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SUPPLEMENTAL INTERIM MEASURES WORK PLAN REVISION 2 AREA OF CONCERN A MILLINGTON SUPPACT TN

5/4/2012

ENSAFE

SUPPLEMENTAL INTERIM MEASURES WORK PLAN

AOC A — NORTHSIDE FLUVIAL DEPOSITS GROUNDWATER

NAVAL SUPPORT ACTIVITY
MID-SOUTH MILLINGTON, TENNESSEE

Revision: 2

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1.0 INTRODUCTION

This Supplemental Interim Measures Work Plan outlines the remedy adjustments proposed for the Area of Concern A (AOC A) — fluvial deposits groundwater at Naval Support Activity. The work plan has been modified in response to the Tennessee Department of Environment and Conservation (TDEC) Division of Solid Waste Management's (DSWM) review and comments (received January 30, 2012) on the September 2011 version of the work plan (revision 0). The Navy's response to comments, submitted on February 29, 2012, was approved by the DSWM in their March 29, 2012 correspondence. The interim measures remedy selection for AOC A has been enhanced in-situ bioremediation which consists of monthly injections of sodium acetate and converting the aquifer chemistry from aerobic to anaerobic conditions to facilitate the anaerobic degradation of trichloroethylene (TCE). The daughter products generated from the TCE degradation, namely cis-1,2-dichloroethlyene (cis-1,2-DCE) and vinyl chloride (VC), undergo aerobic degradation as they move into the downgradient, non-treated areas of the aquifer or when the aquifer reverts back to its naturally aerobic state. Monthly injections of sodium acetate were completed between May 2004 and October 2009 and the remedy transitioned to monitoring only for residual TCE and aerobic degradation of the daughter products while they attenuate to their respective cleanup goals (maximum contaminant levels [MCLs])

In the year of post-remedy monitoring, there have been no indications of contaminant rebound; however, supplemental corrective measures are proposed herein to address lingering hot-spots and regulatory concerns associated with offsite TCE migration. Specifically, three areas are proposed for supplemental interim measures:

- Residual TCE hotspots in fluvial deposits groundwater at Sub-Plumes A and D.
- The former base property boundary where TCE above the maximum contaminant level (MCL) has migrated beyond.
- The former north fuel farm (Solid Waste Management Unit 15) where benzene in fluvial deposits groundwater persists. Although benzene levels have significantly attenuated since the 2004 soil source removal activities, groundwater corrective measures are necessary to expedite achieving the 5 µg/L MCL/groundwater cleanup goal.

Outlined below is a brief summary of each AOC A area and the conceptual remedial approach for each.

2.0 RESIDUAL TCE IN SUB-PLUME AREAS

Semi-annual groundwater monitoring data presented in the 2011 progress report showed anaerobic conditions persisted in the aquifer despite the suspension of carbon substrate injections in 2009 (the remedy transitioned to monitored natural attenuation after the October 2009 Base Cleanup Team meeting and the demonstration in the 2011 AOC A progress report, through multiple lines of evidence that MNA was actively ongoing and a viable remedy to achieve the MCL cleanup goal). Figure 1 compares historical high TCE concentrations with the November 2010 detections at Sub Plume A.

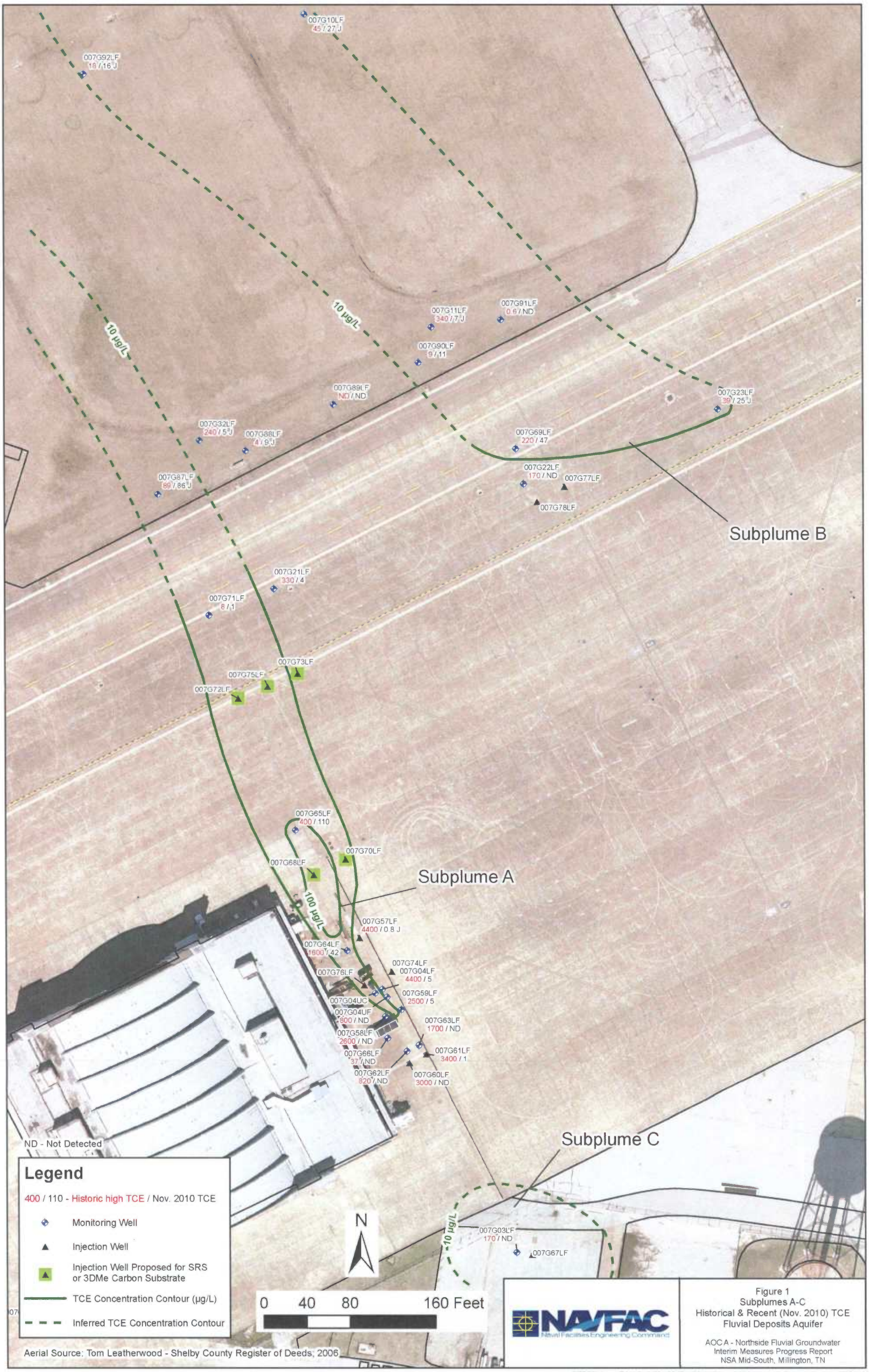
2.1 Sub-Plume A Proposed Task

The objective of the remedial design is to provide a long lasting carbon substrate up and downgradient of 007G65LF so that reductive dechlorination is maintained in the existing anaerobic treatment zones and contaminants of concern (COCs) are continuously degraded as they move through it. Treatment in Sub-Plume A will consist of a supplementing the reductive zones up- and downgradient of 007G65LF.

The proposed treatment zone design parameters are summarized in Table 1:

Table 1
Sub-Plume A Treatment Zone and Aquifer Characteristics

Treatment zone width (perpendicular to groundwater flow)	75 feet
Target treatment interval	30 feet thick 45 to 75 feet bgs
Aquifer matrix	Sand and gravel
Hydraulic conductivity	5.3 ft/day
Hydraulic gradient	0.009 ft/ft
Seepage velocity	87 ft/yr
Effective porosity	0.2
Number of injection wells	2 upgradient 3 downgradient


007G10LF
45 / 27 J
007G92LF
18 / 16 J
10 µg/L
10 µg/L
007G11LF
340 / 7 J
007G91LF
0.6 / ND
007G90LF
9 / 11
007G89LF
ND / ND
007G23LF
39 / 25 J
007G32LF
240 / 5 J
007G88LF
4 / 9 J
007G69LF
220 / 47
007G87LF
69 / 86 J
007G22LF
170 / ND
007G77LF
007G78LF
Subplume B
007G21LF
330 / 4
007G71LF
8 / 1
007G73LF
007G75LF
007G72LF
007G65LF
400 / 110
007G70LF
007G68LF
Subplume A
100 µg/L
007G57LF
4400 / 0.8 J
007G64LF
1600 / 42
007G74LF
007G76LF
007G04LF
4400 / 5
007G59LF
2500 / 5
007G04UC
007G04UF
800 / ND
007G63LF
1700 / ND
007G58LF
2600 / ND
007G66LF
37 / ND
007G61LF
3400 / 1
007G62LF
820 / ND
007G60LF
3000 / ND
Subplume C
ND - Not Detected
Legend
400 / 110 - Historic high TCE / Nov. 2010 TCE
Monitoring Well
Injection Well
Injection Well Proposed for SRS or 3DMe Carbon Substrate
TCE Concentration Contour (µg/L)
Inferred TCE Concentration Contour
N
10 µg/L
007G03LF
170 / ND
007G67LF
0 40 80 160 Feet
Aerial Source: Tom Leatherwood - Shelby County Register of Deeds, 2006
NAVFAC
Naval Facilities Engineering Command
Figure 1
Subplumes A-C
Historical & Recent (Nov. 2010) TCE
Fluvial Deposits Aquifer
AOC A - Northside Fluvial Groundwater
Interim Measures Progress Report
NSA Mid-South, Millington, TN
5/27/2011
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A carbon substrate, such as anemulsified oil or an emulsified poly-lactate, will be injected to provide a long-term carbon source, developing and sustaining biodegradation.

