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DRAFT PILOT STUDY IMPLEMENTATION PLAN SITE 86 OPERABLE UNIT 20 (OU 20) MCB CAMP LEJEUNE NC (DRAFT ACTING AS FINAL)

9/1/2011

CH2M HILL

Draft

Pilot Study Implementation Plan
Site 86, Operable Unit No. 20

Marine Corps Base Camp Lejeune
Jacksonville, North Carolina

Contract Task Order WE-09

September 2011

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Mid-Atlantic

Under the

NAVFAC CLEAN 8012 Program
Contract N62470-11-D-8012

Prepared by

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Acronyms and Abbreviations

AST	aboveground storage tank
bgs	below ground surface
cis-1,2-DCE	cis-1,2-Dichloroethene
CLEAN	Comprehensive Long-term Environmental Action—Navy
CO_2	carbon dioxide
COC	contaminant of concern
CVOC	chlorinated volatile organic compound
DPT	direct-push technology
DO	dissolved oxygen
ERD	enhanced reductive dechlorination
ESRI	Expanded Supplemental Remedial Investigation for Site 86
ft	feet or foot
ft/day	feet per day
ft/year	feet per year
FTL	Field Team Leader
GAC	granular activated carbon
gpm	gallons per minute
HSP	Health and Safety Plan
IDW	investigation-derived waste
ISCO	in situ chemical oxidation
$KMnO_4$	potassium permanganate
μg/L	micrograms per liter
MCAS	Marine Corps Air Station
MCB CamLej	Marine Corps Base Camp Lejeune
mg/L	milligrams per liter
MnO_4^-	permanganate
NAVFAC	Naval Facilities Engineering Command
ORP	oxidation reduction potential
OU	Operable Unit
PPE	personal protective equipment
PVC	polyvinyl chloride
RI	Remedial Investigation
SAP	Sampling and Analysis Plan
SRPC	slow-release permanganate candle

SWMU	solid waste management unit
TCE	trichloroethene
TOC	total organic carbon
UFP	Uniform Federal Policy
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound

SECTION 1

Introduction

This document presents the Pilot Study Implementation Plan for Operable Unit (OU) 20, Site 86, at Marine Corps Base Camp Lejeune (MCB CamLej), Jacksonville, North Carolina (**Figure 1-1**). This Implementation Plan was prepared under the Naval Facilities Engineering Command (NAVFAC)—Mid-Atlantic, Comprehensive Long-term Environmental Action—Navy (CLEAN) Contract N62470-11-D-8012, Contract Task Order WE-09.

The *Final Expanded Supplemental Remedial Investigation, Site 86, Operable Unit No. 20, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina* (CH2M HILL, 2011a) (hereafter referred to as the ESRI) reported that large, diffuse volatile organic compound (VOC) groundwater plumes were located in both the surficial and upper Castle Hayne aquifers at the site. Based on this information, a 6-month pilot study was recommended to reduce the VOC mass in these aquifers. In May 2011, the Partnering Team, consisting of representatives from CH2M HILL, NAVFAC, MCB CamLej, North Carolina Department of Environment and Natural Resources, and U.S. Environmental Protection Agency (USEPA) Region 4, agreed to conduct a field-scale pilot study to evaluate the use of enhanced reductive dechlorination (ERD) with an injection/extraction delivery system for the treatment of trichloroethene (TCE) and its daughter products: cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride (VC), in groundwater. During a subsequent conference call in July 2011, the Partnering Team agreed to include an in situ chemical oxidation (ISCO) study using slow-release permanganate (MnO_4^-) candles (SRPCs) to passively treat VOCs in the surficial aquifer.

This Pilot Study Implementation Plan is organized as follows:

- **Section 1, Introduction**—Overview of the project and Implementation Plan.
- **Section 2, Site Background**—General site background and description of the pilot study areas.
- **Section 3, Pilot Study Descriptions**—Overview of the pilot study objectives and goals and a conceptual technical approach for the pilot studies.
- **Section 4, Pilot Study Implementation**—How the pilot studies will be conducted.
- **Section 5, Health and Safety and Residuals Management**—Issues to be presented in the Health and Safety Plan (HSP) for the project and the process for managing investigation-derived waste (IDW).
- **Section 6, Site Activity Considerations**—Site-specific requirements and constraints applicable during project implementation.
- **Section 7, Reporting**—Reporting that will occur for the field implementation.
- **Section 8, Project Management**—Project schedule and organization.
- **Section 9, References**—References to works cited in this document.

Figures are presented at the end of each section. A Uniform Federal Policy (UFP) Sampling and Analysis Plan (SAP) will be issued under a separate cover to address the collection of analytical data specific to the pilot studies.

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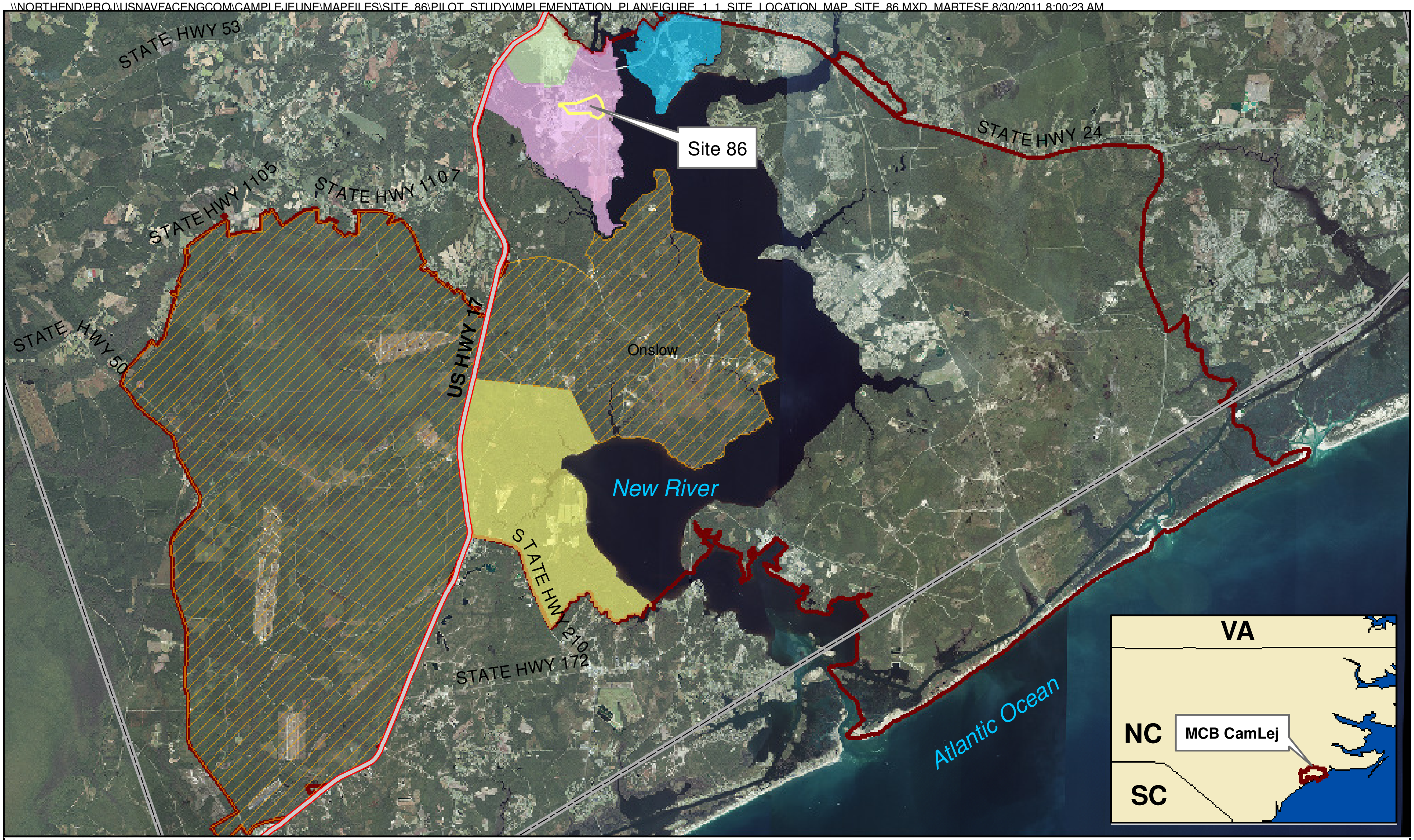

Legend

- Highways
- Greater Sandy Run Training Area
- Stone Bay Rifle Range
- Camp Geiger
- Camp Johnson
- MCAS New River
- Site 86
- Onslow County
- Installation Boundary

N

0 7,500 15,000 30,000 Feet

1 inch = 15,000 feet

Figure 1-1
Site Location Map
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

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SECTION 2

Site Background

Information concerning site history, contaminant concentrations, plume distribution, and subsurface geology, and hydrogeology is documented in the ESRI. A summary of this information is provided in this section.

2.1 Site Description

Site 86 is located on Marine Corps Air Station (MCAS) New River. Most of the site is developed with aircraft hangars, aircraft support buildings, or concrete or asphalt paved areas. A large open area, known as the northeast grass area, is present in the eastern portion of the site.

Historically, the extent of Site 86, formerly known as the Aboveground Storage Tank Area, was defined as the area south of the intersection of Davis and Campbell Streets (**Figure 2-1**). The original area of Site 86 was used for storing petroleum products between 1954 and 1988. In 1954, three 25,000-gallon aboveground storage tanks (ASTs) were installed within an earthen berm, and a small pump house was constructed to transfer fuel oil to and from the ASTs. The three tanks were reportedly used for fuel oil storage until 1974. Between 1979 and 1988, the ASTs were used for temporary storage of used oil. In 1988, the ASTs were emptied and cleaned; they were subsequently removed in 1992.

The original site boundary was established following the completion of a Remedial Investigation (RI) (Baker Environmental, Inc., 1996) and encompassed the ASTs and pump house. During the RI, several VOCs were identified in groundwater, including TCE and its associated daughter products, cis-1,2-DCE and VC. Subsequent RI activities were conducted from 1997 through 2002 to assess the horizontal and vertical extents of the VOC impacts. Additional investigations associated with solid waste management units (SWMUs) 303 and 318, located in the vicinity of the original Site 86 boundary, also identified TCE and VC in groundwater. In August 2006, based on the subsequent RI and SMWU investigations, the Site 86 boundaries were expanded to include most of the industrial area north of the MCAS New River flight line.

In 2009 and 2010, soil and groundwater were additionally assessed during the ESRI. During that investigation, a second VOC plume consisting of TCE, cis-1,2-DCE, and VC was identified in the vicinity of Building AS508 and the grassy area west of Curtis Road and east of the 2006 Site 86 boundary. In 2010, the Site 86 boundary was expanded to include Building AS508 and the grassy area. The eastern portion of Site 86 includes an unlined stormwater drainage ditch that collects runoff from the eastern portion of Site 86, including the industrial area and hangars, and discharges to the New River.

VOCs, including TCE and its daughter products, cis-1,2-DCE and VC, are the primary contaminants of concern (COCs) at Site 86.

2.2 Description of Pilot Study Areas and Rationale for Technology Selection

The highest concentrations of VOCs in the upper Castle Hayne (Zone 1) and surficial (Zone 2) aquifers are located in different areas.

Based on the data summarized in the ESRI, the Partnering Team agreed in May 2011 to conduct a 6-month pilot study, which would include installation of an ERD injection/extraction recirculation system in the upper Castle Hayne aquifer, as well as an injection of an ERD substrate in the surficial aquifer. Based on logistical challenges faced with substrate injections in the surficial aquifer (such as flight line access issues, potential surfacing and implementation time), an ISCO pilot study using SRPC technology was recommended to the Partnering Team and approved in July 2011.

The pilot study technologies were chosen for Zone 1 and Zone 2 based on technical and logistical challenges posed by each zone and the active flight line.

2.2.1 Zone 1 ERD and Bioaugmentation Pilot Study Area

The Zone 1 pilot study will address the VOC plume in the upper Castle Hayne aquifer, in the vicinity of Building AS508 and monitoring well IR86-MW58IW (**Figure 2-1**). Based on the ESRI, VOC contamination appears to be greatest at a depth of 50 feet (ft).

Zone 1 encompasses a 0.3-acre treatability area, which includes drainage swales, portions of an asphalt parking lot, Building AS508 and associated support structures, security fencing, and a grassy area.

Geology and Hydrogeology

The geology of the upper Castle Hayne aquifer in Zone 1 consists of a weakly to completely cemented sandy limestone with shell fragments, which was encountered at approximately 24 ft to 34 ft below ground surface (bgs) and extends to a maximum depth of approximately 64 ft bgs near the monitoring well IR86-MW59 cluster. The proportion of shell fragments is greatest at approximately 45 to 55 ft bgs. Locations of cross-section transects A-A′ and B-B′ are shown on **Figure 2-2.** Subsurface geology along transects A- A′ and B-B′ is depicted on **Figures 2-3** and **2-4**, respectively.

The depth to groundwater in Zone 1 ranges from approximately 4 to 6 ft bgs. The direction of groundwater flow in the upper Castle Hayne aquifer is to the east and slightly north towards the New River (**Figure 2-5**). The data provided in the ESRI indicate that the linear groundwater velocities for the upper Castle Hayne aquifer range from 0.013 to 0.28 feet per day (ft/day) (5 to 102 feet per year [ft/year]).

Groundwater Characterization

Based on data presented in the ESRI, the highest VOCs concentrations in the upper Castle Hayne aquifer are located in the vicinity of monitoring well IR86-MW58IW and direct-push technology (DPT) groundwater sampling location IR86-IS50 (**Figure 2-6**). TCE was detected in the groundwater sample collected in December 2009 from monitoring well IR86-MW58IW, at a concentration of 710 micrograms per liter (µg/L), and in the groundwater sample collected in October 2009 from the DPT location IR86-IS50, at a concentration of 680 μg/L.

Table 2-1 summarizes the geochemical data from groundwater samples collected from monitoring wells within the upper Castle Hayne aquifer in the vicinity of Zone 1. Geochemical data from groundwater samples collected from monitoring wells IR86-MW58IW, IR86-MW59IW, and IR86-MW61IW indicate that the aquifer is generally under anaerobic conditions. Dissolved oxygen (DO) measurements ranged from 0.13 to 0.19 milligrams per liter (mg/L), and oxidation reduction potential (ORP) measurements ranged from -69.4 to -356.1 millivolts.

Measurable levels of ferrous iron were detected at concentrations ranging from 0.5 to 3 mg/L. Neither nitrate or nitrite were detected in any of the groundwater samples, and sulfate was detected only in the groundwater sample collected from monitoring well IR86-MW59IW, at a concentration of 38 mg/L. Total organic carbon (TOC) concentrations ranged from approximately 0.7 to 2.8 mg/L.

Chlorinated solvents are capable of being depleted by natural processes in the upper Castle Hayne aquifer. DO and ORP are at levels favorable for reductive dechlorination. However, the limited native organic carbon present suggests that the natural attenuation process may be slowed and the presence of sulfate suggests that competitive exclusion of dechlorinating bacteria may be occurring.

2.2.2 Zone 2 SRPC Pilot Study Area

The Zone 2 pilot study will address the VOC plume in the surficial aquifer, located in the northeast grass area east of the flight line, in the vicinity of monitoring well IR86-MW61 (**Figure 2-1**). Based on the ESRI, VOC contamination appears to be greatest at a depth of approximately 30 ft.

The Zone 2 SRPC and monitoring well field encompasses a 0.15-acre area. The treatability area will be significantly larger because of the volume of VOC-affected groundwater that will flow through the treatment area (approximately 80 ft long by 10 ft thick) during the 6-month pilot study, assuming a mean groundwater velocity of 0.2 ft/day and an effective porosity of 0.2. The treatment volume is estimated to be on the order of 5.4×10^4 gallons (7,200 cubic ft). Zone 2 is located within a secured, grassy area of the flight line, accessed by Curtis Road east of Site 86.

Geology and Hydrogeology

The geology of the surficial aquifer in Zone 2 is characterized by sand, silty sand, and sandy clay from the surface to approximately 35 ft bgs. Thin, discontinuous layers of silt and clay are also found in this interval. **Figures 2-3** and **2-4** depict the subsurface geology near Zone 2.

The depth to groundwater in Zone 2 is approximately 4 to 6 ft bgs. Groundwater flow in the surficial aquifer is to the east and slightly north towards the New River (**Figure 2-7).** The data provided in the ESRI indicate that the linear groundwater velocities for the surficial aquifer range from 0.028 to 0.400 ft/day (10 to 146 ft/year).

Groundwater Characterization

Based on the data presented in the ESRI, the highest concentrations of VOCs in groundwater, specifically TCE, are in the vicinity of monitoring well IR86-MW61 (**Figure 2-8)**. TCE was detected in groundwater sampled from surficial aquifer monitoring well IR86-MW61 in December 2009, at a concentration of 260 µg/L.

Table 2-1 summarizes the geochemical data from groundwater samples collected from monitoring wells within the surficial aquifer in the vicinity of Zone 2. Geochemical data from groundwater samples collected from surficial monitoring wells IR86-MW56 and IR86-MW58 through IR86-MW65 indicate that the surficial aquifer is under anaerobic to slightly aerobic conditions. DO measurements ranged from 0.12 to 2.95 mg/L and ORP measurements ranged from -204.2 to 35.7 millivolts.

Ferrous iron was detected at concentrations ranging from 0.0 to 3.6 mg/L. Neither nitrate or nitrite were detected, and sulfate was detected at measurable concentrations in three of the nine wells (**Table 2-1**). TOC concentrations ranged from approximately 0.74 to 7.2 mg/L.

Results of $MnO4^-$ soil oxidant demand testing indicated that approximately 6.0 to 6.3 grams of MnO_4^- would be consumed for every kilogram of aquifer material.

TABLE 2-1
Summary of Natural Attenuation Indicator Parameters within Pilot Study Zones
Pilot Study Implementation Plan
Site 86—Operable Unit No. 20
MCB CamLej, Jacksonville, North Carolina

Well ID	Sample Date	DO (mg/L)	ORP (mV)	Ferrous Iron (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	TOC (mg/L)	Iron (mg/L)	Ferric Iron* (mg/L)	Manganese (mg/L)
Zone 1: Upper Castle Hayne Aquifer Monitoring Wells												
IR86-MW58IW	12/16/2009	0.16	-69.4	1.6	0	0	29B	6.8	0.7J	3.6B	2.0	0.048
IR86-MW59IW	12/12/2009	0.13	-356.1	0.5	0	0	38	1U	2.8	1.3B	0.8	0.028
IR86-MW61IW	12/12/2009	0.19	-110.7	3.0	0	0	14B	1U	2.5	4	1	0.079
Zone 2: Surficial Aquifer Monitoring Wells												
IR86-MW56	12/16/2009	0.23	-100.2	3.6	0	0	10B	1U	1.9	3.9B	0.3	0.051
IR86-MW58	12/16/2009	0.18	-33.9	2.0	0	0	32B	1U	7.5	11B	9	0.17
IR86-MW59	12/12/2009	0.15	-87.9	2.0	0	0	9.5	1U	2.1	4.6B	2.6	0.072
IR86-MW60	12/18/2009	0.12	-74.5	0.0	0	0	410	1U	0.74J	8.2	8.2	0.14
IR86-MW61	12/12/2009	0.20	-34.7	2.8	0	0	21B	1U	3.2	3.4	0.6	0.087
IR86-MW62	12/14/2009	0.15	-94.0	1.8	0	0	0.24BJ	1U	1.6	8.4B	6.6	0.16
IR86-MW63	1/13/2010	2.95	-60.0	1.2	0	0	11B	0.82J	1.8	1	0**	0.045
IR86-MW64	12/16/2009	0.23	-204.2	0.0	0	0	16B	1U	0.79J	0.36B	0.36	0.013J
IR86-MW65	3/24/2010	1.61	35.7	NA	NA	NA	7.8	3	0.95J	0.836	NA	0.0885

Notes:
µg/L - Micrograms per liter
mg/L - Mlligrams per liter
mV - Millivolts
DO - Dissolved oxygen
ORP - Oxidation reduction potential
TOC - Total organic carbon

B - Analyte not detected above the level reportec
J - Analyte present, value may or may not be acc
U - The material was analyzed for, but not detected
NA - Not analyzed

* Value calculated by subtracting Ferrous Iron (collected in field) from Total Iron (collected in lab)
** Field measurement of Ferrous Iron was greater than lab measurement of Iron

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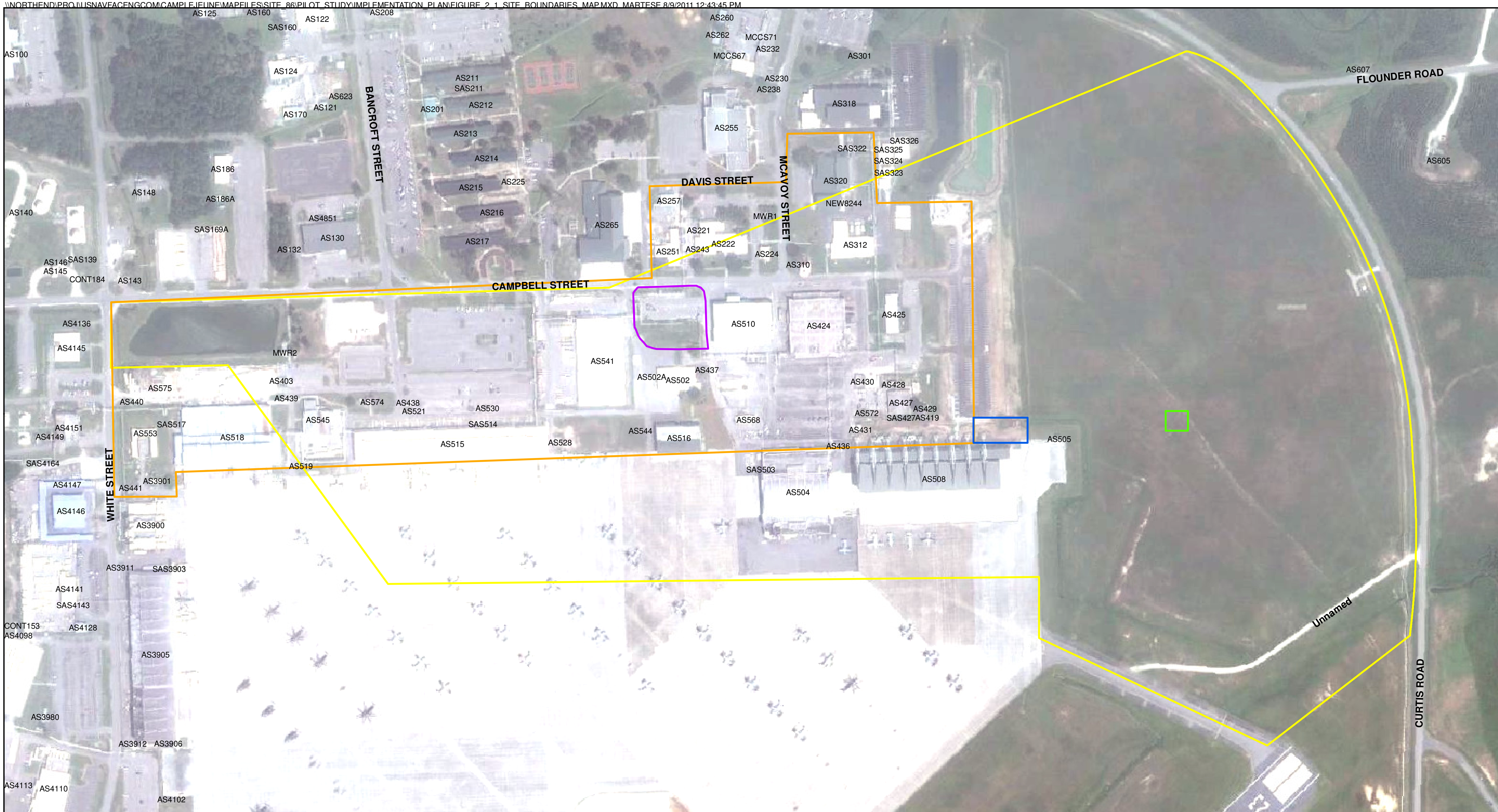

Legend
- Original Site 86 Boundary
- August 2006 Site 86 Boundary
- March 2010 Site 86 Boundary
- Zone 1 Pilot Study Area
- Zone 2 Pilot Study Area

N

0 175 350 700 Feet

1 inch = 350 feet

Google Earth Imagery

Figure 2-1
Site Boundaries Map
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

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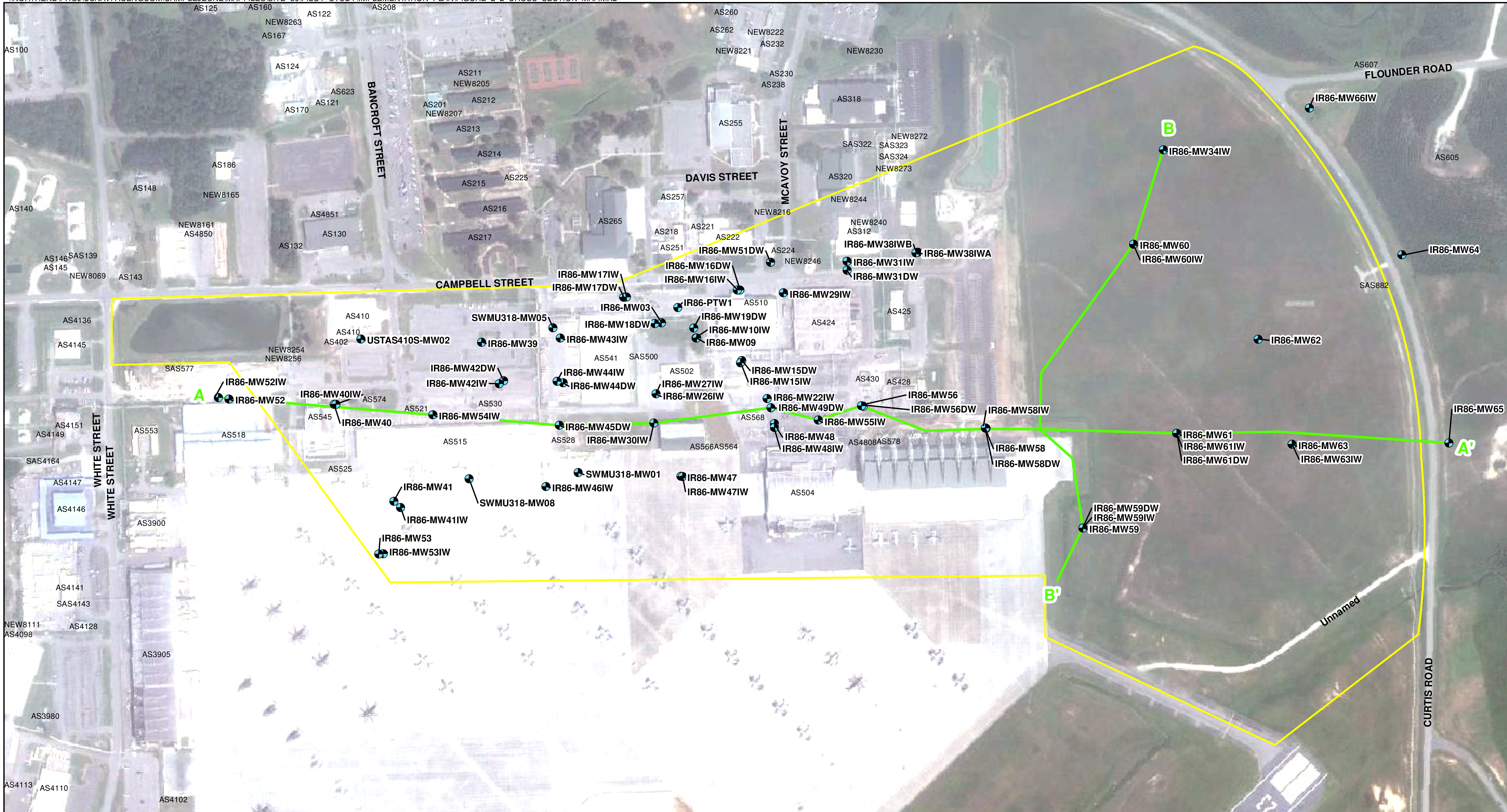

Legend

- Monitoring Well Locations
- Cross Section Location
- March 2010 Site 86 Boundary

N

0 175 350 700 Feet

1 inch = 350 feet

Google Earth Imagery

Figure 2-2
Geologic Cross Section Location Map
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

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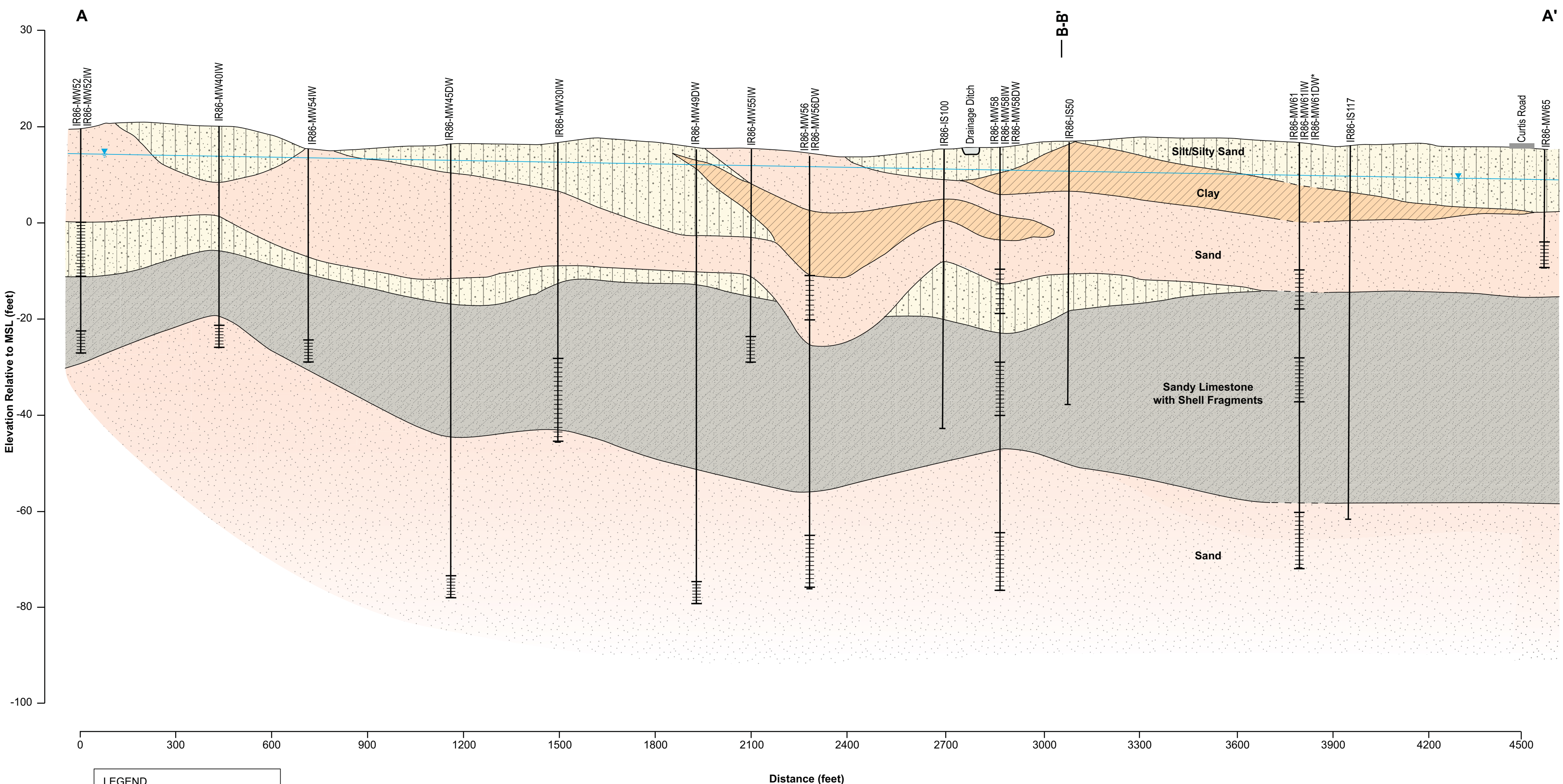

LEGEND

- Silt/Silty Sand
- Clay
- Sand
- Partially to completely cemented sandy limestone with shell fragments
- Screened interval
- Soil boring
- Water table

Horizontal : 1" = 300'
Vertical: 1" = 20'
V.E. = 15x

Notes

1) The depth and thickness of the subsurface strata indicated on this section (profile) were generalized from and interpolated between test locations. Subsurface conditions occurring at the other locations may differ from conditions occurring at indicated locations.

