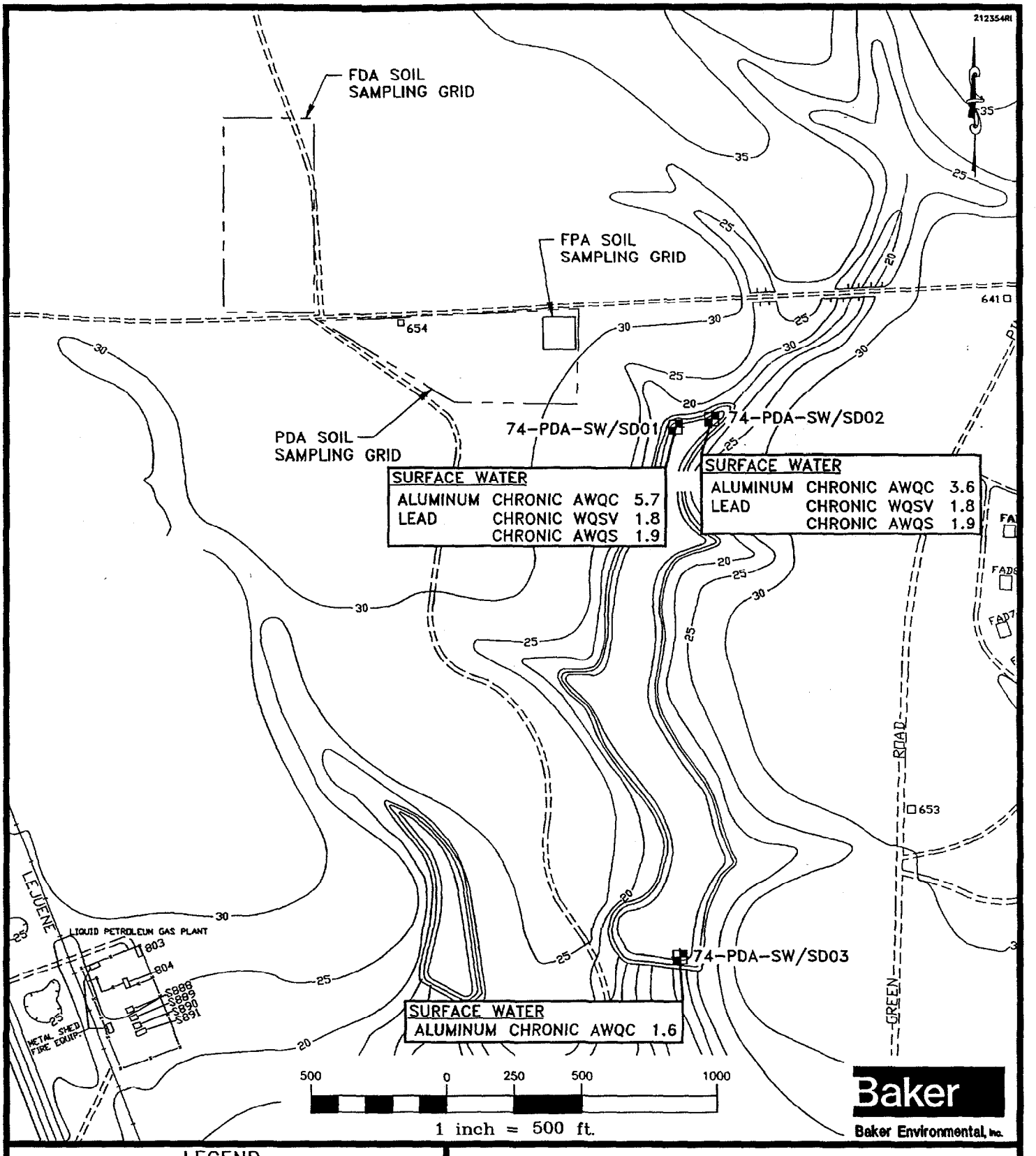
– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

SOURCE: LANTDIV, OCT. 1991

FIGURE 7-4
QUOTIENT INDEX RATIOS EXCEEDANCES
IN SURFACE WATER AND SEDIMENT – SITE 41
CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01544T042




LEGEND

74-PDA-SW/SD01 SURFACE WATER/SEDIMENT SAMPLING STATION

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

SOURCE: LANTDIV, FEB. 1994

FIGURE 7-5
QUOTIENT INDEX RATIOS EXCEEDANCES IN SURFACE WATER AND SEDIMENT - SITE 74
MESS HALL GREASE PIT DISPOSAL AREA
REMEDIAL INVESTIGATION CTO-0212
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

## 8.0 CONCLUSIONS

The following conclusions for Sites 41 and 74 are based on the results of the RI, and the human health and ecological risk assessments.

### 8.1 Site 41

1. Polynuclear aromatic hydrocarbons (PAHs) detected in soil may be the result of reported burning operations during disposal activities. The extent of this contamination is within the central portion of the former disposal area. PAHs were not detected in groundwater.