The injection network is shown on Figure 1 and will consist of existing injection wells:

- Upgradient wells 007G68LF and 007G70LF
- Downgradient wells 007G72LF, 007G73LF, 007G75LF

These wells are screened in the target zone and have been used for previous injections of carbon substrate. The upgradient injections will address residual TCE mass that is near or upgradient of monitoring well 007G65LF while the downgradient injections are intended to provide a treatment barrier to residual TCE mass that may be flowing toward the air infield.

Two carbon substrates have been evaluated as a long-term carbon source for the anaerobic conditions necessary to continue reductive dechlorination of TCE. Both Regenesis and Terra Systems Inc. were contacted for estimates regarding their respective products using data from the mid-field/property line plume area. Either substrate could be used and will likely be determined based on the most competitive price. The injection volume assumptions were calculated based on the conservative assumption that the target concentration is 500 µg/L total VOCs (a baseline minimum threshold for calculations). Table 2 below provides a conceptual approach for each substrate.

Table 2
Conceptual Dosing Alternatives for Sub-Plume A

	Regenesis 3DMe	TerraSystem SRS
Number of wells	2 upgradient	2 upgradient
	3 downgradient	3 downgradient
Substrate Dose per well	820 lbs [1]	810 lbs [4]
Water added per well (mixed with injectant)	980 gal [2]	0
Chase water per well (recommended)	1,000 gal [3]	5,000 gal [5]

Notes:

[1] = Based on barrier application rate of 6.8 lbs 3DMe/SF, total barrier dimensions upgradient of 50 ft (W) by 30 ft (D), downgradient 75 ft (W) by 30 ft (D); assumes barrier is 30 feet long (parallel to groundwater flow). Per conversation with D. Davis, Regenesis, June 6, 2011.

[2] = Standard 10:1 ratio water: concentrate (w/w)

[3] = Regenesis recommends additional chase water to distribute the substrate laterally into the formation; this volume represents an additional injection volume.

[4] = Based on barrier application rate of 0.6 lbs SRS-FR/SF, total barrier dimensions upgradient of 50 ft (W) by 30 ft (D), downgradient 75 ft (W) by 30 ft (D); assumes barrier is 30 feet long (parallel to groundwater flow). Adjustment to dosage made based on reduced hydraulic conductivities in this area compared to TerraSystems proposal dated March 16, 2011.

[5] = TerraSystems SOP recommends injecting 10% of the pore volume to distribute substrate laterally into the formation; this can be untreated site groundwater or carbon filtered tap water. Based on well radius of 20 feet.

Regenesis' 3-D Microemulsion (3DMe) is an emulsified blend of polylactate compounds designed to release carbon substrates over the long term. Approximately 4,100 lbs of 3DMe concentrate would be used to treat Sub-Plume A. This concentrate is diluted at a ratio of 10:1 prior to injections. To optimize lateral dispersivity (given the existing well spacing), additional chase water to further distribute the material within the aquifer would be recommended.

TerraSystems' Slow Release Substrate (SRS) is an emulsified oil product which combines a slowly biodegradable edible oil (soybean oil) with a fast release substrate (e.g., lactate) to stimulate degradation. Approximately 4,050 lbs of SRS would be used to treat Sub-Plume A; the final design would need to consider using a larger oil droplet size (5 microns) to restrict oil movement in the subsurface (SRS-FR) and alternate emulsifiers to create a less mobile emulsifier (described as a "stickier droplet") to minimize the likelihood for SRS washing out of the treatment area.

Terra Systems also recommended following injections with a chase water injection of approximately 10% of the pore volume of the target area, to enhance distribution of the SRS. They suggest using groundwater from downgradient points in the aquifer as the chase water (e.g., "push-pull" scenario).

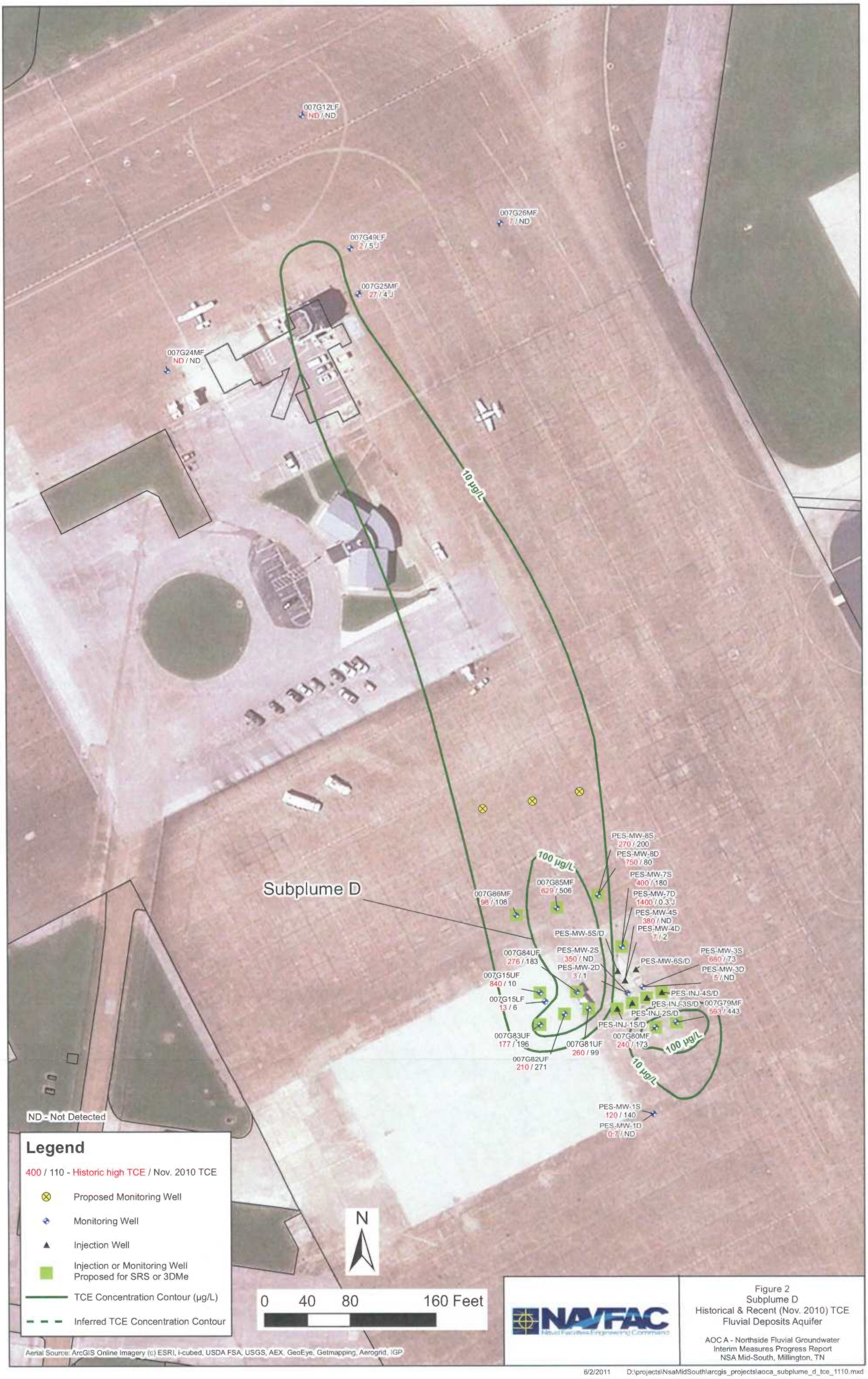
2.2 Sub-Plume D Task

Unlike the other sub-plumes, Sub-Plume D corrective measures were preceded by a Parson's Engineering pilot study that used a vegetable oil carbon substrate, treating the eastern side of the TCE plume originating from the former N-121 hangar. Due to the low solubility of the vegetable oil and delays associated with TCE reduction, the pilot study wells were used for monthly injections of sodium acetate between May 2005 and October 2009. Figure 2 shows historic high TCE concentrations compared with November 2010 concentrations.