2) *IR86-MW61/61IW/61DW boring log not available.

Figure 2-3
Geologic Cross Section A-A'
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB CamLej
North Carolina

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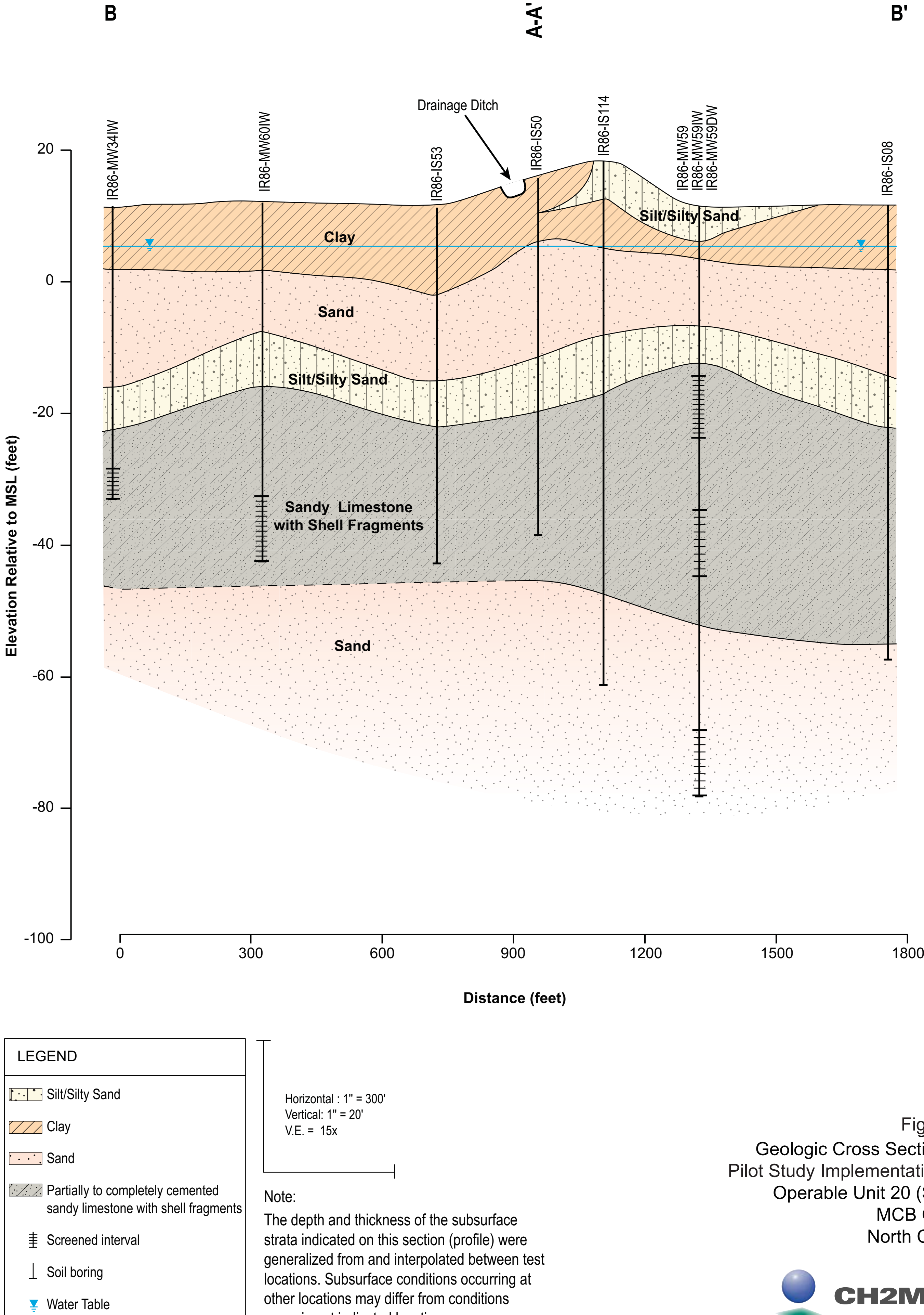

Note:

The depth and thickness of the subsurface strata indicated on this section (profile) were generalized from and interpolated between test locations. Subsurface conditions occurring at other locations may differ from conditions occurring at indicated locations.

Figure 2-4
Geologic Cross Section B-B'
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB CamLej
North Carolina

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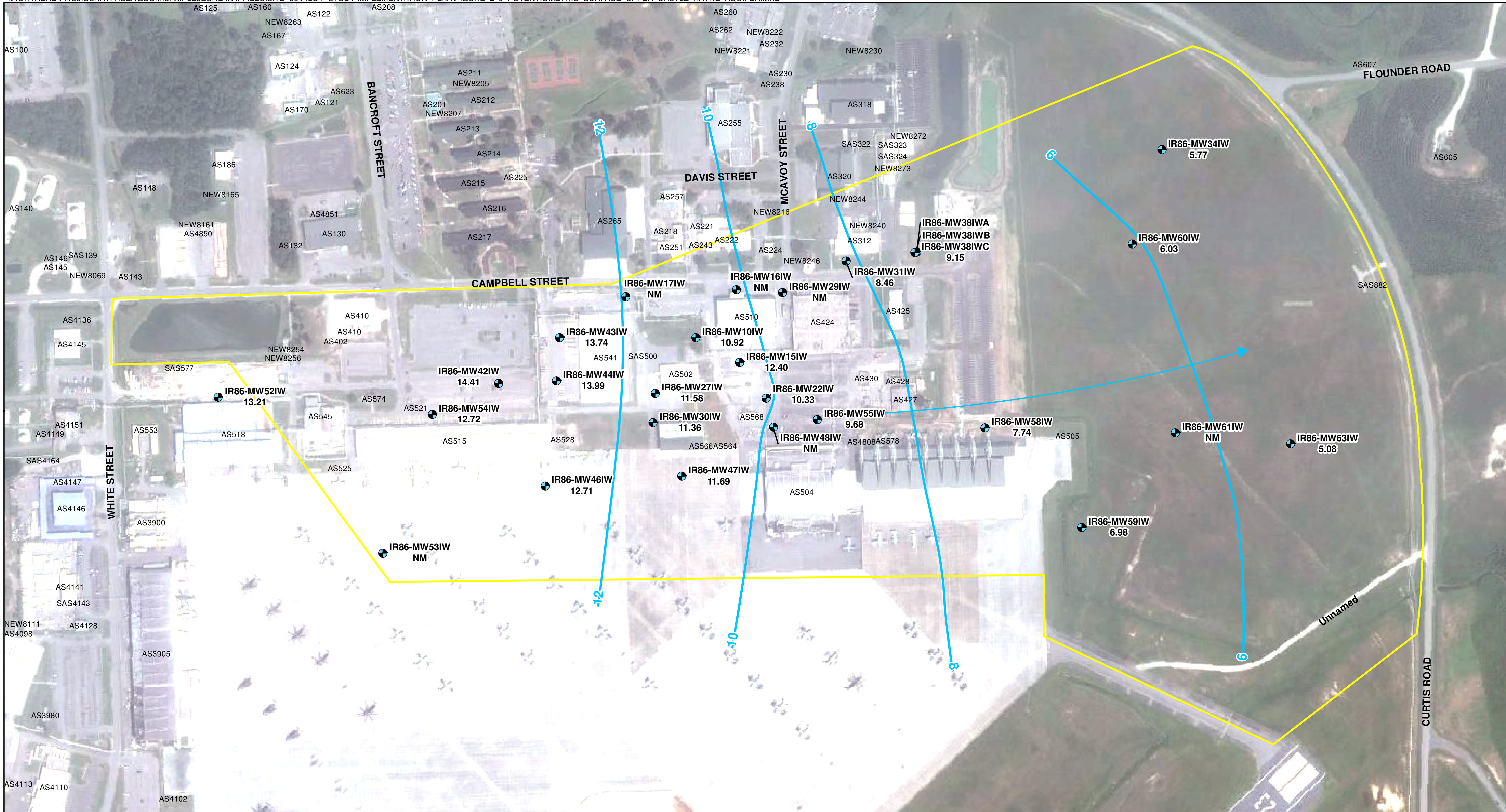

Legend

- Monitoring Well
- Potentiometric Contours
- Groundwater Flow Direction
- Expanded Site 86 Boundary (March 2010)

5.98 - Water Level Elevations

Notes:
- Water level elevations are reported in feet above mean sea level
- Water levels were measured on March 13/14, 2010
- NM - Not Measured

N

0 175 350 700 Feet

1 inch = 350 feet

Google Earth Imagery

Figure 2-5
Potentiometric Surface - Upper Castle Hayne Aquifer
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

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TCE Concentration (µg/L)	
IR86-MW58IW	710
IR86-IS50	680 D
IR86-IS109	5.4
IR86-IS111	38
IR86-IS114	190

Legend

- Upper Castle Hayne Aquifer Monitoring Well
- Direct Push Groundwater Sampling Locations 2007
- Direct Push Groundwater Sampling Locations 2008
- Direct Push Groundwater Sampling Locations 2009
- Expanded Site 86 Boundary (March 2010)

TCE Concentrations

- > 300 µg/L
- > 30 µg/L
- > 3.0 µg/L

Notes:
- All concentrations are reported in µg/L.
- Contours have been interpolated between monitoring well locations. Actual conditions may differ from those shown.
- Samples collected in December 2009, March 2010, and June 2010.
- NCGWQS for TCE = 3.0 µg/L.
- Only detected concentrations of TCE shown in table.
- **Bold** indicates value above NCGWQS.
- J- Analyte present, value may or may not be accurate or precise.

N

0 75 150 Feet

1 inch = 150 feet

Image from Google Earth Pro

Figure 2-6
TCE Concentrations in the Upper Castle Hayne Aquifer
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

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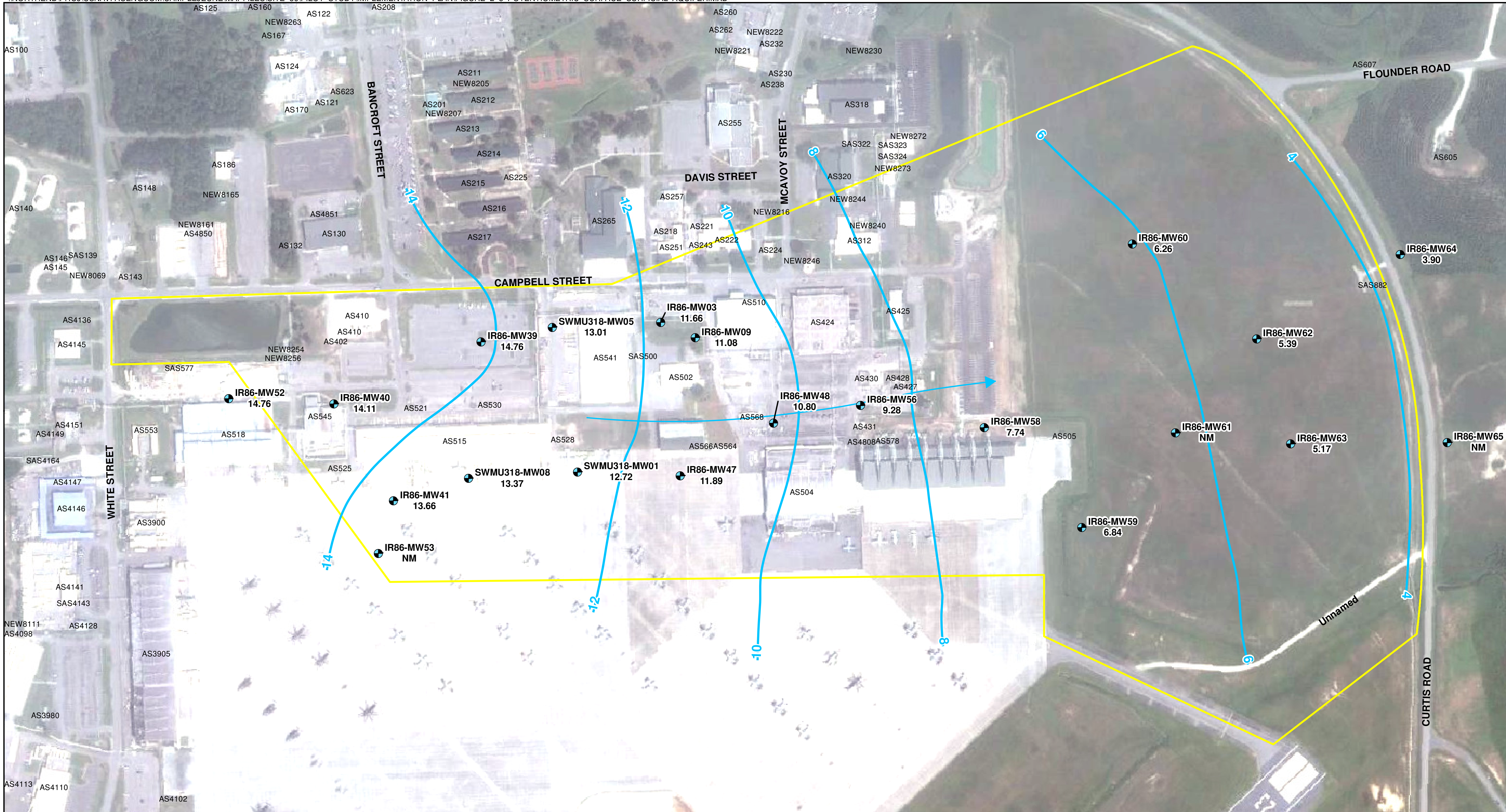

Legend

- Monitoring Well
- Potentiometric Contours
- Groundwater Flow Direction
- Expanded Site 86 Boundary (March 2010)

6.84 - Water Level Elevations

Notes:
- Water level elevations are reported in feet above mean sea level
- Water levels were measured on March 13/14, 2010
- NM - Not Measured

N

0 175 350 700 Feet

1 inch = 350 feet

Google Earth Imagery

Figure 2-7
Potentiometric Surface - Surficial Aquifer
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

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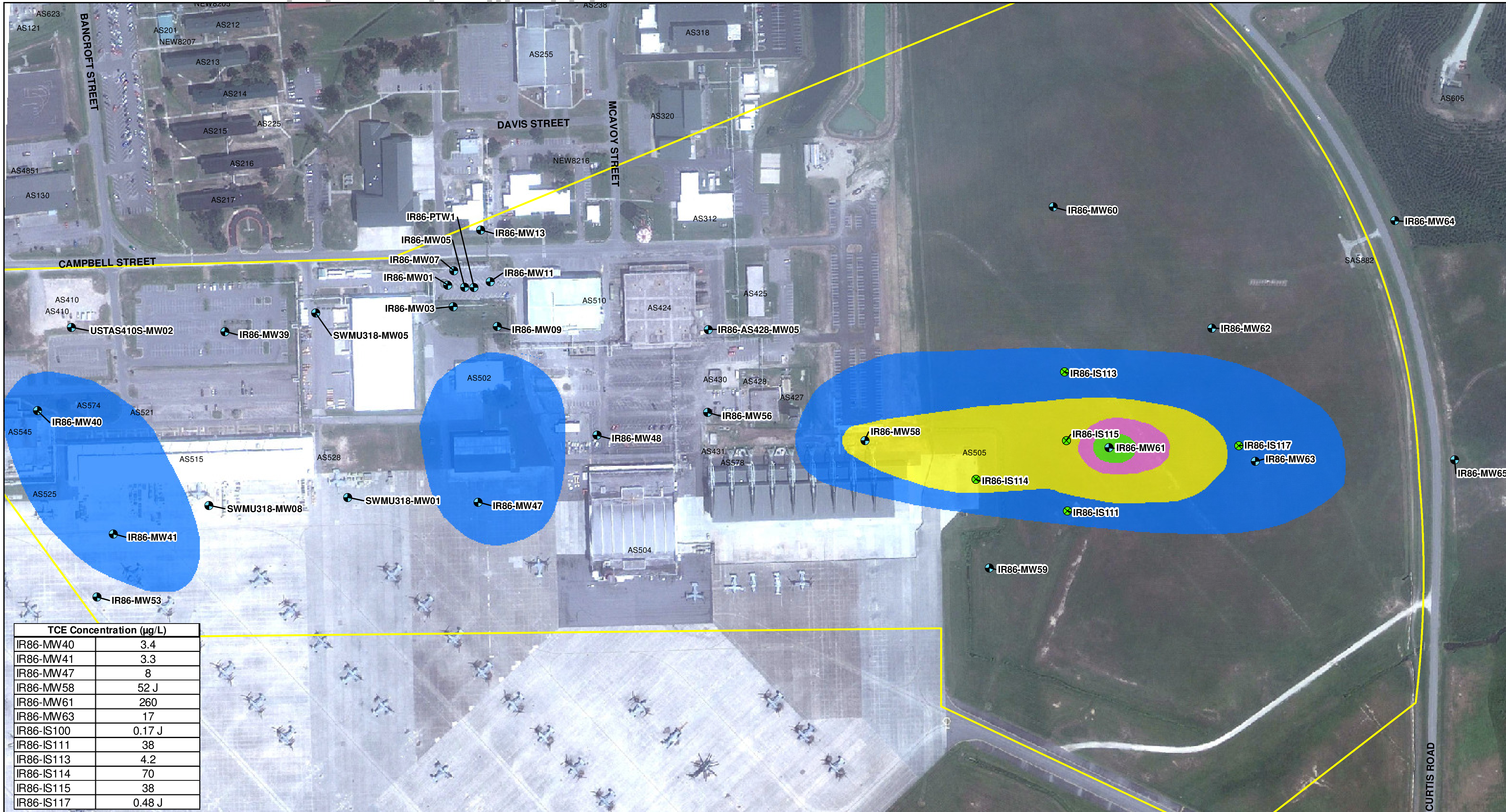


TCE Concentration (µg/L)	
IR86-MW40	3.4
IR86-MW41	3.3
IR86-MW47	8
IR86-MW58	52 J
IR86-MW61	260
IR86-MW63	17
IR86-IS100	0.17 J
IR86-IS111	38
IR86-IS113	4.2
IR86-IS114	70
IR86-IS115	38
IR86-IS117	0.48 J

Legend

- Direct Push Groundwater Sampling Locations 2009
- Surficial Aquifer
- Expanded Site 86 Boundary (March 2010)

TCE Concentrations

- > 250 µg/L
- > 150 µg/L
- > 50 µg/L
- > 3.0 µg/L

Notes:
- All concentrations are reported in µg/L.
- Contours have been interpolated between monitoring well locations. Actual conditions may differ from those shown.
- Samples collected in December 2009, March 2010, and June 2010.
- NCGWQS for TCE = 3.0 µg/L.
- Only detected concentrations of TCE above NCGWQS shown in table.
- J- Analyte present, value may or may not be accurate or precise.

N

0 137.5 275 550 Feet

1 inch = 275 feet

Google Earth Imagery

Figure 2-8
TCE Concentrations in the Surficial Aquifer
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB Cam Lej
North Carolina

CH2MHILL

SECTION 3

Pilot Study Descriptions

This section presents an overview of the pilot studies, as well as study objectives and goals, and describes the methodology that will be used with each technology. The specific implementation plans for the pilot studies are presented in Section 4.

3.1 Pilot Study Overview, Objectives, and Goals

3.1.1 Study Overview

The results of the ERD and ISCO pilot studies will be evaluated to determine if the treatments are viable remedial options. Key tasks associated with the pilot study include the following:

Zone 1

- Installation and development of six injection and two extraction wells
- Installation of six performance monitoring wells
- Installation of an ERD substrate distribution system
- Injection of ERD reagent (sodium lactate) and bioaugmentation culture, with periodic extraction and treatment of groundwater
- Collection of baseline groundwater samples and at 1-, 3-, and 6-month intervals from existing and newly installed monitoring wells to evaluate pilot study effectiveness

Zone 2

- Installation of four performance monitoring wells in Zone 2
- Installation of SRPCs at 30 locations in Zone 2
- Collection of baseline groundwater samples and at 1-, 3-, and 6-month intervals from existing and newly installed monitoring wells to evaluate pilot study effectiveness

3.1.2 Pilot Study Objectives and Goals

The primary objectives of the pilot study are:

- To evaluate the injection/extraction approach as a method for distributing the ERD substrate over relatively broad areas and in areas where access is limited
- To evaluate the overall effectiveness of ERD in terms of reducing contaminant mass in Zone 1
- To evaluate the overall effectiveness of SRPC as a passive remediation remedy in Zone 2
- To obtain sufficient performance data and results to refine remedial alternatives for preparation of a Feasibility Study

- To reduce sufficient VOC mass within Zone 1 and 2 to allow for monitored natural attenuation as a viable remedial option in the Feasibility Study

The objectives and goals will be evaluated for each pilot study by comparing the data gathered during a baseline groundwater sampling to three subsequent sampling events scheduled for 1, 3, and 6 months after the pilot studies have been implemented.

3.2 Technology Description

3.2.1 Enhanced Reductive Dechlorination

ERD is a bioremediation technology used for treating chlorinated volatile organic compounds (CVOCs) in groundwater with the addition of electron donors such as lactate, molasses, vegetable oil, and other commercially available carbon sources. ERD accelerates the naturally occurring process of reductive dechlorination, wherein chlorinated solvents in groundwater are biodegraded by indigenous anaerobic microbes. Anaerobic microbes take electrons from small organic compounds and produce hydrogen. This process is known as fermentation. The microbes then use the electrons in the hydrogen to replace a chlorine atom in the CVOCs.

The principal anaerobic biodegradation pathway for reductive dechlorination of TCE, cis-1,2-DCE, and VC is:

$$\text{TCE} \rightarrow \text{cis-1,2-DCE} \rightarrow \text{VC} \rightarrow \text{ethene}$$

The transformation rates for each step vary but tend to become slower with progress along the breakdown sequence, often resulting in accumulation of cis-1,2-DCE and VC. Further breakdown from cis-1,2-DCE and VC to ethene varies and is based on site-specific conditions.

Biodegradation of CVOCs can be achieved by adding a suitable reagent to the subsurface. The reagent serves two purposes: (a) depleting the supply of competing electron acceptors and creating strongly reducing conditions and (b) providing an electron donor source for reductive dechlorination.

Sodium Lactate

The ERD reagent selected for Zone 1 is a sodium lactate solution. Sodium lactate was selected based on its chemical properties (such as water solubility to improve distribution) and its ability to be used for ERD faster than oil-based substrates.

A 5 percent sodium lactate solution will be injected into the upper Castle Hayne aquifer through six injection wells, and distribution throughout the treatment footprint will be enhanced using two extraction wells. Once in the aquifer, the lactate will ferment into acetate and hydrogen. The hydrogen will function as the primary electron donor. The lactate will also release ethanol, which will also function as an electron donor.

No significant health and safety concerns are associated with lactate; however, it is recommended that eye protection and impervious gloves be donned to avoid irritation.

Bioaugmentation

Bioaugmentation is the introduction of microorganisms into the subsurface to treat contaminated soil or groundwater. Bioaugmentation is used to ensure that contaminants, particularly cis-1,2-DCE and VC, are completely degraded. A bioaugmentation culture will be injected into the upper Castle Hayne aquifer within Zone 1. The bioaugmentation culture will contain the *Dehalococcoides* bacteria. *Dehalococcoides* bacteria are the only known organisms capable of dechlorinating TCE to ethane. In the absence of *Dehalococcoides*, dechlorination of TCE may only progress to cis-1,2-DCE (Site Recovery and Management Labs, 2009). Bioaugmentation has been demonstrated to work with most commonly used electron donors, including lactate, vegetable oils, and slow-release compounds. Bioaugmentation can be inhibited by aerobic conditions, high sulfate concentrations, moderate concentrations of chloroform, and extremely low groundwater temperatures (Site Recovery and Management Labs, 2009).

Injection/Extraction Premise

An injection/extraction (re-circulation) approach was selected because of access limitations associated with the newly constructed Building AS508 and as a method to enhance distribution and reduce the number of injection points. A portion of the upper Castle Hayne aquifer VOC plume lies below Building AS508 and associated support structures, utilities, manmade drainage features, and concrete aircraft wash platforms.

The sodium lactate solution to the upper Castle Hayne aquifer will be delivered via six injection wells along the perimeter of the treatability study area and two centrally located recovery wells. The enhanced hydraulic gradient created by simultaneous injection and extraction is expected to improve distribution of lactate within the aquifer (to be verified by field monitoring).