2. Pesticides were detected in most soil samples; however, the pesticide levels are within base-wide concentrations which are indicative of historical pest control spraying. Low levels of pesticides were detected at isolated areas within the shallow aquifer and the upper portion of the Castle Hayne aquifer, indicating that pesticides have migrated to a limited extent from the soil matrix to shallow groundwater.

3. Although there were many background exceedances associated with the metals results, the data do not suggest a gross metals contamination problem in either the surface or subsurface soils at the site. The majority of elevated metals concentrations exceeded the twice background levels by less than an order of magnitude.

4. Total lead, iron, and manganese were detected above State and Federal groundwater standards in most of the wells during the RI field investigation. Monitoring well 41GW11, which is located in the central portion of the former disposal area, exhibited the highest levels of lead, iron, and manganese. However, the elevated concentrations of total metals may be due to turbidity in the well or sampling techniques rather than from leaching of these metals from soil to groundwater. Resampling of selected shallow monitoring wells using the low-flow sampling technique resulted in significantly lower metal concentrations. Only metals concentrations in well 41GW11 exceeded drinking water standards during this round.

5. Shallow groundwater is apparently discharging from the landfill via two seeps. Surface water samples collected from the seeps have exhibited elevated levels of iron, lead, and manganese. However, the unnamed tributary and Tank Creek do not appear to be significantly impacted by the site or seep discharges. Downstream surface water samples exhibited slightly higher iron and lead levels than upstream samples. Sediment samples along the seep pathway primarily exhibited pesticides above EPA Region IV screening values. High iron concentrations were detected in the seep sediments, suggesting that much of the iron in the seep surface water is being deposited in the sediments through oxidation and precipitation.

6. Under current exposure pathways, there are no adverse human health risks mainly because the site is in a remote area, and there is no exposure pathway associated with the groundwater (i.e., no water supply wells are currently located near the site).

7. Under future potential exposure pathways involving residential use, adverse human health risks would result due to groundwater usage. However, future residential use of the area is unlikely since the site is suspected of containing buried CWM.

8. No adverse human health risks were calculated for the future construction worker. However, buried CWM, if present, would still pose a risk to a construction worker at the site.

9. The risk analysis for environmental media concentrations and terrestrial intake models did not indicate that there are significant ecological risks associated with Site 41 to terrestrial receptors and aquatic receptors in the unnamed tributary and Tank Creek.

10. Based on the results of the human health and ecological risk assessments, there are no areas of concern associated with soils or sediment that require remediation. However, institutional controls should be considered in the FS to restrict site access and land use because of the unacceptable risk calculated for the residential use scenario as well as the suspected buried CWM.

11. Remediation of the groundwater and seep discharges should be considered in the FS because there were some exceedances of State and Federal ARARs. In addition, the seep discharge may pose a future potential threat to the environment and habitat along the unnamed tributary.

**8.2 Site 74**

1. Soil at the former pest control area exhibited pesticides above base background levels, indicating that former pest control activities have resulted in soil contamination. The extent of soil contamination at the former pest control area is limited.

2. Low levels of pesticides were detected in shallow groundwater at the pest control area; however, the levels are below State and Federal drinking water standards.

3. Soil and groundwater at the former grease pit disposal area have not been significantly impacted by former disposal activities. Although organic and inorganic contaminants were detected in soil, the low concentrations and infrequent distribution of the contaminants do not suggest that there is a source area associated with former disposal areas.

4. The subsurface conditions at the former grease pit disposal area are unknown since no intrusive investigations (e.g., trenching) could be conducted due to suspected buried CWM. Therefore, the background information, which indicated that PCBs and other wastes were disposed at the site, cannot be verified.

5. No chemical agents were detected during borehole monitoring by the U.S. Army TEU. In addition, no chemical surety degradation compounds were detected in soil samples.

6. Elevated total metals in groundwater are not believed to be indicative of former disposal activities. Dissolved metal concentrations were below State and Federal drinking water standards.

7. Under current exposure pathways, there are no adverse human health risks associated with the site (i.e., the shallow groundwater is not currently being used for any purpose).

8. Under future potential exposure pathways involving residential use, adverse human health risks would result due to groundwater usage. However, future residential use of the area is unlikely since the site is suspected of containing buried CWM.

9. No adverse human health risks were calculated for the future construction worker. However, buried CWM, if present, would still pose a risk to a construction worker at the site.

10. The risk analysis for environmental media concentrations and terrestrial intake models indicated that there are no significant ecological risks associated with Site 74 to aquatic and terrestrial receptors.

11. Based on the results of the human health and ecological risk assessments, there are no areas of concern associated with the soils that require remediation. However, institutional controls should be considered in the FS to restrict site access and land use because of the unacceptable risk calculated for the residential use scenario as well as the suspected buried CWM.

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