A Sub-Plume D optimization study was completed in August 2009 with the addition of eight new monitoring wells (007G79MF to 007G86MF on Figure 2) to achieve the following objectives:

(1) verify whether the Sub-Plume D conceptual model put forth in the 1999 RFI was still accurate by resampling groundwater in areas outside (west of) the current treatment zone

(2) provide supplemental injection points for carbon substrate delivery across the remainder of the plume, if warranted


007G12LF
ND / ND
007G26MF
7 / ND
007G49LF
2 / 5 J
007G25MF
27 / 4 J
007G24MF
ND / ND
10 µg/L
100 µg/L
Subplume D
007G86MF
98 / 108
007G85MF
629 / 506
PES-MW-8S
270 / 200
PES-MW-8D
750 / 80
PES-MW-7S
400 / 180
PES-MW-7D
1400 / 0.3 J
PES-MW-4S
380 / ND
PES-MW-4D
7 / 2
PES-MW-5S/D
PES-MW-2S
350 / ND
PES-MW-2D
3 / 1
PES-MW-6S/D
PES-MW-3S
680 / 73
PES-MW-3D
5 / ND
007G84UF
276 / 183
007G15UF
840 / 10
007G15LF
13 / 6
PES-INJ-4S/D
PES-INJ-3S/D
PES-INJ-2S/D
PES-INJ-1S/D
007G79MF
593 / 443
007G80MF
240 / 173
007G83UF
177 / 196
007G81UF
260 / 99
007G82UF
210 / 271
PES-MW-1S
120 / 140
PES-MW-1D
0.7 / ND
ND - Not Detected
Legend
400 / 110 - Historic high TCE / Nov. 2010 TCE
Proposed Monitoring Well
Monitoring Well
Injection Well
Injection or Monitoring Well Proposed for SRS or 3DMe
TCE Concentration Contour (µg/L)
Inferred TCE Concentration Contour
N
0 40 80 160 Feet
Aerial Source: ArcGIS Online Imagery (c) ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP
NAVFAC
Naval Facilities Engineering Command
Figure 2
Subplume D
Historical & Recent (Nov. 2010) TCE
Fluvial Deposits Aquifer
AOC A - Northside Fluvial Groundwater
Interim Measures Progress Report
NSA Mid-South, Millington, TN
6/2/2011
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(3) evaluate areas hydraulically upgradient of the former treatment zone for possible source areas

Data from the Sub-Plume D optimization study, presented in the 2010 AOC A Progress Report (EnSafe, November 2010), indicated that the original TCE conceptual plume model was still valid. While TCE concentrations indicative of a possible source area (> 1,000 µg/L) were not identified, relatively high TCE concentrations (629 µg/L at 007G85MF) were identified in the west, off-center, downgradient area of the current treatment zone. The three supplemental injection wells (007G81UF — 007G83UF) constructed upgradient of this area contained TCE concentrations ranging between 169 µg/L and 259 µg/L. The two monitoring wells constructed upgradient of the current injection gallery (007G79MF and 007G80MF) to determine whether a source area was present, contained TCE concentrations ranging between 240 µg/L and 593 µg/L. Relatively high concentration of 1,1-dichloroethene (1,1-DCE) were also detected in these wells, ranging between 680 µg/L and 1,930 µg/L.

The Sub-Plume D contaminants reside in the upper fluvial and move into the middle fluvial deposits proceeding east of the former hangar and hydraulically downgradient — remaining absent in the lower fluvial deposits groundwater. Unlike Sub-Plume A, Sub-Plume D is not migrating beyond the tarmac area and contributing to offsite impacts due likely to the less permeable nature of the upper and middle fluvial deposits relative to the lower fluvial deposit.

The objective of the remedial design is the same as the Sub-Plume A which is to provide a long lasting carbon substrate so that reductive dechlorination is maintained in the existing anaerobic treatment zones. Additionally, the treatment gallery will be expanded to the west to treat the downgradient TCE hot-spots verified during the Sub-Plume D optimization study and TCE hot-spots in wells upgradient from the treatment gallery. Figure 2 shows the wells proposed for injecting carbon substrate. The injection network will consist of the following wells:

- Existing injection wells PESINJ1S/D, PESINJ2S/D, PESINJ3S/D, PESINJ4S/D
- Monitoring wells 007G81UF, 007G82UF, 007G83UF, 007G84UF, 007G85MF, 007G86MF, 007G15UF, PESMW-7S/7D, PESMW-8S/D.
- Upgradient middle fluvial monitoring wells 007G79MF and 007G80MF.

The proposed treatment zone design parameters are summarized in Table 3:

Table 3
Sub-Plume D Treatment Zone and Aquifer Characteristics

Treatment zone width (perpendicular to groundwater flow)	160 feet
Treatment zone length	200 feet
Target treatment interval	40 feet thick 45 to 85 feet bgs
Aquifer matrix	Sand and gravel
Hydraulic conductivity	5.6 ft/day
Hydraulic gradient	0.003 ft/ft
Seepage velocity	31 ft/yr
Effective porosity	0.2
Number of injection wells	21

As discussed previously, a carbon substrate, such as an emulsified oil or an emulsified poly-lactate, will provide a long-term carbon source, developing and sustaining biodegradation. The injection volume assumptions were calculated based on data from Regenesis and Terra Systems Inc., assuming 500 µg/L total VOCs (a baseline minimum threshold for calculations). It should be noted that some wells (notably 007G79MF, 007G80MF, 007G82UF through 007G85MF) may need additional substrate relative to this minimum threshold, based on current concentrations and 1,1-dichloroethylene contribution. Based on Regenesis' information, using 3DMe in this area would require approximately 3,400 lbs of 3DMe concentrate. This concentrate is diluted at a ratio of 10:1 prior to injections, though given hydraulic conductivities and concerns about lateral dispersivity. To optimize lateral dispersivity (given the existing well spacing), additional chase water to further distribute the material within the aquifer would be recommended. Table 4 provides a conceptual approach for each substrate.

Table 4
Conceptual Carbon Dosing Alternatives for Sub-Plume D

	Regenesis 3DMe	**TerraSystem SRS**
Number of wells	21	21
Substrate Dose per well	270 lbs [1, 2]	185 lbs [2, 5]
Water added per well	320 gal [3]	0 gal
Chase water per well (recommended)	350 gal [4]	2,500 gal [6]

Notes:
[1] = Based on barrier application rate of 6.8 lbs 3DMe/SF, total barrier dimensions of 200 ft (W) by 20 ft (D); assumes barrier is 30 feet long (parallel to groundwater flow); add 40% for losses between UF/MF and additional wells. Per conversation with D. Davis, Regenesis, June 6, 2011.
[2] = Dosage may be higher in select wells, based on final design.
[3] = Standard 10:1 ratio water: concentrate (w/w).
[4] = Regenesis recommends additional chase water to distribute the substrate laterally into the formation; this volume represents an additional injection volume.
[5] = Based on barrier application rate of 0.6 lbs SRS-FR/SF, total barrier dimensions of 200 ft (W) by 20 ft (D); assumes barrier is 30 feet long (parallel to groundwater flow); add 40% for losses between UF/MF and additional wells. Adjustment to dosage made based on reduced hydraulic conductivities in this area compared to TerraSystems proposal dated March 16, 2011.
[6] = TerraSystems SOP recommends injecting 10% of the pore volume to distribute substrate laterally into the formation; this can be untreated site groundwater or carbon filtered tap water. Based on well radius of 15 feet.

Based on TerraSystems' information, using SRS in this area would require approximately 3,885 lbs; again, consideration should be given to using a larger oil droplet size (5 microns) to restrict oil movement in the subsurface (SRS-FR), as well as alternate emulsifiers to create a less mobile emulsifier (described as a "stickier droplet").

3.0 OFF-SITE TCE MIGRATION

The AOC A RCRA Facility Investigation (EnSafe, 2000) found TCE concentrations near or slightly above the 5 µg/L MCL off the former base property boundary, approximately 3,500 feet downgradient of the source areas. However perimeter monitoring conducted during the interim corrective measures at well 007G52LF (Figure 3) indicated steady increases in TCE concentrations with a historical high of 22 µg/L in 2010. Solute transport modeling of the AOC A plume conducted by the U.S. Geological Survey found that despite source removal activities, increases in TCE concentrations are expected at the downgradient fringes of the plume as the residual TCE cycles through the aquifer. Given the length of the plume (3,500 feet) and the travel time between the source areas and property perimeter, the model predicted 65 years before TCE concentrations would drop below the 5 µg/L cleanup goal. In light of this time frame, coupled with the recent increases in concentrations, supplemental corrective measures have been proposed to mitigate further TCE offsite migration and to expedite attenuation of the existing concentrations.

The objective of the remedial design is to create a reductive zone at the former property boundary such that COCs are degraded as they move through it. Figure 3 shows the proposed injection wells that will form the treatment gallery spanning the width of the plume. Wells will be installed on 75-foot spacings and constructed of 4-inch diameter Schedule 40 PVC, with 10-foot screens. The screen and filter pack will be constructed of the same size/materials as those used in the aquifer test performed during 1999: 0.010-slot screen and 10/20 silica frac sand. .