3.2.2 Chemical Oxidation

Chemical oxidation delivers chemical oxidants into groundwater to completely oxidize contaminants into carbon dioxide (CO_2) or other innocuous compounds. There are a number of chemicals that successfully degrade chlorinated solvents via chemical oxidation. A key factor in the effectiveness of chemical oxidation is contact between the contaminant and the oxidant.

MnO_4^- is a chemical oxidant with a proven history of effectively treating CVOCs to CO_2. MnO_4^- is a common chemical oxidizing agent with strong oxidation potential, predictable chemistry, good stability, and non-toxic byproducts. Chemical oxidation using MnO_4^- is achieved primarily through direct electron transfers, as shown in the following reaction (USEPA, 2006):

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2(s) + 2\ H_2O$$

Treatment of CVOCs using potassium permanganate ($KMnO_4$) is achieved by adding to the alkene bond, shown as follows in the reactions and TCE with $KMnO_4$ (USEPA, 2006):

$$2\ KMnO_4 + C_2HCl_3 \rightarrow 2\ CO_2 + 2\ MnO_2 + 2\ K^+ + H^+ + 3\ Cl^-$$

The greatest advantage of MnO_4^- is its stability. Persisting for several months, the use of MnO_4^- enables long contact times and transport distances (USEPA, 2006). The oxidation strength and specificity of the MnO_4^- ion improves its longevity compared to non-specific oxidizers such as hydroxyl radicals and ozone.

SRPC Technology

Oxidant injections are often unsuccessful because the injectant fails to meet distribution goals. SRPCs treat groundwater passively, meaning the contaminated groundwater comes in contact with the SRPC under normal groundwater flow conditions. SRPC technology is designed to slowly release MnO_4^- into VOC-contaminated groundwater through molecular diffusion. SRPCs consist of $KMnO_4$ in a paraffin wax matrix. As the paraffin dissolves, $KMnO_4$ crystals become exposed, resulting in the molecular diffusion of MnO_4^- into passing groundwater. The MnO_4^- treatability footprint will vary based on the groundwater velocity, aquifer dispersivity, MnO_4^- persistence in the aquifer, and the soil oxidant demand of the aquifer material.

The SRPC is an emerging technology with limited case studies; however, it is estimated based on site groundwater velocities that each SRPC will have an effective life span of at least 6 months.

SECTION 4
Pilot Study Implementation

This section specifies the implementation plan for each of the Site 86 pilot studies.

4.1 Zone 1 ERD Recirculation System

The Zone 1 ERD Recirculation System pilot study will include the injection of a 5 percent sodium lactate solution into six periphery injection wells, with simultaneous recovery using two centrally located extraction wells. The following tasks have been or will be performed to facilitate the Zone 1 ERD Recirculation System pilot study.

4.1.1 Groundwater Modeling

Groundwater modeling was performed to optimize the ERD treatability study footprint by varying the number, location, pumping rates, and spacing of the injection and extraction well configuration. The model accounted for lateral and vertical groundwater flow to forecast the three-dimensional distribution of substrate for a given array of injection wells. A technical memorandum detailing the modeling is provided in **Appendix A**.

Based on modeling results, a layout consisting of two extraction wells and six injection wells was selected as optimum for treating the extent of highest VOC concentrations in the vicinity of Zone 1. **Figure 4-1** depicts the injection and extraction well locations based on the flow simulation. An extraction rate of 12 gallons per minute (gpm) from each of the two recovery wells was simulated, with a corollary injection rate of 4 gpm for each of the six injection wells. The model indicated distribution of substrate throughout the treatability study area within 30 days of operation.

4.1.2 Utility Location

CH2M HILL will coordinate with MCAS New River personnel and a professional utilities-locating subcontractor to define all subsurface structures that could be affected by drilling activity in the immediate area of the pilot study.

CH2M HILL will mark all boring locations before locating subsurface utilities. All utilities within a 20-ft radius of each proposed boring location will be marked by a licensed professional utilities-locating subcontractor before drilling begins. Preliminary well locations are shown on **Figure 4-1**; final locations will be selected based on the results of subsurface structure and utility locations and other conditions encountered in the field.

4.1.3 Well Installation

Six 4-inch injection wells (IR86-IW01 through IR86-IW08), two 4-inch extraction wells (IR86-EW01 and IR86-EW02), and six 2-inch monitoring wells (IR86-MW through IR86-MW) will be installed in Zone 1 using rotosonic drilling techniques, as shown on **Figure 4-1**. Proposed Zone 1 well construction details are provided in **Table 4-1**.

The injection wells will be installed on the north side of Building AS508, with a row of three wells positioned to the north of IR86-MW-58IW, adjacent to the long axis of the plume, with another row of three wells positioned south of IR86-MW58IW. The injection wells will be spaced approximately 75 ft apart and installed to a depth of 55 ft bgs, with 20 ft of 4-inch inner diameter, 0.020-inch slot “vee-wire” (semi-continuous slot) polyvinyl chloride (PVC) screen. Injection wells may be moved to avoid installing them into pavement or sidewalks.

The extraction wells will be installed at the midpoint between the injection wells, arranged to complete a five-die pattern between the injection wells. The extraction wells will be spaced approximately 75 ft apart and installed to a depth of 55 ft bgs, with 20 ft of 4-inch inner diameter 0.020-inch slot “vee-wire” PVC screen.

To monitor the effectiveness of the system and the radius of influence during operation, six monitoring wells will be installed as shown on **Figure 4-1**. Five monitoring wells will be placed approximately 10, 15, 20, 25, and 30 ft from the injection wells, along the predicted flow path toward the extraction wells. Actual distances may vary owing to site conditions such as the location of utilities or topography. The sixth well will be installed at the midpoint between the two extraction wells. Each monitoring well will be installed to a depth of 50 ft bgs and constructed using 2-inch schedule 40 PVC with 10 ft of 2-inch schedule 40, 0.010-inch slot PVC screen.

TABLE 4-1
Zone 1 Well Construction Summary

Well	Well Diameter (inches)	Total Well Depth (ft)	Screen Length (ft)
IR86 – IW01	4	55	20
IR86 – IW02	4	55	20
IR86 – IW03	4	55	20
IR86 – IW04	4	55	20
IR86 – IW05	4	55	20
IR86 – IW06	4	55	20
IR86 – EW01	4	55	20
IR86 – EW02	4	55	20
IR86 –MW58IWR	2	50	10
IR86 –MW70IW	2	50	10
IR86 –MW71IW	2	50	10
IR86 –MW72IW	2	50	10
IR86 –MW73IW	2	50	10
IR86 –MW74IW	2	50	10

4.1.4 Site Work

Following the installation of the injection, extraction, and monitoring wells in Zone 1, the injection/extraction recirculation system will be installed. System installation components consist of the following:

- Installation of a 208-volt, single phase power source and internet connection
- Excavation of trenches to bury high-density polyethylene system extraction/injection line piping
- Installation of submersible pumps in the extraction wells
- Plumbing of injection and extraction lines to a manifold
- Installation of recirculation system trailer

4.1.5 Substrate Distribution System Layout and Components

The Zone 1 ERD substrate recirculation system site layout is depicted on **Figure 4-2**. A process flow diagram of the recirculation system components is depicted on **Figure 4-3**. As shown on **Figure 4-3**, the primary components of the substrate distribution system are two submersible pumps, a booster pump, cartridge bag filter, two-stage granular activated carbon (GAC) beds containing 500 pounds of GAC each, a dosing pump, static mixer, and six-leg distribution manifold with dedicated flow meters, pressure gauges, and throttling valves. The system will have telemetry and fail-safe interlock controls, including process line pressure sensors and pressure transducers for each injection well to monitor water levels.

A stock 50 percent sodium lactate solution will be supplied in 275 gallon totes by the supplier. These totes will be stored within the fenced area of the substrate distribution system compound.

4.1.6 ERD Substrate and Bioaugmentation Injection

Groundwater will be extracted from each of the two upper Castle Hayne extraction wells using an electric submersible pump and routed through a cartridge bag filter and GAC beds before amendment with a stock 50 percent sodium lactate solution and bioaugmentation culture, for a target injectate concentration of 5 percent sodium lactate solution. The 5 percent sodium lactate solution and bioaugmentation culture will be pumped through a six-leg injection manifold and 1-inch diameter high-density polyethylene conveyance lines to each injection well. Each 0.5-inch manifold leg will be equipped with a flow meter, check valve, and gate valve. A pressure transducer will be installed in each injection well, which will suspend system operation in the event of excessive groundwater mounding and/or pressure drop within the injection well due to well efficiency decline (such as biofouling of the injection well screen). To mitigate biofouling of the well screens, a bleach solution will be injected before and after each period of sodium lactate injection, or as needed based on frequency of mounding and/or pressure drops observed in the system.

Results of the groundwater modeling (see **Appendix A**) indicated that groundwater could be effectively extracted from each of the two extraction wells at a rate of 12 gpm and injected into each of the six injection wells at a rate of 4 gpm. Actual injection and extraction rates will be optimized during system startup.

The 5 percent sodium lactate solution will be injected until groundwater quality parameters measured in monitoring and extraction wells indicate that the sodium lactate solution has been effectively distributed throughout the treatability footprint. TOC measurements will be collected in the field from the two extraction wells using Hach kits. Sodium lactate will be considered effectively distributed when TOC concentrations are greater than 20 mg/L, the recommended TOC concentration for the natural attenuation of solvents (USEPA, 1998; Wiedemeier et al., 1996).

Once effectively distributed, predicted by groundwater modeling to take 30 days, the substrate distribution system will be temporarily suspended and monitored for TOC depletion. Once the concentrations of TOC have been depleted to 10 mg/L or less (estimated to take 30 days), the system will be restarted and the 5 percent sodium lactate solution will be injected a second time until the sodium lactate solution has been effectively distributed. A total of three sodium lactate treatments will be implemented over the 6-month study duration. Each treatment cycle will consist of an estimated 30 days of injection, followed by 30 days of fermentation. An Underground Injection Control permit is provided as **Appendix B**.

4.2 Zone 2 SRPC Permeable Reactive Barrier Pilot Study Setup

4.2.1 Utility Location

CH2M HILL will coordinate with MCAS New River personnel and a professional utilities-locating subcontractor to define all subsurface structures that could be affected by drilling activity in the immediate area of the pilot study.

CH2M HILL will mark all boring locations before locating subsurface utilities. All utilities within a 20-ft radius of each proposed boring location will be marked by a licensed professional utilities-locating subcontractor before drilling begins. Preliminary well and SRPC locations are shown on **Figure 4-4**; final locations will be selected based on the results of subsurface structure and utility locations and other conditions encountered in the field.

4.2.2 Well Installation

Before SRPC deployment occurs, four monitoring wells will be installed within the surficial aquifer, approximately 1, 5, 10, and 15 ft downgradient of the SRPC permeable reactive barrier location. Monitoring wells will be installed to approximately 30 ft bgs, with a screened interval of 20 to 30 ft bgs. Each monitoring well will be constructed using 2-inch schedule 40 PVC with 10 ft of 2-inch schedule 40, 0.010-inch slot PVC screen. Zone 2 well construction details are provided in **Table 4-2**.

TABLE 4-2
Zone 2 Monitoring Well Construction Summary

Well	Well Diameter (inches)	Total Well Depth (ft)	Screen Length (ft)
IR86 - MW66	2	30	10
IR86 - MW67	2	30	10
IR86 - MW68	2	30	10
IR86 - MW69	2	30	10

4.2.3 SRPC Deployment

SRPCs will be deployed at 30 locations within the Zone 2 pilot study area, in the vicinity of surficial monitoring well IR86-MW61, to passively treat VOC-contaminated groundwater as it flows through and downgradient of the SRPC permeable reactive barrier. Each SRPC will measure approximately 1.5 inches in diameter and 3 ft in length and consist of crystalline $KMnO_4$ in a paraffin wax matrix.

Two 80-ft-long transects, each consisting of 15 locations at 3-ft offset spacing, will be installed approximately 10 ft downgradient of surficial monitoring well IR86-MW61 using a DPT drill rig. The easternmost transect of SRPCs will be installed at a depth of 20 to 23 ft bgs, and the westernmost transect will be installed at a depth of 23 to 26 ft bgs.

Two SRPCs will be placed at each location; a DPT drill rig will advance a 3-inch steel casing with an expendable point to the target depth. Once at depth, approximately 6 inches of bentonite will be added to the bottom of the boring. The bentonite will seal the bottom of the boring and inhibit the downward density-driven flow of the relatively dense MnO_4^- solution within the immediate vicinity of the SRPCs. A 6-inch layer of a well-graded sand filter pack will be placed above the bentonite to isolate the SRPCs from the bentonite seal. Two SRPCs will be placed above the sand within the 3-inch casing. Once the SRPCs are in place, the 3-inch casing will be extracted from the aquifer while adding a well-graded sand filter pack. Once above the water table, bentonite will be added to properly seal the boring surface. **Figure 4-4** depicts the approximate locations of the SRPCs and performance monitoring wells. An Underground Injection Control permit is provided as **Appendix B**.

4.3 Groundwater Monitoring

Groundwater samples will be collected from monitoring wells within Zone 1 and Zone 2 pilot study areas to monitor the effectiveness of the respective treatment technologies. Groundwater sampling will be conducted in accordance with the Site 86 UFP-SAP, which will be issued under separate cover. Details associated with groundwater monitoring for each of the two pilot studies are provided below.

4.3.1 Zone 1 Groundwater Monitoring

Groundwater samples will be collected from upper Castle Hayne aquifer monitoring wells associated with the Zone 1 ERD pilot study area (IR86-MW58IWR and IR86-MW70IW through IR86-MW74IW) (**Figure 4-1**). Groundwater samples will be analyzed by a fixed-base laboratory for VOCs, volatile fatty acids, and TOC, as specified in the Site 86 UFP-SAP (CH2M HILL, 2011b), to evaluate the effectiveness of the lactate and bioaugmentation treatments. Bioassay samples will also be collected from select monitoring wells and submitted for quantitative real time polymerase chain reaction-ribonucleic acid expression analysis to assess the performance of the bioaugmentation culture and to track the microbial populations. Four groundwater sampling events will be conducted: baseline, 1 month, 3 months, and 6 months.

4.3.2 Zone 2 Groundwater Monitoring

Groundwater samples will be collected from surficial monitoring wells associated with the Zone 2 SRPC pilot study area (IR86-MW61, IR86-MW63 and IR86-MW66 through IR86-MW69) (**Figure 4-2**). Groundwater samples will be analyzed for VOCs, as specified in the Site 86 UFP-SAP (CH2M HILL, 2011b). Four groundwater sampling events will be conducted: baseline, 1 month, 3 months, and 6 months.

Legend

- Extraction Well
- Injection Well
- Proposed Monitoring Well
- Upper Castle Hayne Aquifer Monitoring Well

TCE Concentrations

- > 300 µg/L
- > 30 µg/L
- > 3.0 µg/L

N

0 15 30 60 Feet

1 inch = 30 feet

Google Earth Imagery

Figure 4-1
Injection-Extraction System Layout
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB Cam Lej
North Carolina

CH2MHILL

Generated By: K. Howell/CLT Checked by: T. Grim/CLT

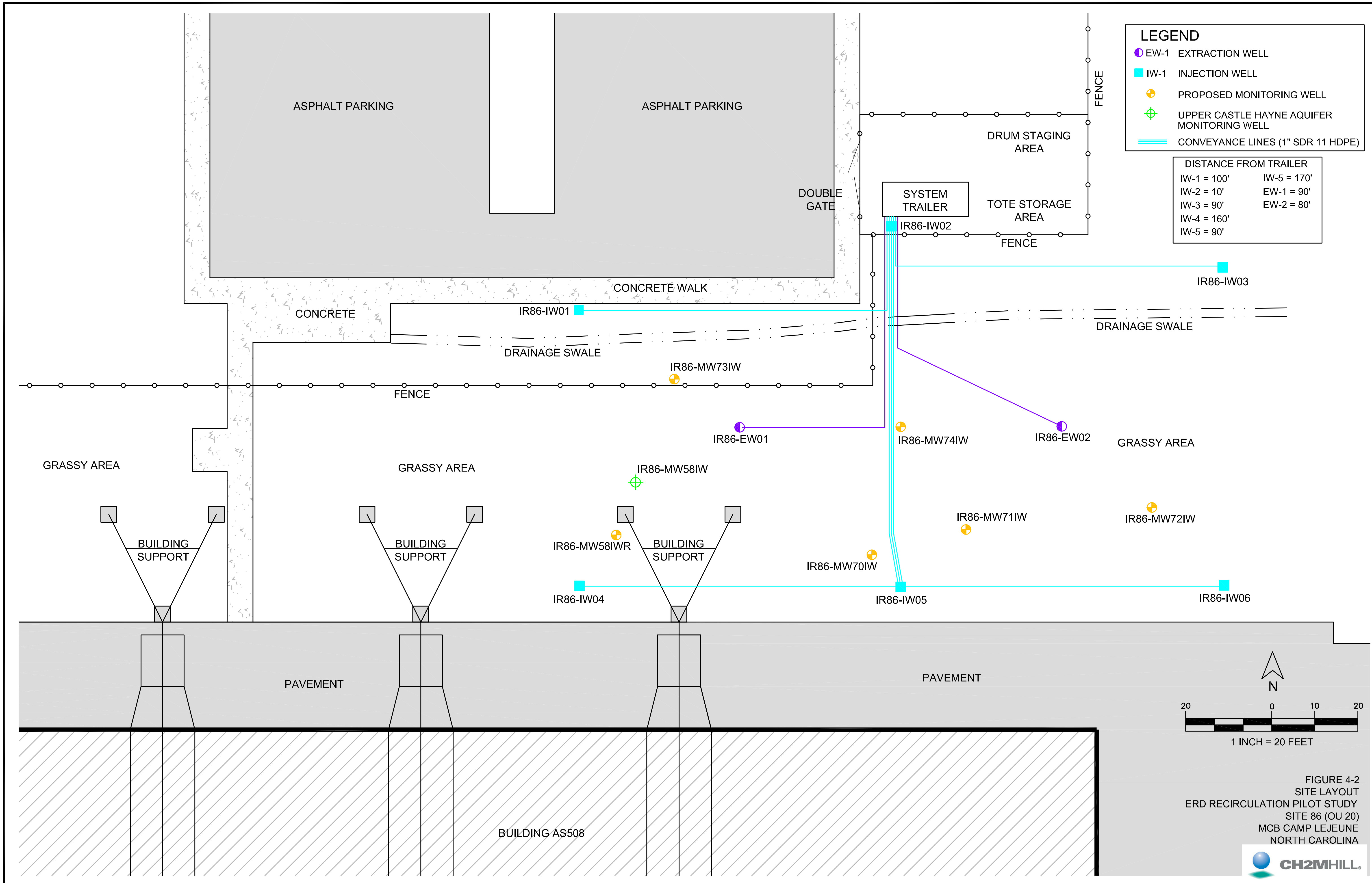


FIGURE 4-2
SITE LAYOUT
ERD RECIRCULATION PILOT STUDY
SITE 86 (OU 20)
MCB CAMP LEJEUNE
NORTH CAROLINA

CH2MHILL.

EBL\Navy Clean\OU 20(Site 86)\2011 Pilot Study\Working Figures

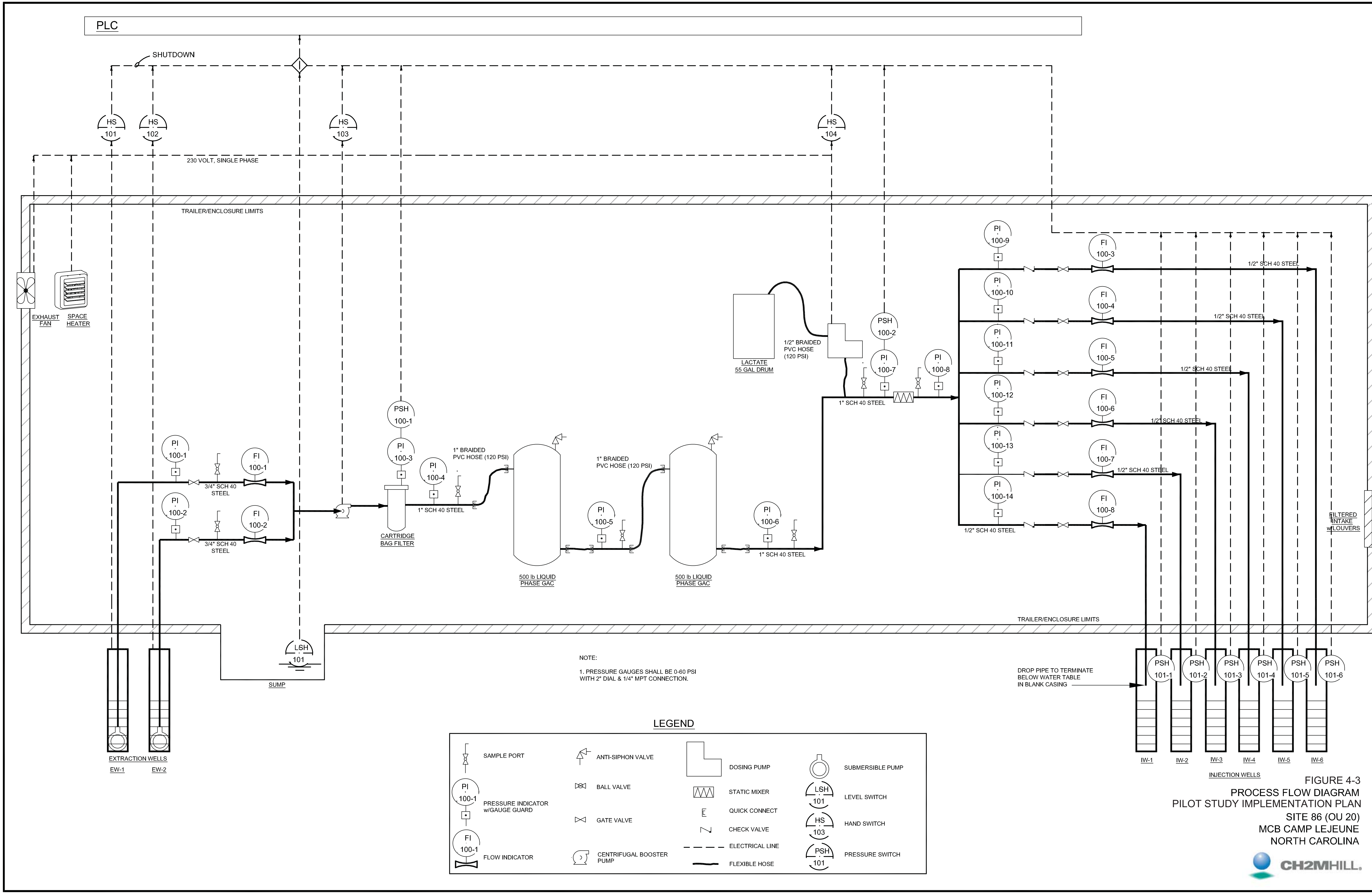
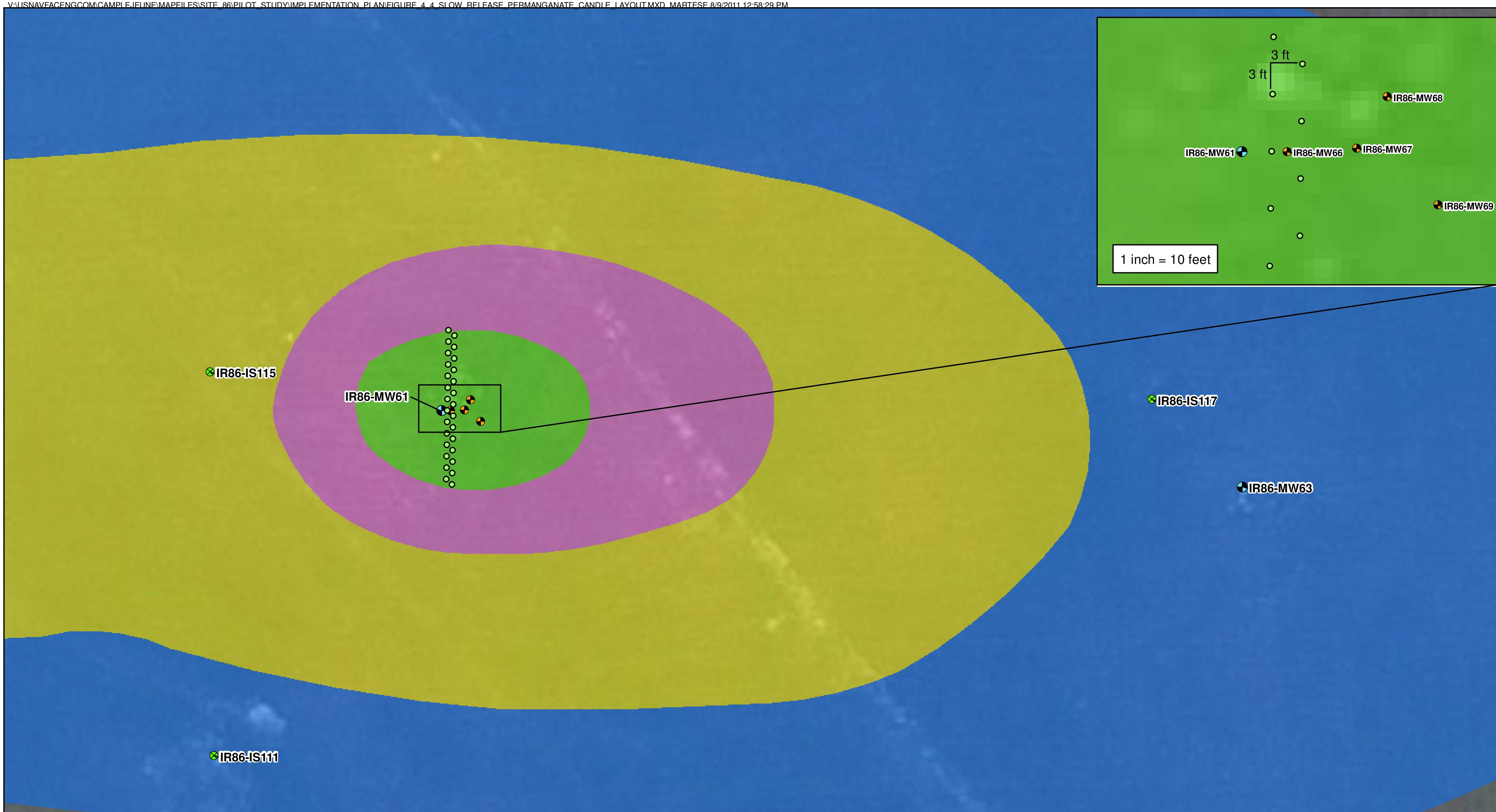


FIGURE 4-3
PROCESS FLOW DIAGRAM
PILOT STUDY IMPLEMENTATION PLAN
SITE 86 (OU 20)
MCB CAMP LEJEUNE
NORTH CAROLINA

CH2MHILL.

V:\USNAVFACENGCOM\CAMPLEJEUNE\MAPFILES\SITE_86\PILOT_STUDY\IMPLEMENTATION_PLAN\FIGURE_4_4_SLOW_RELEASE_PERMANGANATE_CANDLE_LAYOUT.MXD MARTESE 8/9/2011 12:58:29 PM



Legend

- Proposed Slow Release Permanganate Candles
- Proposed Surficial Aquifer Monitoring Well
- Direct Push Groundwater Sampling Locations 2009
- Surficial Aquifer Monitoring Well

TCE Concentrations

Modeled

- > 250 µg/L
- > 150 µg/L
- > 50 µg/L
- > 3.0 µg/L

N

0 25 50 100 Feet

1 inch = 50 feet

Google Earth Imagery

Figure 4-4
Slow Release Permanganate Candle Layout
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

SECTION 5

Health and Safety and Residuals Management

5.1 Health and Safety

An HSP will be prepared in accordance with 29 Code of Federal Regulations Parts 1910 and 1926. The HSP will address the potential hazards associated with the field activities and pilot studies. Subcontractors will be responsible for the health and safety procedures specific to their particular work components and are required to develop and submit an Activity Hazard Analysis to CH2M HILL for review before the start of field work. Subcontractors also must comply with the established HSP, and CH2M HILL will monitor and enforce compliance with the established HSP.

5.2 General Safety

All personnel involved with the injections will undergo training on chemical handling and proper operation of the mixing and injection equipment. The training will also cover personal protective equipment (PPE) and spill response measures. Only trained personnel will be allowed to operate mixing and injection equipment or to respond to spills.

5.3 Residuals Management

Wastes generated during the investigation of potentially contaminated sites are classified as IDW and will be managed to protect the public and the environment in accordance with the Investigation and Remediation Waste Management Plan (CH2M HILL, 2011c).

The waste streams associated with this project may include:

- Soil cuttings from the installation of injection, extraction, and monitoring wells
- Equipment and personnel decontamination fluid
- Development and purge water from the monitoring wells
- Used PPE
- Used sampling supplies
- Uncontaminated general debris

5.3.1 Waste Management

All IDW management actions will be documented in the field notes. Specific waste management procedures are documented in the IDW standard operating procedure (CH2M HILL, 2008).

Decontamination fluids, drilling fluids, development and purge water, and soil cuttings will be collected in 55-gallon steel drums that will be provided by the drilling subcontractor and/or CH2M HILL. The CH2M HILL Field Team Leader (FTL) will coordinate the transportation of all IDW drums to a preapproved staging location on Site 86. A CH2M HILL representative will provide oversight when transferring IDW to the staging location. Each drum will be properly labeled as soon as IDW is introduced into the drum and transferred to the fenced system compound (**Figure 4-2**) before being transported to an approved disposal facility.

Soil and water IDW samples will be collected during well installation activities. Based on available data, both soil and water are expected to be characterized as non-hazardous; however, each drum will be properly labeled with a “Pending Analysis” label as soon as IDW is introduced into the drum. The label must include the contents, accumulation start date, generator name, and USEPA identification number. The drums will be moved by a licensed hazardous waste transporter once a waste profile for water and soil is selected and a waste manifest is approved.

PPE and used sampling supplies associated with the generation of non-hazardous wastes and general debris will be collected in black, non-translucent trash bags and disposed of in a dumpster aboard MCAS New River.

SECTION 6

Site Activity Considerations

The pilot studies will be conducted within a congested area of the MCAS New River. Care will be taken to minimize disturbance of surrounding operations. Considerations related to implementing the pilot studies at Site 86 include, but are not limited to, the following:

- Access, equipment, space, and utility requirements
  - All CH2M HILL and subcontractor personnel will be required to obtain flight line access credentials and, if needed, a flight line driver's license.
  - Subcontractors will be solely responsible for their equipment, instrumentation, materials, and supplies.
  - Drilling subcontractor will be responsible for providing an equipment and materials storage area during the well installation phase.
  - Underground utilities will be identified by a professional utilities-locating subcontractor.
- Site security
  - During working hours, CH2M HILL personnel will secure the work area.
  - Site access during the project will be limited to authorized personnel only.

SECTION 7

Reporting

At the conclusion of each of the pilot studies, a report will be prepared to summarize the field activities and to present the results, conclusions, and recommendations. Results of the pilot studies will be used for the evaluation in the Feasibility Study and potential future remedial designs.

SECTION 8

Project Management

8.1 Project Schedule

The proposed schedule for implementing the pilot studies at Site 86 is presented on **Figure 8-1**. The tasks shown on the schedule correspond to the tasks identified in this Implementation Plan.

8.2 Project Organization

The project organization is presented on **Figure 8-2**. The Partnering Team consists of representatives from CH2M HILL, NAVFAC, MCB CamLej, North Carolina Department of Environment and Natural Resources, and USEPA Region 4.

Mr. Theron Grim, P.G., will serve as the Project Manager for the pilot studies. He will be responsible for overall project management and the overall quality assurance/quality control of project deliverables.

Mr. Christopher Bozzini, P.E., will serve as the Senior Consultant for the pilot studies. He will work with Mr. Grim to ensure the quality of project execution and will review the technical aspects of the work from project scoping to project completion.

Other members of the project team include:

- Task Manager
- Project Engineer/Hydrogeologist
- FTL and field staff
- Technical project staff

All field and subcontractor activity will be under the direction of the FTL.

Figure 8-1
Site 86 Pilot Study
Project Schedule

ID	Task Name	Duration	Start	Finish
1	NTP	0 days	Thu 6/9/11	Thu 6/9/11
2	**PP.PM Project Management**	**349 days**	**Thu 6/9/11**	**Tue 10/9/12**
3	Project Management	349 days	Thu 6/9/11	Tue 10/9/12
4	**PT.WP Work Plan**	**68 days**	**Thu 6/9/11**	**Mon 9/12/11**
5	Subcontractor Procurement	20 days	Thu 6/9/11	Wed 7/6/11
6	Draft UFP-SAP	30 days	Thu 6/9/11	Wed 7/20/11
7	Navy Chemist Review	21 days	Thu 7/21/11	Thu 8/18/11
8	Response to Comments	1 day	Fri 8/19/11	Fri 8/19/11
9	Partnering Team Review	10 days	Mon 8/22/11	Fri 9/2/11
10	Final UFP-SAP	1 day	Mon 9/12/11	Mon 9/12/11
11	**PT.DE Dat Evaluation Modeling**	**25 days**	**Thu 7/14/11**	**Wed 8/17/11**
12	MODFLOW Modeling	25 days	Thu 7/14/11	Wed 8/17/11
13	**PT.MW Monitoring Well Installation**	**29 days**	**Mon 9/26/11**	**Thu 11/3/11**
14	Utility Location	1 day	Mon 9/26/11	Mon 9/26/11
15	Monitoring Well Installation	20 days	Mon 9/26/11	Fri 10/21/11
16	Survey	2 days	Wed 11/2/11	Thu 11/3/11
17	**PT.SI System Installation**	**6 days**	**Mon 10/17/11**	**Mon 10/24/11**
18	Utility Location	1 day	Mon 10/17/11	Mon 10/17/11
19	System Installation	5 days	Tue 10/18/11	Mon 10/24/11
20	**PT.PT Pilot Test**	**125 days**	**Mon 10/17/11**	**Fri 4/6/12**
21	Groundwater Sampling Baseline	5 days	Mon 10/17/11	Fri 10/21/11
22	System Startup	5 days	Mon 10/24/11	Fri 10/28/11
23	Utility Location	1 day	Tue 10/25/11	Tue 10/25/11
24	DPT Installation	5 days	Wed 10/26/11	Tue 11/1/11
25	Groundwater Sampling - 1 month	5 days	Mon 11/21/11	Fri 11/25/11
26	Groundwater Sampling - 3 months	5 days	Mon 1/16/12	Fri 1/20/12
27	Groundwater Sampling - 6 months	5 days	Mon 4/2/12	Fri 4/6/12
28	**PT.RP Pilot Test Report**	**66 days**	**Fri 4/27/12**	**Fri 7/27/12**
29	Draft Pilot Test Report	20 days	Fri 4/27/12	Thu 5/24/12
30	NAVFAC/Base Review	15 days	Fri 5/25/12	Thu 6/14/12
31	Incorporate Comments	5 days	Fri 6/15/12	Thu 6/21/12
32	Partnering Team Review	20 days	Fri 6/22/12	Thu 7/19/12
33	Incorporate Comments	5 days	Fri 7/20/12	Thu 7/26/12
34	Submit Final Pilot Test Report	1 day	Fri 7/27/12	Fri 7/27/12
35	**SA.DM Sample Management**	**271 days**	**Thu 6/16/11**	**Thu 6/28/12**
36	Lab and Data Validator Procurement	20 days	Thu 6/16/11	Wed 7/13/11
37	Lab analytical - Final Groundwater	14 days	Mon 4/9/12	Thu 4/26/12
38	QA/QC Raw data	10 days	Fri 4/27/12	Thu 5/10/12
39	Send to Data Validator	5 days	Fri 5/11/12	Thu 5/17/12
40	QA/QC Validated Data	10 days	Fri 6/1/12	Thu 6/14/12
41	Upload to Database	10 days	Fri 6/15/12	Thu 6/28/12

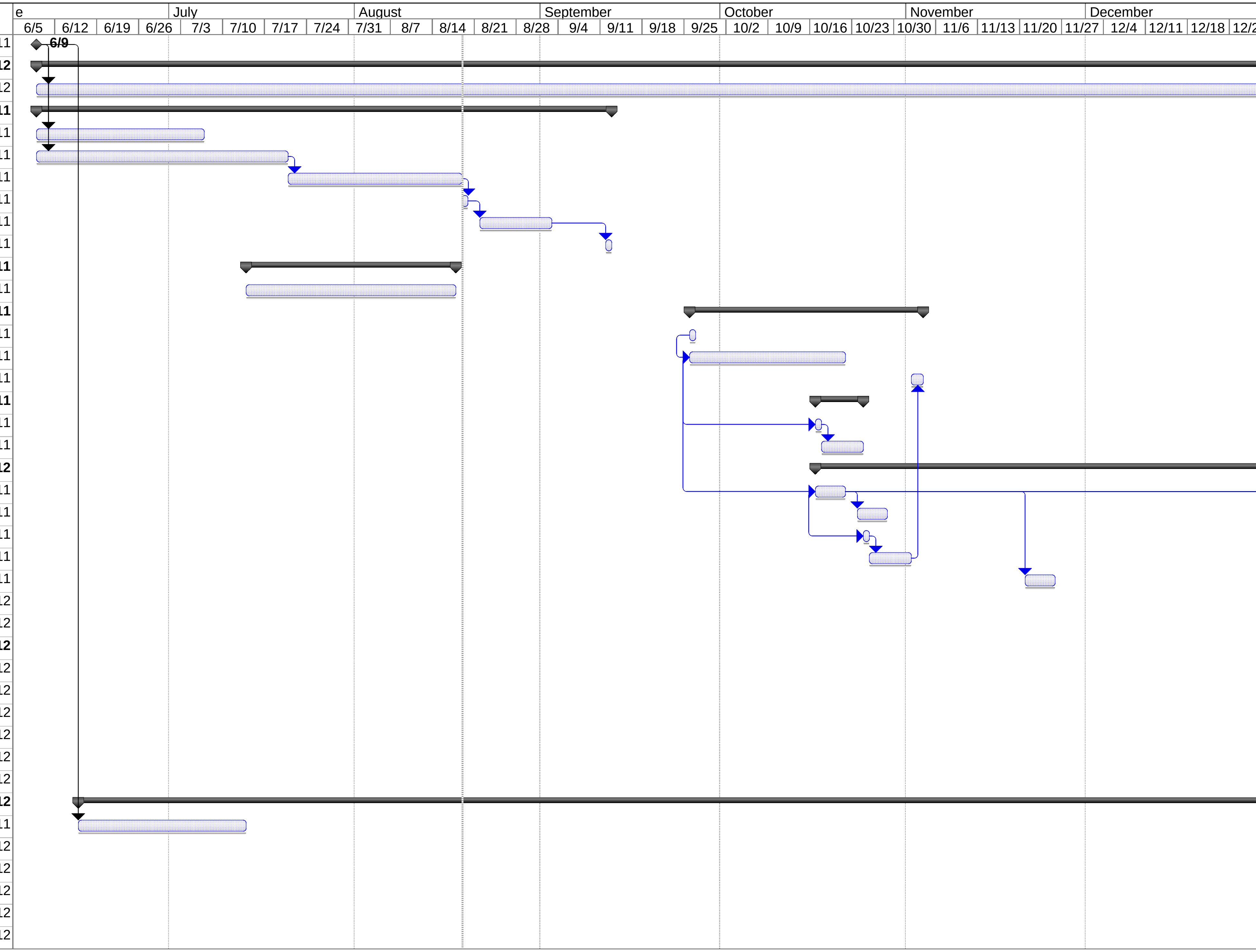
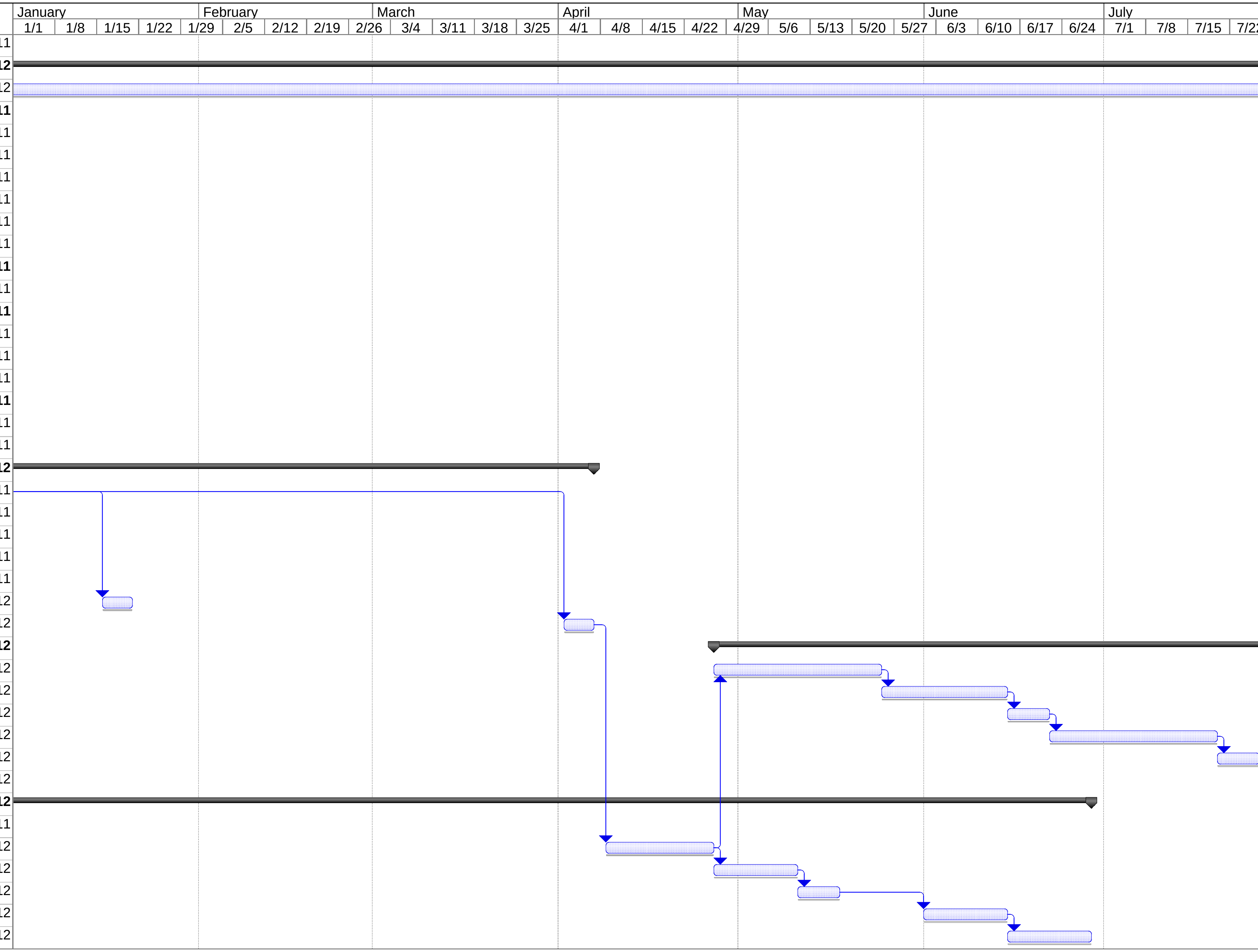


Figure 8-1
Site 86 Pilot Study
Project Schedule

ID	Task Name	Duration	Start	Finish
1	NTP	0 days	Thu 6/9/11	Thu 6/9/11
2	**PP.PM Project Management**	**349 days**	**Thu 6/9/11**	**Tue 10/9/12**
3	Project Management	349 days	Thu 6/9/11	Tue 10/9/12
4	**PT.WP Work Plan**	**68 days**	**Thu 6/9/11**	**Mon 9/12/11**
5	Subcontractor Procurement	20 days	Thu 6/9/11	Wed 7/6/11
6	Draft UFP-SAP	30 days	Thu 6/9/11	Wed 7/20/11
7	Navy Chemist Review	21 days	Thu 7/21/11	Thu 8/18/11
8	Response to Comments	1 day	Fri 8/19/11	Fri 8/19/11
9	Partnering Team Review	10 days	Mon 8/22/11	Fri 9/2/11
10	Final UFP-SAP	1 day	Mon 9/12/11	Mon 9/12/11
11	**PT.DE Dat Evaluation Modeling**	**25 days**	**Thu 7/14/11**	**Wed 8/17/11**
12	MODFLOW Modeling	25 days	Thu 7/14/11	Wed 8/17/11
13	**PT.MW Monitoring Well Installation**	**29 days**	**Mon 9/26/11**	**Thu 11/3/11**
14	Utility Location	1 day	Mon 9/26/11	Mon 9/26/11
15	Monitoring Well Installation	20 days	Mon 9/26/11	Fri 10/21/11
16	Survey	2 days	Wed 11/2/11	Thu 11/3/11
17	**PT.SI System Installation**	**6 days**	**Mon 10/17/11**	**Mon 10/24/11**
18	Utility Location	1 day	Mon 10/17/11	Mon 10/17/11
19	System Installation	5 days	Tue 10/18/11	Mon 10/24/11
20	**PT.PT Pilot Test**	**125 days**	**Mon 10/17/11**	**Fri 4/6/12**
21	Groundwater Sampling Baseline	5 days	Mon 10/17/11	Fri 10/21/11
22	System Startup	5 days	Mon 10/24/11	Fri 10/28/11
23	Utility Location	1 day	Tue 10/25/11	Tue 10/25/11
24	DPT Installation	5 days	Wed 10/26/11	Tue 11/1/11
25	Groundwater Sampling - 1 month	5 days	Mon 11/21/11	Fri 11/25/11
26	Groundwater Sampling - 3 months	5 days	Mon 1/16/12	Fri 1/20/12
27	Groundwater Sampling - 6 months	5 days	Mon 4/2/12	Fri 4/6/12
28	**PT.RP Pilot Test Report**	**66 days**	**Fri 4/27/12**	**Fri 7/27/12**
29	Draft Pilot Test Report	20 days	Fri 4/27/12	Thu 5/24/12
30	NAVFAC/Base Review	15 days	Fri 5/25/12	Thu 6/14/12
31	Incorporate Comments	5 days	Fri 6/15/12	Thu 6/21/12
32	Partnering Team Review	20 days	Fri 6/22/12	Thu 7/19/12
33	Incorporate Comments	5 days	Fri 7/20/12	Thu 7/26/12
34	Submit Final Pilot Test Report	1 day	Fri 7/27/12	Fri 7/27/12
35	**SA.DM Sample Management**	**271 days**	**Thu 6/16/11**	**Thu 6/28/12**
36	Lab and Data Validator Procurement	20 days	Thu 6/16/11	Wed 7/13/11
37	Lab analytical - Final Groundwater	14 days	Mon 4/9/12	Thu 4/26/12
38	QA/QC Raw data	10 days	Fri 4/27/12	Thu 5/10/12
39	Send to Data Validator	5 days	Fri 5/11/12	Thu 5/17/12
40	QA/QC Validated Data	10 days	Fri 6/1/12	Thu 6/14/12
41	Upload to Database	10 days	Fri 6/15/12	Thu 6/28/12



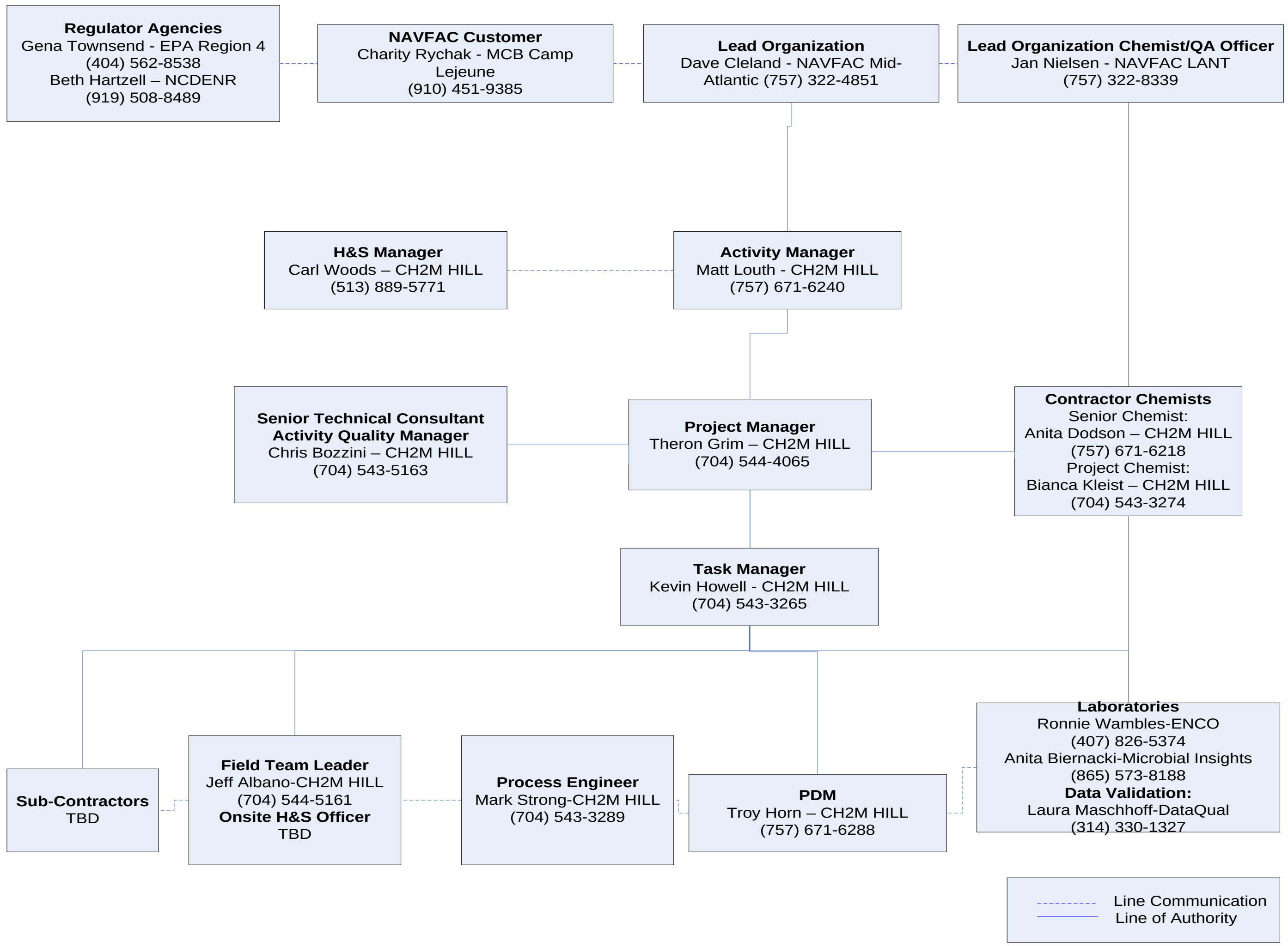


Figure 8-2
Project Organization Chart
Site 86 Pilot Study Implementation Plan
MCB CamLej
North Carolina

SECTION 9

References

Baker Environmental, Inc. 1996. *Remedial Investigation Report, Operable Unit No. 20 (Site 86)*, August.

CH2M HILL. 2008. *Final Master Project Plans, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina.*

CH2M HILL. 2011a. *Final Expanded Supplemental Remedial Investigation Site 86-Operable Unit No, 20, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina*. September.

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CH2M HILL. 2011c. *Investigation and Remediation Waste Management Plan, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina.* February.

Site Recovery and Management Labs. 2009. *KB-1 Bioaugmentation*. http://www.siremlab.com/kb1bioaugmentation.html. Accessed May 14.

United States Environmental Protection Agency (USEPA). 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water.* EPA 600-R-98-128. September.

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Appendix A
Groundwater Modeling Technical Memorandum

Pilot Study Groundwater Modeling Evaluation for Operable Unit 20 (Site 86)

PREPARED FOR: Project File

PREPARED BY: Darren Meadows/CH2M HILL/RDD
Nate Brown/CH2M HILL/RDD

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Jeff Albano/CH2M HILL/CLT

DATE: August 16, 2011

PROJECT NUMBER: 423849.PT.DE

Introduction

CH2M HILL plans to implement a pilot study to test the effectiveness of in situ treatment of a volatile organic compound (VOC) groundwater plume beneath Site 86, Operable Unit No. 20, at Marine Corps Base Camp Lejeune, North Carolina (**Figure 1**). The conceptual design of the pilot study includes the following elements:

- Installing extraction and injection wells screened in the Upper Castle Hayne aquifer in the trichloroethene (TCE) source area near the northeastern edge of Hangar AS508. **Figure 2** depicts the TCE plume in the Upper Castle Hayne aquifer. The target treatment area coincides with the area exhibiting TCE concentrations equal to and greater than 300 micrograms per liter (µg/L).
- Installing conveyance piping and an ex situ treatment vessel and substrate feed vessel between these extraction and injection wells to facilitate routing, treating, and dosing extracted groundwater, before it enters the injection wells and is distributed back into the Upper Castle Hayne aquifer.

Budgetary and logistical constraints limit the number of extraction and injection wells to a maximum of eight wells. The goal of the pilot study is to test the effectiveness of enhanced reductive dechlorination (ERD) in the Upper Castle Hayne aquifer beneath the TCE source area, which is located approximately 2,200 feet upgradient of the New River.

This technical memorandum documents the application of a numerical groundwater flow and transport model to aid in designing a well configuration and pumping regime for the extraction/injection substrate delivery system. The Site 86 Groundwater Flow Model (GFM) was developed for the expanded supplemental remedial investigation (CH2M HILL, 2011) as a screening-level tool for testing hypotheses related to the physical properties of the aquifer, subsurface solute conditions, and the potential effectiveness of different remediation scenarios.

Modeling Objectives

A modified version of the Site 86 GFM was used to meet the following objectives:

- To aid in siting extraction and injection wells to maximize the potential extent of the in situ treatment zone.
- To aid in estimating pumping rates of the extraction and injection wells.
- To estimate the duration of ERD effectiveness in the in situ treatment zone.

Computer Code Description

The Site 86 GFM is described in detail in *Expanded Supplemental Remedial Investigation Site 86-Operable Unit No. 20, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina* (CH2M HILL, 2011). This model was developed with the MODFLOW-2000 (MF2K) code (Harbaugh et al., 2000) to solve the groundwater flow equations and establish a set of steady-state groundwater elevations and associated fluxes consistent with average 2010 conditions. The MF2K code simulates single-density, three-dimensional groundwater flow through porous media using the finite-difference method (McDonald and Harbaugh, 1988).

The MT3DMS code (Zheng and Wang, 1999) was used in conjunction with MF2K to simulate the distribution of injected substrate within the pilot study area. The modeling process includes running MF2K to establish a three-dimensional, steady-state representation of the groundwater flow system, followed by running MT3DMS to retrieve the necessary hydraulic results from MF2K and solving the governing solute transport equations necessary to simulate substrate transport. As a result, both MF2K and MT3DMS are required to simulate substrate transport.

Model Application

A modified version of the Site 86 GFM was used to achieve the modeling objectives. The original Site 86 GFM used a consistent grid cell spacing on approximately 100-foot centers. The grid was refined in the pilot study area to a cell spacing on approximately 10-foot centers to provide greater spatial resolution. The original Site 86 GFM simulated transport of TCE and vinyl chloride, whereas the modified Site 86 GFM was used to simulate transport of injected substrate. The modified Site 86 GFM also differed from the original model in that it does not simulate dual domain mass transfer processes, but rather uses a simplified single domain transport formulation (immobile porosity is not included in the substrate transport calculations).

The anticipated substrate is 50-percent sodium lactate; however, the simulated substrate was its total organic carbon (TOC) equivalent, because this is the component of the sodium lactate that the microbes consume, which creates the reductive conditions that augment dechlorination. For modeling purposes, it was assumed that a 1,500-milligrams-per-liter (mg/L) 50-percent sodium lactate solution would be injected. This equates to a TOC concentration of 482 mg/L. It was further assumed that the lowest concentration at which TOC remains effective at enhancing the reductive dechlorination process would be 20 mg/L. This value is based on professional judgment and ERD studies conducted by

CH2M HILL at other sites. Therefore, the model simulated extraction rates equal to injection rates, with an injected TOC concentration of 482 mg/L. The forecast in situ treatment zone extents were visualized for a given well configuration by color-flooding simulated TOC concentrations of 40 mg/L and higher in the simulated Upper Castle Hayne aquifer.

Transport parameters include the bulk density, mobile porosity, dispersivity, distribution coefficient, and first-order TOC biodegradation half-life. Table 1 lists the modeled transport parameter values. The bulk density and mobile porosity values of 1.72 grams per cubic centimeter (g/cm^3) and 0.15, respectively, are based on an assumed total porosity of 0.35 and professional judgment. The longitudinal, transverse, and vertical dispersivity values of 6, 0.6, and 0.06 feet, respectively, are based on a substrate transport distance of approximately 80 feet and the Xu and Eckstein (1995) formulation, as modified by Al-Suwaiyan (1996). The distribution coefficient value (milliliters per gram, or mL/g) is used by the model to compute sorption of the substrate to the porous medium. In this case, the mL/g value was set to 0.0, indicating no sorption of TOC. A TOC biodegradation half-life of 20 days is based on sodium lactate studies conducted by CH2M HILL at other sites.