Treatment at the property line will consist of an emulsified oil or emulsified poly-lactate to form a long-lasting reactive barrier. The proposed treatment zone design parameters are summarized in Table 5:

Table 5
Property Boundary Treatment Zone and Aquifer Characteristics

Treatment zone width (perpendicular to groundwater flow)	750 feet
Target treatment interval	15 feet thick
	70 to 85 feet bgs
Aquifer matrix	Sand and gravel
Hydraulic conductivity	59 ft/day
Hydraulic gradient	0.003 ft/ft
Seepage velocity	323 ft/yr

Figure 3
Perimeter Monitoring
Historical & Recent (Nov. 2010) TCE

AOC A - Northside Fluvial Groundwater
Interim Measures Progress Report
NSA Mid-South, Millington, TN

Aerial Source: ArcGIS Online Imagery (c) ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP

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A carbon substrate will be injected to provide a long-term carbon source, developing and sustaining biodegradation. Given aquifer properties, the primary design considerations will be:

- Maximizing carbon substrate delivery, given rapid groundwater velocities
- Optimizing a well-based delivery system, given the target treatment depth
- Determining reinjection frequencies, given unknowns regarding carbon advection versus consumption

Two critical issues must be addressed prior to implementation:

a) That groundwater velocities will not sweep the carbon downgradient (e.g., that emulsion properties are sufficient that the emulsion breaks within the target zone and adheres to the aquifer matrix)

b) That the injection strategy distributes the substrate effectively throughout the entire target zone (e.g., compensates for the hydraulic conductivity and achieves sufficient lateral dispersion that the barrier is laterally contiguous)

Unlike in slower-velocity aquifers, advection is the dominant mechanism; mixing, diffusion, or dispersion will be minimal within the degradation plume (e.g., to distribute TOC within the aquifer). As a result, injection spacing must be either very close, or high volume injections must be used to distribute substrate within the aquifer.

Injectate

Based on Regenesis' recommended dosing, approximately 10,000 lbs of 3DMe concentrate will be required at the property line. This concentrate is diluted at a ratio of 10:1 prior to injections, though given hydraulic conductivities and concerns about lateral dispersivity, Regenesis does recommend additional chase water to further distribute the material within the aquifer. Table 6 provides a conceptual approach for each substrate.

Table 6
Conceptual Carbon Dosing Alternatives for Off-Site TCE Migration

	Regenesis 3DMe	TerraSystem SRS
Number of wells	10	10
Spacing between wells	75 feet	75 feet
Substrate Dose per well	1,000 lbs [1]	900 lbs [4]
Water added per well	1,200 gal [2]	0 gal
Chase water per well (recommended)	1,500 gal [3]	9,000 gal [5]

Notes:
[1] = Based on barrier application rate of 10 lbs 3DMe/SF, total barrier dimensions upgradient of 750 ft (W) by 15 ft (D); assumes barrier is 30 feet long (parallel to groundwater flow). Based on Regenesis proposal, March 16, 2011.
[2] = Standard 10:1 ratio water: concentrate (w/w).
[3] = Regenesis recommends additional chase water to distribute the substrate laterally into the formation; this volume represents an additional injection volume.
[4] = Based on barrier application rate of 0.8 lbs SRS-FR/SF, total barrier dimensions upgradient of 750 ft (W) by 15 ft (D); assumes barrier is 30 feet long (parallel to groundwater flow). Dosage based on TerraSystems proposal dated March 16, 2011.
[5] = TerraSystems SOP recommends injecting 10% of the pore volume to distribute substrate laterally into the formation; this can be untreated site groundwater or carbon filtered tap water. Based on well radius of 35 feet.

After evaluating hydraulic conductivity data, Terra Systems recommended using a larger oil droplet size (5 microns) to restrict oil movement in the subsurface (SRS-FR); they also suggested using alternate emulsifiers to create a less mobile emulsifier (described as a "stickier droplet") to minimize the likelihood for SRS washing out of the barrier area. Based on Terra Systems' recommended dosing, approximately 9,000 lbs of SRS-FR will be required at the property line. Terra Systems also recommended following injections with a chase water injection of approximately 10% of the pore volume of the target area, to enhance distribution of the SRS. They suggest using groundwater from downgradient points in the aquifer as the chase water (e.g., "push-pull" scenario).

Geochemical Characterization

Geochemical conditions in the target zone will be confirmed prior to finalizing the remedy design. The proposed injection wells shall be sampled for VOCs and geochemical parameters prior to initiating the remedy, so that the conceptual plume model is confirmed and data can be discussed with vendors to finalize the remedy design. The final remedy design (i.e., injection quantities, mixtures, targeted depth intervals) will be provided to TDEC before conducting the proposed injections.

Given the significant distance between offsite well 007G52LF and the next set of wells located along Shipp road (007G55LF and 007G56LF), two additional monitoring wells are proposed at the location shown on Figure 4 for downgradient monitoring of the treatment system.

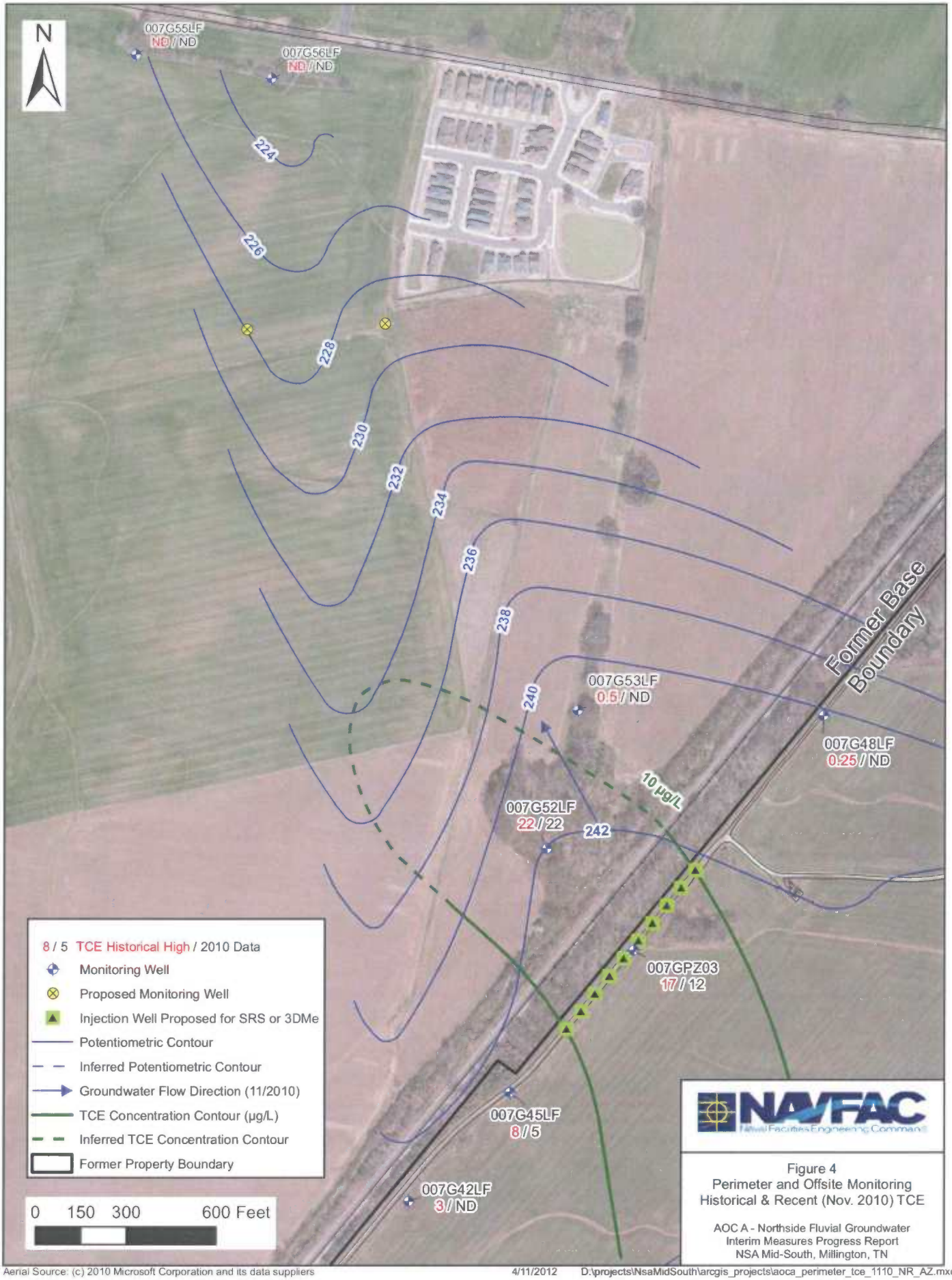


Figure 4
Perimeter and Offsite Monitoring
Historical & Recent (Nov. 2010) TCE

AOC A - Northside Fluvial Groundwater
Interim Measures Progress Report
NSA Mid-South, Millington, TN

Aerial Source: (c) 2010 Microsoft Corporation and its data suppliers 4/11/2012 D:\projects\NsaMidSouth\arcgis_projects\aoca_perimeter_tce_1110_NR_AZ.mxd

4.0 ESTIMATED REMEDIAL TIME FRAMES

Using TCE degradation rates associated with the former interim measures, allows an estimate of the remedial timeframes for achieving the TCE cleanup goal through the proposed corrective measures. The approach for estimating degradation rates is comparable to the statistical method outlined in the USEPA's *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater* (EPA 600/R-11/204 December 2011).

Estimated degradation rates, provided in Table 7, were similar in all four AOC A sub-plumes; wells close to the injection points had relatively high degradation rates (on the order of 0.8 to 0.9), indicating rapid degradation close to carbon delivery locations. While downgradient wells had TCE degradation rates generally ranging from 0.2 to 0.6; these rates are assumed to be more representative of "average" conditions within the treatment areas. The geometric mean degradation rate for all wells is 0.38.

For wells containing TCE above the MCL, predicted remedial timeframes are presented in Table 7, assuming carbon substrate injections are resumed. TCE MCL remedial timeframes range from 2012 through 2019 for the supplemental interim measures proposed at Sub-Plumes A and D. For wells already in compliance with the MCL, the date of actual compliance is presented as a calibration or check against the degradation rate estimate. Most wells calibrate within +/- 12 months.

Assuming carbon substrate injections are implemented at the property line, and that the aquifer response is conservatively 50% of that seen at the source areas (or 0.2), TCE concentrations are expected to reach the MCL in offsite well 007G52LF by 2018. Appendix A contains the trend and remedial time frame analyses for each well and sub-plume.

Remedy Monitoring and Future Injections

Either substrate is expected to last approximately 1 to 3 years in the aquifer, depending upon microbial consumption rates, advection, etc. Geochemical and VOC monitoring will be used to determine the frequency of future injections. The remedial design can be modified on an as-needed basis based on monitoring data to optimize the remediation system. These optimization approaches may include (but are not limited to): additional wells, increased injectate volumes, increased injection frequencies, etc.

Table 7
Remedial Timeframe Analysis — NSA Mid-South
AOC A
Sub Plumes A-D

Sub-Plumes and Wells	Current TCE Concentration	Natural Log	Degradation Rate	Predicted Compliance Date	In Compliance?	Analysis Range	Notes
Sub Plume A							
58LF	1	0	0.47	July-10	Y	07/2000-11/2010	
04LF	5	1.609437912	0.45	November-12	Y	05/1999-11/2010	
64LF	MNA	3.737669618	0.54	November-15	N	04/2005-11/2010	Continued MNA Monitoring
65LF	110	4.700480366	0.16	September-32	N	04/2005-11/2010	Proposed for re-treatment
32LF	5	1.609437912	0.69	October-08	Y	09/2003-11/2010	High degradation rate due to well in close proximity to injection point.
87LF	86	4.454347296	0.21	January-25	N	09/2010-11/2010	Proposed for re-treatment
Sub Plume B							
22LF	1	0	0.47	March-05	Y	09/2002-11/2010	
69LF	47	3.850147602	0.25	July-20	N	02/2005-11/2010	
11LF	7	1.945910149	0.15	July-15	N	11/1997-11/2010	
Sub Plume C							
3LF	1	0	0.63	October-06	Y	09/2002-11/2010	
Sub Plume D							
3S	73	4.290459441	0.31	September-19	N	08/2005-11/2010	
4S	1	0	1.08	January-08	Y	08/2004-11/2010	High degradation rate due to well in close proximity to injection point.
7D	0.3	-1.203972804	1.46	July-08	Y	05/2004-11/2010	High degradation rate due to well in close proximity to injection point.
7S	180	5.192956851	0.3094	October-17	N	11/2004-11/2010	Proposed for re-treatment
8D	80	4.382026635	0.2238	May-25	N	09/2002-11/2010	Proposed for re-treatment
8S	200	5.298317367	0.1157	January-43	N	11/2007-11/2010	Proposed for re-treatment
85MF	506	6.226536669	0.1784	November-36	N	10/2009-11/2010	Proposed for re-treatment
		geomean k =	0.35				
		arithmetic k =	0.45				

Property Line Calculations — Estimate of Remedial Timeframe

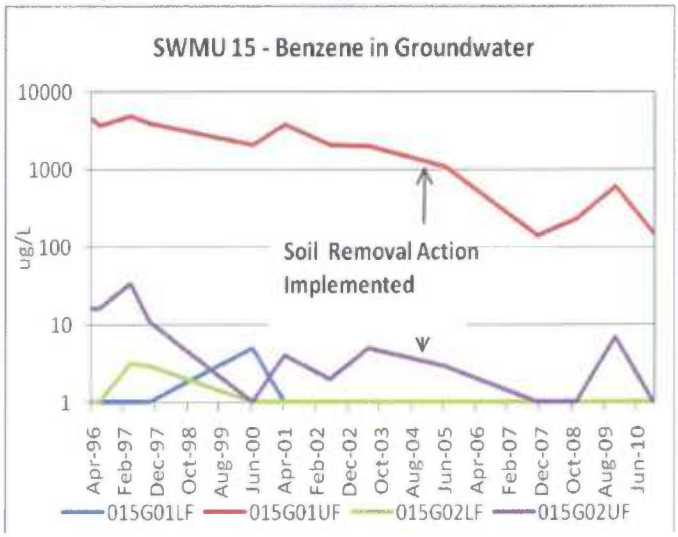
	Current Concentration	Natural Log	Predicted Degradation Rate *	Estimated Y Intercept	Predicted Compliance Date
PZ03	12	2.48490665	0.2	404.67	Apr-15
52LF	22	3.091042453	0.2	405.27	Apr-18

* Rate roughly half of the geometric mean of the rate observed at other AOC A sites.