TABLE 1
Summary of Transport Parameter Values for TOC
Pilot Study Groundwater Modeling Evaluation

Parameter	TOC
Bulk Density (g/cm^3)	1.72
Mobile Porosity	0.15
Dispersivity (feet) (longitudinal/transverse/vertical)	6 / 0.6 / 0.06
Distribution Coefficient (mL/g)	0.0
Biodegradation Half-life (days)	20

ρ_b = bulk density
θ_m = mobile porosity
K_d = distribution coefficient

Results

Several well configurations were evaluated as part of the modeling effort. The most effective well configuration is shown on **Figure 3**. This configuration consists of two extraction wells located within a rectangle composed of six injection wells. The extraction and injection well locations are slightly biased downgradient of the TCE plume center, so that more of the leading edge of the target treatment area (i.e., 300 µg/L TCE and greater) is included in the forecast in situ treatment area. These extraction and injection well locations also avoid being co-located with known subsurface utilities and buildings.

Various pumping scenarios were also evaluated as part of the modeling effort. Extraction and injection was simulated in Model Layer 3, which represents the upper 20 feet of the Upper Castle Hayne aquifer. The scenarios differed in the duration of extraction and injection (i.e., substrate delivery), ranging from 1 to 4 weeks. Of the scenarios evaluated, continuous extraction and injection for 4 weeks maximized the forecast extent of the in situ treatment zone. These results imply that the steady-state extent of the forecast in situ treatment zone may not be achieved without operation of the subsurface delivery wells for a period of more than 4 weeks. If the TOC follows first-order biodegradation in the field according to a TOC attenuation half-life of 20 days, then a steady-state in situ treatment zone would not be established without continued operation for approximately 72 days, according to Equation 1, as follows:

$$t = \frac{-\ln\left(C_t / C_o\right)}{\left[-\ln(0.5) / t_{½}\right]} \quad (1)$$

where

C_o = injected TOC concentration (482 mg/L assumed)

$t_{½}$ = TOC attenuation half-life (20 days assumed)

C_t = in situ TOC concentration at time, t (40 mg/L assumed)

t = time required for injected TOC to attenuate from C_o to C_t (72 days calculated)

Based on previous aquifer tests near the pilot study area and injection studies at other sites, it was assumed that the injection wells would not accommodate more than 4 gallons per minute (gpm). To maintain a closed extraction/injection system, each extraction well was assigned a pumping rate of 12 gpm to balance the combined extraction and injection rate of 24 gpm.

Figure 3 shows the simulated well configuration and in situ treatment area where TOC concentrations were at least 40 mg/L at different simulation times. Ideally, the extraction and injection delivery system would be located slightly south of the location shown on Figure 3. However, the presence of the parking apron and Hangar AS508 prohibits the placement of wells farther south. The pumping scenario used in this simulation assumed 1 month of continuous recirculation, followed by 2 months without recirculation. The blue-shaded area on Figure 3 depicts the simulated in situ treatment area immediately following the 1 month of recirculation. The green-shaded and yellow-hatched areas show the simulated in situ treatment area 1 and 2 months after recirculation, respectively.

Modeling results suggest that after 1 month of recirculation, an effective concentration of TOC would be distributed over an area covering most of the target treatment area (Figure 3). Modeling results further indicate how quickly the TOC could be consumed following recirculation. By 2 months following recirculation, the model suggests that TOC would occur at effective ERD concentrations only in the immediate vicinity of the injection wells. By 3 months following recirculation, the model suggests that TOC would no longer be present at effective ERD concentrations in the pilot study area.

Model Limitations

A modified version of the Site 86 GFM was used to simulate processes of the physical subsurface system at the proposed pilot study area at Site 86. The model is imperfect because it does not accurately describe all aspects of interrelated physical and chemical processes beneath the site. However, CH2M HILL incorporated as many details of the physical system into the original Site 86 GFM as possible, given the limited available data.

The minimal available data limits the degree to which the model assumptions and results can be constrained. Therefore, the modeling solutions discussed herein should be considered non-unique, representing one potential outcome among others that could be plausible.

Additional information related to the aquifer's physical and chemical parameters and their spatial distributions would help constrain the model. As more hydraulic and system performance data become available through time, hydraulic and chemical properties should be periodically evaluated and compared with the assumptions in the Site 86 GFM.

Works Cited

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Xu, M. and Y. Eckstein. 1995. Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Scale. *Journal of Ground Water*. Vol. 33, No. 6. pp. 905-908.

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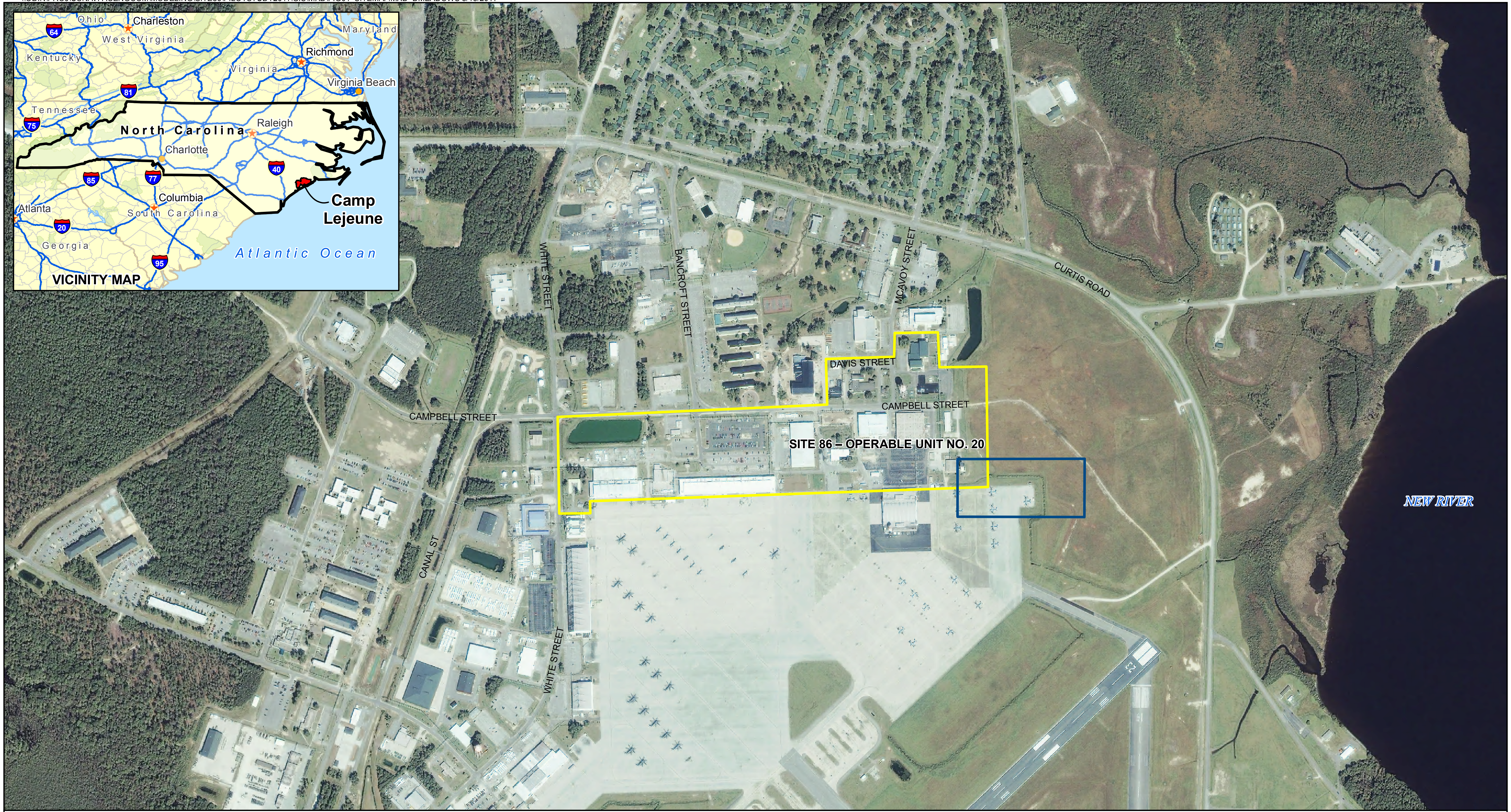


NOTE: DATE OF AERIAL PHOTOGRAPHY, OCTOBER 2006 (GeoEye 2006©).

LEGEND

PILOT STUDY AREA

MARCH 2010 SITE 86 BOUNDARY

N

0 350 700 1,400 Feet

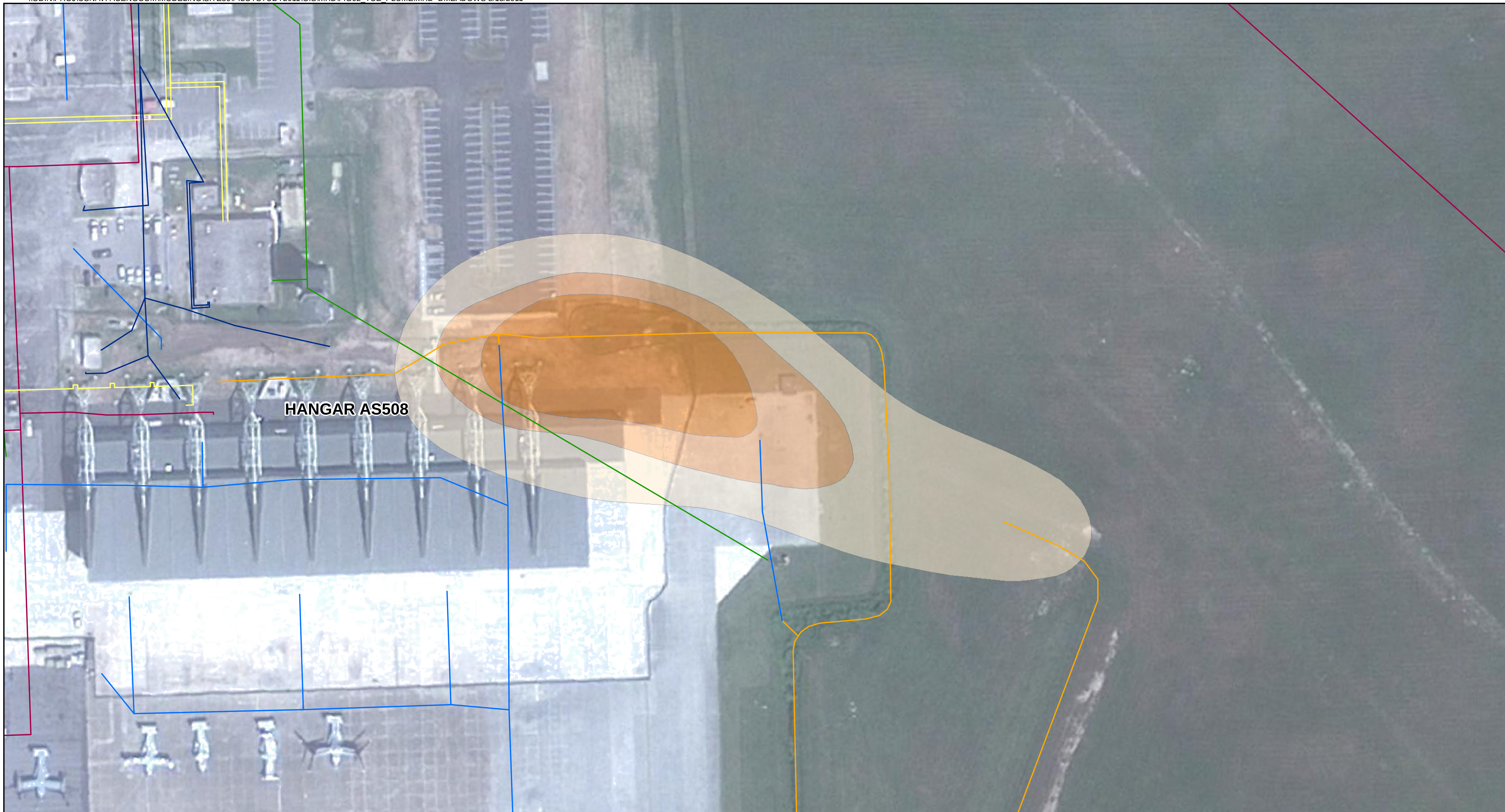
1 inch = 700 feet

Figure 1
Site Map
Pilot Study Groundwater Modeling Evaluation
Operable Unit 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

Generated By: D. Meadows/RDD Checked by: N. Brown/RDD

\\ODIN\PROJ\USNAVFACENGCOM\MODELING\SITE86\PILOTSTUDY2011\GIS\MXD\FIG02_TCE_PLUME.MXD DMEADOWS 8/15/2011



LEGEND

TCE Concentration (μg/L)

- 3 to 30
- 31 to 300
- > 300 (Target Treatment Area)
- Storm Sewer Utility Line
- Wastewater Utility Line
- Storm Sewer Drainage Line

N

0 25 50 100 Feet

1 inch = 100 feet

Figure 2
TCE Plume in the Upper Castle Hayne Aquifer
Pilot Study Groundwater Modeling Evaluation
Operable Unit 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

O:\USNAVFACENGCOM\MODELING\SITE86\PILOTSTUDY2011\GIS\MXD\FIG3_MODELRESULTS.MXD DMEADOWS 8/15/2011

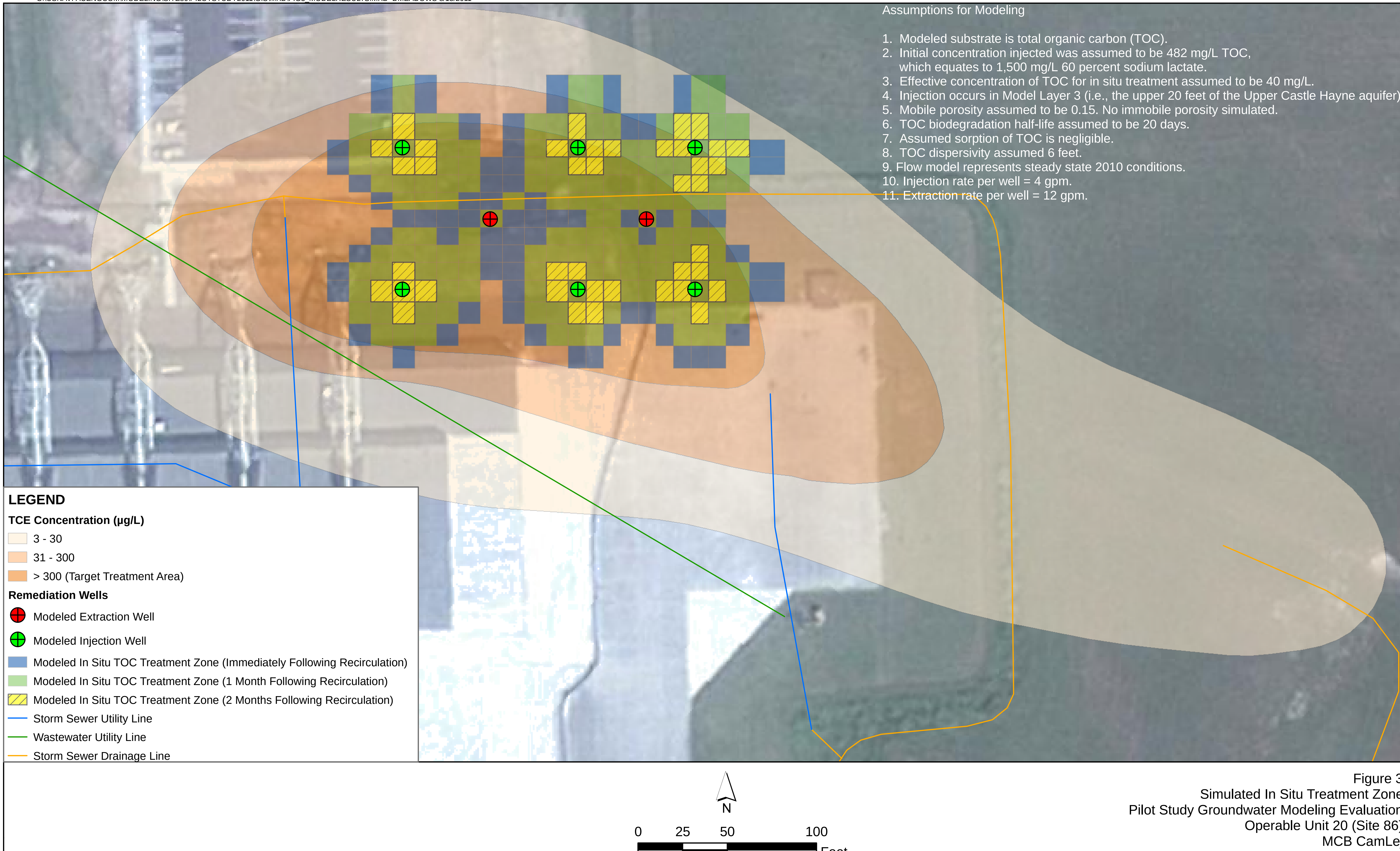


Figure 3
Simulated In Situ Treatment Zone
Pilot Study Groundwater Modeling Evaluation
Operable Unit 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

Appendix B
Underground Injection Control Permit

State of North Carolina
Department of Environment and Natural Resources
Division of Water Quality
Non-Discharge Permit Application Form
(THIS FORM MAY BE PHOTOCOPIED FOR USE AS AN ORIGINAL)

GROUNDWATER REMEDIATION SYSTEMS

This permit application form is for systems which use either infiltration galleries or injection wells to discharge treated groundwater into the subsurface. Each section of this application must be completed unless otherwise noted. Contact the Aquifer Protection Section at (919) 733-3221 to obtain Groundwater Remediation Permit Application Guidelines.

I. GENERAL INFORMATION:

1. Applicant's name (please specify the name of the municipality, corporation, individual, etc.): Marine Corps Base Camp Lejeune
2. Print Owner's or Signing Official's name *and* title (the person who is legally responsible for the facility and its compliance): Mr. John Towson/Director of Environmental Management Division
3. Mailing address: EMD/EDQ Building 12 Post Lane
   City: Camp Lejeune State: NC Zip: 28542
   Telephone Number: (910) 451-1143
4. Project Name (please specify the name of the facility or establishment - should be consistent on all documents included in this application package: Marine Corps Base Camp Lejeune Operable Unit 20, Site 86
5. Location of Remediation Activities (Street Address): Marine Corps Air Station New River Building AS508
   City: Camp Lejeune State: NC Zip: 28542
6. County of Remediation Acitivities: Onslow
7. Latitude: 34 degrees 43' 04" N ; Longitude 77 degrees 26' 25.6" W of Remediation Activities.
8. Contact person who can answer questions about application:
   Name: Theron Grim Telephone Number: (704) 544-4065
9. Application Date: September 2011
10. Fee Submitted: $ NA (Refer to fee schedule at http://h2o.enr.state.nc.us/aps/gpu/NDgwRemedy.htm)

II. PERMIT INFORMATION: Application No. (will be completed by DWQ): ______

1. Specify whether project is: X new; _____ renewal*; _____ modification
   * For renewals, complete only sections I, II, and applicant signature (on page 8). Submit only pages 1, 2, and 8 (original and three copies of each). Engineer's signature not required for renewal without other modifications.
2. If this application is being submitted as a result of a renewal or modification to an existing permit, list the existing permit number ______ and its issue date ______

III. INFORMATION ON CONTAMINATED GROUNDWATER:

1. List the principal products or services provided by facility: Facility consists of several aircraft maintenance hangers.

2. Remediation Site Owner: X Federal; ___ State; ___ Private; ___ Public; ___ Native American Lands;
   ___ Other (specify) ____

3. Groundwater Incident Number (if known): ____

4. Is this application for facilities subject to UST Trust Fund reimbursement? ______ Yes; X No.

5. Has a comprehensive site assessment and corrective action plan been submitted and approved for this project?
   ____ Yes; ____ No. Please provide two copies of each and two copies of the approval letter (if applicable).

6. Provide a brief description of the events or cause of the groundwater contamination:
   Several air craft maintenance hangers and aircraft wash racks are located in the vicinity. It is believed that chlorinated solvents were historically stored and used at the site. A single source of the contamination has not. been identified.

7. List contaminants detected: Trichloroethene, cis-1,2-Dichloroethene, Vinyl Chloride

8. Volume of groundwater to be remediated per day: approximately 34,560 gallons (per day)

9. Explanation of how volume was determined: The estimate is based on two extraction wells pumping approximately 12 gpm continuously for 24 hours.

IV. GENERAL DESIGN INFORMATION:

1. Specify the type of system that is being installed: ______ infiltration gallery; X injection well;
   ______ other (specify): ____

2. Provide a brief description of all components of the treatment and disposal system (i.e., treatment units, pumps, tanks, chemical feed system, injection and/or recovery wells, etc.):

   A description of the treatment process is provided in Section 4.1.5 of the Pilot Study Implementation Plan, and is shown on Figure 4-3.

3. 15A NCAC 2C .0213 (Well Construction Standards, Applicable to Injection Wells) requires that contaminant levels in the fluid injected into any well be monitored; therefore, a sampling port must be provided on the effluent lines (treated water prior to being injected into the wells or infiltration gallery). The permit will specify the requirements for monitoring this effluent. Identify the location in the plans/specifications where the sampling port design is detailed:

Sampling ports are shown on Figure 4-3 of the Pilot Study Implementation Plan.

V. DESIGN INFORMATION FOR INFILTRATION GALLERIES:

1. Specify the dimensions of each infiltration gallery:
   (a) L= ________ ft. W= ________ ft. D= ________ ft.
   (b) L= ________ ft. W= ________ ft. D= ________ ft.
   (c) L= ________ ft. W= ________ ft. D= ________ ft.

2. The static groundwater level at the gallery location is _____________ feet. The vertical separation between the gallery trench bottom and the mean seasonal high water table is _____________ feet.

3. A North Carolina licensed soil scientist must provide an evaluation of the soils where the infiltration gallery will be located and must specify an acceptable loading rate (amount of water gallery can accept). This evaluation should determine whether the loading rate shall be based upon only the surface area of the infiltration gallery or whether it is appropriate to include some of the side wall depth.
   a. What is the area used to determine the loading rate? ____________________ square feet. This area should include only the surface area. No side wall depth should be included in this calculation.
   b. The recommended loading rate is ___________________________________ (Attach all calculations).
   c. Indicate the theory behind the loading rate determination: ______________________________

4. Briefly describe any mounding of groundwater, above the static groundwater levels, that may result from infiltration (Attach calculations and/or diagrams): ______________________________

VI. DESIGN INFORMATION FOR INJECTION WELLS:

1. Identify the principal aquifer to which the injection wells will be discharging:
   Castle Hayne aquifer.

2. Is the aquifer identified above the same aquifer from which the contaminated groundwater was extracted?
   X Yes ___ No. If No, describe how the aquifers are hydraulically related: ______________________________

3. Briefly describe any mounding of groundwater, above the static groundwater levels, that may result from the injection (please attach calculations and/or diagrams): The remediation system will include six injection wells and two extraction wells. It is anticipated that mounding will not occur due to the the extraction of groundwater. A description is provided in Attachment A of the Pilot Study Implementation Plan.

4. Characteristics of injection well(s) [attach additional sheets if necessary]: Please see attached documentation.

Injection Well Characteristics	Well A Injection Wells (6)	Well B Extraction Wells (2)	Well C
Depth (feet)	55 feet	55 feet	
Diameter (inches)	4 inch	4 inch	
Injection rate (GPM)	Approximately 4 GPM	Approximately 12 GPM	
Injection volume (GPD)	Approximately 6,917 GPM		
Injection pressure (PSI)	Approximately 2.2 PSI (5 feet of H2O)		
Injection temp. (°C)	Approximately 15-20 degrees C		
Casing material	PVC	PVC	
Depth of casing (feet)	35 feet	35 feet	
Casing diameter (inches)	4 inch	4 inch	
Casing schedule number	40	40	
Cement grout (primary or inner casing)	from 31 ft. to 2 ft.	from 31 ft. to 2 ft.	from _____ ft. to _____ ft.
Cement grout (outer casing, if applicable)	from _____ ft. to _____ ft.	from _____ ft. to _____ ft.	from _____ ft. to _____ ft.
Screened or uncased interval (if applicable)	from 35 ft. to 55 ft.	from 35 ft. to 55 ft.	from _____ ft. to _____ ft.
Type of screen manufactured or hand slotted (if applicable)	0.020-inch slot "vee-wire" PVC screen	0.020-inch slot "vee-wire" PVC screen	
Screens inner diameter (inches-if applicable)	4 inch	4 inch	
Gravel pack (if applicable)	from 33 ft. to 55 ft.	from 33 ft. to 55 ft.	from _____ ft. to _____ ft.
Well contractor	Drill Pro	Drill Pro	
Contractor Registration No.	3551	3551	

VII. ADDITIONAL INFORMATION:

1. Classification of the closest downslope surface waters: SA-HQW (as established by the Environmental Management Commission and specified on page 7 of this application).

2. In accordance with 15A NCAC 2T .1605 (a)(I), (b), describe which measure is being utilized to prevent overflows into downslope surface waters or adjacent aquifers in the event of a power failure or equipment malfunction.

   The remediation system will be equipped with engineering controls; including pressure indicators and pressure switches, which will prevent excessive pressures or overflows. The system will run off of electricity supplied to Camp Lejuene. If electricity is interrupted by a power failure, the system and ancillary pumps will shut down due to the absence of electricity.

3. The applicable buffers should be met in accordance with 15A NCAC 2T .1606. Some of those buffers are described below:

   a. 100 feet between injection wells or infiltration galleries and any private or public water supply source;
   b. 25 feet for surface water diversions;
   c. 100 feet for surface water bodies;
   d. 50 feet from rock outcrops;
   e. 100 feet from subsurface groundwater lowering drainage system or groundwater lowering ditches (where the botton of the ditch intersects the SHWT);
   f. 50 feet from injection well and infiltration gallery treatment and disposal systems and property under seperate ownership.

   If any of the applicable buffers cannot be met, please explain how the proposed buffers will provide equal or better protection of the surface or groundwaters with no increased potential for nuisance conditions:

4. Substances may be added to enhance in situ treatment. If microbial additives or cultures are added in the effluent, the approval must be provided by the North Carolina Division of Epidemiology certifying its use for remediation purposes. In lieu of the Division of Epidemiology approval, risk assessment data, toxicological exposure data, or approval from another State may be provided certifying an exposure risks. Will any substances be added to the effluent to enhance in situ treatment? _X__ Yes; _____ No. If Yes, provide a detailed description of these substances, including amounts to be added. In addition, please attach any studies which describes the instances in which these substances have been used:

   A description of the sodium lactate and bioaugmentation culture to be added to the effluent is provided in Section 3.2.1 of the pilot Study Implementation Plan. A description of the amounts to be added is provided in Section 4.1.6 of the Pilot Study Implementation Plan.