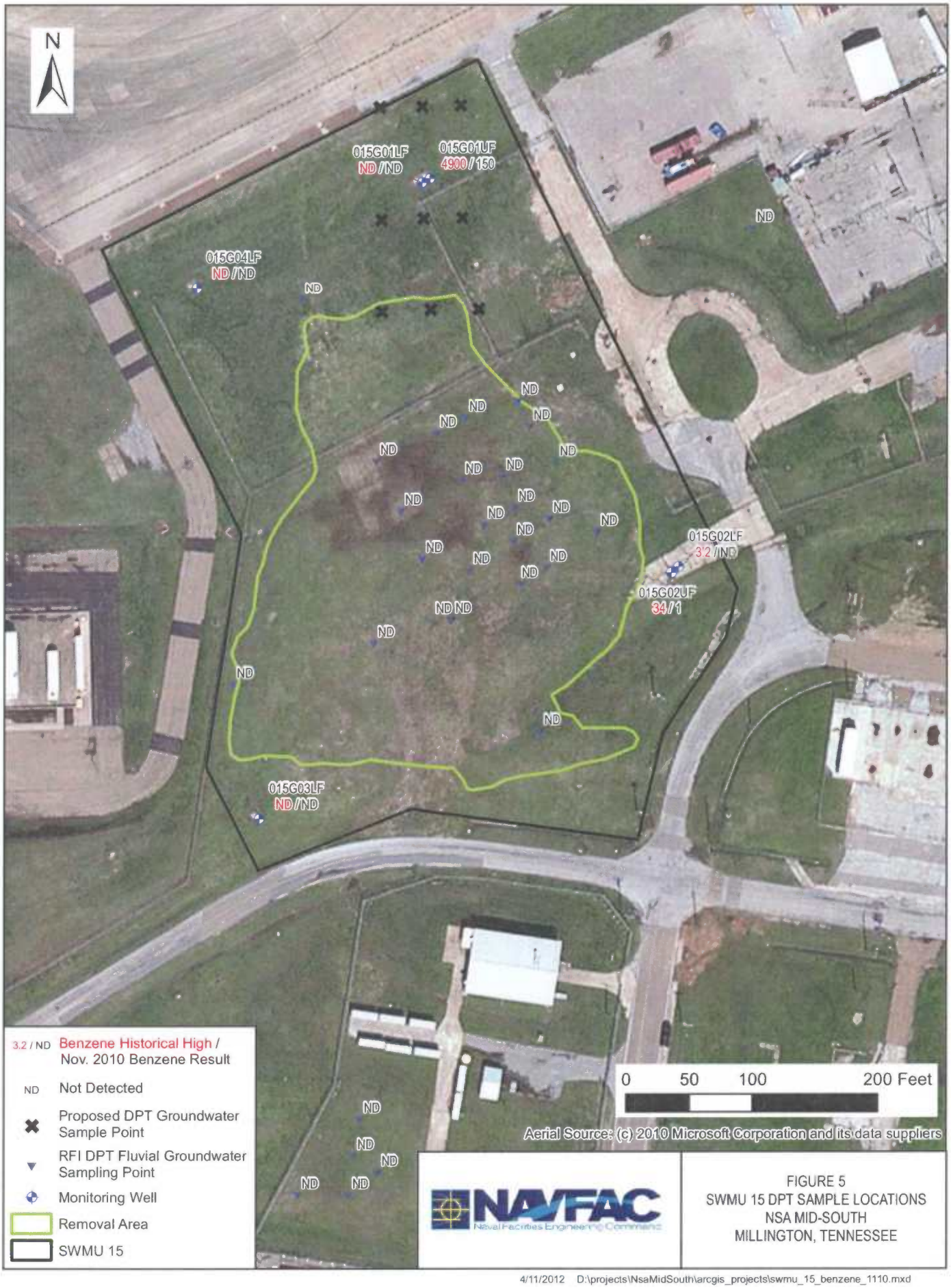
5.0 SWMU 15 BENZENE

The 1999 SWMU 15 RFI identified elevated benzene and total petroleum hydrocarbon contamination in the loess soil and perched groundwater at the former north fuel farm. Additionally, elevated benzene concentrations (4,900 µg/L) were identified in the upper fluvial deposits groundwater at well 015G01UF (Figure 5). The 2003 Corrective Measures Study Report concluded that the benzene in groundwater would provide a carbon source to the downgradient TCE hot spots at Sub-Plume A, therefore, subsequent corrective measures focused on the loess soil and perched groundwater, leaving the upper fluvial contaminants to attenuate and feed the downgradient Sub-Plume A area. Two soil removal actions concluding in 2004 resulted in the excavation of 57,000 tons of petroleum-contaminated soil. The footprint of the removal and the SWMU 15 wells that undergo annual AOC A monitoring are provided in Figure 5.

The benzene trend graph illustrates that the most impacted well, 015G01UF, located downgradient of the former fuel farm, has had significant reductions since the soil removal action. Before the soil removal actions, benzene in groundwater reached 4,900 µg/L while a decrease to 150 µg/L was detected in latest sampling in 2010.



The objective of the proposed remedial design is to stimulate aerobic biodegradation such that benzene is degraded as groundwater migrates to the north. Treatment at SWMU 15 will consist of an aerobic treatment zone up- and downgradient of 015G01UF. The areas containing elevated benzene (> 50 µg/L) will require further definition to ensure the remedy is appropriately focused. The active remedy will focus on treating benzene concentrations above 50 µg/L while MNA monitoring will be evaluated for residual concentrations to determine whether it is suitable remedy to meet the 5 µg/L cleanup goal (MCL). Figure 5 shows proposed groundwater sample locations that will be collected using direct push technology (DPT) methods to characterize the extent of benzene upgradient and downgradient of well 015G01UF. A subset of locations will be sampled at multiple intervals between 40 and 60 feet to ensure the vertical extent is also appropriately characterized. Any identified areas upgradient of 015G01UF containing concentrations greater than 50 µg/L benzene will be targeted for remediation. Following data evaluation, the appropriate area and depth intervals will be targeted for remediation based on the following design parameters summarized in Table 8:



NAVFAC
Naval Facilities Engineering Command

FIGURE 5
SWMU 15 DPT SAMPLE LOCATIONS
NSA MID-SOUTH
MILLINGTON, TENNESSEE

4/11/2012 D:\projects\NsaMidSouth\arcgis_projects\swmu_15_benzene_1110.mxd

Table 8
SWMU 15 Treatment Zone and Aquifer Characteristics

Treatment zone width (perpendicular to groundwater flow)	To be determined
Treatment zone length (parallel to groundwater flow)	To be determined
Target treatment interval	To be determined 40 to 55 feet bgs
Aquifer matrix	Sand and gravel
Hydraulic conductivity	5.6 ft/day
Hydraulic gradient	0.003 ft/ft
Seepage velocity	31 ft/yr
Effective porosity	0.2
Number of injection points (DPT)	To be determined

Two remediation approaches can be considered for SWMU 15, based on the findings of the investigation described above:

- Aerobic remediation of residual benzene and associated compounds. Oxygen Release Compound (ORC) or ORC Advanced, both of which provide slow-release oxygen into the aquifer, can be injected via DPT techniques within zones containing the most elevated benzene concentrations. Determining reinjection frequencies will be a part of the site remedy, given unknowns regarding residual source material and total oxygen demand. During the investigation described above, supplemental data collection to support an ORC remedy should include the following:

  - Oxidation/reduction potential
  - Dissolved oxygen
  - pH
  - Total petroleum hydrocarbons
  - MTBE
  - Total/ferrous iron
  - Sulfate/sulfide
  - Nitrate/nitrite
  - Biological oxygen demand
  - Chemical oxygen demand
  - Biological parameters (aerobic/anaerobic benzene degraders)

- Anaerobic remediation of benzene and associated compounds. Current purge data suggests that groundwater at SWMU 15 is anaerobic, likely due to residual petroleum hydrocarbons in soil and/or groundwater. Microbial depletion of dissolved oxygen is likely to continue over

the long term. Anaerobic degradation of benzene is possible through nitrate reduction, and to a lesser degree via iron and sulfate reduction. Further assessment of groundwater conditions, as described in the investigation above, is required to determine the feasibility of this remedial approach. Supplemental data collection should include the following parameters:

- Oxidation/reduction potential
- Dissolved oxygen
- pH
- Total petroleum hydrocarbons
- MTBE
- Total organic carbon
- Total/ferrous iron
- Sulfate/sulfide
- Nitrate/nitrite
- Total/dissolved manganese
- Biological parameters (aerobic/anaerobic benzene degraders)

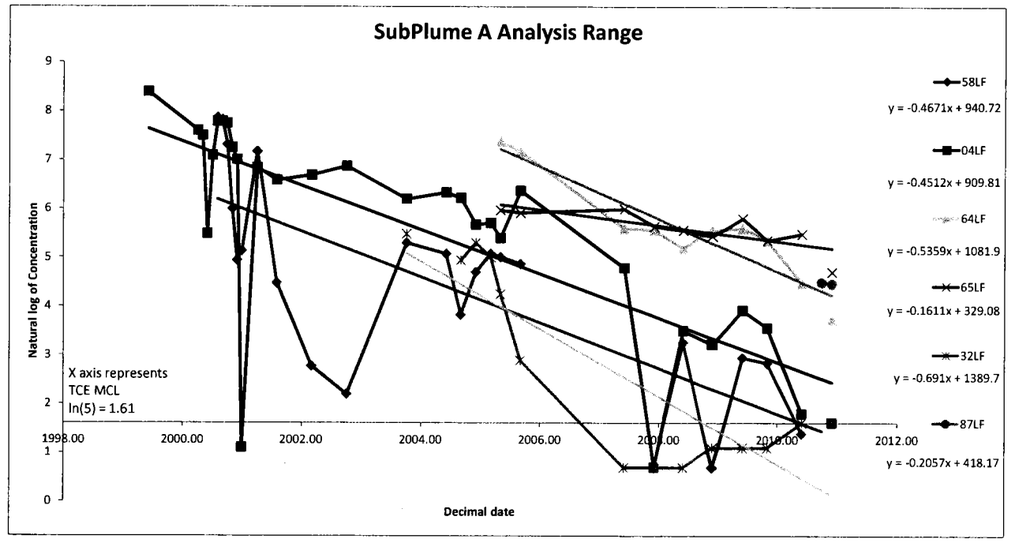
6.0 SCHEDULE AND REPORTING

Following approval of this work plan and before commencing field activities, the Navy will submit a Sampling and Analysis plan for approval by TDEC. Injection permits will also be requested from the TDEC Division of Water and a variance from the Shelby County Health Department. EnSafe estimates 6 months for completing the activities which will be summarized in the status report along with remedy recommendations for SWMU 15. The ongoing semi-annual monitoring will be used to gauge the effectiveness of the supplemental remedial activities and the progress will be discussed in the annual progress reports.

Appendix A
Trend Analysis/Remedial Timeframe Analysis for Sub-Plumes A-D

Sub Plume A
Trend Analysis/Remedial Timeframe Analysis
Basis - EPA 600/R-11/204 December 2011 ***An Approach for Evaluating the Progress of Natural Attenuation in Groundwater***

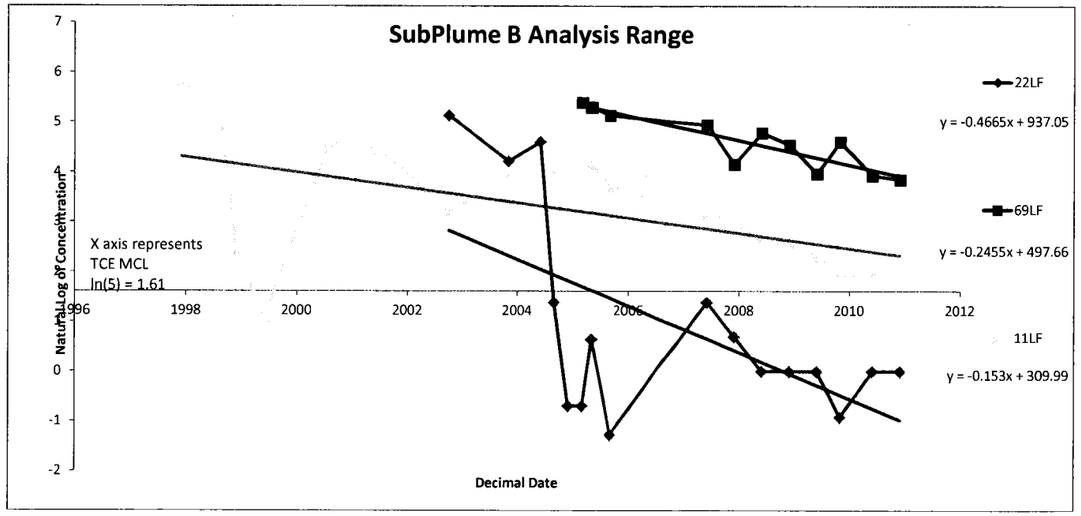
Location	Decimal date	007G58LF		007G04LF		007G64LF		007G65LF		007G32LF		007G87LF	
Units		ug/l	ln	ug/l	ln	ug/l	ln	ug/l	ln	ug/l	ln	ug/l	ln
Mar-95	1995.25			2	0.693147								
May-95	1995.42			390	5.966147								
Nov-95	1995.92			1100	7.003065								
Apr-96	1996.33			160	5.075174								
Apr-97	1997.33			870	6.768493								
Nov-97	1997.92			1400	7.244228								
Aug-98	1998.67			3300	8.101678								
Sep-98	1998.75			180	5.192957								
Nov-98	1998.92			3500	8.160518					22	3.09104245		
Feb-99	1999.17									1	0		
May-99	1999.42			4400	8.38936					3	1.09861229		
Mar-00	2000.25	210	5.347108	2000	7.600902								
Apr-00	2000.33	69	4.234107	1800	7.495542								
May-00	2000.42	1200	7.090077	240	5.480639								
Jun-00	2000.50	2000	7.600902	1200	7.090077								
Jul-00	2000.58	2600	7.863267	2400	7.783224					16	2.77258872		
Aug-00	2000.67	2500	7.824046	2400	7.783224								
Sep-00	2000.75	1500	7.31322	2300	7.740664								
Oct-00	2000.83	400	5.991465	1400	7.244228								
Nov-00	2000.92	140	4.941642	1100	7.003065								
Dec-00	2001.00	170	5.135798	3	1.098612								
Mar-01	2001.25	1300	7.17012	930	6.835185								
Jul-01	2001.58	88	4.477337	720	6.579251					85	4.44265126		
Feb-02	2002.17	16	2.772589	800	6.684612								
Sep-02	2002.75	9	2.197225	960	6.866933					7	1.94591015		
Sep-03	2003.75	200	5.298317	490	6.194405					240	5.48063892		
May-04	2004.42	160	5.075174	560	6.327937	1100	7.003065	110	4.70048				
Aug-04	2004.67	46	3.828641	500	6.214608	1400	7.244228	190	5.247024	140	4.94164242		
Nov-04	2004.92	110	4.70048	290	5.669881	1000	6.907755	220	5.393628	200	5.29831737		
Feb-05	2005.17	160	5.075174	300	5.703782	1300	7.17012	280	5.63479	150	5.01063529		
Apr-05	2005.33	150	5.010635	220	5.393628	1600	7.377759	390	5.966147	70	4.24849524		
Aug-05	2005.67	130	4.867534	580	6.363028	1300	7.17012	370	5.913503	18	2.89037176		
May-07	2007.42			120	4.787492	270	5.598422	400	5.991465	2	0.69314718		
Nov-07	2007.92	2	0.693147	2	0.693147	260	5.560682	280	5.63479	2	0.69314718		
May-08	2008.42	26	3.258097	33	3.496508	180	5.192957	260	5.560682	2	0.69314718		
Nov-08	2008.92	2	0.693147	25	3.218876	260	5.560682	230	5.438079	3	1.09861229		
May-09	2009.42	19	2.944439	50	3.912023	270	5.598422	330	5.799093	3	1.09861229		
Oct-09	2009.83	17	2.833213	35	3.555348	210	5.347108	210	5.347108	3	1.09861229		
May-10	2010.42	4	1.386294	6	1.791759	88	4.477337	240	5.480639	5	1.60943791		
Sept-10	2010.75											89	4.48863637
Nov-10	2010.92	1	0	5	1.609438	42	3.73767	110	4.70048	5	1.60943791	86	4.4543473



	Current TCE Concentration	natural log	Degradation Rate	Predicted Compliance Date	Predicted Compliance Date	Analysis Range	Y Intercept	Goal	natural log	
58LF	1	0	0.4671	2010.512871	Jul-10	07/2000-11/2010	940.72	5	1.609437912	
04LF	5	1.609437912	0.4512	2012.855856	Nov-12	05/1999-11/2010	909.81	5	1.609437912	
64LF	42	3.737669618	0.5359	2015.843557	Nov-15	04/2005-11/2010	1081.9	5	1.609437912	
65LF	110	4.700480366	0.1611	2032.71609	Sep-32	04/2005-11/2010	329.08	5	1.609437912	addressed in redesign
32LF	5	1.609437912	0.691	2008.814127	Oct-08	09/2003-11/2010	1389.7	5	1.609437912	
87LF	86	4.454347296	0.2057	2025.087808	Jan-25	09/2010-11/2010	418.17	5	1.609437912	

Sub Plume B
Trend Analysis/Remedial Timeframe Analysis
Basis - EPA 600/R-11/204 December 2011 ***An Approach for Evaluating the Progress of Natural Attenuation in Groundwater***

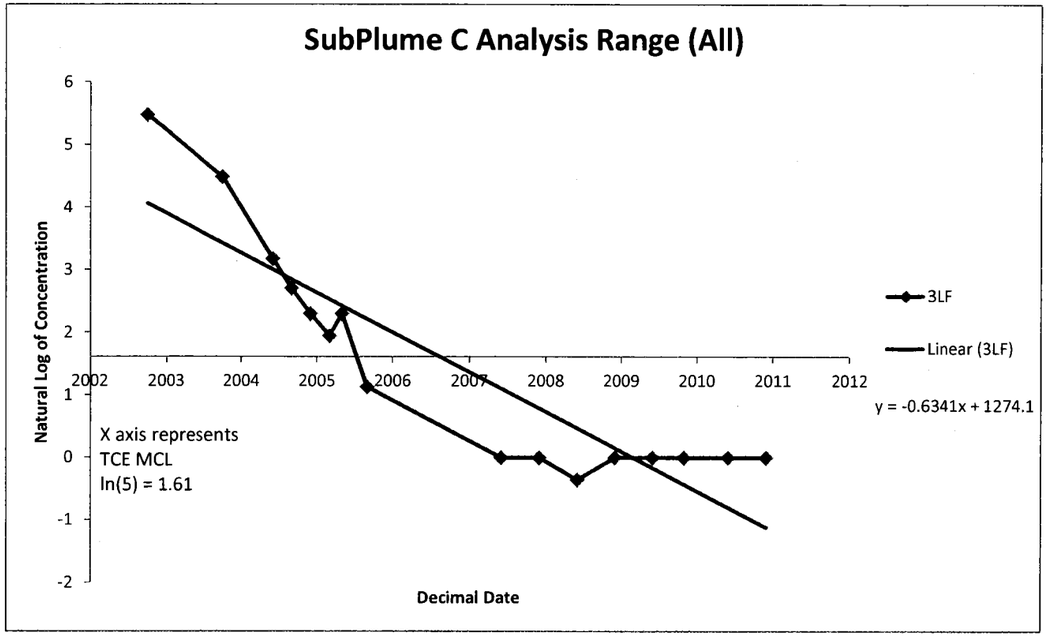
Location	Decimal Date	007G22LF		007G69LF		007G11LF	
Analyte		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)	
RSL Tap		2.00518		2.00518		2.00518	
MCL		5		5		5	
Units		ug/l	ln	ug/l	ln	ug/l	ln
Apr-96	1996.333333					230	5.438079309
Aug-96	1996.666667					57	4.043051268
Apr-97	1997.333333					93	4.532599493
Nov-97	1997.916667					340	5.828945618
Aug-98	1998.666667	12	2.48490665			130	4.86753445
Nov-98	1998.916667	9	2.197224577			11	2.397895273
May-99	1999.416667	80	4.382026635			3	1.098612289
Jul-00	2000.583333	120	4.787491743			100	4.605170186
Jul-01	2001.5	92	4.521788577			87	4.465908119
Sep-02	2002.75	170	5.135798437			24	3.17805383
Sep-03	2003.833333	68	4.219507705			50	3.912023005
May-04	2004.416667	100	4.605170186	200	5.298317367		
Aug-04	2004.666667	4	1.386294361	200	5.298317367	57	4.043051268
Nov-04	2004.916667	0.5	-0.693147181	190	5.247024072		
Feb-05	2005.166667	0.5	-0.693147181	220	5.393627546		
Apr-05	2005.333333	1.9	0.641853886	200	5.298317367	65	4.17438727
Aug-05	2005.666667	0.28	-1.272965676	170	5.135798437	41	3.713572067
May-07	2007.416667	4	1.386294361	140	4.941642423	23	3.135494216
Nov-07	2007.916667	2	0.693147181	64	4.158883083	20	2.995732274
May-08	2008.416667	1	0	120	4.787491743	14	2.63905733
Nov-08	2008.916667	1	0	94	4.543294782	13	2.564949357
May-09	2009.416667	1	0	53	3.970291914	10	2.302585093
Oct-09	2009.833333	0.4	-0.916290732	100	4.605170186	7	1.945910149
May-10	2010.416667	1	0	51	3.931825633	7	1.945910149
Nov-10	2010.916667	1	0	47	3.850147602	7	1.945910149