THIS APPLICATION PACKAGE WILL NOT BE ACCEPTED BY THE DIVISION OF WATER QUALITY UNLESS ALL OF THE APPLICABLE ITEMS ARE INCLUDED WITH THE SUBMITTAL

a. One original and two copies of the completed and appropriately executed application form.

b. The appropriate permit processing fee in accordance with 15A NCAC 2T .0105 (e). (See webpage: http://h2o.enr.state.nc.us/lau/fees.html)

c. Submit three copies of the Corrective Action Plan and comprehensive site assessment.

d. Three copies of the existing permit if a renewal or modification.

e. Three sets of detailed plans and specifications signed and sealed by a North Carolina Professional Engineer. The plans must include a general location map; a topographic map which extends one mile beyond property boundaries and depicts the facility and each of its intake and discharge structures (with the quadrangle name); a scaled site-specific map which indicates where borings or hand auger samples were taken; and a map showing the groundwater treatment/disposal facilities, buffers, structures and property lines. A map must also identify any hazardous waste treatment, storage, and disposal facilities; each well where fluids from the facility are injected underground; and those wells, springs and other surface water bodies and drinking water wells listed in public records or otherwise known to the applicant within a quarter mile of the facility property boundary. Each sheet of the plans, including any plan pages that are incorporated into a bound document, and the first page of the specifications, must be signed/sealed by a North Carolina Professional Engineer.

f. Three copies of a tabulation of data on all wells which are within the area of review and which penetrate the proposed injection zone. Such data shall include an identification number (same number referenced on map required in "e" above) for each well, a description of each well type, date installed, depth of well, and record of completion or abandonment (if available).

g. A soil scientist report which includes texture, color, and structure of the soils down to a depth of seven feet; depth, thickness and type of any restrictive horizons, hydraulic conductivity in the most restrictive horizon, Cation Exchange Capacity, depth of the mean seasonal high water table, soil pH, soil maps (if available, even if unpublished), and recommended loading rates (when using an infiltration gallery). This report must be signed by the soil scientist.

h. A hydrogeologic description, soils description, and cross section of the subsurface to a depth that includes the known or projected depth of contamination. The number of borings shall be sufficient to determine significant changes in lithology, the vertical permeability of the unsaturated zone, the hydraulic conductivity of the saturated zone, the depth to the mean seasonal high water table, and a determination of transmissivity and specific yield of the unconfined aquifer (show calculations used for transmissivity and specific yield). Report should also indicate whether the aquifer is attributable to fracture porosity storage or stratigraphically controlled (bedding planes). Include a general map and cross section illustrating the regional geologic setting.

i. Describe the proposed injection procedure and describe expected changes in pressure and direction of movement of injected fluid (provide data from fracture studies where applicable). Applicant must demonstrate complete hydraulic control over contaminant plume and injectate if injectate does not meet 2L standards.

j. Proposal for groundwater monitoring (e.g., schedule, analytical methods, etc.).

k. Describe the method for determining mechanical integrity of injection well over a five year period.

l. A complete analysis of the contaminated groundwater to include, but not limited to BTEX, volatile and semivolatile compounds, pH, nitrates, and phosphates or any additional information the Director deems necessary to evaluate the proposed treatment and disposal system.

m. Describe contaminant concentrations in the effluent given the proposed treatment. Include expected treatment efficiency. Provide calculations or documentation to show how proposed degree of treatment was derived.

n. Diagram of the contaminant plume both horizontally and vertically, including vadose zone contamination (isoconcentration maps and plume cross sections). Include direction of groundwater flow for both surface aquifer and deep aquifers.

o. Three copies of all reports, evaluations, agreements, supporting calculations, etc., must be submitted as a part of the supporting documents which are signed and sealed by the North Carolina Professional Engineer. Although certain portions of this required submittal must be developed by other professionals, inclusion of these materials under the signature and seal of a NC PE signifies that he or she has reviewed this material and has judged it to be consistent with his or her proposed design.

p. An properly executed page 7, which has been completed by the appropriate Regional Aquifer Protection personnel, and reincorporated into the application form prior to submittal of the application package.

This form must be completed by the appropriate DWQ regional office and included as a part of the project submittal information.

INSTRUCTIONS TO APPLICANT

In order to determine the classification of the watershed in which the subject facility will be located, you are required to submit this form, with items 1 through 7 completed, to the appropriate Division of Water Quality Regional Aquifer Protection Supervisor (see attached listing) prior to submittal of the application for permitting. At a minimum, you must include an 8.5" by 11" copy of the portion of a 7.5 minute USGS Topographic Map which shows the subject surface waters. You must identify the location of the facility and the closest downslope surface waters (waters for which you are requesting the classification) on the submitted map copy. **The application may not be submitted for final permitting until this form is completed by the appropriate regional office and included with the submittal.**

1. Applicant (please specify the name of the municipality, corporation, individual, or other): MCB Camp Lejeune. P.O.C. is Mr. John Towson/Director of Environmental Management Division
2. Address of Applicant: EMD/EDQ Building 12 Post Lane
   City: Camp Lejeune State: NC Zip: 28542
   Telephone Number: (910) 451-1143 Fax Number: (__) ______
3. County(ies) where the facility is located: Onslow
4. Project Name: Marine Corps Base Camp Lejeune Operable Unit 20, Site 86
5. Name of closest surface waters: New River
6. Map name and date: ______
7. Applicant Signature: ______

TO: REGIONAL AQUIFER PROTECTION SUPERVISOR

Please provide me with the classification of the watershed and appropriate river basin where these activities will occur, as identified on the attached map segment:

Name of surface waters: ______

Classification (as established by the EMC): ______

Proposed Classification, if applicable: ______

River Basin the Facility is Located: ______

Signature of regional office personnel: ______ Date: ______

Name and Complete Address of Engineering Firm: 11301 Carmel Commons Blvd Suite 304

City: Charlotte State: NC Zip: 28226

Telephone Number: (704) 544-4040 Fax Number: (704) 544-4041

Professional Engineer's Certification:

I, ____________________, attest that this application for ____________________

has been reviewed by me and is accurate and complete to the best of my knowledge. I further attest that to the best of my knowledge the proposed design has been prepared in accordance with the applicable regulations. Although certain portions of this submittal package may have been developed by other professionals, inclusion of these materials under my signature and seal signifies that I have reviewed this material and have judged it to be consistent with the proposed design.

North Carolina Professional Engineer's Seal, Signature, and Date:

Applicant's Certification (signing authority must be in compliance with 15A NCAC 2T .0106(b) and (c)):

I, ____________________, attest that this application for ____________________

has been reviewed by me and is accurate and complete to the best of my knowledge. I understand that if all required parts of this application are not completed and that if all required supporting information and attachments are not included, this application package will be returned to me as incomplete.

Signature ____________________ Date ____________________

THE COMPLETED APPLICATION PACKAGE, INCLUDING ALL SUPPORTING INFORMATION AND MATERIALS, SHOULD BE SENT TO THE FOLLOWING ADDRESS:

NORTH CAROLINA DIVISION OF WATER QUALITY

AQUIFER PROTECTION SECTION

GROUNDWATER PROTECTION UNIT

1636 MAIL SERVICE CENTER

RALEIGH, NORTH CAROLINA 27699-1636

TELEPHONE NUMBER: (919) 733-3221

FAX NUMBER: (919) 715-0588

DIVISION OF WATER QUALITY REGIONAL OFFICES

Asheville Regional APS Supervisor
2090 U.S. Highway 70
Swannanoa, NC 28778
(828) 296-4500
Fax (828) 299-7043

Avery	Macon
Buncombe	Madison
Burke	McDowell
Caldwell	Mitchell
Cherokee	Polk
Clay	Rutherford
Graham	Swain
Haywood	Transylvania
Henderson	Yancey
Jackson	

Washington Regional APS Supervisor
943 Washington Square Mall
Washington, NC 27889
(252) 946-6481
Fax (252) 946-9215

Beaufort	Jones
Bertie	Lenoir
Camden	Martin
Chowan	Pamlico
Craven	Pasquotank
Currituck	Perquimans
Dare	Pitt
Gates	Tyrell
Greene	Washington
Hertford	Wayne
Hyde	

Raleigh Regional APS Supervisor
3800 Barrett Drive, Suite 101
Raleigh, NC 27609
(919) 791-4200
Fax (919) 571-4718

Chatham	Nash
Durham	Northampton
Edgecombe	Orange
Franklin	Person
Granville	Vance
Halifax	Wake
Johnston	Warren
Lee	Wilson

Fayetteville Regional APS Supervisor
Systel Building, Suite 714
Fayetteville, NC 28301
(910) 486-1541
Fax (910) 486-0707

Anson	Moore
Bladen	Robeson
Cumberland	Richmond
Harnett	Sampson
Hoke	Scotland
Montgomery	

Mooresville Regional APS Supervisor
610 East Center Ave., Suite 301
Mooresville, NC 28115
(704) 663-1699
Fax (704) 663-6040

Alexander	Lincoln
Cabarrus	Mecklenburg
Catawba	Rowan
Cleveland	Stanly
Gaston	Union
Iredell	

Wilmington Regional APS Supervisor
127 Cardinal Drive Extension
Wilmington, NC 28405-3845
(910) 796-7215
Fax (910) 350-2004

Brunswick	New Hanover
Carteret	Onslow
Columbus	Pender
Duplin	

Winston-Salem Regional APS Supervisor
585 Waughtown Street
Winston-Salem, NC 27107
(910) 771-4600
Fax (910) 771-4630

Alamance	Rockingham
Alleghany	Randolph
Ashe	Stokes
Caswell	Surry
Davidson	Watauga
Davie	Wilkes
Forsyth	Yadkin
Guilford	

Underground Injection Control Permit Application

Marine Corps Base Camp Lejeune
IR Site 86
Jacksonville, North Carolina

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Mid-Atlantic

Under the

NAVFAC CLEAN 8012 Program
Contract N62470-11-D-8012

Prepared by

CH2MHILL

11301 Carmel Commons Blvd., Suite 304
Charlotte, North Carolina 28226
NC Engineering License #F-0699

State of North Carolina
Department of Environment and Natural Resources
Division of Water Quality

APPLICATION FOR PERMIT TO CONSTRUCT AND/OR USE A WELL(S) FOR INJECTION

Type 5I Wells – *In Situ* Groundwater Remediation / Type 5T Wells – Tracer Injection

- Do **not** use this form for remediation systems that extract contaminated groundwater, treat it, and reinject the treated groundwater.
- Submit **TWO** copies of the completed application and all attachments to the address on the last page of this form.
- Any changes made to this form will result in the application package being returned.

Application Number (*to be completed by DWQ*)**:** ________________________________

I. GENERAL INFORMATION:

1. Applicant's Name (generally the responsible party): Marine Corps Base Camp Lejeune
2. Signing Official's Name*: Mr. John Towson Title: Director of Environmental Management Division

   * Signing Official must be in accordance with instructions in part VI on page 7.
3. Mailing address of applicant: EMD/EDQ Building 12 Post Lane

   City: Camp Lejeune State: NC Zip: 28542

   Telephone number: 910-451-7693 Fax number: 910-451-1143
4. Property Owner's Name (if different from Applicant): ________________________________
5. Property Owner's mailing address: ________________________________

   ____

   City: ________________________________ State: ________ Zip: ________
6. Name and address of contact person who can answer questions about the proposed injection project:

State of North Carolina
Department of Environment and Natural Resources
Division of Water Quality

APPLICATION FOR PERMIT TO CONSTRUCT AND/OR USE A WELL(S) FOR INJECTION

Type 5I Wells – *In Situ* Groundwater Remediation / Type 5T Wells – Tracer Injection

- Do **not** use this form for remediation systems that extract contaminated groundwater, treat it, and reinject the treated groundwater.
- Submit **TWO** copies of the completed application and all attachments to the address on the last page of this form.
- Any changes made to this form will result in the application package being returned.

Name:_ Theron Grim ____ Title:_ Project Manager ______________

Company:_____CH2M HILL____

Address: 11301 Carmel Commons Blvd Suite 304____

City:___Charlotte____ State:_NC_____ Zip: _2822_____6_________

Telephone number:____704-544-4065_______________ Fax number:___704-544-4041_______________

Email Address:_Theron.Grim@ch2m.com___________________

II. PERMIT INFORMATION:

1. Project is: ☒ New (Modification of existing permit (Renewal of existing permit **without** modification

   (Renewal of existing permit **with** modification

2. If this application is being submitted for renewal or modification to an existing permit, provide: existing permit number ____________________ and the issuance date _______________________________

For renewal without modifications, fill out sections I & II only, sign the certification on the last page of this form, and obtain the property owner's signature to indicate consent (if the applicant is not the owner).
For all renewals, submit a status report including monitoring results of all injection activities to date.

APPLICATION FOR PERMIT TO CONSTRUCT AND/OR USE A WELL(S) FOR INJECTION
Type 5I Wells – *In Situ* Groundwater Remediation / Type 5T Wells – Tracer Injection

III. INCIDENT & FACILITY DATA

A. FACILITY INFORMATION

1. Facility name: Marine Corps Base Camp Lejeune Operable Unit 20, Site 86
2. Complete physical address of the facility: Marine Corps Air Station New River Building AS508

   City: Cam p Lejeune County: Onslow State: NC Zip: 28542

B. INCIDENT DESCRIPTION

1. Describe the source of the contamination: Several air craft maintenance hangers and aircraft wash racks are located at Site 86. It is believed that chlorinated solvents were historically stored and used at the site. A single source of the contamination has not been identified.
2. List all contaminants present in soils or groundwater at the site (contaminants may be listed in groups, e.g., gasoline, diesel, jet fuel, fuel oil, chlorinated ethenes, chlorinated ethanes, metals, pesticides/herbicides, etc): Chlorinated ethenes, primarily trichloroethene, cis-1,2-dichloroethene, and vinyl chloride
3. Has LNAPL or DNAPL ever been observed at the site (even if outside the injection zone)?

   Yes If yes, list maximum measured separate phase thickness ______________ **feet**

   No If no, list maximum concentration of total VOCs observed at site: 833 **ppb**
4. Agency managing the contamination incident:
   - (UST Section
   - (DWQ Aquifer Protection Section
   - (Hazardous Waste Section
   - ☒ Superfund Section (including REC Program and DSCA sites)
   - (Solid Waste Section
   - (Other: ______________
5. Incident managers name Beth Hartzell and phone number (919) 508-8489
6. Incident number or other site number assigned by the agency managing the contamination incident: CERCLA Site 86

C. PERMITS

List all permits or construction approvals that have been issued for the **facility or incident**, including those not directly related to the proposed injection operation:

1. Hazardous Waste Management program permits under RCRA: RCRA Hazardous Waste Permit HWSA# NC6170022580
2. DWQ Non-Discharge or NPDES permits: N/A
3. County or DEH subsurface wastewater disposal permits: N/A
4. Other environmental permits required by state or federal law: N/A

IV. INJECTION DATA

A. INJECTION FLUID DATA

1. List all proposed injectants.
NOTE: Any substance to be injected as a tracer or to promote in situ *remediation must be reviewed by the Occupational and Environmental Epidemiology Section (OEES) of the Division of Public Health, Department of Health and Human Services. Review the list of approved injectants or contact the UIC Program to determine if the injectants you are proposing have been reviewed by OEES.*

Injectant:______Permanganate (Slow-Release Potassium Permanganate Candle)_____

Concentration at point of injection:_____< 6 % (solubility of Potassium Permanganate)______

Percent if in a mixture with other injectants:______________________________

Injectant:______Sodium Lactate (Wilclear ERD product)_____________

Concentration at point of injection:_____5%____________________________

Percent if in a mixture with other injectants:______________________________

Injectant:__TSI DC™ Bioaugmentation Culture, Terra Systems

Concentration at point of injection:_____5 x 10^{10} cell/L____________________

Percent if in a mixture with other injectants:______________________________

2. Source of fluids used to dilute or chase the injectants listed above:
( ) None
(_) Municipal water supply
(X) Groundwater from private well or any well within ¼ mile of injection site
(_) Air
(X) Other: See Attached Non Discharge Permit Application______________________

3. If any well within ¼ mile of injection site, a private well, or surface water is to be used as the fluid source, supply the following information:

   a. Location/ID number of source: Pilot Study Area – ______________________

   b. Depth of source: _55 feet______________________________

   c. Formation:___Castle Hayne Aquifer____________________________

   d. Rock/Sediment type:___Sand and Limestone_________________________

   e. In Attachment C, provide a current, complete chemical analysis of the water from the source well, including analyses for all contaminants suspected or historically recognized in soil or groundwater on the site.
   *NOTE: If contaminated groundwater is to be used as the dilution or chase fluid, this is **not** the proper permit application form. You must apply for a closed-loop groundwater remediation permit using application form GWRS.* **See Attached Non Discharge Permit Application**

B. PROPOSED OPERATING PARAMETERS

1. Duration of Injection: 180 days
   a. Maximum number of separate injection events: 3
   b. Expected duration of each injection event: 5 days for installation of Slow Release Permanganate Candles
      30 days for sodium lactate/bioaugmentation culture injection
   c. Expected duration between events (if more than one event):_
2. Injection rate per well: 4 gallons per minute (gpm)
3. Total Injection volume: average = 34,650 gallons per day (gpd); 1×10^6 gallons per event (if separate events)
4. Injection pressure: average = 2.2 pounds/square inch (psi)
5. Temperature at point of injection: 55 ^oF
6. Briefly describe how the above parameters will be measured and controlled: inline flow gauges
7. Estimated hydraulic capacity of the well: 20 gpm

C. INJECTION WELL CONSTRUCTION DATA

1. Injection will be via:
   a. Slow Release Permanganate Candles installed via direct push technology.
   b. Proposed well(s) to be constructed for use as an injection well. Provide the data in (2) through (6) below as proposed construction specifications.

2. Well Drilling Contractor's Name: Parratt-Wolff (DPT)
   NC Well Contractor Certification number: 2489 NC

   Well Drilling Contractor's Name: Groundwater Protection/Drill Pro (Injection Wells)
   NC Well Contractor Certification number: 3551 NC

3. Date to be constructed: October 2011 Number of borings: 30 DPT/4 injection wells
   Approximate depth of each boring (feet): 30 feet (DPT)/55 feet (injection wells)

4. Screened interval/Injection interval of injection wells:
   DPT boring depth: 20 to 30 feet below ground surface.
   Injection well screened interval: 35 to 55 feet below ground surface.

5. Well casing (N/A if injection is through direct push rods):

Type: PVC (_) Stainless steel (_) Other:___________

   Casing depth: ground surface to 35 feet below ground surface

6. Grout (N/A if injection is through direct push rods):
   Type: (Cement (Bentonite (X) Other: cement/bentonite mix
   Grout depth: ground surface to 20 feet below ground surface for DPT borings/ 1 to 31 feet below ground surface

V. ATTACHMENTS

Provide the following items as separate attachments with the given headings:

A. SITE HISTORY

Provide a brief description of the site history including:

(1) site usage historically and present,
(2) origin of the contamination,
(3) previous remedial action(s).

NOTE: G.S. 89E-18 requires that any geologic plans, reports, or documents in which the performance is related to the public welfare or safeguarding of the environment be prepared by a licensed geologist or subordinate under their direction. G.S. 89E-13 requires that all drawings, reports, or documents involving geologic work prepared or approved by a licensed geologist, or a subordinate under their direction, be signed and sealed by the licensed geologist.

B. HYDROGEOLOGIC DESCRIPTION

Provide a hydrogeologic description, soils description, and cross section of the subsurface to a depth that includes the known or projected depth of contamination. The hydrogeologic description shall include:

(1) the regional geologic setting;
(2) significant changes in lithology;
(3) the hydraulic conductivity, transmissivity, and specific yield of the aquifer to be used for injection, including a description of the test(s) used to determine these parameters; and
(4) the depth to the mean seasonal high water table.

C. INJECTION FLUID COMPOSITION

Describe the chemical, physical, biological and radiological characteristics of each injectant. Attach the Material Safety Data Sheet (MSDS) for each injectant. If a private well or a well within ¼ mile of the injection site is used as the source well, include chemical analysis of source fluid here.

D. INJECTION RATIONALE

Attach a brief description of the rationale for selecting the injectants and concentrations proposed for injection, including:

(1) goals of the injection project;
(2) explanation and/or calculations of how the proposed injectant volume and concentration were determined;
(3) a description of the reactions between the injectants and the contaminants present including specific breakdown products or intermediate compounds that may be formed by the injection; and
(4) summary results of modeling or testing performed to investigate the injectant's potential or susceptibility to change (biological, chemical or physical) in the subsurface.

E. INJECTION PROCEDURE AND EQUIPMENT

Provide a detailed description of all planned activities related to the proposed injection including but not limited to:

(1) construction plans and materials;
(2) operation procedures;
(3) a detailed diagram of the surface and subsurface portions of the system; and
(4) a planned injection schedule.

F. MONITORING PLAN

Provide a plan for monitoring the results of the injection, including:

(1) a list of existing and proposed monitoring wells to be used;
(2) a list of monitoring parameters and analytical methods to be used; and
(3) a schedule for sampling to monitor the proposed injection.

NOTE: The selected monitoring wells must be located so as to detect any movement of injection fluids, process by-products, or formation fluids outside the injection area or zone. The monitoring parameters should include the target contaminants as well as secondary or intermediate contaminants which may result from the injection and other parameters which may serve to indicate the progress of the intended reactions, such as pH, ORP, dissolved oxygen, and other electron acceptors and donors. The monitoring schedule should be consistent with the pace of the anticipated reactions and rate of transport of the injectants and contaminants.

G. WELL DATA

Provide a tabulation of data on **all** existing or abandoned wells within ¼ mile of the injection well(s) which penetrate the proposed injection zone, including, but not limited to, monitoring wells and wells proposed for use as injection wells. Such data shall include a description of each well's use (water supply, monitoring, etc), total depth, screened or open borehole depth interval, and well construction or abandonment record, if available.

H. MAPS

Attach the following scaled, site-specific maps:

(1) Area map based on the most recent USGS 7.5' topographic map of the area, at a scale of 1:24,000 and showing the location of the proposed injection site.
(2) Site map including:
  a. all property boundaries;
  b. all buildings within the property boundary;
  c. existing and proposed injection wells or well field(s)
  d. any existing sources of potential or known groundwater contamination, including waste storage, treatment or disposal systems within ¼ mile of the injection well or well system;
  e. all surface water bodies within ¼ mile of the injection well or well system; and
  f. **all** existing or abandoned wells within ¼ mile of the injection well(s) which penetrate the proposed injection zone, including, but not limited to, monitoring wells and wells proposed for use as injection wells.
(3) Potentiometric surface map(s) including:
  a. direction of groundwater movement
  b. existing and proposed monitoring wells
  c. existing and proposed injection wells
(4) Contaminant plume map(s) including:
  a. the horizontal extent of the contaminant plume, including isoconcentration lines
  b. existing and proposed monitoring wells
  c. existing and proposed injection wells
(5) Cross-section(s) to the known or projected depth of contamination, including:
  a. horizontal and vertical extent of the contaminant plume, including isoconcentration lines
  b. major changes in lithology
  c. existing and proposed monitoring wells
  d. existing and proposed injection wells

VI. CERTIFICATION (to be signed as required below or by that person's authorized agent)

NCAC 15A 2C .0211(b) requires that all permit applications shall be signed as follows:

1. for a corporation: by a responsible corporate officer
2. for a partnership or sole proprietorship: by a general partner or the proprietor, respectively
3. for a municipality or a state, federal, or other public agency: by either a principal executive officer or ranking publicly elected official
4. for all others: by the well owner.

If an authorized agent is signing on behalf of the applicant, then supply a letter signed by the applicant that names and authorizes their agent.

I hereby certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments therein, and that, based on my inquiry of those individuals immediately responsible for obtaining said information, I believe that the information is true, accurate, and complete. I am aware that there are penalties, including the possibility of fines and imprisonment, for submitting false information. I agree to construct, operate, maintain, repair, and if applicable, abandon the injection well(s) and all related appurtenances in accordance with the approved specifications and conditions of the Permit.

Printed Name and Title:____

Signature:____ Date:_____________________

VII. CONSENT OF PROPERTY OWNER (if the property is not owned by the applicant)

("Owner" means any person who holds the fee or other property rights in the well being constructed. A well is real property and its construction on land shall be deemed to vest ownership in the land owner, in the absence of contrary agreement in writing.)

As owner of the property on which the injection well(s) are to be constructed and operated, I hereby consent to allow the applicant to construct each injection well as outlined in this application and agree that it shall be the responsibility of the applicant to ensure that the injection well(s) conform to the Well Construction Standards (Title 15A NCAC 2C .0200).

Printed Name and Title:____

Signature:____ Date:_____________________

Submit **<u>TWO</u>** copies of the completed application package, including all attachments, to:

UIC Program
Aquifer Protection Section
North Carolina DENR-DWQ
1636 Mail Service Center
Raleigh, NC 27699-1636
Telephone (919) 733-3221

Attachment A – Site History

Table 2-1
Previous Investigations and Remedial Actions
Site 86 Pilot Study
MCB CamLej
North Carolina

Investigation Phase	Date	Reference	Conclusions
Preliminary Site Investigation (PSI)	1990	Dewberry & Davis, 1990	In1990, a PSI was conducted to evaluate the Site 86 AST area. Soil samples were collected and analyzed for total petroleum hydrocarbon (TPH) and VOCs. The analytical data indicated that TPH and VOCs were present in soil and were likely attributable to localized surface spills from ASTs.
Site Assessment (SA)	1992	O'Brien & Gere, 1992	In 1992, an SA was completed to evaluate the nature and extent of subsurface contamination at the Site 86 AST area. Soil and groundwater samples were collected and analyzed. The analytical results indicated that soil and groundwater collected from Site 86 was impacted with concentrations of TPH and VOCs.
Remedial Investigation (RI)	1995-1996	Baker, 1996	In 1995, an RI was conducted to characterize the nature and extent of contamination identified in the SA. Soil samples were collected and analyzed for VOCs, target compound list (TCL) semivolatile organic compounds (SVOCs), TCL pesticides, TCL polychlorinated biphenyls (PCBs), TPH, and target analyte list (TAL) metals. Groundwater samples were collected and analyzed for VOCs and SVOCs, TAL metals, total suspended solids (TSS), and total dissolved solids (TDS). A limited number of groundwater samples were also analyzed for pesticides, PCBs, and TAL dissolved metals. Surface and subsurface soil samples contained concentrations of metals and SVOCs above the human health risk-based levels. Groundwater samples contained concentrations of VOCs and metals above the human health risk-based levels.
Post-RI Investigation Activities	1997-1998	Baker, 1998	In 1997, post-RI assessment activities were conducted to refine the vertical and horizontal extent of VOCs in groundwater. Groundwater samples were collected and analyzed for VOCs. The results indicated that the horizontal extent of VOCs in groundwater was not delineated.
Amended RI	2001-2002	CH2M HILL, Baker, CDM, 2003	In 2001-2002, Amended RI field investigation activities were conducted to further characterize the groundwater contamination plume and to re-evaluate impacts to human health and the environment identified in the RI. The Amended RI concluded that the extent of VOC contamination in the soil at Site 86 was limited, and that two groundwater plumes were identified in the vicinity of Site 86. The plume near Site 86 was adequately defined; however, an unrelated upgradient plume was not defined.
RCRA Facilities Investigation	2005	CH2M HILL, 2006a	In 2005-2006, an RFI was conducted to evaluate SWMUs 303 and 318. Based on the results, surface and subsurface soil samples contained concentrations of VOCs, SVOCs, and metals above human health risk-based levels, and groundwater samples contained concentrations of VOCs, SVOCs, and metals exceeding applicable human health risk-based levels. The RFI recommended the removal of contaminated soil from beneath the wash pad near SWMUs 303 and 318 and further investigation of groundwater contamination to determine the

Table 2-1
Previous Investigations and Remedial Actions
Site 86 Pilot Study
MCB CamLej
North Carolina

Investigation Phase	Date	Reference	Conclusions
			source of the chlorinated solvents contamination at the SWMUs.
Interim Measure	2005	Shaw, 2006	In 2005, Shaw removed approximately 1,200 tons of impacted soil from SWMUs 303 and 318 under Interim Measure. Confirmatory soil samples indicated that all target contaminants were below applicable screening criteria.
Air/Ozone Pilot Study	2004-2006	CH2M HILL, 2006b	In 2004, a 950-foot long, 65-foot deep horizontal directionally drilled (HDD) well was constructed with a 350-foot section of screen. Additionally, 12 monitoring wells were installed in the upper Castle Hayne aquifer. Groundwater monitoring was conducted throughout the Pilot Study. The results of the Pilot Study indicated that TCE was reduced by 99 percent. The zone of influence created by sparging operations was observed to propagate 50 feet on either side of the well. Groundwater samples collected from 13 of the 16 monitoring wells within the treatment area contained target VOCs below the North Carolina Groundwater Quality Standard (NCGWQS) within 1 year of the start of system operation.
Expanded Supplemental Remedial Investigation (ESRI)	2006-2010	CH2M HILL, 2010a	In February 2007, a passive soil gas survey was conducted to identify potential sources of VOCs within the expanded site boundary. A total of 195 passive soil gas samples were collected on a variable grid pattern. Two borings were advanced to characterize lithology and to identify depths for discrete groundwater sampling activities. The lithologic data indicated that a layer of weakly to completely cemented sandy fossiliferous limestone was present between 40 to 60 feet below ground surface (bgs). In June 2007, 18 borings were advanced to approximately 60 feet bgs. Discrete groundwater samples were collected from the surficial and upper Castle Hayne aquifer. In October and November 2007, 17 monitoring wells screened in the surficial, upper Castle Hayne, and middle Castle Hayne aquifers were installed and sampled with 21 existing monitoring wells. Results indicated the presence of multiple plumes of contamination across Site 86 that had not been delineated. In October of 2008, five borings were installed and discrete groundwater samples were collected. Based on the results, four monitoring wells screened within the upper Castle Hayne aquifer were installed in the western portion of Site 86. Results indicated the presence of elevated VC concentrations. This discovery suggested that an additional source of contamination may be present along the eastern edge of the flight line. In October 2009, discrete groundwater samples were collected from DPT borings. Based on the results of the samples, three intervals were identified for further investigation. Eleven additional discrete groundwater samples were collected to further evaluate the potential sources and extent of impacts. During the advancement of the DPT borings, surface and subsurface soils were also collected to evaluate potential source

Table 2-1
Previous Investigations and Remedial Actions
Site 86 Pilot Study
MCB CamLej
North Carolina

Investigation Phase	Date	Reference	Conclusions
			areas. To confirm the results of the DPT groundwater screening, 18 monitoring wells screened in the surficial, upper Castle Hayne, and middle Castle Hayne aquifers were installed. Upon completion, the 18 new and 47 existing monitoring wells were sampled to assess site-wide groundwater conditions. To evaluate the drainage ditch receiving stormwater discharge from the flight line and Site 86 industrial area, eight sediment and six surface water samples were collected. Based on the data collected from 2006 to 2010, the ESRI concluded that the nature and extent of soil and groundwater contamination was defined at Site 86. Human health and ecological risk assessments (ERAs) were completed for the ESRI. The human health risk assessment (HHRA) concluded that potential future contact with groundwater may result in risk or hazards above USEPA's acceptable risk range and hazard levels. The ERA concluded that the overall risk is to ecological receptors was acceptable.
ESRI	2006-2010	CH2M HILL, 2010a	A Feasibility Study (FS) was recommended to identify remedial action objectives; potential treatment, resource recovery, and containment technologies that will satisfy these objectives; screen the technologies based on their effectiveness, implementability, and cost; assemble the technologies into treatment alternatives; and analyze the alternatives against evaluation criteria.