	Current Concentration	natural log	Degradation Rate	Predicted Compliance Date	Predicted Compliance Date	Analysis Range	Y Intercept	Goal	natural log
22LF	1	0	0.4665	2005.231644	Mar-05	⁄2002-11/20	937.05	5	1.60944
69LF	47	3.85015	0.2455	2020.572554	Jul-20	⁄2005-11/20	497.66	5	1.60944
11LF	7	1.94591	0.153	2015.559229	Jul-15	./1997-11/20	309.99	5	1.60944

Sub Plume C
Trend Analysis/Remedial Timeframe Analysis
Basis - EPA 600/R-11/204 December 2011 ***An Approach for Evaluating the Progress of Natural Attenuation in Groundwater***

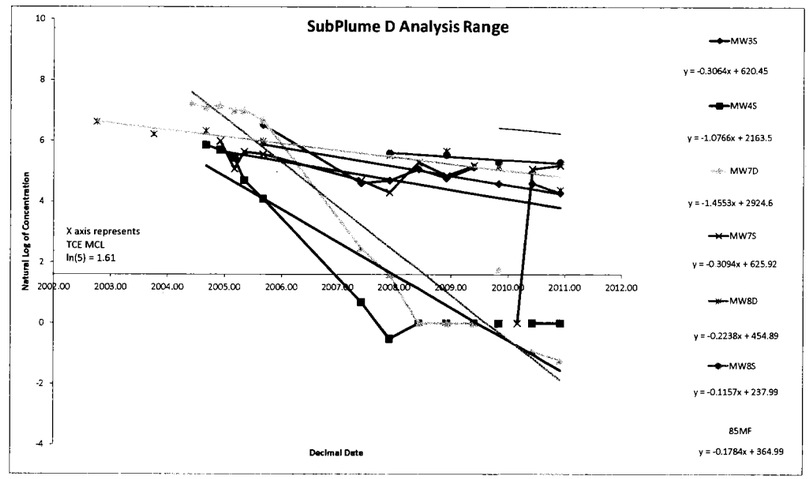
Location	Decimal Date	007G03LF	
Analyte		TRICHLOROETHYLENE (TCE)	
RSL Tap		2.00518	
MCL		5	
Units		ug/l	ln
Mar-95	1995.25	63	4.143135
May-95	1995.416667	73	4.290459
Nov-95	1995.916667	98	4.584967
Apr-96	1996.333333	97	4.574711
Apr-97	1997.333333	160	5.075174
Nov-97	1997.916667	170	5.135798
Mar-00	2000.25	26	3.258097
Apr-00	2000.333333	17	2.833213
May-00	2000.416667	18	2.890372
Jun-00	2000.5	16	2.772589
Jul-00	2000.583333	14	2.639057
Aug-00	2000.666667	16	2.772589
Sep-00	2000.75	18	2.890372
Oct-00	2000.833333	17	2.833213
Nov-00	2000.916667	15	2.70805
Dec-00	2001	14	2.639057
Mar-01	2001.25	12	2.484907
Jul-01	2001.583333	29	3.367296
Feb-02	2002.166667	34	3.526361
Sep-02	2002.75	240	5.480639
Sep-03	2003.75	89	4.488636
May-04	2004.416667	24	3.178054
Aug-04	2004.666667	15	2.70805
Nov-04	2004.916667	10	2.302585
Feb-05	2005.166667	7	1.94591
Apr-05	2005.333333	10	2.302585
Aug-05	2005.666667	3.1	1.131402
May-07	2007.416667	1	0
Nov-07	2007.916667	1	0
May-08	2008.416667	0.7	-0.35667
Nov-08	2008.916667	1	0
May-09	2009.416667	1	0
Oct-09	2009.833333	1	0
May-10	2010.416667	1	0
Nov-10	2010.916667	1	0



	Current Concentration	natural log	Degradation Rate	Predicted Compliance Date	Predicted Compliance Date	Analysis Range	Y Intercept	Goal	natural log
3LF	1	0	0.6341	2006.766381	Oct-06	09/2002-11/2010	1274.1	5	1.609437912

Sub Plume D
Trend Analysis/Remedial Timeframe Analysis
Basis - EPA 600/R-11/204 December 2011 ***An Approach for Evaluating the Progress of Natural Attenuation in Groundwater***

Location	Decimal date	PESGMW3S		PESGMW4S		PESGMW7D		PESGMW7S		PESGMW8D		PESGMW8S		007G85MF	
Analyte		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)		TRICHLOROETHYLENE (TCE)	
RSL Tap		2.00518		2.00518		2.00518		2.00518		2.00518		2.00518		2.00518	
MCL		5		5		5		5		5		5		5	
Units		ug/l	ln	ug/l	ln	ug/l	ln	ug/l	ln	ug/l	ln	ug/l	ln	ug/l	ln
Apr-96	1996.33														
Aug-96	1996.67														
Apr-97	1997.33														
Nov-97	1997.00														
Aug-98	1998.67														
Jul-00	2000.58														
Jul-01	2001.58														
Sep-02	2002.75	320	5.768320996	380	5.940171253	1000	6.907755279	180	5.192956851	750	6.620073207	170	5.135798437		
Oct-02	2002.83														
Sep-03	2003.75	420	6.040254711	220	5.393627546	660	6.492239835	190	5.247024072	500	6.214608098	120	4.787491743		
May-04	2004.42	620	6.429719478	270	5.598421959	1400	7.244227516	280	5.634789603						
Aug-04	2004.67	490	6.194405391	350	5.857933154	1200	7.090076836	340	5.828945618	560	6.327936784	210	5.347107531		
Nov-04	2004.92	560	6.327936784	300	5.703782475	1300	7.170119543	400	5.991464547						
Feb-05	2005.17	600	6.396929655	230	5.438079309	1100	7.003065459	160	5.075173815						
Apr-05	2005.33	200	5.298317367	110	4.700480366	1100	7.003065459	280	5.634789603						
Aug-05	2005.67	680	6.522092798	60	4.094344562	800	6.684611728	260	5.560681631	400	5.991464547	190	5.247024072		
May-07	2007.42	100	4.605170186	2	0.693147181	12	2.48490665	110	4.700480366						
Nov-07	2007.92	110	4.700480366	0.6	-0.510825624	5	1.609437912	74	4.304065093	250	5.521460918	270	5.598421959		
May-08	2008.42	160	5.075173815	1	0	1	0	200	5.298317367						
Nov-08	2008.92	120	4.787491743	1	0	1	0	130	4.86753445	290	5.669880923	260	5.560681631		
May-09	2009.42	170	5.135798437	1	0	1	0	180	5.192956851						
Aug-09	2009.67													476	6.165417854
Oct-09	2009.83	100	4.605170186	1	0	6	1.791759469	180		180	5.192956851	200	5.298317367	629	6.444131257
Feb-10	2010.17								#NUM!					560	6.327936784
May-10	2010.42	100	4.605170186	1	0	0.4	-0.916290732	160	5.075173815					600	6.396929655
Nov-10	2010.92	73	4.290459441	1	0	0.3	-1.203972804	180	5.192956851	80	4.382026635	200	5.298317367	506	6.226536669



	Current Concentration	natural log	Degradation Rate	Predicted Compliance Date	Predicted Compliance Date	Analysis Range	Y Intercept	Goal	natural log	
3S	73	4.290459441	0.3064	2019.714628	Sep-19	8/2005-11/201	620.45	5	1.60943791	
4S	1	0	1.0766	2008.072229	Jan-08	8/2004-11/201	2163.5	5	1.60943791	
7D	0.3	-1.203972804	1.4553	2008.514095	Jul-08	5/2004-11/201	2924.6	5	1.60943791	
7S	180	5.192956851	0.3094	2017.810479	Oct-17	1/2004-11/201	625.92	5	1.60943791	
8D	80	4.382026635	0.2238	2025.382315	May-25	9/2002-11/201	454.89	5	1.60943791	addressed in redesign
8S	200	5.298317367	0.1157	2043.047209	Jan-43	1/2007-11/201	237.99	5	1.60943791	addressed in redesign
85MF	506	6.226536669	0.1784	2036.886559	Nov-36	0/2009-11/201	364.99	5	1.60943791	addressed in redesign