Attachment B – Site Physical Characteristics

Physical Characteristics

Site 86 comprises industrial buildings, maintenance hangars, asphalt roads, and parking lots. In addition, a stormwater retention pond is located in the northwestern corner of the site. The MCAS New River flight line is located within the southern portion of the site and includes aircraft hangars and military aircraft. The eastern portion of the flight line is the focus of the ongoing investigation activities, as the highest TCE concentrations have been detected from a DPT groundwater collected near a drainage ditch in this area (**Figure 3**).

Most of Site 86 is either paved or developed with buildings. The topographic relief within Site 86 is minimal, with a slight slope to the east towards the New River. The area has been developed so that stormwater runoff drains west towards the retention pond located at the intersection of White and Campbell Streets, northeast towards the retention pond adjacent to Buildings AS318 and AS320, south to the storm drains on the Tarmac, or to the open drainage ditches surrounding the flight line (**Figure 3**). Stormwater from Site 86 eventually discharges into the New River, approximately three-quarters of a mile to the east. Relatively high runoff and low infiltration rates are expected in the vicinity of the buildings, parking lots, and roadways; however, higher rates of infiltration are expected in the grass-covered areas.

Site Geology

The surficial deposits present at Site 86 belong to the undifferentiated Formation and are shown to vary in thickness from 30 feet in the western portion of the site (IR86-MW52 cluster) to approximately 40 feet near the central portion of the site (IR86-MW58 cluster). These deposits consist of mostly sand and silty sand, with lenses of sandy clay in the central and eastern portion of the site.

In the vicinity of Site 86, the River Bend Formation consists of weakly to completely cemented sandy limestone with fossilized shell fragments, which was observed at approximately 30 feet to 40 feet bgs and ranged in thickness from 15 feet in the western portion of the site to 45 feet in the northeast grass area. The proportion of shell fragments is greatest at approximately 45 to 55 feet bgs.

Below the cemented sands of the River Bend Formation, greenish gray sand with some silty sand lenses and fossils was observed at approximately 40 feet bgs in the western portion of the site (IR86-MW40IW) and at approximately 75 feet bgs in the eastern portion of the site (IR86-IS117**.** This greenish gray sand was not encountered in the northern portion of the site but was observed at approximately 60 feet bgs (IR86-MW59DW) in the southern portion of the site. This unit was observed to the borehole termination depth of approximately 90 feet bgs during installation of the middle Castle Hayne aquifer monitoring wells. The River Bend Formation overlies the Castle Hayne Formation.

Site Hydrogeology

Groundwater elevations measured in March 2010 ranged from 3.90 feet above mean sea level (msl) (IR86-MW64) to 16.33 feet above msl (USTCSFF-DW06). The western portion of the site exhibited the highest groundwater elevations. In general, the groundwater flow direction within the surficial aquifer and the upper and middle Castle Hayne aquifer zones is toward the east or northeast.

Vertical gradients were calculated between adjacent wells screened in the surficial and upper Castle Hayne aquifers and the upper Castle Hayne and middle Castle Hayne aquifers using groundwater elevation data collected in March 2010. The vertical hydraulic potential is calculated using paired wells and by dividing the difference in water level elevations by the vertical distance between the center points of the screened intervals. Throughout most of the site, downward vertical gradients were calculated to exist between the surficial and upper Castle Hayne aquifer zones, ranging from 0.002 foot per foot (ft/ft) to 0.112 ft/ft. Slight upward vertical gradients were estimated to exist north of Hangar AS504 and along the drainage ditch, adjacent to the flight line. Within the Castle Hayne aquifer, slight downward vertical gradients exist between the upper Castle Hayne and middle Castle Hayne aquifer zones, ranging from 0.003 ft/ft to 0.049 ft/ft.

Based on *in situ* aquifer testing (slug tests) and the results of the aquifer constant rate pumping test, the following hydraulic conductivity values were estimated: in the surficial aquifer 2.8 feet per day (ft/day) to 40 ft/day, with a geometric mean of 6.95 ft/day; in the upper Castle Hayne aquifer, 1.26 ft/day to 28 ft/day, with a geometric mean of 3.15 ft/day; and in the middle Castle Hayne aquifer, 0.06 ft/day to 3 ft/day, with a geometric mean of 0.45 ft/day. The technical literature (Cardinell et al., 1993) includes a range of hydraulic conductivity for the Castle Hayne aquifer of 14 ft/day to 91 ft/day.

Using an effective porosity value for silty sand of 30 percent (Fetter, 1986), linear seepage velocities for the surficial aquifer were estimated to range from 0.028 ft/day to 0.400 ft/day (10 to 146 feet per year [ft/year]), from 0.013 ft/day to 0.28 ft/day (5 to 102 ft/year) in the upper Castle Hayne aquifer, and from 0.001 ft/day to 0.04 ft/day (0.4 to 15 ft/year) in the middle Castle Hayne aquifer.

Attachment C – Injection Substrate Composition

MATERIAL SAFETY DATA SHEET

CAIROX® Potassium Permanganate

Section 1 Chemical Product and Company Identification

PRODUCT NAME: CAIROX® potassium permanganate, $KMnO_4$

SYNONYMS:
Permanganic acid potassium salt
Chameleon mineral
Condy's crystals
Permanganate of potash

MANUFACTURER'S NAME: CARUS CHEMICAL COMPANY

MANUFACTURER'S ADDRESS:
Carus Chemical Company
1500 Eighth Street
P. O. Box 1500
LaSalle, IL 61301

TRADE NAME: CAIROX® potassium permanganate

TELEPHONE NUMBER FOR INFORMATION: 815/223-1500

EMERGENCY TELEPHONE NO: 800/435-6856

AFTER HOURS NO. 815/223-1565
5:00 PM-8:00 AM Central Standard Time
Monday-Friday, Weekends and Holidays

CHEMTREC TELEPHONE NO.: 800/424-9300

Section 2 Composition/Information on Ingredients

Material or component	CAS No.	%	Hazard Data	
Potassium permanganate	7722-64-7	97% min. $KMnO_4$	PEL-C	5 mg Mn per cubic meter of air
			TLV-TWA	0.2 mg Mn per cubic meter of air

Section 3 Hazards Identification

1. Eye Contact
   Potassium permanganate is damaging to eye tissue on contact. It may cause severe burns that result in damage to the eye.

2. Skin Contact
   Contact of solutions at room temperature may be irritating to the skin, leaving brown stains. Concentrated solutions at elevated temperature and crystals are damaging to the skin.

3. Inhalation
   Acute inhalation toxicity data are not available. However, airborne concentrations of potassium permanganate in the form of dust or mist may cause damage to the respiratory tract.

4. Ingestion
   Potassium permanganate, if swallowed, may cause severe burns to mucous membranes of the mouth, throat, esophagus, and stomach.

Section 4 First Aid Measures

1. Eyes
   Immediately flush eyes with large amounts of water for at least 15 minutes holding lids apart to ensure flushing of the entire surface. Do not attempt to neutralize chemically. Seek medical attention immediately. Note to physician: Soluble decomposition products are alkaline. Insoluble decomposition product is brown manganese dioxide.

2. Skin
   Immediately wash contaminated areas with large amounts of water. Remove contaminated clothing and footwear. Wash clothing and decontaminate footwear before reuse. Seek medical attention immediately if irritation is severe or persistent.

3. Inhalation
   Remove person from contaminated area to fresh air. If breathing has stopped, resuscitate and administer oxygen if readily available. Seek medical attention immediately.

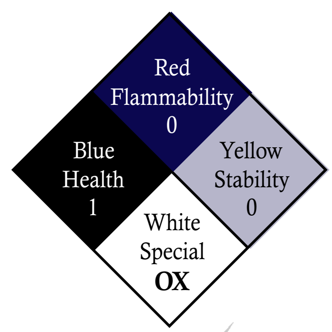
4. Ingestion
   Never give anything by mouth to an unconscious or convulsing person. If person is conscious, give large quantities of water. Seek medical attention immediately.

Section 5 Fire Fighting Measures

NFPA* HAZARD SIGNAL

Health Hazard (less than 1 hour exposure)	1	=	Materials which under fire conditions would give off irritating combustion products. Materials which on the skin could cause irritation.
Flammability Hazard	0	=	Materials that will not burn.
Reactivity Hazard	0	=	Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.
Special Hazard	OX	=	Oxidizer

***National Fire Protection Association 704**



FIRST RESPONDERS:

Wear protective gloves, boots, goggles, and respirator. In case of fire, wear positive pressure breathing apparatus. Approach site of incident with caution. Use Emergency Response Guide NAERG 96 (RSPA P5800.7). Guide No. 140.

FLASHPOINT	None	
FLAMMABLE OR EXPLOSIVE LIMITS	Lower: Nonflammable	Upper: Nonflammable
EXTINGUISHING MEDIA	Use large quantities of water. Water will turn pink to purple if in contact with potassium permanganate. Dike to contain. Do not use dry chemicals, CO_2, Halon® or foams.	
SPECIAL FIREFIGHTING PROCEDURES	If material is involved in fire, flood with water. Cool all affected containers with large quantities of water. Apply water from as far a distance as possible. Wear self-contained breathing apparatus and full protective clothing.	

Section 6 Accidental Release Measures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

Clean up spills immediately by sweeping or shoveling up the material. Do not return spilled material to the original container. Transfer to a clean metal drum. EPA banned the land disposal of D001 ignitable waste oxidizers. These wastes must be deactivated by reduction. To clean floors, flush with abundant quantities of water into sewer, if permitted by Federal, State, and Local regulations. If not permitted, collect water and treat chemically (Section 13).

PERSONAL PRECAUTIONS

Personnel should wear protective clothing suitable for the task. Remove all ignition sources and incompatible materials before attempting clean-up.

Section 7 Handling and Storage

WORK/HYGENIC PRACTICES

Wash hands thoroughly with soap and water after handling potassium permanganate, and before eating or smoking. Wear proper protective equipment. Remove contaminated clothing.

VENTILATION REQUIREMENTS

Provide sufficient area or local exhaust to maintain exposure below the TLV-TWA.

CONDITIONS FOR SAFE STORAGE

Store in accordance with NFPA 430 requirements for Class II oxidizers. Protect containers from physical damage. Store in a cool, dry area in closed containers. Segregate from acids, peroxides, formaldehyde, and all combustible, organic or easily oxidizable materials including anti-freeze and hydraulic fluid.

Section 8 Exposure Controls/Personal Protection

RESPIRATORY PROTECTION

In the case where overexposure may exist, the use of an approved NIOSH-MSHA dust respirator or an air supplied respirator is advised. Engineering or administrative controls should be implemented to control dust.

EYE

Faceshield, goggles, or safety glasses with side shields should be worn. Provide eye wash in working area.

GLOVES

Rubber or plastic gloves should be worn.

OTHER PROTECTIVE EQUIPMENT

Normal work clothing covering arms and legs, and rubber or plastic apron should be worn.

Section 9 Physical and Chemical Properties

APPEARANCE AND ODOR	Dark purple solid with a metallic luster, odorless
BOILING POINT, 760 mm Hg	Not applicable
VAPOR PRESSURE (mm Hg)	Not applicable
SOLUBILITY IN WATER % BY SOLUTION	6% at 20ºC (68ºF), and 20% at 65ºC (149ºF)
PERCENT VOLATILE BY VOLUME	Not volatile
EVAPORATION RATE (BUTYL ACETATE=1)	Not applicable
MELTING POINT	Starts to decompose with evolution of oxygen (O_2) at temperatures above 150ºC (302ºF). Once initiated, the decomposition is exothermic and self-sustaining.
OXIDIZING PROPERTIES	Strong oxidizer
SPECIFIC GRAVITY	2.7 @ 20ºC (68ºF)
VAPOR DENSITY (AIR=1)	Not applicable

Section 10 Stability and Reactivity

STABILITY Under normal conditions, the material is stable.

CONDITIONS TO AVOID Contact with incompatible materials or heat (>150ºC/302ºF).

INCOMPATIBLE MATERIALS Acids, peroxides, formaldehyde, anti-freeze, hydraulic fluids, and all combustible organic or readily oxidizable inorganic materials including metal powders. With hydrochloric acid, toxic chlorine gas is liberated.

HAZARDOUS DECOMPOSITION PRODUCTS When involved in a fire, potassium permanganate may liberate corrosive fumes.

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION Material is not known to polymerize.

Section 11 Toxicological Information

Potassium permanganate: Acute oral LD_{50}(rat) = 780 mg/kg Male (14 days); 525 mg/kg Female (14 days)
The fatal adult human dose by ingestion is estimated to be 10 grams. (Ref. Handbook of Poisoning: Prevention, Diagnosis & Treatment, Twelfth Edition)

EFFECTS OF OVEREXPOSURE

1. Acute Overexposure
   Irritating to body tissue with which it comes into contact.

2. Chronic Overexposure
   No known cases of chronic poisoning due to potassium permanganate have been reported. Prolonged exposure, usually over many years, to heavy concentrations of manganese oxides in the form of dust and fumes, may lead to chronic manganese poisoning, chiefly involving the central nervous system.

3. Carcinogenicity
   Potassium permanganate has not been classified as a carcinogen by OSHA, NTP, IARC.

4. Medical Conditions Generally Aggravated by Exposure
   Potassium permanganate will cause further irritation of tissue, open wounds, burns or mucous membranes.

   Registry of Toxic Effects of Chemical Substances
   RTECS #SD6476000

Section 12 Ecological Information

Entry to the Environment

Potassium Permanganate has a low estimated lifetime in the environment, being readily converted by oxidizable materials to insoluble manganese dioxide (MnO_2).

Bioconcentration Potential

In non-reducing and non-acidic environments manganese dioxide (MnO_2) is insoluble and has a very low bioaccumulative potential.

Aquatic Toxicity

Rainbow trout, 96 hour LC_{50}: 1.8 mg/L
Bluegill sunfish, 96 hour LC_{50}: 2.3 mg/L

Section 13 Disposal Consideration

DEACTIVATION OF D001 IGNITABLE WASTE OXIDIZERS BY CHEMICAL REDUCTION

Reduce potassium permanganate in aqueous solutions with sodium thiosulfate (Hypo), or sodium bisulfite or ferrous salt solution. The thiosulfite or ferrous salt may require some dilute sulfuric acid to promote rapid reduction. If acid was used, neutralize with sodium bicarbonate to neutral pH. Decant or filter, and mix the sludge with sodium carbonate and deposit in an approved landfill. Where permitted, the sludge can be drained into sewer with large quantities of water. Use caution when reacting chemicals. Contact Carus Chemical Company for additional recommendations.

Section 14 Transport Information

U. S. DEPARTMENT OF TRANSPORTATION INFORMATION:

Proper Shipping Name:	49 CFR 172.101	Potassium Permanganate
ID Number:	49 CFR 172.101	UN 1490
Hazard Class:	49 CFR 172.101	Oxidizer
Division:	49 CFR 172.101	5.1
Packing Group:	49 CFR 172.101	II

Section 15 Regulatory Information

TSCA Listed in the TSCA Chemical Substance Inventory

CERCLA **Hazardous Substance**

Reportable Quantity: RQ - 100 lb — 40 CFR 116.4; 40 CFR 302.4

RCRA Oxidizers such as potassium permanganate meet the criteria of ignitable waste. 40 CFR 261.21

SARA TITLE III Information

Section 302	Extremely hazardous substance: Not listed
Section 311/312	Hazard categories: Fire, acute and chronic toxicity
Section 313	CAIROX® potassium permanganate contains 97% Manganese Compound as part of the chemical structure (manganese compounds CAS Reg. No. N/A) and is subject to the reporting requirements of Section 313 of Title III, Superfund Amendments and Reauthorization Act of 1986 and 40 CFR 372.

Section 15 Regulatory Information (cont.)

STATE LISTS	Michigan Critical Materials Register:	Not listed
	California Proposition 65:	Not listed
	Massachusetts Substance List:	5 F8
	Pennsylvania Hazard Substance List:	E
FOREIGN LISTS	Canadian Domestic Substances List (DSL)	Listed
	Canadian Ingredient Disclosure List	Listed
	European Inventory of Existing Chemical Substances (EINECS)	2317603

Section 16 Other Information

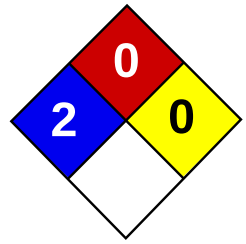
NIOSH	National Institute for Occupational Safety and Health
MSHA	Mine Safety and Health Administration
OSHA	Occupational Safety and Health Administration
NTP	National Toxicology Program
IARC	International Agency for Research on Cancer
TSCA	Toxic Substances Control Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act of 1986
PEL-C	OSHA Permissible Exposure Limit-OSHA Ceiling Exposure Limit
TLV-TWA	Threshold Limit Value - Time Weighted Average (American Conference of Governmental Industrial Hygienists)

Kenneth Krogulski
Kenneth Krogulski
May 2000

CARUS

Responsible Care®
A Public Commitment

The information contained is accurate to the best of our knowledge. However, data, safety standards and government regulations are subject to change; and the conditions of handling, use or misuse of the product are beyond our control. Carus Chemical Company makes no warranty, either express or implied including any warranties of merchantability and fitness for a particular purpose. Carus also disclaims all liability for reliance on the completeness or confirming accuracy of any information included herein. Users should satisfy themselves that they are aware of all current data relevant to their particular uses.



Health	2
Fire	0
Reactivity	0
Personal Protection	H

Material Safety Data Sheet
Sodium Lactate, 60% MSDS

Section 1: Chemical Product and Company Identification

Product Name: Sodium Lactate, 60%

Catalog Codes: SLS1315, SLS2737

CAS#: Mixture.

RTECS: Not applicable.

TSCA: TSCA 8(b) inventory: Sodium lactate; Water

CI#: Not available.

Synonym:

Chemical Name: Not applicable.

Chemical Formula: Not applicable.

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Sodium lactate	72-17-3	60
Water	7732-18-5	40

Toxicological Data on Ingredients: Sodium lactate LD50: Not available. LC50: Not available.

Section 3: Hazards Identification

Potential Acute Health Effects:
Very hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Non-corrosive for skin. Non-sensitizer for skin. Non-permeator by skin. Inflammation of the eye is characterized by redness, watering, and itching. Skin inflammation is characterized by itching, scaling, reddening, or, occasionally, blistering.

Potential Chronic Health Effects:
Very hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Non-corrosive for skin. Non-sensitizer for skin. Non-permeator by skin. CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. Repeated or prolonged inhalation of vapors may lead to chronic respiratory irritation.

Section 4: First Aid Measures

Eye Contact:
Check for and remove any contact lenses. Immediately flush eyes with running water for at least 15 minutes, keeping eyelids open. Cold water may be used. Do not use an eye ointment. Seek medical attention.

Skin Contact:
After contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and groin. Cold water may be used. Cover the irritated skin with an emollient. If irritation persists, seek medical attention.

Serious Skin Contact:
Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek medical attention.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation: Not available.

Ingestion:
Do not induce vomiting. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Non-flammable.

Auto-Ignition Temperature: Not applicable.

Flash Points: Not applicable.

Flammable Limits: Not applicable.

Products of Combustion: Not available.

Fire Hazards in Presence of Various Substances: Not applicable.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions: Not applicable.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:
Dilute with water and mop up, or absorb with an inert dry material and place in an appropriate waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Absorb with an inert material and put the spilled material in an appropriate waste disposal. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system.

Section 7: Handling and Storage

Precautions:

Do not breathe gas/fumes/ vapour/spray. In case of insufficient ventilation, wear suitable respiratory equipment If you feel unwell, seek medical attention and show the label when possible. Avoid contact with skin and eyes Keep away from incompatibles such as acids.

Storage:
No specific storage is required. Use shelves or cabinets sturdy enough to bear the weight of the chemicals. Be sure that it is not necessary to strain to reach materials, and that shelves are not overloaded.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors below their respective threshold limit value.

Personal Protection:
Splash goggles. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Vapor respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits: Not available.

Section 9: Physical and Chemical Properties

Physical state and appearance: Liquid.

Odor: Not available.

Taste: Not available.

Molecular Weight: Not applicable.

Color: Not available.

pH (1% soln/water): Neutral.

Boiling Point: The lowest known value is 100°C (212°F) (Water).

Melting Point: Not available.

Critical Temperature: Not available.

Specific Gravity: The only known value is 1 (Water = 1) (Water).

Vapor Pressure: The highest known value is 17.535 mm of Hg (@ 20°C) (Water).

Vapor Density: The highest known value is 0.62 (Air = 1) (Water).

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: See solubility in water.

Solubility: Easily soluble in cold water, hot water.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Highly reactive with acids.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

Section 11: Toxicological Information

Routes of Entry: Eye contact. Inhalation. Ingestion.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans:
Very hazardous in case of skin contact (irritant), of ingestion, of inhalation. Non-corrosive for skin. Non-sensitizer for skin. Non-permeator by skin.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Not available.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations: TSCA 8(b) inventory: Sodium lactate; Water

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).

Other Classifications:

WHMIS (Canada): CLASS D-2B: Material causing other toxic effects (TOXIC).

DSCL (EEC):
R38- Irritating to skin. R41- Risk of serious damage to eyes.

HMIS (U.S.A.):

Health Hazard: 2

Fire Hazard: 0

Reactivity: 0

Personal Protection: h

National Fire Protection Association (U.S.A.):

Health: 2

Flammability: 0

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Splash goggles.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

Created: 10/10/2005 12:06 PM

Last Updated: 11/01/2010 12:00 PM

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall ScienceLab.com be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if ScienceLab.com has been advised of the possibility of such damages.

TSI DC Bioaugmentation Culture® Material Safety Data Sheet

SECTION 1 - MATERIAL IDENTIFICATION AND INFORMATION

Material Name: DHC microbial consortium (TSI-DC)

Date Prepared: 01-01-2010 CAS #: N/A (Not Applicable)

Prepared By: Dr. Mike Lee Formula #: N/A

Material Description: Non-hazardous, naturally occurring non-altered anaerobic microbes and enzymes in a water-based medium.

SECTION 2 – INGREDIENTS

Components	%	OSHA PEL	ACG l H TLV	OTHER LIMITS
Non-Hazardous Ingredients	100	N/A	N/A	N/A

SECTION 3 – PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: 100°C (water)

Vapor Pressure @ 25°C: 24 mm Hg (H_20)

Vapor Density: N/A

Solubility in Water: Soluble

Specific Gravity ($H_20 = 1$): 0.9 - 1

Melting Point: 0°C (water)

Evaporation Rate ($H_20 = 1$): 0.9 – 1

pH: 6.0 - 8.0

Water Reactive: No

Appearance and Odor: Murky, yellow water. Musty odor.

TSI DC Bioaugmentation Culture® is an enriched natural bacteria culture that contains greater than 10^{10} Dehalococcoides/L for bioaugmentation. This culture dechlorinates tetrachloroethene (PCE) and trichloroethene (TCE) to the non-toxic product ethene. The culture also biodegrades 1,1,1-trichloroethane to 1,1-dichloroethene, 1,1-dichloroethane, and chloroethane. It also can biodegrade carbon tetrachloride and chloroform to methylene chloride and innocuous products. It can be used at sites where bacteria capable of complete reductive dechlorination are not present or there is a need to decrease the remediation time frame.

Attachment D – Injection Rationale

D. Injection Rationale

A description of the rationale for selecting the injectants and concentrations for the Site 86 Pilot Study is provided below:

Injection Project Goals

- To evaluate the injection/extraction approach as a method for distributing the ERD substrate over relatively broad areas and in areas where access is limited
- To evaluate the overall effectiveness of ERD in terms of reducing contaminant mass in Zone 1
- To evaluate the overall effectiveness of SRPC as a passive remediation remedy in Zone 2
- To obtain sufficient performance data and results to refine remedial alternatives for preparation of a Feasibility Study
- To reduce sufficient VOC mass within Zone 1 and 2 to allow for monitored natural attenuation as a viable remedial option in the Feasibility Study

The objectives and goals will be evaluated for each pilot study by comparing the data gathered during a baseline groundwater sampling to three subsequent sampling events scheduled for 1, 3, and 6 months after the pilot studies have been implemented.

Injectant Requirement Determination

Current site conditions, including concentrations of VOCs and total organic carbon and groundwater plume geometry, were evaluated to determine the quantity of injectant required within each treatment area.

Based on data presented in the Expanded Supplemental Remedial Investigation (ESRI-CH2M HILL, 2010), the highest VOCs concentrations in Zone 1 are located in the vicinity of monitoring well IR86-MW58IW and direct-push technology (DPT) groundwater sampling location IR86-IS50 (**Figure 2**). TCE was detected in the groundwater sample collected in December 2009 from monitoring well IR86-MW58IW, at a concentration of 710 micrograms per liter (µg/L), and in the groundwater sample collected in October 2009 from the DPT location IR86-IS50, at a concentration of 680 µg/L. Therefore, the Zone 1 pilot study will address the VOC plume in the in the vicinity of Building AS508 and monitoring well IR86-MW58IW by injecting an ERD substrate (sodium lactate) and a bioaugmentation culture to reduce the VOC mass in groundwater.

Based on the data presented in the ESRI, the highest VOCs concentrations in Zone 2, specifically TCE, are in the vicinity of monitoring well IR86-MW61 (**Figure 3)**. TCE was detected in groundwater sampled from surficial aquifer monitoring well IR86-MW61 in December 2009, at a concentration of 260 µg/L. Therefore, the Zone 2 pilot study will address the VOC plume located in the northeast grass area east of the flight line, in the vicinity of monitoring well IR86-MW61 (**Figure 3**) using a passive SPRC approach.

Injectant Reactivity and Breakdown Products

Sodium Lactate

The ERD reagent selected for Zone 1 is a sodium lactate solution. Sodium lactate was selected based on its chemical properties (such as water solubility to improve distribution) and its ability to be used for ERD faster than oil-based substrates.

A 5 percent sodium lactate solution will be injected into the upper Castle Hayne aquifer through six injection wells, and distribution throughout the treatment footprint will be enhanced using two extraction wells. Once in the aquifer, the lactate will ferment into acetate and hydrogen. The hydrogen will function as the primary electron donor. The lactate will also release ethanol, which will also function as an electron donor.

No significant health and safety concerns are associated with lactate; however, it is recommended that eye protection and impervious gloves be donned to avoid irritation.

Bioaugmentation

Bioaugmentation is the introduction of microorganisms into the subsurface to treat contaminated soil or groundwater. Bioaugmentation is used to ensure that contaminants, particularly cis-1,2-DCE and VC, are completely degraded. A bioaugmentation culture will be injected into the upper Castle Hayne aquifer within Zone 1. The bioaugmentation culture will contain the ***Dehalococcoides*** bacteria. ***Dehalococcoides*** bacteria are the only known organisms capable of dechlorinating TCE to ethane. In the absence of ***Dehalococcoides***, dechlorination of TCE may only progress to cis-1,2-DCE (Site Recovery and Management Labs, 2009). Bioaugmentation has been demonstrated to work with most commonly used electron donors, including lactate, vegetable oils, and slow-release compounds. Bioaugmentation can be inhibited by aerobic conditions, high sulfate concentrations, moderate concentrations of chloroform, and extremely low groundwater temperatures (Site Recovery and Management Labs, 2009).

SRPC Technology

Oxidant injections are often unsuccessful because the injectant fails to meet distribution goals. SRPCs treat groundwater passively, meaning the contaminated groundwater comes in contact with the SRPC under normal groundwater flow conditions. SRPC technology is designed to slowly release MnO4- into VOC-contaminated groundwater through molecular diffusion. SRPCs consist of KMnO4 in a paraffin wax matrix. As the paraffin dissolves, KMnO4 crystals become exposed, resulting in the molecular diffusion of MnO4- into passing groundwater. The MnO4- treatability footprint will vary based on the groundwater velocity, aquifer dispersivity, MnO4- persistence in the aquifer, and the soil oxidant demand of the aquifer material.

The SRPC is an emerging technology with limited case studies; however, it is estimated based on site groundwater velocities that each SRPC will have an effective life span of at least 6 months.

Injectant Subsurface Behavior

Enhanced Reductive Dechlorinization

ERD is a bioremediation technology used for treating chlorinated volatile organic compounds (CVOCs) in groundwater with the addition of electron donors such as lactate, molasses, vegetable oil, and other commercially available carbon sources. ERD accelerates the naturally occurring process of reductive dechlorination, wherein chlorinated solvents in groundwater are biodegraded by indigenous anaerobic microbes. Anaerobic microbes take electrons from small organic compounds and produce hydrogen. This process is known as fermentation. The microbes then use the electrons in the hydrogen to replace a chlorine atom in the CVOCs.

The principal anaerobic biodegradation pathway for reductive dechlorination of TCE, cis-1,2-DCE, and VC is:

$$\text{TCE} \rightarrow \text{cis-1,2-DCE} \rightarrow \text{VC} \rightarrow \text{ethene}$$

The transformation rates for each step vary but tend to become slower with progress along the breakdown sequence, often resulting in accumulation of cis-1,2-DCE and VC. Further breakdown from cis-1,2-DCE and VC to ethene varies and is based on site-specific conditions.

Biodegradation of CVOCs can be achieved by adding a suitable reagent to the subsurface. The reagent serves two purposes: (a) depleting the supply of competing electron acceptors and creating strongly reducing conditions and (b) providing an electron donor source for reductive dechlorination.

Chemical Oxidation

Chemical oxidation delivers chemical oxidants into groundwater to completely oxidize contaminants into carbon dioxide (CO_2) or other innocuous compounds. There are a number of chemicals that successfully degrade chlorinated solvents via chemical oxidation. A key factor in the effectiveness of chemical oxidation is contact between the contaminant and the oxidant.

MnO_4^- is a chemical oxidant with a proven history of effectively treating CVOCs to CO_2. MnO_4^- is a common chemical oxidizing agent with strong oxidation potential, predictable chemistry, good stability, and non-toxic byproducts. Chemical oxidation using MnO_4^- is achieved primarily through direct electron transfers, as shown in the following reaction (USEPA, 2006):

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2(s) + 2\,H_2O$$

Treatment of CVOCs using potassium permanganate ($KMnO_4$) is achieved by adding to the alkene bond, shown as follows in the reactions and TCE with $KMnO_4$ (USEPA, 2006):

$$2\ KMnO4 + C2HCl3 \rightarrow 2\ CO2 + 2\ MnO2 + 2\ K+ + H+ + 3\ Cl-$$

The greatest advantage of MnO4- is its stability. Persisting for several months, the use of MnO4- enables long contact times and transport distances (USEPA, 2006). The oxidation strength and specificity of the MnO4- ion improves its longevity compared to non-specific oxidizers such as hydroxyl radicals and ozone.

Attachment F – Monitoring Plan

F. Monitoring Plan

Zone 1 Well Installation

Six 4-inch injection wells (IR86-IW01 through IR86-IW08), two 4-inch extraction wells (IR86-EW01 and IR86-EW02), and six 2-inch monitoring wells (IR86-MW through IR86-MW) will be installed in Zone 1 using rotosonic drilling techniques, as shown on **Figure 4**. Proposed Zone 1 well construction details are provided in **Table 1**.

The injection wells will be installed on the north side of Building AS508, with a row of three wells positioned to the north of IR86-MW-58IW, adjacent to the long axis of the plume, with another row of three wells positioned south of IR86-MW58IW. The injection wells will be spaced approximately 75 ft apart and installed to a depth of 55 ft bgs, with 20 ft of 4-inch inner diameter, 0.020-inch slot “vee-wire” (semi-continuous slot) polyvinyl chloride (PVC) screen. Injection wells may be moved to avoid installing them into pavement or sidewalks.

The extraction wells will be installed at the midpoint between the injection wells, arranged to complete a five-die pattern between the injection wells. The extraction wells will be spaced approximately 75 ft apart and installed to a depth of 55 ft bgs, with 20 ft of 4-inch inner diameter 0.020-inch slot “vee-wire” PVC screen.

To monitor the effectiveness of the system and the radius of influence during operation, six monitoring wells will be installed as shown on **Figure 4**. Five monitoring wells will be placed approximately 10, 15, 20, 25, and 30 ft from the injection wells, along the predicted flow path toward the extraction wells. Actual distances may vary owing to site conditions such as the location of utilities or topography. The sixth well will be installed at the midpoint between the two extraction wells. Each monitoring well will be installed to a depth of 50 ft bgs and constructed using 2-inch schedule 40 PVC with 10 ft of 2-inch schedule 40, 0.010-inch slot PVC screen.

TABLE 1
Zone 1 Well Construction Summary

Well	Well Diameter (inches)	Total Well Depth (ft)	Screen Length (ft)
IR86 – IW01	4	55	20
IR86 – IW02	4	55	20
IR86 – IW03	4	55	20
IR86 – IW04	4	55	20
IR86 – IW05	4	55	20
IR86 – IW06	4	55	20
IR86 – EW01	4	55	20
IR86 – EW02	4	55	20
IR86 –MW58IWR	2	50	10
IR86 –MW70IW	2	50	10
IR86 –MW71IW	2	50	10

TABLE 1
Zone 1 Well Construction Summary

Well	Well Diameter (inches)	Total Well Depth (ft)	Screen Length (ft)
IR86 –MW72IW	2	50	10
IR86 –MW73IW	2	50	10
IR86 –MW74IW	2	50	10

Zone 2 Well Installation

Before SRPC deployment occurs, four monitoring wells will be installed within the surficial aquifer, approximately 1, 5, 10, and 15 ft downgradient of the SRPC permeable reactive barrier location. Monitoring wells will be installed to approximately 30 ft bgs, with a screened interval of 20 to 30 ft bgs (**Figure 6**). Each monitoring well will be constructed using 2-inch schedule 40 PVC with 10 ft of 2-inch schedule 40, 0.010-inch slot PVC screen. Zone 2 well construction details are provided in **Table 2**.

Table 2
Zone 2 Monitoring Well Construction Summary

Well	Well Diameter (inches)	Total Well Depth (ft)	Screen Length (ft)
IR86 - MW66	2	30	10
IR86 - MW67	2	30	10
IR86 - MW68	2	30	10
IR86 - MW69	2	30	10

Zone 1 Groundwater Monitoring

Groundwater samples will be collected from upper Castle Hayne aquifer monitoring wells associated with the Zone 1 ERD pilot study area (IR86-MW58IWR and IR86-MW70IW through IR86-MW74IW) (**Figure 4**). Groundwater samples will be analyzed by a fixed-base laboratory for VOCs, volatile fatty acids, and TOC, as specified in the Site 86 UFP-SAP (CH2M HILL, 2011b), to evaluate the effectiveness of the lactate and bioaugmentation treatments. Bioassay samples will also be collected from select monitoring wells and submitted for quantitative real time polymerase chain reaction-ribonucleic acid expression analysis to assess the performance of the bioaugmentation culture and to track the microbial populations. Four groundwater sampling events will be conducted: baseline, 1 month, 3 months, and 6 months.

Zone 2 Groundwater Monitoring

Groundwater samples will be collected from surficial monitoring wells associated with the Zone 2 SRPC pilot study area (IR86-MW61, IR86-MW63 and IR86-MW66 through IR86-MW69) (**Figure 6**). Groundwater samples will be analyzed for VOCs, as specified in the Site 86 UFP-

SAP (CH2M HILL, 2011b). Four groundwater sampling events will be conducted: baseline, 1 month, 3 months, and 6 months.

Attachment G – Maps

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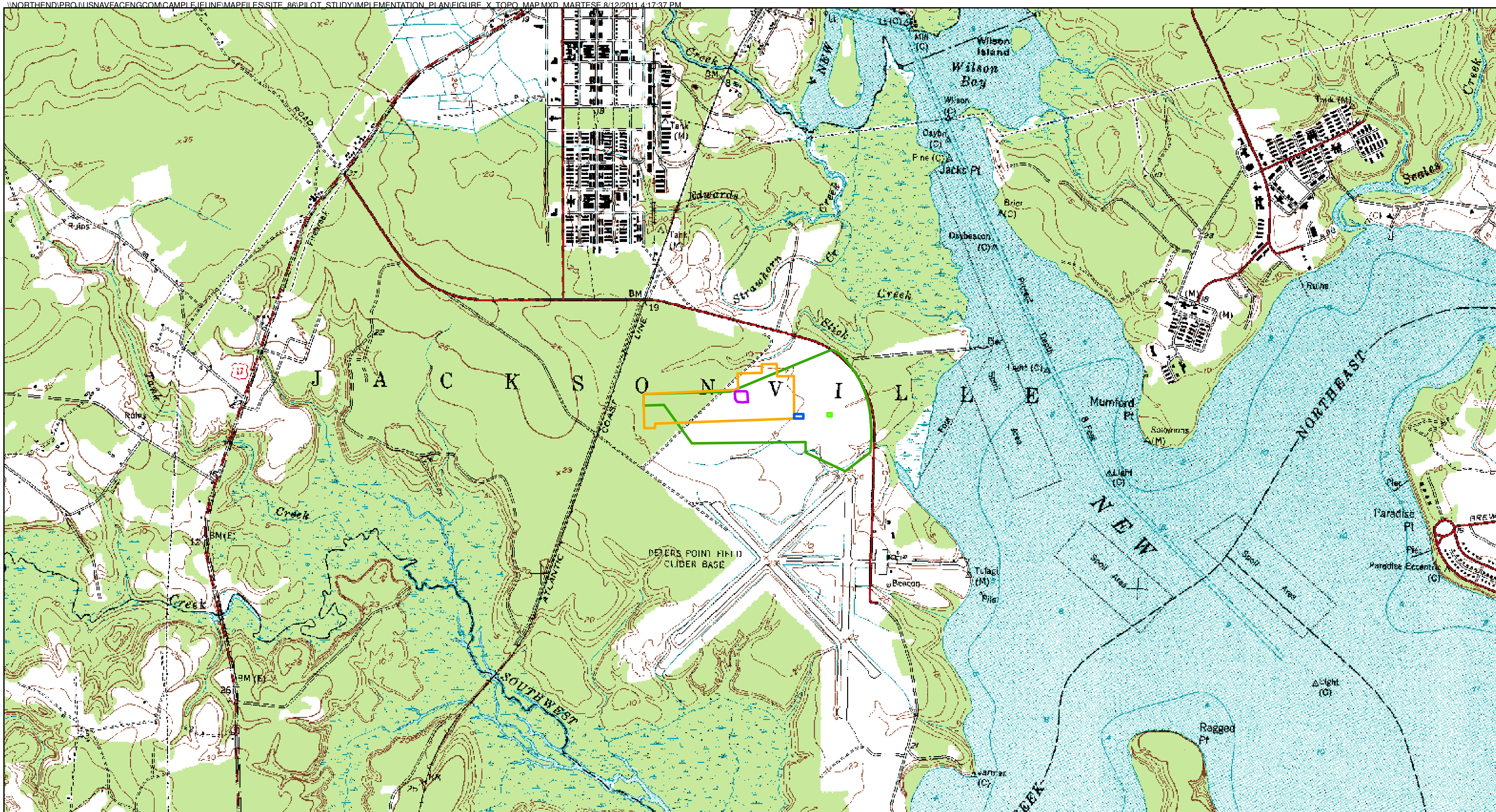

Legend

- Zone 1 Pilot Study Area
- Zone 2 Pilot Study Area
- Original Site Boundary
- August 2006 Site 86 Boundary
- March 2010 Site 86 Boundary

Jacksonville South, Quadrangle
North Carolina - Onslow Co.
7.5 Minute Series (Topographic)
NW/4 New River 15' Quadrangle

N

0 1,000 2,000 4,000 Feet

1 inch = 2,000 feet

Figure 1
Topographic Map
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

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TCE Concentration (µg/L)	
IR86-MW58IW	710
IR86-IS50	680 D
IR86-IS109	5.4
IR86-IS111	38
IR86-IS114	190

Legend

- Upper Castle Hayne Aquifer Monitoring Well
- Direct Push Groundwater Sampling Locations 2007
- Direct Push Groundwater Sampling Locations 2008
- Direct Push Groundwater Sampling Locations 2009
- Expanded Site 86 Boundary (March 2010)

TCE Concentrations

- > 300 µg/L
- > 30 µg/L
- > 3.0 µg/L

Notes:
- All concentrations are reported in µg/L.
- Contours have been interpolated between monitoring well locations. Actual conditions may differ from those shown.
- Samples collected in December 2009, March 2010, and June 2010.
- NCGWQS for TCE = 3.0 µg/L.
- Only detected concentrations of TCE shown in table.
- **Bold** indicates value above NCGWQS.
- J- Analyte present, value may or may not be accurate or precise.

N

0 75 150 Feet

1 inch = 150 feet

Image from Google Earth Pro

Figure 2-6
TCE Concentrations in the Upper Castle Hayne Aquifer
Pilot Study Implementation Plan
Operable Unit No. 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL

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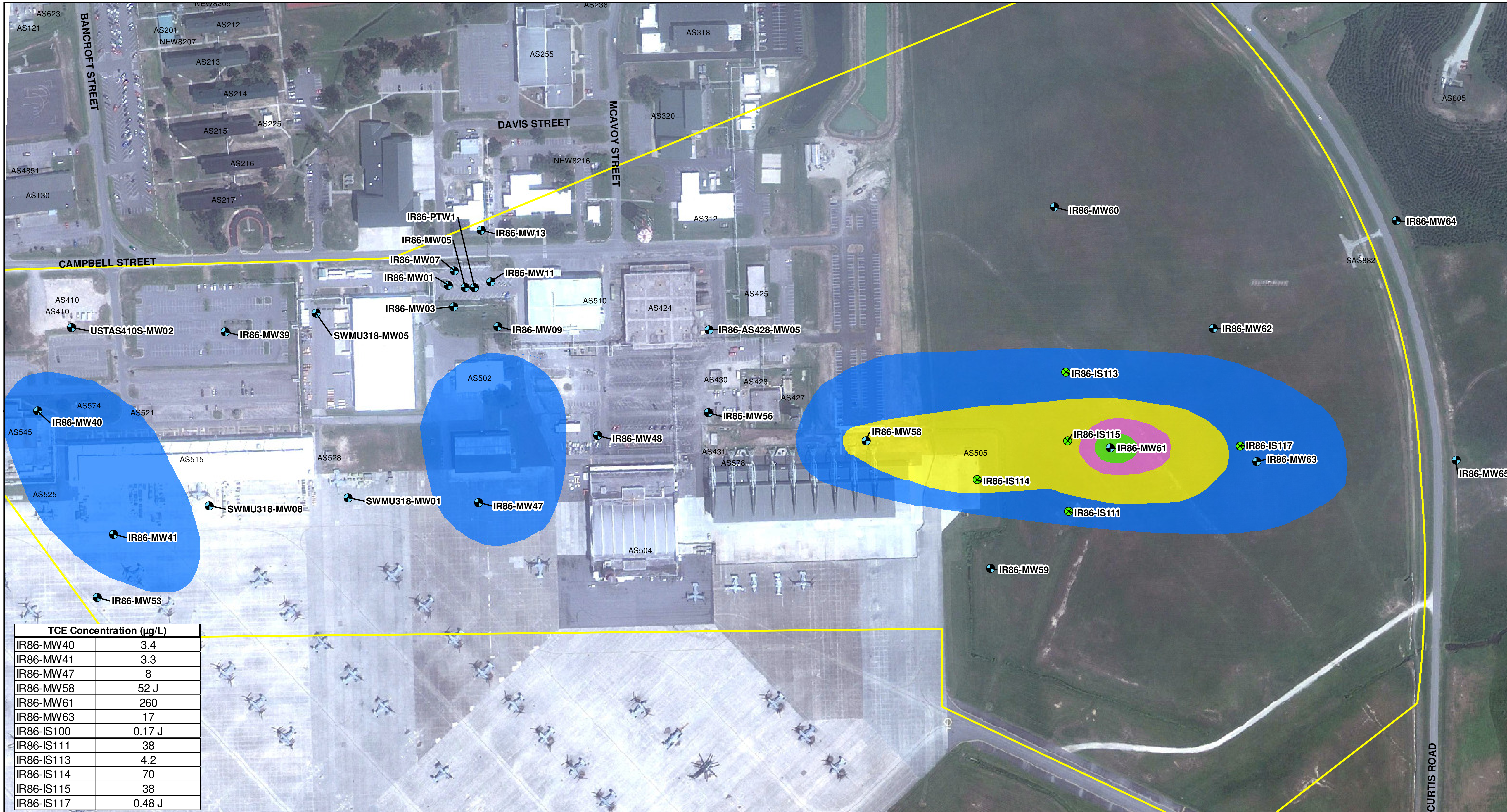

TCE Concentration (µg/L)	
IR86-MW40	3.4
IR86-MW41	3.3
IR86-MW47	8
IR86-MW58	52 J
IR86-MW61	260
IR86-MW63	17
IR86-IS100	0.17 J
IR86-IS111	38
IR86-IS113	4.2
IR86-IS114	70
IR86-IS115	38
IR86-IS117	0.48 J

Legend

- Direct Push Groundwater Sampling Locations 2009
- Surficial Aquifer
- Expanded Site 86 Boundary (March 2010)

TCE Concentrations

- > 250 µg/L
- > 150 µg/L
- > 50 µg/L
- > 3.0 µg/L

Notes:
- All concentrations are reported in µg/L.
- Contours have been interpolated between monitoring well locations. Actual conditions may differ from those shown.
- Samples collected in December 2009, March 2010, and June 2010.
- NCGWQS for TCE = 3.0 µg/L.
- Only detected concentrations of TCE above NCGWQS shown in table.
- J- Analyte present, value may or may not be accurate or precise.

N

0 137.5 275 550 Feet

1 inch = 275 feet

Google Earth Imagery

Figure 2-8
TCE Concentrations in the Surficial Aquifer
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB Cam Lej
North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CAMPLEJEUNE\MAPFILES\SITE_86\PILOT_STUDY\IMPLEMENTATION_PLAN\FIGURE_4_1_INJECTION_EXTRACTION_SYSTEM_LAYOUT.MXD MARTESE 8/30/2011 11:46:04 AM

Legend

- Extraction Well
- Injection Well
- Proposed Monitoring Well
- Upper Castle Hayne Aquifer Monitoring Well

TCE Concentrations

- > 300 µg/L
- > 30 µg/L
- > 3.0 µg/L

N

0 15 30 60 Feet

1 inch = 30 feet

Google Earth Imagery

Figure 4-1
Injection-Extraction System Layout
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB Cam Lej
North Carolina

CH2MHILL

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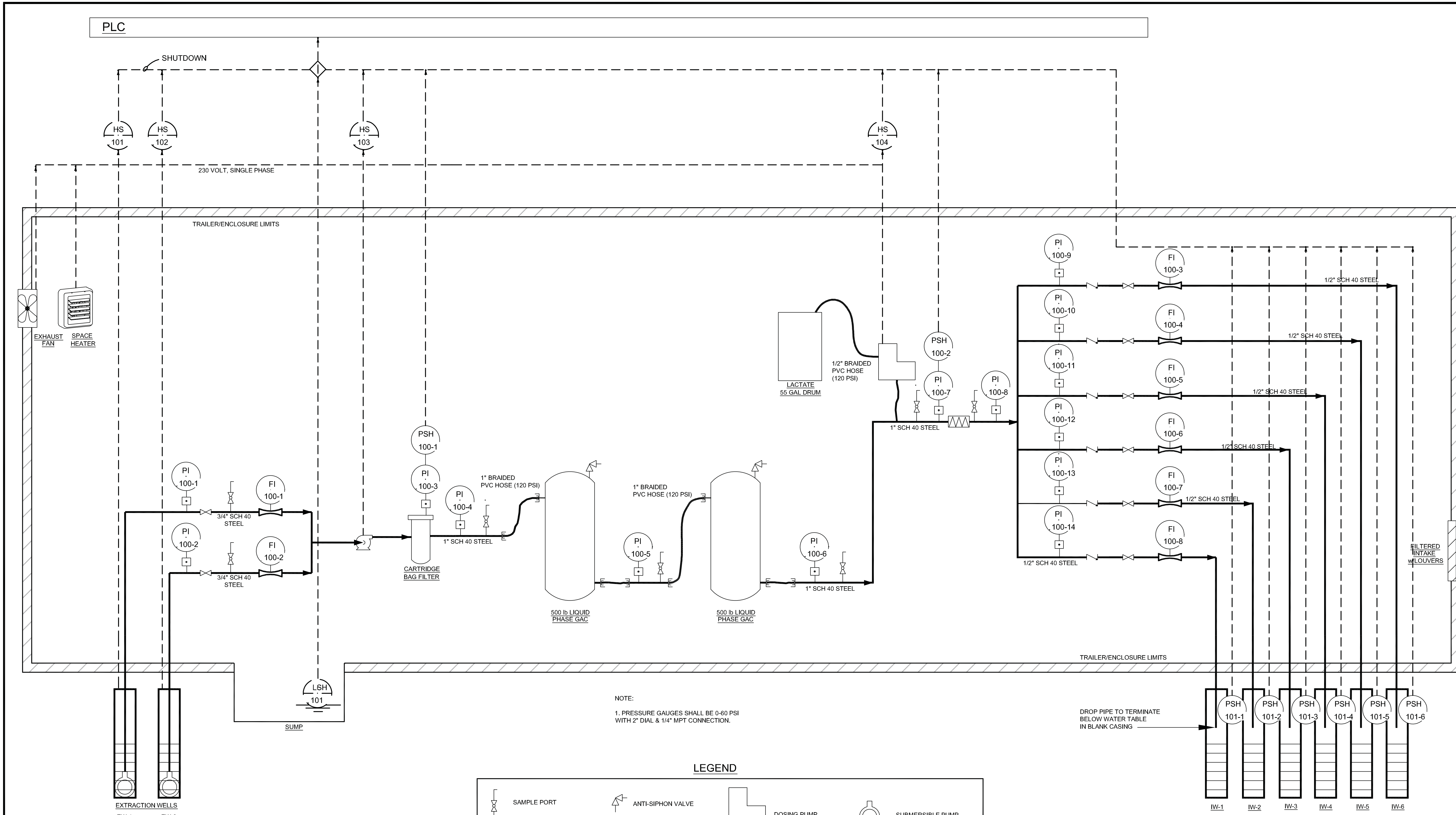
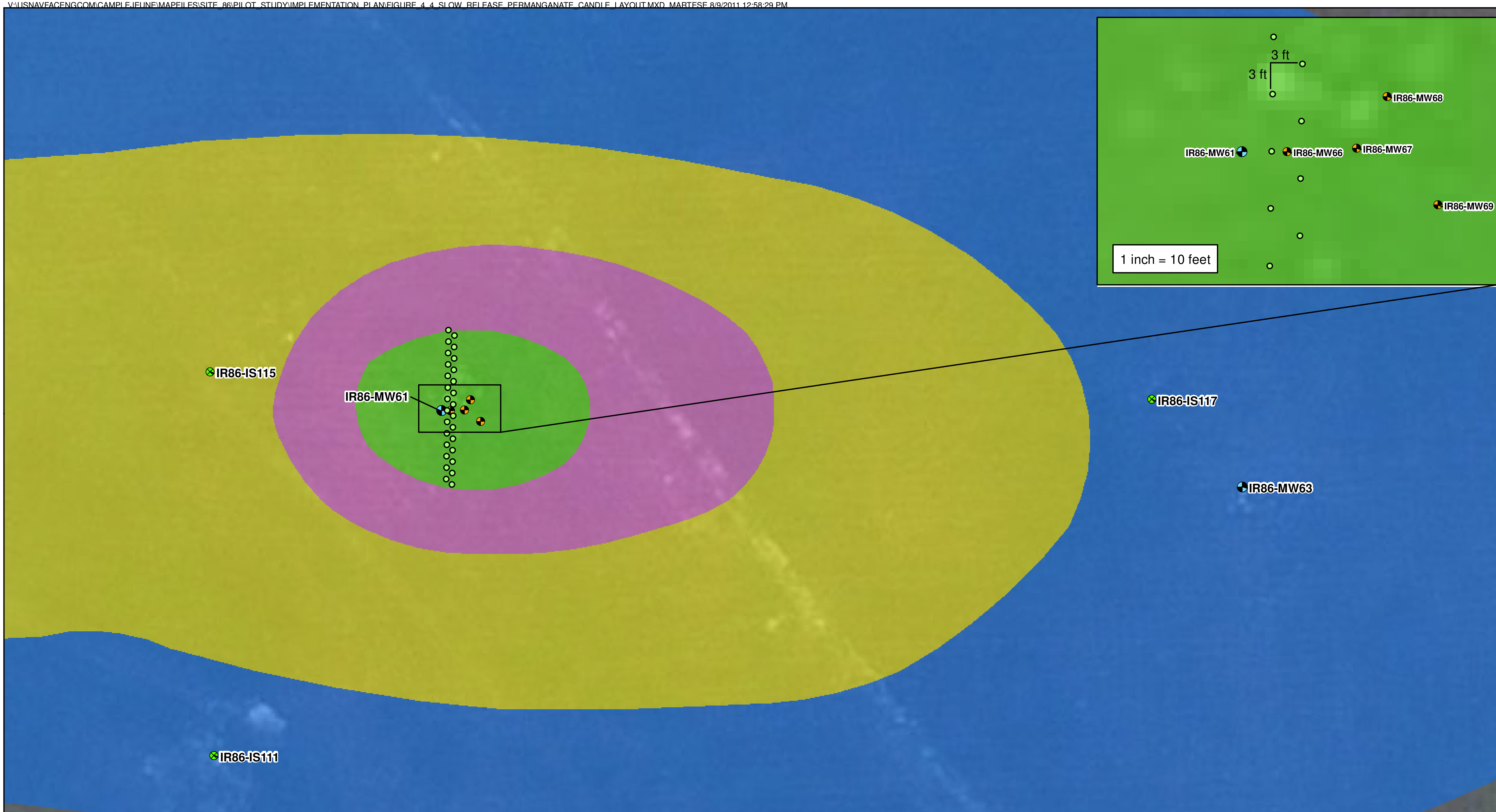


FIGURE 4-3
PROCESS FLOW DIAGRAM
PILOT STUDY IMPLEMENTATION PLAN
SITE 86 (OU 20)
MCB CAMP LEJEUNE
NORTH CAROLINA

EBL\Navy Clean\OU 20(Site 86)\2010 Pilot Study\Working Figures

V:\USNAVFACENGCOM\CAMPLEJEUNE\MAPFILES\SITE_86\PILOT_STUDY\IMPLEMENTATION_PLAN\FIGURE_4_4_SLOW_RELEASE_PERMANGANATE_CANDLE_LAYOUT.MXD MARTESE 8/9/2011 12:58:29 PM



Legend

- Proposed Slow Release Permanganate Candles
- Proposed Surficial Aquifer Monitoring Well
- Direct Push Groundwater Sampling Locations 2009
- Surficial Aquifer Monitoring Well

TCE Concentrations

Modeled

- > 250 µg/L
- > 150 µg/L
- > 50 µg/L
- > 3.0 µg/L

N

0 25 50 100 Feet

1 inch = 50 feet

Google Earth Imagery

Figure 4-4
Slow Release Permanganate Candle Layout
Pilot Study Implementation Plan
Operable Unit 20 (Site 86)
MCB CamLej
North Carolina

CH2MHILL